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JADE

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NOTE.

The following pages contain a preliminary presentation of certain investigations and studies which are being carried on by the undersigned, with the co-operation of several scientists and scholars.

HEBER R. BISHOP.

JADE AS A MINERAL.

GENERAL DEFINITION.

Jade is a term generally employed to designate a number of minerals of tough compact texture and of color varying from nearly white to very dark green, which have been used from the earliest times in worked forms as weapons, utensils, and ornaments. The term, however, properly includes only two species, Jadeite and Nephrite, and it is to a study of these minerals that the greater part of the following pages is devoted.

Jadeite and Nephrite are chemically quite distinct substances, but notwithstanding this fact they are strikingly alike in many of their properties. Both are hard and compact and usually of distinctly fibrous texture, owing to which they are exceedingly tough, and may be carved into very delicate forms. Both are more or less translucent in most of their varieties and are of various colors, although shades of green are most characteristic for both. In thin sections all varieties of both minerals appear nearly or entirely colorless and quite transparent. Both minerals are susceptible of taking a high polish, and the polished surfaces frequently exhibit a very characteristic sheen.

In addition to the many characters shared by both minerals each has properties peculiar to itself which may be briefly stated.

Jadeite is a silicate of aluminium and sodium. It almost always contains in addition small quantities of iron, calcium, and magnesium ; in the variety called Chloromelanite the iron amounts to as much as ten per cent. Its chemical composition and crystalline character make it a member of the pyroxene group of minerals. It occurs very rarely in distinct crystals, its usual form being a massive crystalline aggregate of closely felted fibres or granules. Its hardness is about 7, or that of quartz. Its specific gravity is close to 3.33. It fuses readily before the blowpipe to a clear glass and is not decomposed by hydrochloric acid until after having been fused.

Nephrite is a silicate of calcium and magnesium, with generally a small amount of iron replacing magnesium. It belongs to the *amphibole* group of minerals, being identical in composition with the minerals tremolite and actinolite of that group. It is distinguished from them solely by its structure, which is always that of a closely felted, compact aggregate of fine fibres, never in discrete crystals as are those minerals. Its hardness is 6.5. Its specific gravity is close to 3.0. It fuses with some difficulty to a greenish glass and is not decomposed by hydrochloric acid.

It is evident from this outline of the characteristics of jadeite and nephrite that the strong resemblance which has caused them to be classed together under the common name of Jade is due to comparatively superficial characters ; but the certain discrimination between them often requires a more or less complete investigation of all their properties, chemical and physical. This discrimination becomes the more difficult owing to the fact that the two substances not infrequently occur intermixed in the same specimen, the nephrite having been formed from the jadeite by a gradual alteration of its chemical and physical constitution. In such cases it is by means of the study of thin sections with the microscope that it is alone possible to discover the true nature of the mineral.

The dual nature of the material composing the objects to be described in the present work must be kept in mind in reading the following pages, in which will be found full descriptions of the properties of both jadeite and nephrite, the two being considered successively under each separate heading.

COLOR.

Jadeite.—The color of jadeite is highly diversified, exhibiting an almost indefinite variety of shades and tints.

The commoner colors are, however, tones of white and various shades of green.

Pure white is not common. A silvery white, translucent like chalcedony, is shown in the Chinese bowl No. 3091 of the collection, and the tea-cup No. 3101. Such specimens are known as "Camphor Jade."

Sugar-white material having the appearance of that variety of marble known as saccharine is occasionally found. No. 13460, a fragment from Burma, is of this character.

Grayish-, greenish-, bluish-, or yellowish-white tones are more frequent than the pure white. Examples are very numerous. Gray of various tones is found, as in parts of No. 3041, a Chinese vase dating from the Ming dynasty.

A pale lavender color is especially characteristic of the Burmese jadeite and is highly prized. Specimens of this tint are generally translucent and highly crystalline, giving a frosted appearance on polished surfaces. Nos. 3212, a small double-gourd vase, 13107, a tiny figure of the god of longevity, and the eight wine-cups numbered 13009 are good examples. Patches of the lavender tint are often intermingled with green in colorless material, as in No. 3236.

Many shades of green occur in jadeite. Specimens are found colored a pale greenish-white as in the cylindrical brush-holder No. 3166. Again, this tint is seen as cloudings in white with transitions to deeper tones as in No. 13-059. Lettuce-green is shown in the quadrangular vase No. 3015, the flower vase No. 3041, and the miniature dish No. 3211 ; apple-green in the gourd-shaped vase No. 3271, and grass-green in the tea-cup No. 3046.

Emerald-green is the most prized color both for its beauty and its rarity. A good example is the incense-burner No. 3104. It sometimes occurs in small patches in the midst of white or otherwise colored material as in Nos. 3064, 3202, 3258, 3272, and many others. The jewelled jades No. 13-312, are cut from masses of very translucent and uniformly colored deep emerald-green, and are probably the finest examples extant. Emerald-green is the *fei-ts'ui* of the Chinese, and is among their most highly valued varieties of jadeite.

Greens of darker tone are less common in jadeite. Pear-leaf green is seen in the Guatemalan hatchet No. 13330.

Pale bluish-green of almost aquamarine tint is seen in No. 3126, which forms a transition to the distinctly blue tints shown in No. 3127, a specimen said to be absolutely unique. No. 3126 is a mixture of opaque white and pale blue. No. 3127 is bluish-green with veinings of decided, almost prussian-blue and brown stains on the surface.

A bluish-lavender color is peculiar to the Tibetan material, which is remarkable for its wonderful delicacy, and it is found in pieces of considerable size. A beautiful example illustrating this color is No. 13186, the small figure of the Venus de Milo made in Paris for Mr. Bishop.

The two bowls Nos. 3231 and 3232 are a delicate greenish-blue with irregular veins of rich moss-green tint from 1 to 12 mm. in length. To such coloring the Chinese have given the poetical descriptive name of "melting snow enclosing bits of moss."

Transitions from the greens to decided tones of yellow are uncommon. Yellowish-green of strong tone, associated with emerald-green, is seen in the rice-bowls numbered 3098 and 3262.

The variety of jadeite called chloromelanite is characterized by containing a large percentage of iron replacing in part its aluminium. As its name implies, it is of dark-green color often appearing quite black except in the thinnest splinters, when it is seen to be of a slightly translucent blackish-green color. No. 13242, a long narrow hatchet from Mexico, is a typical example of this material.

Nephrite.—The color of nephrite varies almost as widely as does that of jadeite, but is characterized by the greater frequency of darker shades of green. White is much more frequent than in jadeite, yet pure white is rare. Very faint tones of greenish-, bluish-, and grayish-white are more common than pure white. The Collection furnishes numerous examples of these, of which several may be mentioned: *e. g.*, the beautiful beaker-shaped vase No. 3071; the alter-set of three pieces numbered 13013, 13014, and 13015; as well as Nos. 13063, 3092, 13104, 13165, 13197, and many others.

Pale yellow of waxy aspect, varying somewhat in tone, is exceedingly rare, yet the Collection includes several beautiful examples, of which 13033, 13043, 13044, and 13045 may be mentioned.

Gray, which is somewhat rare, is well exemplified in Nos. 3037, 3143, 3030, 3279. It is chiefly due to minute inclusions of opaque black particles in a white matrix, and varies in depth of tint according to the abundance of inclusions. It is thus often speckled or clouded as in the bowl numbered 3090. The rich gray is often in combination with inky black, as in the little cylindrical penholder No. 3038. A very light yellowish-gray is seen in No. 13253, and an opaque olive-gray in No. 3124.

Brown of various shades occurs. Pale brown transparent material of horn-like consistency is very characteristic. It is shown in No. 3255, an ornamented musical stone. Darker tints are shown in Nos. 3246 and 13047, and are specially apt to occur as stainings or veins in material of other colors—green, yellow, white, as is seen in Nos. 3077, 3062, and 3249. Tints of gray and brown in irregular mixtures are often found in nephrites that have been exposed to great heat or that have long lain in the earth, in contact perhaps with other substances, such as the ancient Chinese pieces to which Dr. Bushell has given the name "tomb jades." In such specimens are found grayish- and brownish-yellows, often with veinings or stainings of russet or dead-oak-leaf brown. Nos. 13167, 13158, and 13200 are typical of this class.

All the foregoing colors are, however, comparatively rare, the most typical nephrites being of some shade of green. Olive-green is seen in Nos. 3160 and 3205; seaweed-green in Nos. 13055; 13212, 13118, and others; golden emerald-green as in No. 13035; spinach-green as in Nos. 3018 and 13056; sage-green as in Nos. 3183, 3051, 13095, 13175; light sage-green, 3025 and 13082; dark sage-green, 3003 and 13054; and dark-green to greenish-black as in Nos. 3125, 13005, and many others.

Many of these green colors occur very uniformly in considerable masses of the mineral. Again, two or more tints are found commingled, and such varieties have been likened by the Maoris to "moss seen at the bottom of a pool of limpid water." This description might apply to No. 3062 and others. The rich, transparent emerald-green of the *fei-ts'ui* jadeite is not found of equal purity in nephrite, those which approximate to this color having always a yellowish cast.

The entire Collection was arranged on a color basis only; that is, the specimens regardless of locality or substance were classified according to the various colors and tints, and formed a series presenting an almost continuous gradation from white to black. The nephrites predominated, in whites with tints of gray or green, and nearly all the dark grass- or sage-green or the grays resulting from inclusions of chromic iron or other materials in the white magma; the brilliant greens, emerald-greens, and light greens in a white field belonged to the jadeite group.

The following notes specially prepared for this work by Professor F. W. Clarke, Chief Chemist to the United States Geological Survey, explain all that is known as to the origin of the various colors observed in jadeite and nephrite, which may be considered as natural colors—that is, those produced at the time of crystallization of the minerals and due to their peculiar chemical composition or to original inclusions within their substances.

NOTES ON THE COLOR OF JADE.

Absolutely pure jadeite should be white, without a tinge of color. So also an ideal nephrite, containing only lime and magnesia, should be colorless. The colors which actually exist are due to admixtures of other substances, and in general terms they are not difficult to explain. Occasionally, however, anomalies seem to exist. At all events the analytical data which are given do not in every case account for the color or lack of color observed.

The colorific agents to which jade owes its different hues are mainly the compounds or iron, of manganese, and of chromium. Manganese is relatively unimportant. Were silicates of manganese present in sufficient quantities they would impart to jade a pinkish or amethystine tint; but in all observed cases they serve merely to modify the colors produced by iron. The latter are enfeebled by the presence of manganese, but not to any very great degree in this group of minerals. Free oxides of manganese are black; and they in small amounts might give a grayish cast to jade or even appear as black stainings. Finely disseminated chromite may also account for black and gray colorations; but chromium is much more important as the source of the brilliant emerald-green of certain jadeites. This particular tint is probably always due to chromium; which has been repeatedly identified in the jade by Damour, by von Fellenberg, and by myself; although in the analyses of material from the Bishop Collection its determination seems to have been overlooked or neglected.

To the compounds of iron most of the colorations of jade are due. As included magnetite, finely subdivided, iron may give black and gray tintings. As ferric hydroxide it produces yellows and browns. Ferrous silicates yield colorations ranging from pale green to almost black, and ferric silicates offer shades of yellow, brown, and black. Some silicates of iron are blue, but this tint is not common. Since iron may occur in more than one condition in a single specimen of jade, it is evident that a great variety of blendings are possible, and that the amount of iron present will not alone account for the color seen. In general, the green jades, excluding the emerald-green, owe their color to ferrous silicates; and the quantity of the latter determines the depth of the shade. With ferric silicates in small amount yellows and browns appear; and these, commingled with the ferrous greens, may give many intermediate shades. Ordinary bottle glass, green and brown, offers good examples of the character of the colors which are here seen separately; and it is easy to realize how a blending of the two in one melting-pot would yield a wide range of hues; brown and green tending in part to neutralize each other. In the coarser varieties of bottle glass the colors appear to advantage only by transmitted light; by reflected light the material is black or nearly so. Since jade is not transparent it is seen only by reflected light, and dark shades are produced by relatively small amounts of the colorific agent.

Although the principles thus laid down concerning the colorations due to iron are simple enough, their application to the actual analyses is exceedingly difficult. In general, the white or light-colored jades are low, and the darker specimens high in iron. In this statement surface stainings are left out of account. The difficulty about interpreting analyses more closely is due to our lack of knowledge as to the way in which the iron is actually combined; the representation of it as oxides being but a conventional and partial statement of the truth. Thus a jade might contain 1.60 of ferric oxide, and 0.72 of ferrous, and this could mean one of several things. The two oxides might be united as magnetite, forming black inclusions, and giving a gray coloration. Or both might be combined as silicates, with another result as to color. Or the ferrous oxide might represent a ferrous silicate, while the ferric oxide was combined with water in the form of rust. To actually determine the true state of affairs would be difficult, and in some cases even hardly possible. In fact, all three of the conditions above suggested might coexist, and then their disentanglement would be almost hopeless.

Upon careful scrutiny of the analyses various anomalies appear which so far are not explainable by the evidences now in the hands of the writer. Take for example the four following cases, and contrast the proportion of iron with the reported color:

No. 13192H	— 4.10 per cent. ferric oxide.	Milky white.
No. 13246	— 4.28 " " " "	Seaweed-green, clouded with brown.
No. 13006	— 3.99 " " " "	Pea-green.
No. 3125	— 3.64 " " " "	Dark greenish-black.

These differences of tint are extraordinary. First, a sample high in iron is white, and another somewhat lower in iron is nearly black. Ferrous oxide is not reported in any of the four, and yet greens appear in three of the specimens. It would seem on the face of the reports as if ferrous iron had been neglected, all the iron having been estimated in the ferric state. But this supposition does not account for No. 13192H, which, upon general principles, ought to be deeply colored.

In other cases the results obtained by analysis are more satisfactory. For example, four specimens of jade are described as seaweed-green, and their contents of iron and manganese appear as follows:

	Ferric oxide.	Ferrous oxide.	Manganese oxide.
No. 13211	4.93	0.11	. . .
No. 13246	4.28	. . .	trace
No. 13212	4.64	0.16	0.38
No. 13118	3.39	0.85	0.22

Here there is a decided family resemblance, although the indications are for brown tints rather than the green which actually occurs. But, as has been already indicated, the mode of combination of the iron is uncertain; and perhaps a more careful scrutiny of the samples would explain the colors found. On this subject the last word has evidently not been said.

Concerning some of the more unusual and delicate shades which occur in jadeite and nephrite there is little to say. The evidence for their interpretation is lacking. Possibly some of the pale yellows may be due to titanium; but the blues and lavenders are unexplained. Some silicates of iron are blue or bluish, and vanadium might give similar hues. Glaucophane, which Professor Penfield has identified in some of the nephrites is often blue or lavender, crocidolite is dark blue, and the presence of either would account for the observed phenomenon. Brown stainings and streakings are caused by ferric hydroxide; and surface blackening is often attributed to carbon derived from organic matter. In some cases a grayish tint may be produced by microscopic inclusions of mica. Such inclusions have been observed, but they are not very common.

In addition to the natural colors treated of by Professor Clarke, there is another group of colors which are due to agencies of various sorts affecting the jade after its formation, such as weathering, absorption of coloring materials either natural or artificial, and the action of fire. To some one of these agencies or to a combination of them are due most of the veins or stainings, chiefly in tones of gray, brown, and black, to which reference has already been made.

The presence in worked jade of these colors, streaks, etc., is not always a detriment, inasmuch as lapidary-artists, especially in China, are in the habit of carefully selecting such parts of a specimen as have stains, tints, and markings of brown and yellow, and very skilfully taking advantage of the coloring to add an additional charm to the leaf, the finger-tip, fruit, or any ornament which is to be given a prominent place in the perfected object. This adaptation of material to design, and of design to material, is splendidly exemplified in the Collection.

The effects of weathering and the absorption of natural stains are best exemplified by the group of specimens in the Collection to which the name of Tomb Jades has been applied, and to which a separate chapter will be devoted in this volume. Such objects are all of great antiquity, and have been subjected to the altering agencies during long burial in the earth in tombs or in the ruins of ancient cities.

A natural staining may be the result of the infiltration of oxide of iron, manganese, or other substances, while the jade is still in the bed-rock; or while it is being rolled along in the bed of a river after being detached from the bed-rock; or lastly, while buried in the ground.

Another remarkable change of color is that due to calcination, generally the result of conflagration. A notable example of this, a small quadrangular vase, No. 3217, was recovered after the looting and destruction of the Summer

Palace at Peking in 1860. In this object the lower part is a light grayish-green, with a black staining that is due to infiltration in the cracks where the piece had been subjected to slight heat or staining from pyroligneous and other acids produced by the conflagration, but was not brought into direct contact with the fire. The upper part, however, which has suffered actual contact, changed to a yellowish but opaque substance, resembling calcined bone. An extreme example of this kind is the tiny incense-burner, No. 3017, which has been so much altered as to have lost almost all trace of its ever having been jade. Its delicate carving remains, however, and the polish is still there to a great extent; but the whole piece is now a minutely crackled grayish-white opaque substance, almost resembling a jasper-like substance like porcellanite.

DIAPHANEITY.

The degree of transparency of the jade minerals varies considerably with the color and structure of individual specimens. Unpolished specimens of all colors are at best only translucent and more commonly quite opaque except in very thin splinters. But the removal of the inequalities of the surface by polishing greatly heightens the translucency.

Jadeite is on the whole less translucent than nephrite. The light-colored varieties are generally subtranslucent to translucent, having in this respect much the character of chalcedony. But some of the white jadeites are quite opaque, and on the other hand in some of the coarser-grained varieties such as No. 13009 single perfectly transparent crystals of considerable dimensions may be seen embedded in the translucent matrix.

In green jadeites a subtranslucent character is more common, extending in the chloromelanite variety to a more or less pronounced opacity. But the rare emerald-green jadeite as seen in the Kleczkowsky jewels, No. 13212, is sometimes almost perfectly transparent, rivalling the emerald in both color and water.

The *nephrites* may be more uniformly described as translucent, the degree of translucency depending on the depth of the color and the thickness of the specimen. White, semi-transparent varieties are sometimes found, as in the little tea-cup No. 3147, which is so transparent that print held against the back of the specimen may be read through a thickness of 2 or 3 mm. of material.

The same quality of semi-transparency is seen in some of the green varieties, notably those from New Zealand, which the Maoris have picturesquely likened to "a clear stream on whose bottom green moss and grasses luxuriate."

Such semi-transparent or highly translucent specimens are termed *Precious nephrite*, but their quality never equals that of the emerald-green jadeites. Many of the more massive pieces of worked nephrite appear opaque because of their thickness only, the edges or thin fragments always showing a pronounced translucency.

LUSTRE.

The lustre of both jadeite and nephrite on fresh fractures is dull and wax-like, with very few reflecting surfaces. Polished jadeite has ordinarily a vitreous lustre, while nephrite when polished frequently exhibits an oily lustre as if it had been rubbed with oil. This oily appearance is highly characteristic of many of the green nephrites.

OPALESCENCE.

Opalescence, lacking however the play of color, is sometimes to be observed on polished specimens of both jadeite and nephrite. It may be likened to the light effect obtained when some finely veined, naturally colored, translucent, oriental chalcedonies are viewed by transmitted light. An admirable example illustrating this property is the framed jadeite screen No. 13192I. The specimen is a mixture of large irregular patches of a white and a lavender-tinted material through which are long irregular veinings of rich, translucent sea-green, in part almost opaque when quite thick. By reflected light a large part of the surface exhibits a pinkish-lavender opalescence, which is remarkably pleasing and beautiful.

SHEEN.

It is characteristic of many minerals, such as crocidolite, chrysotile, and satin-spar (fibrous gypsum), which have a parallel-fibrous structure, that on polished surfaces the light is reflected with a peculiar lustre comparable to the sheen of raw silk. It results from a distortion of the light-figure reflected from the uneven surface of the individual fibre. When such substances are cut with a domed surface—*en cabachon*, as it is called—the reflection takes the form of a band or streak of light which changes its position as the stone is moved. Nephrite, owing to its fibrous structure, sometimes exhibits such a sheen, occasionally so strongly as to suggest the possibility of obtaining by proper cutting a jade cat's-eye. In rare instances where the fibres are twisted and curved into approximately circular forms an effect like that termed asterism by jewellers is produced.

Numerous examples of this quality of sheen are contained in the Bishop Collection. A typical example of sheen is No. 13248, a nephrite hatchet found among the remains of the ancient pile-dwellings at Neufchâtel. In this beautiful gray shimmering sheen is seen on both faces, evidently caused by the reflection of the light from the many minute lamellæ or folia of which the piece is made up. The crude nephrite hatchet No. 13221, from Neufchâtel has one black weathered surface, but the reverse has a remarkably brilliant sheen apparently due to minute fractures nearly parallel to its surface. Perhaps the most beautiful example in the Collection illustrating the sheen is No. 13102B, the nephrite celt from the North Island, New Zealand. By reflected light it shows a silky structure. The material is as finely fibrous in one direction as a compact New Zealand actinolite. It exhibits a sheen and a chatoyancy comparable to that of a greenish chrysoberyl cat's-eye if cut into a gem of similar form. No. 13231, the lake-dwellers' chisel from Neufchâtel, exhibits a brown pearly sheen by reflected light, while the knife from the same locality, No. 13223, has a peculiar green sheen. A beautiful satiny sheen in large patches due to the reflection of light from the large fibres may be seen in the five wine-cups Nos. 13257, 13258, and 13244 A, B, C.

Peculiar internal reflections due to other causes are found in both jadeite and nephrite. In the sinewy or horn-like varieties of nephrite the parting planes which traverse the mineral in various directions often cause an almost white, a golden, or a yellow reflection. The same effect is produced where the mineral has been bruised by pounding with a stone or other blunt instrument, the fracture surfaces, which are generally round in shape, giving dull reflections.

Again, inclusions of foreign minerals such as the very common black cystals of chromite or mica scales are the cause of characteristic internal reflections.

CRYSTALLINE SYSTEM AND OPTICAL PROPERTIES.

Jadeite, by Professor S. L. Penfield.

Except for the information gained by the study of thin sections under the microscope, our knowledge of the crystalline character of jade has up to the present time been limited, as distinct crystals have not been available for study. The angle of the prismatic cleavage has been given by Des Cloizeaux * as 85°20′, by Krenner † as 86°55′ and by Arzruni ‡ as 86°56′ to 87°20′ (Note). Thanks to the careful observations of Mr. George F. Kunz, attention has been called to a specimen of jadeite from Tibet (No. 13323 of the Collection), which in places possesses a somewhat coarser crystalline structure than the mineral usually exhibits. On breaking up some of this material two crystals were found, from which the data necessary for the deter-

* Bulletin de la Société Minéralogique de France, Vol. 4, p. 158, 1881.

† Flugblatt, April, 1883.

‡ Zeitschrift für Ethnologie, Vol. 15, p.186, 1883.

Note: For a full list of observations of this angle see the table annexed to this chapter.

mination of the exact crystalline character of the mineral could be determined. The crystals were prisms measuring about 2 mm. in length and 0.5 mm. in diameter, and the isolated ones were terminated only at one end by crystal faces. They were colorless and had a vitreous lustre. They belong to the monoclinic system of crystallization, and their habit is represented by Figs. 1 and 2. The forms that were observed are similar to those which occur on pyroxene and ægerite, and are as follows: The orthopinacoid *a* (100), two prisms *m* (110) and *n* (130), with two faces of the monoclinic pyramid *s* ($\bar{1}11$) forming the termination.

Considering the small size of the crystals, the reflections

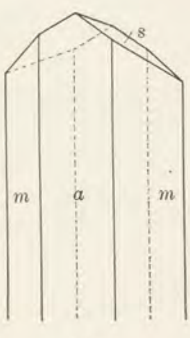


Fig. 1

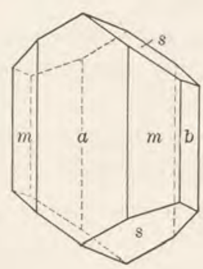


Fig. 2

from their faces were good, and the axial ratio may be considered therefore as very nearly exact. The following axial ratio was derived from the measurements marked in the accompanying table by an asterisk. For the sake of comparison there are also given the axial ratios of the closely related minerals of the pyroxene group. Ægerite from the nepheline syenite of southern Norway by Brögger.* Pyroxene (variety augite) from Vesuvius by von Rath †. Spodumene from Norwich, Mass., by J. D. Dana ‡.

* Zeitschrift für Mineralogie und Krystallographie, XVI., p. 318, 1889.

† Poggendorf's Annalen, Erganzungs, Band 6, p. 340, 1873.

‡ Mineralogy, Sixth edition, p. 366.

	a		*b*		*c*	$\beta = 100 \wedge 001$
Jadeite	1.103	:	1	:	0.613	72°44½′
Ægerite	1.097	:	1	:	0.601	73° 9′
Pyroxene	1.092	:	1	:	0.589	74°10′
Spodumene	1.124	:	1	:	0.635	69°40′

The measurements that were made are as follows :

	Measured	Calculated
$a \wedge m$,	$100 \wedge 110 = 46°29'$ *	
$m \wedge m$,	$110 \wedge 1\bar{1}0 = 92°38'–93°10'$	92°58′
$m \wedge m$,	$110 \wedge \bar{1}10 = 86°51'–87°13'$	87° 2′
$a \wedge n$,	$100 \wedge 130 = 72°25'$	72°26′
$n \wedge n$,	$130 \wedge \bar{1}30 = 34°43'$	35° 8′
$n \wedge n$,	$130 \wedge 1\bar{3}0 = 145°26'$	144°52′
$s \wedge s$,	$\bar{1}11 \wedge \bar{1}\bar{1}1 = 61°12'$ *–61° 5′	61°12′
$a \wedge s$,	$100 \wedge \bar{1}11 = 76°56'–77°10'$	76°59′
$m \wedge s$,	$\bar{1}10 \wedge \bar{1}11 = 58°23'$ *–58°13′	58°23′
$m \wedge s$,	$\bar{1}\bar{1}0 \wedge \bar{1}11 = 102°37'–102°10'$	102°21½′

The close crystallographic relationship between jadeite, ægerite, and pyroxene is shown not only by the similarity in their axial ratios, but also by the fact that their crystals have almost the same habit. A common development of the ægerite crystals from Norway is exactly like Fig. 1,

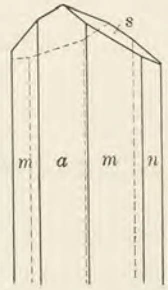


Fig. 3

and Fig. 3 represents the ordinary habit of augite (pyroxene) crystals.

The optical properties of the crystals correspond to monoclinic symmetry. A crystal lying on its pinacoid face *a* (100) shows an extinction parallel to its prismatic edges when examined under the microscope in polarized light. In convergent light one of the axes of a biaxial interference figure may be seen rather near the limit of field. The plane of the optical axes is the clinopinacoid (010). When supported, with the symmetry plane horizontal, in a liquid of high index of refraction, the extinction angle was found to be 34° from the vertical axis in the obtuse angle β.* The divergence of the optical axis 2V was found to be approximately 70°. This was determined by supporting a short section of a crystal in oil by means of the device described by Professor C. Klein †, and turning until the optical axes came into the centre of the field. The direction of one of the optical axes coincides almost exactly with the vertical axis.

Twinning has been observed by Max Bauer ‡ in jadeite from Tammaw in Upper Burma. It follows one of the usual twin laws of pyroxene, twinning plane the basal pinacoid, and is repeated in thin lamellæ, producing what are known as polysynthetic twins similar to those common in plagioclase feldspar. Twinned prisms were frequently found bent throughout and fringed at the ends. It appears that the twins were most numerous in the portions that had suffered the greatest crushing, and were absent where the effects of pressure were not well marked. We must conclude, therefore, that under favorable conditions crushing and pressure would produce in the jadeite a rearrangement of the molecules into twins similar to that observed in calcite. This, however, must have happened only in rare cases, for it has not hitherto been observed.

Nephrite, by Dr. Charles Palache.

All mineralogists agree in classifying nephrite as a variety of the monoclinic amphibole *actinolite*, whose chemical, and, in general, physical properties as well, it possesses. The distinction of nephrite as a variety is based on its structure alone, it being characterized by a very fine

* For other observations of this angle see the table given below.

† Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, Vol. 24, p. 435, 1891.

‡ Jahrbuch für Mineralogie, 1896, Vol. 1, p. 21.

fibrous texture, the fibres being generally so curved and interwoven as to render it exceedingly tough. The extreme fineness of the fibres makes it difficult, even with high magnification in thin section, to obtain satisfactory observations of the cleavage, and the same cause, together with the frequently curved character of the fibres, makes the extinction angles somewhat uncertain. Most of the observations in the annexed table to which any degree of reliability may be attached were made upon larger isolated crystals of actinolite embedded in the nephrite substance.

The angles given by the principal text-books for actinolite, and therefore to be accepted for nephrite, are as follows:

1.—E. S. Dana, System of Mineralogy, 1892, p. 389.
2.—Hintze, Handbuch der Mineralogie, 1894, p. 1186 ff.
3.—Levy et Lacroix, Les Minéraux des Roches, 1886, p. 144.

	Prism (cleavage) angle.	Angle of extinction to cleavage in clinopinacoid section.
1.—	55°49′	15°
2.—	55°49′	16°-18°30′
3.—	55°49′	15°

Dana considers that some nephrite may belong to the amphibole *tremolite*, the extinction angle of which is 16°-18°.

The cleavage angle and optical properties, expecially the extinction angle in sections parallel to the clinopinacoid, of jadeite and nephrite, are the most important properties for their determination in microscopic sections. The first of the two tables which follow contains all the observations of these two values given by various authors in the large literature of "Jade," and the second contains a record of the extinction angles measured by Mr. R. D. George from the micro-sections made from specimens in the Bishop collection and studied by Professor J. P. Iddings.

The measurements given in Table I. of both cleavage and extinction vary widely in their reliability. Observations made in thin sections of minerals are liable to an error, which cannot be checked, due to imperfect orientation of the section to the direction desired. This error is to a certain extent eliminated if a large number of observations of different crystals in the section is taken ; but in many of the observations quoted there is no satisfactory evidence that care in this direction has been taken.

The observations are arranged in the table in order of the date of publication, the jadeites being grouped separately from the nephrites. The angle given under the heading of "extinction" is, in all cases where not otherwise stated, the angle of extinction against the trace of the cleavage in sections parallel to the clinopinacoid. In Table II. the specimens are grouped, first as jadeites and nephrites, and then according to locality, with descending size of the extinction angle.

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES.

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
1	Jadeite	Probably Asiatic	?	H. Fischer		20°–34°	Zeitschrift für Krystallographie, 1880, iv., p. 371	Monoclinic. First determination of crystal system
2	Jadeite	Tibet ?	Raw material. Cleavage measured on isolated fibres	Des Cloizeaux	85°20′	31°–32°	Bulletin Société Minéralogique de France, 1881, p. 158	Monoclinic (or triclinic ?) Also poor cleavage parallel to clinopinacoid
3	Jadeite	Rabber, Hanover	Axe ; private ownership	A. Arzruni	86–89°25′	On basal section angles of 35° and 54° to the two cleavages	Zeitschrift für Ethnologie, Berlin, 1881, p. 281	Triclinic because cleavages were not equal and extinction unsymmetrical
4	Jadeite ?	Unteruhldingen, Switzerland	Axe — material mixed with quartz and not certainly jadeite	A. Arzruni	82° about	36°	Zeitschrift für Ethnologie, Berlin, 1882, xiv., p. 566	
5	Jadeite	Upper Burma	Raw material	Krenner	86°55′	33°34′	"Flugblatt," 9 April, 1883, Abstract Jahrbuch für Mineralogie 1883, ii., p. 173	Monoclinic

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES—(*Continued*).

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
6	Jadeite	Lüscherz	Material not homogeneous	A. Arzruni	87°–89°	38°5′	Zeitschrift für Ethnologie, Berlin, 1883, xv., p. 186	
7	Jadeite	Orient	Measurements made on isolated fibres with goniometer	A. Arzruni	85°56′	33°–40°	Zeitschrift für Ethnologie, Berlin, 1883, xv., 186	Cleavages unequal. Triclinic ?
8	Jadeite	Mogoung, Upper Burma	Raw material original of Damour's analysis. Cleavage measured on fibres with goniometer	A. Arzruni	86°56′–87°20′	35° (average) 41° (highest) On basal section, angles of 34° and 48° to the two cleavages	" " "	Triclinic. Cleavages unequal and extinction unsymmetrical in basal section
9	Jadeite	Mexico	Average of many specimens	A. Arzruni	85°30′	32°–35° On basal section 35° and 50° to the two cleavages	" " "	" "
10	Jadeite ?	Burma	Called amphibole paramorph after jadeite on account of cleavage	A. Arzruni	55°30′		" " "	Cleavage probably measured between prism and pinacoid, hence discordant result (about half)

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES—(*Continued*).

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
11	Jadeite	Neuenberger Lake, Switzerland	Axe	A. Arzruni	" Pyroxene cleavage "	18°30′–30°30′	" Antiqua," Zürich, 1884	
12	Jadeite	" " "	Raw material	A. Arzruni	" "	On basal section 24°30′ and 64° 30′ to the two cleavages	" "	Triclinic on same grounds as above
13	Jadeite	Central Italy	Axe ?	A. Arzruni	86°	34°	Zeitschrift für Ethnologie, Berlin, 1884, xvi., 358	
14	Jadeite	Tibet	Raw material	M. Cohen	" Almost rectangular "	41° maximum	Jahrbuch für Mineralogie, 1884, i., p. 71	Monoclinic
15	Jadeite	Mogoung, Burma	Raw material in Freiburg Museum	Schoetensack	87°	35°	Zeitschrift für Ethnologie, Berlin, 1885, xvii., 162	
16	Jadeite	" Little Tibet " ?	" " "	"	Pyroxene cleavage	43°	" " "	
17	Jadeite	Hissarlik	Fragment worked	A. Arzruni		28°–35°	Zeitschrift für Ethnologie, Berlin, 1886, xviii., 136	

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES—(*Continued*).

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
18	Jadeite	Oaxaca, Mexico	Bead in National Museum, Washington	Clarke and Merrill	"Nearly at right angles"	35°–40°	Proceedings of U. S. National Museum, 1888, p. 115	Monoclinic
19	Jadeite	Zaachita, Mexico	" " "	" "	Pyroxene cleavage		" " "	"
20	Jadeite	Sardinal, Costa Rica	Fragment " "	" "	" "	35°–40°	" " "	"
21	Jadeite	Barencamp, near Wesel, Germany	Axe owned in Dresden	Lossen for A. B. Meyer	87° about	40°–43°	Abhandlungen und Berichte der königlichen und ethnologischen Museum zu Dresden, 1890–91, No. 1	
22	Jadeite	Schafhausen, near Aachen, Germany	Axe in City Museum of Aachen	Arzruni for A. B. Meyer	"Nearly at right angles"	40° maximum	" " "	
23	Jadeite	Stotsheim, Alsace	Axe in Dresden Museum	" "	" "	40° maximum	" " "	"Altogether like the axe from Schafhausen"

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES—(*Continued*).

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
24	Jadeite	Tammaw, Burma	Raw material	Max Bauer	"Augite cleavage"	40° maximum	Jahrbuch für Mineralogie, 1896, i., p. 21	Monoclinic because cleavages are equal and extinction in basal section symmetrical to the cleavages
25	Nephrite	Irkutsk, Siberia	Raw material	Jannetaz and Michel		11° about	Bulletin de la Société Minéralogique de France, 1881, iv., 178	Measured on isolated fibres
26	Nephrite	Murthal, Steiermark	Raw material	A. Arzruni / Berwerth		12° / 17°	Mittheilungen der Anthropologischen Gesellschaft zu Wien, 1883, vol. xii., 217	
27	Nephrite	Potsdam, Germany	Glacial boulder ?	A. Arzruni	52°–56½°	15°–17°	Zeitschrift für Ethnologie, Berlin, 1883, xv., 180	Measured on larger crystals embedded in fibrous aggregate
28	Nephrite	Eslohe, Germany	" "	A. Arzruni	60° about	up to 14°50′	" " "	" "

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES—(*Continued*).

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
29	Nephrite	"Dresdener Apotheke" probably Asiatic (Meyer)	Raw material	A. Arzruni		13°15′–18°	" " "	Nephrite derived by alteration of a pyroxene (?)
30	Nephrite	"Turkei," Leipzig ? probably same as last (Meyer)	Raw material	A. Arzruni	$44\frac{1}{2}$°	10°30′	" " "	Measured section oblique and angles therefore too small
31	Nephrite	Bjelaja River, Siberia	Raw material	A. Arzruni	51°–$55\frac{1}{4}$°		Zeitschrift für Ethnologie, Berlin, 1883, xv, 180	Larger crystals in slide
32	Nephrite	New Caledonia	?	A. Arzruni		17°30′ about	" " "	
33	Nephrite	Alaska	Axe in Bremen Museum	Arzuni for A. B. Meyer		"Nearly parallel"	21st Jahresberichte der Vereins für Erdkunde, Dresden, 1884	
34	Nephrite	Jordansmühl in Silesia	Raw material	H. Traube	55°–57°	12°–16°	Jahrbuch für Mineralogie. Beilage Band iii., 1884, p. 420	Crystal boundaries as well as cleavage seen in section

I.—TABLE OF CLEAVAGE AND EXTINCTION ANGLES—(*Continued*).

No.	Material	Locality	Character of Material	Observer	Angle of Cleavage	Angle of Extinction	Reference	Remarks
35	Nephrite	Manas (Dsungarei)	Worked material in Freiburg Museum	Schoetensack		12°–16°	Zeitschrift für Ethnologie, Berlin, 1885, xvii., 157	
36	Nephrite	Khoten, Bucharei	Worked (?) material in Freiburg Museum	"		16°	" " "	
37	Nephrite	Kowak River, Alaska	Raw material in U. S. National Museum, Washington	Clarke and Merrill		0°–15°	Proceedings U. S. National Museum, 1888, p. 115	
38	Nephrite	New Zealand	" " "	" "		0°–20°	" " "	
39	Nephrite	Ak-Deniz, N. Syria	Axe in Dresden (?) Museum	Arzruni for A. B. Meyer		17° about	Abhandlungen und Berichte der königliche zoologischen und ethnologischen Museum zu Dresden, 1890–91, No. 1	One crystal showed an extinction of 41½°
40	Nephrite	Schahidulla-Chodja, Kuen Lun Mts.	Raw material	A. Arzruni		"Practically parallel"	Zeitschrift für Ethnologie, Berlin, 1892, p. 23	Fine fibrous ground mass.
					56°	11°–16°	" " "	Crystals embedded in above

II.—TABLE OF EXTINCTION ANGLES.

Number	Material	Locality	Description	Specific Gravity	Highest Angle of Extinction	Remarks
13206B	Jadeite	China	Medallion	3.3303	43°45′	
13255	Jadeite	China	Plate	3.3373	43°10′	
13195	Jadeite	China	Dish	3.3381	42°10′	
13243	Jadeite	China	Fragment of Pendant	3.3287	41°35′	
3126	Jadeite	China	Vase	3.3328	40°30′	
3016	Jadeite	China	Sceptre	3.2657	41°00′	
13323	Jadeite	Tibet	Crude Jade	3.3359	40°10′	
3248	Jadeite	China	Bowl	3.3394	40°00′	
3127	Jadeite	China	Vase	3.3316	36°30′	
13180	Jadeite ?	Burma	Crude fragment	3.2991	42°30′	Probably jadeite, but partial analysis shows high percentage of iron replacing alumina
13102C	Jadeite	Burma	Crude jade	3.2578	41°00′	
13267	Jadeite	Burma	Boulder fragment	3.1223	40°35′	Chemical analysis shows mixture of about half jadeite with other silicates. Extinction angles probably belong to jadeite
13215	Jadeite	Burma	Boulder fragment	3.2175	40°30′	

II.—TABLE OF EXTINCTION ANGLES.

Number	Material	Locality	Description	Specific Gravity	Highest Angle of Extinction	Remarks
13192D	Jadeite	Burma	Fragment	3.3309	40°30′	
13336	Jadeite	Burma	Boulder fragment	3.3122	35°15	
13242	Jadeite	Mexico	Celt	3.3034	42°00′	
13193	Jadeite ?	Mexico	Mask	2.8320	41°00′	Chemical analysis shows jadeite mixed with equal parts of albite feldspar
13241	Jadeite	Switzerland	Chisel	3.3832	36°50′	
13249	Jadeite	Switzerland	Hatchet	3.3745	34°10′	Readings approximate because of fine granular form
3131	Nephrite and Jadeite	China	Tomb jade	2.9587	43°00′	Extinction angles probably read on few jadeite crystals embedded in nephrite mass
13214	Nephrite and Jadeite	China	Boulder fragment	2.9825	40°30′	All but two readings of extinction angles above 18°10′ and probably made on jadeite crystals embedded in nephrite
3148	Nephrite and Jadeite	China	Sculptured rock-mass	2.9549		Readings fall into two groups : 00°00′–15°40′......Nephrite ? 21°25′– 40°30′......Jadeite ?
13205	Nephrite and Jadeite	China	Thumb-ring	2.9896	39°15′	High extinction angle probably observed on small amount of jadeite shown to be present by analysis

II.—TABLE OF EXTINCTION ANGLES.

Number	Material	Locality	Description	Specific Gravity	Highest Angle of Extinction	Remarks
13275	Nephrite	China	Vase	2.9552	34°10′	High extinction angle may have been observed on small amount of jadeite which may be present
13200.	Nephrite	China	Part of a Kwei	2.9430	18°10′	One reading gave 26°45′, probably obtained from jadeite shown by analysis to be present in small amount
13131	Nephrite	China	Worked jade	2.9630	18°30′	One reading gave 25°00′, probably obtained from jadeite which might be present in small amount
13266	Nephrite	China	Carved Celt	2.9506	18°15′	One reading gave 24°25′, probably obtained from jadeite shown by analysis to be present in small amount
13192H	Nephrite	China	Medallion	2.9706	16°30′	One reading gave 24°00′, probably obtained from jadeite shown by analysis to be present in small amount
13262R	Nephrite	China	Medallion	2.9520	13°00′	One reading gave 22°00′, probably obtained from jadeite shown by analysis to be present in small amount
13008	Nephrite	China	Dish	2.9564	16°00′	One reading gave 20°00′, probably obtained from jadeite shown by analysis to be present in considerable amount (14%)

II.—TABLE OF EXTINCTION ANGLES.

Number	Material	Locality	Description	Specific Gravity	Highest Angle of Extinction	Remarks
3246	Nephrite	China	Wine-jug	2.9243	18°20′	
3242	Nephrite	China	Tomb jade	2.9629	17°00′	Large part parallel. Measurements from coarser scattered fibres
13026	Nephrite	China	Worked jade	2.9574	17°00′	In this section many fibres with extinction of 12°00′–15°00′+
13095	Nephrite	China	Dish	2.9758	16°30′	Large part parallel
13268	Nephrite	China	Boulder fragment	2.9690	16°30′	Large part parallel
3156	Nephrite	China	Vase	2.9539	16°00′	Large part parallel
3136	Nephrite	China	Screen-picture	2.9609	15°00′	
13203	Nephrite	China	Tomb jade	2.9309	14°00′	
12262E	Nephrite	China	Medallion	2.9546	13°00′	Large part parallel
3119	Nephrite	China	Wine-cup	2.9497	6°00′	Readings approximate
13212	Nephrite	Turkestan	Boulder fragment	3.0033	15°00′	Large part parallel
3125	Nephrite	India	Sword-guard	3.0783	15°00′	Large part parallel
13128	Nephrite	India	Worked piece	2.9951	11°00′	

II.—TABLE OF EXTINCTION ANGLES.

Number	Material	Locality	Description	Specific Gravity	Highest Angle of Extinction	Remarks
13207	Nephrite	Siberia ?	Implement	2.9673	16°00′	
13211	Nephrite	Siberia	Unworked boulder	3.0138	15°30′	
13246	Nephrite	Siberia	Slab from boulder	3.0070	14°00′	Large part apparently parallel; measurements uncertain owing to curved fibres
13217	Nephrite	Siberia ?	Hatchet	3.0076	11°00′	Large part parallel; readings approximate only
13218	Nephrite	Siberia ?	Chisel	3.0150	00°00′	Apparently all parallel; extinctions not sharp
13233	Nephrite	Switzerland	Hatchet	3.0118	14°00′	Largely parallel
13251	Nephrite	Switzerland	Hatchet	2.9035	13°00′	Mainly parallel
13250	Nephrite	Switzerland	Hatchet	3.0037	8°00′	Measurements approximate
13223	Nephrite	Switzerland	Hatchet	3.0034	00°00′	Extinction is parallel with the fibres
13248	Nephrite	Switzerland	Hatchet	2.9836	00°00′	Apparently parallel, but impossible to make good measurements
13210	Nephrite	Jordansmühl	Unworked fragment	2.9451	15°30′	
13122	Nephrite	Brit. Colum.	Knife	2.9987	12°00′	Large part parallel

II.—TABLE OF EXTINCTION ANGLES.

Number	Material	Locality	Description	Specific Gravity	Highest Angle of Extinction	Remarks
13334	Nephrite	Alaska	Crude fragment	2.9487	00°00′	Measureable fibres all parallel
13335	Nephrite	Alaska	Crude fragment	2.9604	?	Section too thick and too finely fibrous to afford readings of any value
13118	Nephrite	New Zealand	Slab	3.0103	15°00′	A good deal is parallel
13088	Nephrite	New Zealand	Boulder fragment	3.0000	15°00′	Finer fibres mainly parallel
13030	Nephrite	New Zealand	Unworked fragment	3.0122	15°00′	Readings approximate
13216	Nephrite	New Caledonia	Hatchet	2.9311	13°00′	Large part parallel ; measurements uncertain owing to curving of fibres
13086	*Diopside*	New Zealand	Adze	3.2663	3°00′	Large part parallel ; readings uncertain. Extinction low for diopside, which was determined by analysis
13005	?	Switzerland	Axe	3.0919		Angles 16°20′–26°00′. By analysis this specimen is composed of nephrite, jadeite, acmite, zoisite, and quartz, and it is not possible to say to which of these minerals the extinction angles appertain

STRUCTURE.

Reference has already been made to the fact that both jadeite and nephrite are known only as massive aggregates of crystalline particles and never as complete crystal individuals. The structure of these aggregates varies considerably, and presents some characters which are peculiar to one or the other mineral ; but in far the greater number of cases the grain of the mass is too fine to permit of the recognition of the character of the individuals composing it by the unaided eye or even with the assistance of a lens. In such cases it is necessary to have recourse to the microscope, studying the structure in thin section. The paper by Professor Iddings on the Microscopical Petrography of Jade, which follows, treats in full of the characters thus observed which are among the most important means of distinguishing between the jade minerals, and throw a flood of light on the origin and history of both jadeite and nephrite.

The macroscopic structural features are of less fundamental importance and may be dismissed with a much briefer treatment.

Jadeite.—The structure of jadeite is either granular or fibrous, the former being the more characteristic. It may be studied to the best advantage in such thin, translucent, highly polished objects as the bowls, cups, and plates which are so abundantly represented in the Bishop Collection. On holding such a specimen against a light each crystal composing it stands out from its neighbors quite sharply owing to the fact that the light strikes the surface and cleavages of each one at a different angle, giving each a slightly different appearance. Thus examined, we see that the individual grains are sometimes of prismatic shape, that is, with one diameter much longer than the others ; sometimes equidimensional, with diameters up to 3 mm. in exceptional cases such as No. 13206B.

Generally the grains interlock at their edges, the boundary between any two being jagged and irregular in the extreme. In very rare cases, however, as in No. 13323, already referred to in the paper by Penfield, the individual grains of jadeite do not come into immediate contact, but each has developed its own crystal boundaries, and the complete crystals are cemented by a small amount of an undetermined interstitial mineral.

In those specimens in which the grains are prismatic the prisms are more or less interwoven and often curved; when the prismatic development is so pronounced that the individuals become fibrous the structure is best described as felted, since the fibres intermingle in the most confused manner; at the same time the grain becomes finer, so that the eye cannot readily separate the particles.

In the granular jadeites the grain varies even in parts of the same specimen from the coarsest to the finest, patches of large granules often occurring like "eyes" in a fine-grained mass.

A rather fine granular structure of very uniform character is the ordinary and typical structure for jadeite; distinctly fibrous specimens in which the grain is coarse enough to be distinguished even with the lens being so rare as to be noteworthy. The beads which form the string numbered 3095 show this latter character well.

Nephrite.—The structure of nephrite is characteristically fibrous and of such fine grain that the individual fibres are but rarely visible except under the microscope. The fibres are arranged in the aggregate in many ways: parallel to one another over considerable areas, tufted or in fan-shaped groups, or curved, twisted, interlocked, and felted in most intricate fashion. But all these arrangements of fibres are visible under the microscope only, and the coarser visible structures are due to groups of fibres although dependent largely for their origin on the intimate internal structure.

The visible structures are of several distinct types. A marked bedded or slaty structure results from the parallelism of the fibres in distinct layers, adjacent layers having a different direction of the fibres. As a consequence of this structure the mass can be cut more easily along the plane of the "bedding" than across it, and it is a noticeable fact that in art objects the artist generally arranges his designs so that the principal cutting will be across this bedding, thus making the object stronger and more enduring; and in the making of cylinders and vases from which a central core is to be removed by the use of a cylindrical drill, the core can be more readily broken out or detached from the mass. The same is true of the prehistoric workman, many of the objects left by him showing that the flat sides are parallel with the bedding of the material because the fashioning of the celt or other object was not only more easily done in this way, but the workman was surer of success in the operation.

A sinewy or hornlike appearance is extremely common and characteristic in nephrite, being visible on both rough and polished surfaces. It seems to be due to the grouping of fibres in tufted or fan-shaped bundles, sometimes of considerable size and separated from one another by indistinct parting surfaces which are often curved into irregular forms.

An apparent granular structure in some nephrites is shown to be due generally to the alteration of original jadeite to nephrite, each relatively larger granule of jadeite becoming a mass of interwoven fibres which retains some of its individuality. The great significance of this alteration is fully treated in the following section on the microstructure of jade.

A peculiar type of nephrite which markedly differs from the normal in its appearance is that termed by collectors *Puddingstone Jade.* By transmitted light specimens of this variety show nodular areas varying from the size of a pin up to two inches across of a golden-yellow nephrite cemented together by a dark olive-green variety of the same mineral which occasionally has brighter grass-green streaks. This apparent nodular structure is evidently due simply to color differences, the result probably of alterations in the state of oxidation of the iron in the mineral, progressing from numerous isolated centres. While therefore not strictly a structural modification of nephrite, the variety is so distinct as to be held worthy of more than passing notice. The specimens in this Collection which illustrate this peculiar feature are Nos. 3059, 3060, 3173, 3238, and 3034.

The compact texture and the extraordinary toughness of both jadeite and nephrite are clearly due directly to the character of their structure, the intimate intergrowth of their constituent particles, whether fibrous or granular, producing a similar result in these respects. But the fibrous nature of the nephrite substance gives it properties of cohesion altogether superior to those of jadeite, as will be shown in a later chapter of this work.

MICROSCOPICAL PETROGRAPHY OF JADE.

BY JOSEPH P. IDDINGS.

The microscopical study of the jade in the Bishop Collection was made upon 170 thin sections, which were prepared from pieces sawn from the jade objects, and represent 93 different specimens. Of these, 23 are jadeite, and the remainder nephrite; a number consisting of both minerals. The microscopical investigation was undertaken as a purely petrographical study, without reference to ethnological theories, and without knowledge as to the localities from which the specimens were collected. The results are, therefore, independent of any preconceived ideas regarding the source of the material. With the exception of a specimen of jadeite containing microscopic garnets, from Lake Neufchâtel, all the specimens examined are so related petrographically that they might have been parts of one and the same mass of rock. Nevertheless, it must not be forgotten that rocks which are identical mineralogically and chemically occur in widely distant parts of the earth.

The pure jadeite specimens consist of precisely similar pale-green pyroxene, which is almost colorless in thin section. The slight variations in size of grain are only such as often occur in different parts of one rock mass.

The coarser-grained forms that are microscopically alike are from China (3248, 13192D, 13206B); and from Burma (13102C and possibly 13215). While another form from Burma (13180) and one from Mexico (13242) differ only slightly from these. Other jadeites from China and Burma are identical with one another and are somewhat finer-grained (3126, 3127, 3095, 13195, 13243, 13255, 13364, 13365, 13368, 13373).

A review of the specimens of nephrite shows that those varieties exhibiting most clearly the metamorphism of jadeite into nephrite come from China. Microscopically identical nephrites, consisting of confused aggregations of amphibole fibres, having a faint suggestion of the patches derived from previous jadeite come from British Columbia (13207), Lake Constance (13251), China (3119, 13007C, 13007G, 13262E), New Zealand (13088), British Columbia or Alaska (13122), and China or possibly from India (13095). Nephrites that are microscopically alike in being composed of parallel fibres, that are sometimes curved, are from Siberia (13218), New Zealand (13118, 13030), India (13128), and Lake Neufchâtel (13233, 13248). Another group that have like microscopical structure includes specimens from New Caledonia (13216), Siberia (13246), Irkutsk, Siberia (13211), India (3123, 13095), and China (3242).

From these examples it is evident that varieties of jade from widely distant parts of the earth, when studied in thin sections, are in some cases identical, even in the most microscopic detail. But it is to be remarked that the pronounced differences in shades of color that characterize different specimens of jade when studied in mass, disappear almost completely when the jade is cut into sections 0.001 of an inch in thickness. When the color is intense in the mass it may be recognized as slight coloring of the almost colorless minerals. But less-pronounced variations of color are not distinguished in the thin sections.

It is also to be noted that jade from some countries varies in its composition and microstructure from jadeite to fibrous nephrite; similar variations occurring in different countries.

The following is the systematic description of the thin sections studied microscopically. They are arranged without regard to locality, but according to their mineralogical composition and microstructure. The jadeites are described first, and then the transitional modifications that demonstrate the metamorphism of the jadeite into nephrite. Then the more and more fibrous varieties of nephrite. Owing to the microscopical identity of some of the specimens, certain of them are classed together and described at one time.

The photomicrographs which illustrate this part of the work were taken with oxyhydrogen zircon light on orthochromatic plates, using a yellow screen. They nearly all represent the appearance of the thin sections of jade as seen in plane polarized light between crossed nicols, and have a magnification of 60 diameters.

No. 13215. The sections which exhibit most plainly the true character of the pyroxene mineral or jadeite are those made from 13215. The thin section, .022 mm. thick, is transparent in part, and partly greenish white. Under the microscope the rock is seen to consist of an aggregation of irregularly shaped crystals of nearly colorless pyroxene with many cracks. The cracks follow the outlines of the crystals, the prismatic cleavage, and a transverse parting, probably basal. In places the pyroxene crystals become long prisms, and lie at all angles in the section ; sometimes being grouped in fan-like aggregates or bundles. In several places they lie embedded in a colorless mineral, which acts as a matrix for the pyroxene crystals. In these places they have sharply defined crystal forms. The long prisms are well developed in the prismatic zone, and have the orthopinacoid (100) and unit prisms (110); and sometimes the clinopinacoid (010) less pronounced. Thus they are sometimes flattened parallel to the orthopinacoid. Terminal planes were not observed. Cross-sections exhibit distinct prismatic cleavage. The form of the crystals is similar to that of ægerite, from which this pyroxene differs by being colorless in thin sections. Cross-sections exhibit the emergence of an optic axis when examined in convergent polarized light. Longitudinal sections yield a maximum angle of extinction of about 35 degrees. Hence the angle between the optic axes is about 70 degrees. Longitudinal sections that have been cut nearly perpendicular to an optic axis exhibit the plane of the optic axes parallel to th. side of the prism, indicating a monosymmetric crystal. One of these crystal sections also exhibits narrow lamellæ, parallel to the sides of the prism, which appear to be the result of twinning, and a transverse parting nearly at right angles to the prism.

These crystals, magnified 60 diameters, are shown in photomicrographs No. 13215a and 13215b in the accompanying Plate A. Several small cross-sections are seen. The matrix appears as a uniformly gray mineral. Photomicrograph No. 13215c in the same plate shows the granular portion of the same rock magnified the same amount. It consists wholly of colorless jadeite, and was photographed in polarized light between crossed nicols. In photomicrograph No. 13215a the nicols were nearly parallel.

The colorless mineral acts as a cement or matrix for the jadeite prisms, and appears to consist of relatively large individuals, not an aggregate of small ones. It has a low index of refraction, and very low double refractory. In places it is twinned in polysynthetic lamellæ, making 90 degrees with one another. The exact nature of this mineral is not determinable by optical means alone. It is possibly analcite; this is further indicated by the chemical analysis.

No. 13206B. The coarsest-grained variety examined is 13206B. It is an aggregate of colorless jadeite crystals that can be seen without the aid of a lens; the largest crystals being 3 mm. long. The size of the crystals varies greatly, from that just mentioned to microscopic dimensions. The large and small crystals are intimately mingled without any definite arrangement, or any suggestion of a porphyritic structure. The sections of some of the large crystals are nearly free from cleavage cracks, while others are crowded with them. The section is about .055 mm. thick, and the polarization colors are brilliant, ranging into yellows and reds of the second order. This indicates a double refraction of about .019. Some of the crystals exhibit a slight undulatory extinction. Cross-sections show that the prismatic cleavage is perfect. The substance of the jadeite is very pure and free from inclusions in most crystals, a few show minute specks that seem to be incipient decomposition, which results in the clouding of the crystals by particles that appear white by incident light. These crystals are not twinned, and there are no other minerals present. The chemical analysis shows that the rock is 98 per cent. pure jadeite.

No. 3248. Another coarse-grained form is represented by the so-called galvanized or frosted specimen, 3248. The crystals are about the size of the largest of that just described (13206B), or 3 mm. in diameter. There are fewer small crystals. Undulatory extinction is a pronounced characteristic. The rock has evidently been subjected to great straining forces. Large cross-sections with prismatic cleavage cracks resolve themselves between crossed nicols into aggregates of jadeite with slightly different optical orientations. They break up into optical "fields" (*Felder erscheinungen*) and may be traversed by several lines indicating distinct ruptures. In some longitudinal sections this same mottling is very pronounced, in others it resembles more closely the curving mottling of bird's-eye maple, so characteristic of all micas. The resemblance is often deceptive, but other characteristics prove the pyroxenic nature of the mineral. There has also been developed a delicate lamination which is plainly due to twinning in thin plates parallel to the orthopinacoid. The striations are sometimes straight, sometimes curved. There seems to be a second twinning inclined to the first, which produces less distinct striations. (This is most likely parallel to the basal plane.) This appears to be connected to some extent with the mottled effect. In places the rock has been crushed and dragged, producing streaks of fine grains and particles of pyroxene, that have the same color, index of refraction, and double refraction as the large crystals. Here the pyroxene has been crushed to powder that has been compacted, and is indistinguishable by the unaided eye from the other parts of the rock, and is scarcely distinguishable from the larger crystals without the use of crossed nicols. The jadeite has been crushed by dynamic forces without having the crystallographic character altered. The rock exhibits a partial dynamic metamorphism without any signs of chemical or mineralogical metamorphism.

In another thin section of this same specimen (3248) the large jadeite crystals exhibit the same mottling between crossed nicols, and twin lamination whose curved forms bear a direct relation to the lines of rupture in the rock, where fine fragments of jadeite, and brilliantly polarizing fibres of the same mineral, form veins through the rock and act as cement between the unbroken larger crystals.

No. 13192D. A rock of almost the same character is 13192D. It consists wholly of irregularly shaped crystals of colorless jadeite, averaging 2 mm. in size, exhibiting undulatory extinction and twinned lamination produced by dynamical stress. There is a small amount of crushed jadeite as cement. An incipient decomposition has clouded the central parts of some crystals to a slight extent. Another thin section of the same specimen exhibits more of the crushed jadeite, and some of the crystal grains are colored light green and are faintly pleochroic between bluish-green and yellowish-green. The color is not related to any change in the interference phenomenon. Some of the larger crystals contain numerous fluid inclusions which are long and narrow and are arranged parallel to the axis of the crystal. Where these inclusions are crowded together there is a clouding similar to that already alluded to, suggesting that these fluid inclusions are secondary.

No. 13180. A slightly different modification of the jadeite aggregate is found in 13180. It consists of large and small irregular crystals of pyroxene, the small ones acting as a kind of cement in some parts of the rock. In other places there is an approach to an orderly arrangement of the crystals in several directions, the somewhat prismatic crystals appearing as though woven together. There are besides acicular microscopic prisms that traverse the rock in several directions; a number of the needles enclosed in one jadeite being parallel to one another. These needles are colorless amphibole or actinolite. They have a lower index of refraction than the pyroxene. Some of the jadeite crystals are colored green as in the specimen just described (13192D).

No. 13102C. Coarsely granular jadeite, apparently all the same mineral. Nothing but jadeite seems to be present.

Nos. 13364, 13365, 13368, 13373. These sections are alike in being very pure jadeite, almost entirely free from inclusions of other material. They consist of irregularly shaped anhedrons of colorless jadeite, varying in size from a diameter of 1 mm. to minute microscopic grains. The grain is not uniform throughout the material, and in No. 13365 there are prismatic forms and a somewhat parallel arrangement of the prisms. Pyroxene prismatic cleavage is pronounced, and extinction angles were measured as high as 32° and 40°. In 13365 the cross section of a microscopic prism shows the presence of the unit prism and orthopinacoid in nearly equal development. The cloudy white color of the specimen is due to microscopic cracks and minute particles whose character is not determinable. In 13368 there is a small amount of green mineral in fine-grained aggregation, somewhat fibrous. It is pleochroic from green to yellow and has a lower refraction than jadeite. It is the same mineral that occurs in No. 13371, which is amphibole, nephrite.

No. 13195 presents a somewhat laminated modification, in which the crystals of jadeite are all quite small, grading to microscopic; the longest crystal being about .8 mm. The lamination is due to the nearly parallel arrangement of some prisms, and to the alternation of layers of coarser and finer grains. The rock is very fresh and pure, without other constituent minerals, and there is little or no sign of decomposition or alteration by dynamic forces. Another section of 13195 shows small aggregates of secondary inclusions as clouding in the centre of some of the crystals.

Nos. 13243 and 13255 are almost identical with the one last described (13195) in size of crystals, and to a less extent in the degree of lamination. There is a slight central clouding in some crystals and a small amount of crushing. They are wholly jadeite without other minerals.

No. 3126 is quite the same as the last specimens in size and aggregation of jadeite crystals, but there are scattered patches with very irregular outline of another mineral. The irregular outline is caused by the projection into this mineral of crystals of jadeite as though into a cavity. In some cases the rare mineral is crowded with minute crystals of jadeite. In each patch the mineral constitutes one individual with one orientation; sometimes two occur together. It is colorless, with much lower refraction than the pyroxene, and with moderate double refraction. The same mineral occurs in other specimens of jadeite rock. Its mineralogical nature was not made out, but it is probably albite.

No. 3127 is quite the same in composition as the last, but the jadeite crystals are more lath-shaped, with jagged outline and somewhat parallel arrangement. In places they are very minute, and carry larger crystals of jadeite, with no optical distortion; that is, without evidence of having been strained. They are clouded at the centre. Parts of the rock show signs of having been crushed and dragged. There is a very small amount of the colorless mineral, which is supposed to be albite.

No. 13336 is a comparatively coarse-grained aggregation of jadeite crystals, the larger of which are 0.6 mm. in diameter. The rock is colorless in thin section, with small spots of clouded material which is grayish-white in incident light. It is almost wholly jadeite, the clouded matter being indeterminable and presumably the beginnings of decomposition. The grains or anhedrons of jadeite are irregular in shape, that is, allotriomorphic, and are of various sizes. In some cases the prismatic cleavage is distinct. Areas that appear as one crystal often prove to be compounded of many individuals when seen between crossed nicols. The variations in grain and the curving of some cleavage lines, the mottling of the larger crystals when viewed between crossed nicols indicating strains and the first stages of granulation, together with the streaked arrangement of the smaller anhedrons, prove that the rock has been subject to forces that have crushed it to some extent. In places there are patches of a colorless mineral with lower index of refraction than that of jadeite, and with the double refraction and polysynthetic twinning of plagioclase feldspar. It acts as a matrix in which small prisms of jadeite lie at all positions, and against which the jadeite is automorphic. It exhibits no signs of alteration, whether of decomposition or of crushing. These facts point to its being of later origin than the dynamic metamorphism of the rock. But the areas of feldspar are so small that the evidence is not conclusive, and they may possibly have been formed when the jadeite crystallized. They certainly formed after the adjacent and enclosed jadeite crystallized. The chemical analysis shows that the mass is slightly higher in silica than if it consisted wholly of pyroxene. And a calculation of the possible mineral constituents based on a knowledge of the presence of feldspar shows that the material analysed probably consisted of

Pure jadeite molecules	86.15 per cent. by weight	
Diopside "	6.17	
$R'''_2 R SiO_6$ "	2.05	
Total jadeite	94.37	94.37
Albite molecules	4.89	
Anorthite "	.56	
Total feldspar	5.45	5.45
	Total .	99.82

The feldspar would have the composition $Ab_9 An_1$; that is, oligoclase-albite. The thin section does not show 5 per cent. of feldspar, but the material analyzed may have done so, since it is not distributed uniformly through the jadeite.

No. 3095. A more fibrous modification of the jadeite is found in 3095, which might almost be mistaken for fibrous amphibole. But some of the more compact crystals are seen in cross-section with pyroxenic prismatic cleavage, and the whole mass is clearly the same kind of mineral, having the same index of refraction. It appears as though rather large compact crystals of jadeite had been changed into groups of nearly parallel prisms of the same mineral. These are bent in various directions and grade into fine grains of jadeite. In this case, as in that of some of the coarse-grained rocks, dynamical action has changed the form of the pyroxene without altering its mineralogical character.

No. 13323 is almost pure jadeite. In thin section the specimen is almost colorless, with a whitish tinge. It is traversed by numerous irregular cracks, as though the rock had been subjected to crushing. There are minute colorless veins crossing the section independent of the cracks. They are made up of larger crystals of the same mineral as the mass of the specimen. The whole is an aggregation of irregularly shaped crystals of jadeite. They do not exhibit crystallographic outlines, and vary in size, the majority being very minute. The substance of the jadeite is colorless and exhibits the usual cleavage and optical properties. There are scattered through it microscopically small opaque specks, usually with irregular outline, whose exact character is indeterminable. They are most probably magnetite. There are also small crystals of a colorless mineral, with index of refraction slightly higher than that of the surrounding jadeite, and having a double refraction about half as great as that of jadeite. Its outline in cross-section is square and eightsided like that of a pyroxene. In longitudinal section it is rectangular, as though bounded by prism and basal plane. It appears to be either a tetragonal or orthorhombic mineral, having the axis of greatest elasticity parallel to the length of the prism. It is so filled with inclusions of jadeite that good interference figures were not obtained, hence its uniaxial or biaxial character could not be determined. It is therefore not possible to state its mineral character. The most probable assumption is that it is andalusite. Its quantity is not large, so that its presence does not materially affect the character of the rock, which is an almost pure jadeite.

No. 13242 is an aggregate of small jadeite crystals with a few larger ones of irregular shape. The mass is streaked with greenish, dark-colored specks, which appear under the microscope as opaque particles crowded together in the larger jadeite crystals as products of alteration. Parts of the jadeite grains are colored pale-green. In places the jadeite crystals are grouped in fan-like aggregates of radiating prisms. Cross-sections of these exhibit the characteristic prismatic cleavage. These crudely spherulitic aggregates occur in bands grading into small-grained layers. There are rather numerous patches of the colorless mineral (? albite), and somewhat lenticular crystals about 0.8 mm. long, and smaller. They are strongly pleochroic with amphibole cleavage. Cross-sections show the orthopinacoid (100) strongly developed, besides the unit prism faces (110). The colors are dark bluish-green to pale yellow. Longitudinal sections were not observed. The colors of this amphibole suggest an impure glaucophane.

No. 13193 consists of irregularly shaped crystals of jadeite scattered through albite, which form interlocking crystals of variable size; some individuals enclosing a number of crystals of jadeite. The substance of albite is very pure and fresh, and exhibits a characteristic cleavage and optical properties. Twinning in polysynthetic lamellæ is developed to only a slight extent. Many crystals are not twinned. Estimating the specific gravity of albite at 2.64, and that of jadeite at 3.34, then to obtain a specific gravity for the rock equal to 2.8278 would require 27 per cent. jadeite and 73 per cent. albite, and the theoretical chemical composition of the whole would be about

SiO_2 . . .	66.37
Al_2O_3 . . .	20.92
Na_2O . . .	12.70
	99.99

It would appear as though both minerals crystallized at one time. Their intimate association is interesting because of their chemical relation, jadeite being a metasilicate of alumina and soda, while albite is a polysilicate of alumina and soda. They might have formed from a mass too rich in silicate to form jadeite wholly, and too poor in silicate for albite to form singly.

No. 3148. This specimen proves very clearly the origin of the fibrous amphibole or nephrite which constitutes the remaining thin sections which were studied microscopically. The same thing is shown by several other specimens, but this one is perhaps the most conclusive. In thin section 3148 is a microcrystalline to microcryptocrystalline aggregation of colorless fibres and flakes or scales, having a confused arrangement, which in places approaches a more definite grouping, in which the fibres lie in several directions. In each of these directions the fibres are approximately parallel and slightly curving, so that streaks or bands of fibres extinguish the light synchronously between crossed nicols. The polarizing colors of these minute fibres are grays of the first order. They grade into thicker and more compact crystals with higher interference colors. These crystals exhibit distinct prismatic amphibole cleavage in cross-section, and are sometimes automorphic in the prism zone.

Through this mass are scattered fragmentary crystals of colorless jadeite, like that forming the rocks just described. It is distinguished from the amphibole by its higher refraction, appearing to rise considerably above the body of the rock. Its double refraction is also higher. Its prismatic cleavage is also characteristic. A lamellar twinning is present, and in places is curved and apparently the result of strain. Bordering and traversing the large jadeite crystals in seams is amphibole, sometimes oriented parallel to the jadeite, sometimes not. The amphibole is compact in some cases and fibrous in others. The transition is into compact amphibole, which frays out into curved fibres at the ends. It is evident that the fibrous amphibole composing this rock has been derived from colorless pyroxene or jadeite, remnants of which still exist in the rock. Another section of this rock shows the same microstructure, but none of the pyroxene remnants. Still another section of the same rock shows patches of fibres, most of which extinguish at nearly one time. These are banded by parallel lines of fibres with a different orientation. These patches represent the extent of jadeite crystals that were twinned in the usual manner, each crystal having been altered to a mass of amphibole fibres, most of which are parallel to one another, a part lying at various angles. The chemical analysis shows no jadeite to have been present in the material analyzed.

No. 13267. The prisms are acicular and fibrous. There is more of an approach to streaked or parallel fibrous structure, though the needles cross one another at various angles. This structure is shown in photomicrographs numbered 13267 in Plates B and C. The amphibole has a pale-green color in thin section, the crystals being pleochroic,—yellowish-green parallel to the prism axis and bluish-green at nearly right angles. It is a mixture of jadeite and amphibole in the proportion of three to two, and consists of very minute fibres with a preponderating parallel arrangement, producing a more or less pronounced fibration or lamination in the rock. The chemical analysis shows that the specimen is a mixture of jadeite and amphibole rich in soda and magnesia.

No. 13205. A very good example of this alteration is shown in a thin section from 13205, which has been photographed (Plate A). In the illustration the colorless jadeite appears dark, and the delicate twin striations are clearly seen. The jadeite in this rock is highly striated.

No. 13275. A precisely similar case is found in rock 13275, which is a mass of microscopic to submicroscopic fibres of amphibole, with occasional larger compact crystals. Scattered through the mass are small fragments of colorless jadeite, as in the previous case. The alteration has gone farther, and only a little jadeite remains.

No. 3131. Another example of amphibole alteration is found in one thin section, 3131. It is a confused aggregate of amphibole fibres, which, on account of the thickness of the rock sections, exhibit rather high interference colors. The index of refraction, however, is that of amphibole. There is a curved parting to the mass, and the appearance of rounded aggregates of colorless material in a gray matrix. This suggests the grain of the original pyroxene rock. A few fragments of colorless jadeite remain, as in 13275. There are a few curved and distorted microscopic crystals of colorless mica or muscovite. The other section of 3131 might be described as a jadeite consisting almost wholly of jadeite, with few individuals of the colorless indeterminable mineral. The two thin sections are quite different from one another.

No. 13214 presents the same conditions as the foregoing. A few fragments of jadeite remain; the mass of the rock consisting of amphibole fibres, that in places reach the size of compact crystals.

No. 13266 is the same, with a small amount of colorless jadeite in fan-shaped aggregates. These are shown in the photomicrograph (Plate A), the lighter gray portions being amphibole fibres.

No. 13200 consists of minutely fibrous amphibole, and considerable compact amphibole in irregularly shaped crystals, in clusters and streaks through the rock. This is shown in the photomicrograph (Plate C). There are also remnants of small jadeite crystals in aggregations and streaks, and sometimes in spherulitic clusters, as in 13266. The irregular and jagged outline of the pyroxene grains is exactly the same in both these thin sections.

No. 3016 presents an instance in which the relation between the colorless pyroxene or jadeite and equally colorless amphibole is not so evident. The rock consists of microscopic prisms and shorter crystals of pyroxene in an irregular aggregation, together with larger crystals of compact amphibole. The outline of the amphibole is determined by the adjacent pyroxene crystals. The two are distinguished by their optical characteristics and prismatic cleavage. The prisms of pyroxene are bounded in the prism zone by the faces of the unit prism, yielding nearly square cross-sections. The prisms penetrate the larger crystals of amphibole, and lie enclosed in them in all directions. In some cases the acicular prisms of pyroxene are located on both sides of a fracture line in the amphibole, or along the boundary between two amphibole crystals. The two minerals appear to be nearly contemporaneous crystallizations; the pyroxene being somewhat the earlier. The amphibole is not fibrous and does not seem to have resulted from the alteration of pyroxene. It is, however, quite the same in appearance as the compact amphibole, which is secondary. Its exact origin in this case is doubtful. The structure is very well shown in the photomicrograph (Plate B). The nearly square cross-section of pyroxene, the prismatic sections, and acicular crystals of the same mineral can be seen in the broader areas of the compact amphibole. In places there is a green color which occurs both in the jadeite and the amphibole. They are slightly pleochroic, as in other cases already noted.

No. 3136. The microstructure of 3136 is clearly the result of amphibolic alteration of jadeite. The rock consists of microcrystalline to microcryptocrystalline aggregation of fibres of colorless amphibole that extinguish light between crossed nicols in irregular patches, some of which are banded in parallel lines. These patches correspond to the originally twinned pyroxene. In places the amphibole is in compact crystals. There is a curved fibration in one direction through the rock, along which it has cracked. A few small clouded spots appear to be impure muscovite. The rock is a nephrite.

No. 3246. This is also the microstructure of 3246, except that the patches are larger, showing that the original rock was a coarser-grained jadeite rock. There is also a mottling similar in size to that noticed in the large crystals of jadeite, where it was the result of strain (compare with jadeite No. 3248). This and all of the succeeding specimens are nephrite.

No. 13262R has exactly the same microstructure and composition as No. 3246.

No. 13008. The same is true of No. 13008. The once coarse-grained aggregate of pyroxene crystals is perfectly mapped out by the patches of similarly oriented amphibole fibres arranged in a direction corresponding to the twinned positions of the pyroxene lamellæ.

No. 13268. The same structure is shown on a larger scale in 13268. There are similar mottled patches. But the mottling is so coarse that the details of its structure can be seen. It consists of fan-like bundles of fibres crossing one another in two or more directions, sometimes producing spherulitic aggregates, with four long arms. In other places the fibres are arranged in lines of lenticular or spindle-shaped bundles, which produce curving lines. Between the latter are fibres in other orientations, probably bundles seen in cross-section. This appears to be the same structure that produces the mottling in the finer-grained forms, but it is not so easily analyzed in those cases, because of the difficulty of getting thin enough sections.

No. 13131 is the same as 13008 in all respects. In one place there is a banding of the fibres as though there had been a dragging of the material in that direction.

No. 13211. The long streaks of parallel fibres are more marked in 13211, which is otherwise like the previous sections. Its microstructure is shown in photomicrograph (Plate C).

No. 3156. A transition from the patchy structure shown by the last few sections into a uniform aggregation of minute fibres is seen in 3156. The two structures are parts of the same rock. In the finer-grained portion are groups of compact amphiboles yielding fan-shaped sections.

No. 13203 belongs to this class of rocks, and is nearly identical with those just described, except that there are areas of fibres that are almost wholly parallel, so that they approach closely to compact amphibole. This structure is shown in the photomicrograph (Plate C).

Nos. 13371, 13374. These are nephrite with an intense emerald-green mineral in irregular patches and spots. The sections differ somewhat in texture. No. 13371 consists of bladed, prismatic, and irregularly shaped anhedrons, in places with parallel arrangement. Some crystals are colorless, others pale green, others intense brilliant green. In size they vary from anhedrons about 1 mm. in diameter to microscopically minute particles. The more strongly colored crystals have higher refraction and in places exhibit aggregate polarization. The colors of the different crystals vary in shade, but are of like tone, with marked pleochroism from emerald-green to greenish-yellow and yellow. The paler crystals are undoubtedly amphibole, as is shown by the prismatic cleavage. But the strongly colored mineral differs somewhat optically from most amphiboles; however, it is referred to amphibole provisionally, and may be a variety not yet described. No. 13374 contains more colorless amphibole.

The remaining thin sections of nephrite exhibit many instances of exactly similar microstructure and of identical mineral composition. They may be described in groups, which differ from one another only in slight modifications in the arrangement of the amphibole fibres. In all of them there is little or no trace of the original granular pyroxene rock. But all the structures have been observed in direct connection with others that exhibit the evidence of their origin, or that still contain fragments of pyroxene. So that it is reasonable to assume that all of the nephrite studied in this collection has been formed by the amphibolical alteration of colorless pyroxene or jadeite.

In the following thin sections—Nos. 3119, 13207, 13251, 13007C, 13007G, 13088, 13095, 13122, 13262E—there is sometimes a faint suggestion of the patches derived from previous pyroxene, but the amphibole fibres are in a confused aggregation, with occasionally longer streaks of nearly parallel fibres. In the case of 13251 there is a yellowish stain in part of the section, which seems to be occasioned by hydrous oxide of iron. A brown mineral in another part of the same section is in thin plates, not definitely bounded by crystallographic planes. Its exact nature is uncertain, but it suggests brown mica.

Nos. 13007C and 13007G, although differing in color in the specimens, are closely alike in thin section. The texture in the large green slab (13007G) varies from place to place, which may be seen on the back of the specimen; hence thin sections will vary according to the place from which they were cut. Some of it is extremely fine-grained; in places it is in patches of coarser grain. The two specimens consist of the same mineral and have almost identical specific gravity. Under the microscope the thin sections are also alike in being made up of minute scales and fibres of nephrite through which are scattered, in 13007G, patches consisting of parallel fibres, sometimes curved, of the same mineral, nephrite; while in 13007C there are occasional patches consisting of compact nephrite, not fibrous. The difference is slight and would not show in the specimen.

No. 13192H is one of this kind with rather more parallelism to the fibres in places, and with traces of the original pyroxenic grains in the arrangement of the fibres. Prismatic crystals of amphibole are more abundant. They lie in several directions. Sometimes a number close to one another will have parallel orientations which are shown by the exact parallelism of a group of cross-sections of amphibole prisms.

No. 13026 is similar to the one last mentioned.

The following thin sections—Nos. 3125, 3245, 13095, 13246, 13211, 13216—are alike in having a microstructure caused by a nearly uniform mixture of amphibole fibres, which are in fan-shaped divergent clusters, sometimes approaching a spherulitic arrangement. 13095 carries a few microscopic flakes of colorless mica.

No. 13212. In 13212 some of the bundles of fibres are longer and larger, and needles of compact amphibole are sparingly present. Three photomicrographs, Nos. 13212 *a*, *b*, and *c* on Plate B, were made from thin sections of this specimen. The bundles of fibres have several orientations, which can be seen in the illustrations.

No. 13210. In 13210 the compact prisms of amphibole are much more numerous, and give the rock a more distinctly marked microstructure, which is well shown in photomicrograph (Plate B). The prisms grade into fibres, are in nearly parallel groups, and cross one another in several directions.

The following thin sections are nephrites consisting of very minute fibres with a preponderating parallel arrangement, producing more or less fibration or lamination in the rock:

Nos. 13250, 13380, and 13381. In these sections the delicate fibres are curved in several directions or extinguish light in irregular patches. There is a yellowish-brown tabular mineral, with six sides to some crystals. The same substance also occurs in minute particles. It appears to be a hydrous oxide of iron.

No. 13217 is one of this class of rocks, with somewhat larger fibres. There are numerous crooked cracks parallel to the direction of fibration.

No. 13086 consists of very minute fibres and particles, with banded structure shown in photomicrograph (Plate C); some bands being clouded, others transparent. There are small opaque spots that are light green by incident light, and irregularly shaped crystals of a reddish-brown isotropic mineral, which is surrounded by a white opaque substance resembling leucoxene. It is probably perovskite.

No. 13334. This specimen is nephrite in an aggregation of extremely fine fibres that lie parallel to one another and have been bent into contorted and crenulated bands. There is some clouding of the material which is white by incident light and yellowish by transmitted light. In places the fibres are less crinkled and the substance is nearly transparent, and the double refraction is more uniform as shown by the interference colors, but there is some mottling. Throughout much of the section there is aggregate polarization indicating very minute confused fibres. The thin section cut across the fibres exhibits less crinkling and a less fibrous texture and indicates that the fibres are flattened or bladed. The nephrite is very free from inclusions of other minerals, and as shown by the chemical analysis is very pure nephrite, having the composition of tremolite with less than four per cent. of ferrous oxide.

Nos. 13006, 13030, 13118, 13128, 13218, 13233, 13248. All these specimens have the fibres in parallel, and sometimes in curved arrangement, with a parallel or laminated structure strongly marked and accompanied by crooked cracks in most cases. The rock appears to have been crushed or dragged, and the structure indicates a high degree of dynamic metamorphism.

No. 13335 is nephrite, consisting of confused fibres of amphibole, extremely minute, in some places crinkled and contorted, in other places in streaks of parallel fibres. It is traversed by short crooked cracks containing dark coloring matter. The nephrite is stained yellow with streaks of brown. The fibres are so minute that they overlie one another in the thin section and produce aggregate polarizations between crossed nicols.

No. 13223. The most extreme case of this kind is found in 13223; the fibres are almost perfectly parallel, with striations that seem to be due to twinning parallel to the orthopinacoid. The structure resembles that of silicified wood in longitudinal section, and is shown in photomicrograph (Plate C).

Three specimens remain to be described which differ slightly from those already treated, but which are nephrite or jadeite with other minerals in variable quantities:

No. 13249 is a jadeite, composed of very small, irregularly shaped crystals or grains of colorless jadeite and pale-green amphibole. These have a crudely parallel orientation, producing a lamination or fibration of the mass, which is further emphasized by streaks of minute grains of an almost colorless mineral with high index of refraction and high double refraction. Some crystals of it are well developed and sharply defined, and appear in quadratic or tetragonal pyramids, with very short prisms in some cases. These characteristics are those of zircon, but its determination is questionable. There is also a little iron-oxide, probably magnetite, in irregularly shaped grains associated with the (?) zircon. The green color of the amphibole is quite pronounced in some crystals, and in one instance is strong blue-green. The chemical analysis shows that the specimen consists of jadeite with sixteen per cent. of nephrite.

No. 13005 is a rock of quite different composition, although consisting mainly of amphibole. The amphibole is in minute, irregularly shaped crystals, and some larger ones that exhibit distinct green color, with pleochroism from yellowish to bluish-green. In places the green amphibole occurs in distinct prismatic crystals, with the prism faces and cleavage well developed. Between these minute crystals is a colorless mineral, with lower refraction and low double refraction, of very pure substance suggesting quartz. It is wholly allotriomorphic, or interstitial, acting as a cement for the other minerals. Though in very small areas, it is very widely scattered through the rock, and is present in considerable amount for an accessory mineral. Scattered through the rock in much greater quantity are small particles of an almost colorless mineral whose form and optical properties correspond to those of klino-zoisite. It constitutes about forty per cent. of the rock. With it is associated a small amount of epidote, distinguished by its yellow color in thin sections. There are small, irregularly shaped grains of highly refracting yellowish mineral, possibly titanite, with attached grains of magnetite. There are a few small crystals of colorless garnet.

No 13241 is a fine-grained aggregate of colorless to pale-green jadeite crystals with a curving parallel arrangement of the more or less prismatic crystals. There are abundant colorless garnets about 0.15 to 0.30 mm. in diameter, without distinct crystal outline. There is a subordinate amount of colorless mica-like mineral with the optical properties of pennine clinochlore. There are also numerous minute grains of a yellow mineral with high refraction, which is probably sphene. The structure of this rock is shown in the photomicrograph (Plate A), taken between crossed nicols. Consequently the garnets appear as black spots.

Since the above was written a number of thin sections of European material have been examined. Of eight thin sections representing nephrite from Jordansmühl, Silesia (Nos. 13471 to 13478 inclusive), three (Nos. 13471, 13472, and 13474) are almost identical. They consist of nephrite in fibres, flakes, and bladed crystals irregularly aggregated with larger crystals; in some cases broad and grading into the fibrous forms; in others, long acicular prisms. All are the same kind of amphibole. Cross-sections of prisms show the characteristic amphibole cleavage, and prismatic faces modified by orthopinacoid and less pronounced clinopinacoid. There is a small amount of an opaque, black mineral probably magnetite, also minute, microscopic, brown particles included in the larger amphiboles. No. 13475 is the same as those just described, but with much smaller scales and fibres and little compact amphibole. No. 13475 is more fibrous, and No. 13477 is very fine-grained with schistose arrangement of the crystals.

Two other sections of nephrite from Jordansmühl differ somewhat from the preceding. No. 13476 is a microscopically fine-grained aggregate of amphibole anhedrons about .02 mm. in diameter. There is, besides, a brownish-black mineral partly surrounded by a yellowish, highly refracting granular aggregate with very weak double refraction, which is also scattered through the nephrite. Its character has not been determined. No. 13478 is a mixture of fibrous and compact crystals of amphibole—nephrite—

with irregular anhedrons of a colorless mineral having the optical properties of zoisite.

The three sections of nephrite from Reichenstein (Nos. 13479, 13480, 13481) are of very simple character. No. 13479 consists of a fine-grained aggregation of minute anhedrons of amphibole with scattered microscopic grains of arsenopyrite. No. 13481 is composed of more fibrous amphibole with schistose structure and contains considerable arsenopyrite in lenticular masses. No. 13480 is an extremely fine fibrous and scaly aggregate of amphibole.

No. 13482, the Schwemsal nephrite, consists of minute flakes and fibres of amphibole in spherulitic bundles and patches.

TENACITY.

The great tenacity of jade has long been known as perhaps its most characteristic property. Lapidaries who are familiar with the jade group of minerals, state that it requires several fold more time to cut or carve a piece of jadeite or nephrite than it does to cut or carve a similar object from rock-crystal or agate, both harder than the nephrite form of jade; and its resistance to blows and pressure has frequently been proved by direct experiment. It is said that a stone battle-axe brought back by Columbus, when tried by Peter Martyr on a piece of iron, cut into the metal without injuring the stone.* It is not definitely stated that the axe was of jade, but the results fit in well with the later and better authenticated experiments.

In 1860 Krantz, the mineral dealer of Bonn, having attempted unsuccessfully to break a large block with a sledge-hammer, sent it to the Krupp Gun Works at Essen, where it was placed under a steam-hammer to be broken. The anvil on which it was placed was ruined, while the mass of nephrite remained unhurt. Later, the block was broken into many fragments by heating it to redness and then throwing it into water.

* Bastian, *Culturlander des alten Amerika*, 1878, I. 592, quoted in Meyer's *Jadeit und Nephrit Objecte*, II. 2.

A more scientific experiment was that made by von Schlagintweit, the great Asiatic explorer, who has made us so familiar with jade and its occurrences in Chinese Turkistan. He selected a fine light-colored specimen of the best quality of nephrite, 70 cubic centimetres in volume, with two flat fracture faces. This was placed on an anvil within an upright tube, and on the exposed face of the specimen was placed a steel chisel edge down, the blade measuring 2.5 cm. by 0.1 mm. thick. A cylindrical mass of iron weighing 50 kilos. was then allowed to fall upon the upper end of the chisel, through a distance of 35 cm. Under this test the tenacity of the mineral was found to be so great that the edge of the chisel was turned, and a metallic mark resembling a wide lead-pencil mark was left on the surface of the nephrite, which was uninjured except that on the under side of the specimen where it had rested on the anvil three small initial protuberances had been somewhat bruised by the blow, as indicated by three white spots.

In 1898 Professor Jaczewsky, who had discovered great beds of nephrite in Siberia (described by him in a later section of this work), made some preliminary tests which he kindly communicated to us. Two cubes of different kinds of Siberian nephrite were cut and submitted to a crushing test in the big Werder machine in the laboratory of the School of Bridges and Highways of Emperor Alexander I., at St. Petersburg, under the supervision of Mr. B. Vassenko. The results are here given :

No. 1. Specific gravity, 3.003, green nephrite, somewhat transparent at the edges, and showing traces of fissuration on its polished surface, was crushed under a pressure of 4222 kg. to the square centimeter = 60,050 lbs. per square inch.

No. 2. A perfectly black nephrite without fissures, specific gravity 2.993, failed under a pressure of 7759 kilos. to the square centimeter = 110,000 lbs. per square inch.

Both broke with a sharp report.

In order to obtain the most scientific results in regard to the strength of both minerals, Mr. Bishop arranged for three series of resistance tests that should be as far as possible both exhaustive and authoritative. These were :

Resistance to impact,
Resistance to compression, and
Resistance to tension.

The Impact experiments were conducted at the Engineering Laboratory of Harvard University, by Mr. Logan Waller Page, Geologist to the Highway Commissioners of the Commonwealth of Massachusetts, and were made on half-inch cubes of carefully selected typical material from three different localities :

(1) No. 13336. Jadeite from Burma ; specific gravity, 3.3122 ; hardness, 7 ; color, greenish blue-white, with occasional green spots ; remarkably homogeneous and compact.

(2) No. 13268. Nephrite boulder from China (probably of Turkistan origin) ; specific gravity, 2.9690 ; hardness, 6.5 ; color, greenish-gray, apparently very compact, with a few spots of what seemed to be manganous oxide.

(3) No. 13030. Nephrite boulder from the West Island, New Zealand ; specific gravity, 3.1022 ; hardness, 6.5 ; color, rich dark green.

His report is as follows :

IMPACT TESTS ON JADE.

BY LOGAN WALLER PAGE.

In finding out the possible range of the application and usefulness of any material in the arts, among the qualities most important to be determined is its power of resisting blows, or impact. The momentary stresses set up as a result of a blow will vary with the precise form of the stressed body and with the method of application of the blow. If the body is a right prism or cylinder, and is supported at the bottom, and the effect of the blow is distributed evenly over the whole upper surface, the stresses set up will be purely compressive, of course, with the exception of the accompanying shearing stresses along planes inclined to the ends. If such a body is supported on top, and the blow coming above is resisted by a yoke attached to the lower end of the body, the stresses set up will be chiefly tensile. If the body be in the form of a beam, and the blow applied anywhere between the two supports, there will be compressive, tensile, and shearing stresses. It is, therefore, necessary, in testing the resistance to impact offered by a body, to specify exactly the conditions under which the test is conducted.

The standard impact test adopted in the engineering laboratory of Harvard University subjects the material to be tested to blows from a falling hammer, through an intervening plunger. The power of resisting such treatment, that is, of sustaining it without fracture, is the evidence of a property which may be called "toughness." This term is not altogether satisfactory, for since there are two ways in which a body subjected to impact may resist fracture, there are two ways in which it may be interpreted. It may be a malleable material capable of considerable plastic or permanent deformation (as, for example, lead or copper), in which case the energy of the blow is used up in permanently deforming it. Or it may be a substance which permits a large elastic deformation, and has a high elastic limit; in which case considerable energy will be required to stress the material to that elastic limit. A material of this latter class, which is also capable of but slight or no permanent deformation, is commonly called a brittle material.

Jade appears to belong to the class of brittle substances which permit of no plastic deformation, and which consequently fracture when stressed to the elastic limit. For such a material an expression for the resistance to impact can be readily found.

Let R be the energy of the blow causing fracture,
E the modulus of elasticity of the material,
P the stress at the elastic limit, which is also the maximum compressive stress,
d the strain at the elastic limit,
K some constant,

Then $R = KPd$,

But $E = \frac{P}{d}$

Therefore $R = \frac{P^2}{E}$

that is to say,—the power of resisting impact is proportional to the square of the ultimate compressive stress, and inversely as the modulus of elasticity of the material. This assumes that the blow is evenly distributed over the top surface of the test specimen. In actual practice, however, it is not possible to bring about this ideal condition, and the blow will be received and its effect concentrated on a few high points on the receiving surface, with the result that the material will be unequally stressed in its different parts, and will break down locally at the high points. As this would give conditions that could not be repeated at will, it is considered undesirable to attempt to get uniform distribution of the stress, and an intentional concentration at the center of the upper surface has been substituted. To effect this concentration a plunger is used, the lower and bearing surface of which is spherical. The stresses set up in the material as the result of a blow delivered through such a plunger are undoubtedly more complex than would be the case with a flat-end hammer or plunger, but as the object of the test is not to obtain any physical constants, but to find comparative powers of resisting impact, that consideration is of small account compared with the advantage obtaïned in uniformity of conditions during the standard test.

The tests were carried on at the engineering laboratory of Harvard University. The machine used consists of a one-kilogramme hammer, which is guided by two vertical rods. The hammer is raised by a screw, and can be dropped automatically from any desired height. It falls on a plunger which rests on the test-cube. The lower and bearing surface of the plunger is spherical in shape, having a radius of 1 cm. The test-cube is adjusted so that the centre of its upper surface is tangent to the spherical end of the plunger, and the plunger is pressed firmly upon the cube by two spiral springs which are held by the guide rods. The plunger is made of a very hard steel, and its spherical end is tempered in the same manner as the tip of an armor-piercing projectile, and it is bolted to a crosshead which is free to slide on the two vertical rods. The bottom of the test-cube is held by a device which prevents it moving when a blow is struck by the hammer. A small lever carrying a brass pencil at its free end is connected to the side of the crosshead by a link motion, arranged so that it gives a vertical movement to the pencil six times as great as the movement of the crosshead. The pencil presses against the drum, and its movement is recorded on a strip of silicated paper fastened thereon. The drum is turned automatically through a small angle at each stroke of the hammer. In this way a record is obtained of the movement of the plunger at each blow of the hammer.

In the present tests seven half-inch cubes of jade were employed, four from Burma, two from China, and one from New Zealand. The method adopted for testing these cubes consisted of a 1 cm. fall of the hammer for the first blow, and an increased fall of 1 cm. for each succeeding blow until the cube was destroyed. The automatic record obtained on the drum shows the behaviour of the test-cube at each blow of the hammer. When the hammer strikes the plunger, if the blow is within the elastic limit of the test-cube beneath it, the plunger recovers; if not, the plunger stays at the point to which it is driven and which is recorded on the drum. The number of blows required to destroy a test-cube is generally used as a measure of its power of resisting impact, but the energy in centimetre-grammes of the destroying blow, or the total energy expended, does equally well.

Before testing the jade several trial tests were made to ascertain if the machine was in thorough working order. The material selected for this purpose was a highly metamorphic siliceous slate, which was exceedingly hard. This particular stone was selected at the advice of an eminent petrographical authority, who expressed the opinion that it would stand a higher impact test than jade, an opinion in which the writer fully concurred. The four specimens tested stood on the average 16 blows, or a breaking blow of 16,000 centimetre-grammes of energy; the total amount of energy expended on each specimen was 136,000 centimetre-grammes.

The four cubes of Burmese jadeite (labelled 13336) were tested first, then the two cubes of nephrite from a boulder from China (labelled 13268), and finally the one of nephrite from New Zealand (labelled 13030). The tests are numbered in the order in which they were made.

TESTS ON BURMESE JADEITE (NO. 13336).

Test No. 1.—The load was applied at right angles to the striation and cleavage cracks of the cube, which though very apparent were not so numerous as in some of the other specimens. There were also a few flaws visible, though probably of insufficient size to weaken the specimen to any degree. The average height of the specimen from five measurements between the load surfaces was .506 of an inch. Just 100 blows were required to break this cube, or a final blow of 100,000 centimetre-grammes; the total energy expended was 5,050,000 centimetre-grammes.

Test No. 2.—The cube was broken with the load parallel to the striation and cleavage cracks, the latter of which were almost invisible. The average height of the cube was .5004 of an inch. It stood 103 blows, or a final blow of 103,000 centimetre-grammes; the total energy expended was 5,356,000 centimetre-grammes.

Test No. 3.—The cube used in this test was very much striated, and contained several cracks of considerable size parallel to the striation. The load was applied parallel to the striation and cleavage cracks. The average height of the cube was .584 of an inch. It stood 112 blows, or a final blow of 112,000 centimetre-grammes; the total enery expended was 6,328,000 centimetre-grammes.

Test No. 4.—The striation in this cube was very slight, and there was almost an absence of cleavage cracks. The load was applied at right angles to the striation. The average height of the cube was .503 of an inch. It stood 131 blows, or a final blow of 131,000 centimetre-grammes; the total energy expended was 8,646,000 centimetre-grammes.

TESTS ON CHINESE NEPHRITE (NO. 13268).

Test No. 5.—The cube used in this test had very little striation, but cleavage cracks were apparent. The load was applied at right angles to the cleavage cracks. The average height of the cube was .510 of an inch. It stood 81 blows, or a final blow of 81,000 centimetre-grammes; the total energy expended was 3,321,000 centimetre-grammes.

Test No. 6.—The load was applied parallel to the cleavage cracks in the cube; the striation was also parallel but very slight. Its average height was .511 of an inch. It stood 39 blows, or a final blow of 39,000 centimetre-grammes; the total energy expended was 780,000 centimetre-grammes.

TEST ON NEW ZEALAND NEPHRITE (NO. 13030).

Test No. 7.—There was no striation in this cube and only one cleavage crack, to which the load was applied at right angles. The average height of the cube was .496 of an inch. It stood 85 blows, or a final blow of 85,000 centimetre-grammes; the total energy expended was 3,655,000 centimetre-grammes.

TABLE OF RESULTS.

Locality	Test number	Direction of blow	Number blows to produce fracture	Energy of final blow in cen.-gra.	Total energy expended in producing fracture in cen.-grs.
Burma (No. 13336)	1	Right angles to cleavage	100	100,000	5,050,000
Burma (No. 13336)	2	Parallel to cleavage	103	103,000	5,356,000
Burma (No. 13336)	3	Parallel to cleavage	112	112,000	6,328,000
Burma (No. 13336)	4	Right angles to cleavage	131	131,000	8,646,000
China (No. 13268)	5	Right angles to cleavage	81	81,000	3,321,000
China (No. 13268)	6	Parallel to cleavage	39	39,000	780,000
New Zealand (No. 13030)	7	Right angles to cleavage	85	85,000	3,655,000

TABLE OF AVERAGED RESULTS.

Locality	Direction of blow to cleavage	Number of cubes used	Number blows to produce fracture	Energy of final blow in cen.-grs.	Total energy expended in producing fracture in cen.-grs.
Burma	Parallel	2	107.5	107,500	5,842,000
	Right angles	2	115.5	115,500	6,848,000
China	Parallel	1	39	39,000	780,000
	Right angles	1	81	81,000	3,321,000
New Zealand	Right angles	1	85	85,000	3,655,000

The table of averaged results shows, as was anticipated, that the strength of the specimen was greater when the blow was perpendicular to the cleavage planes than when it was parallel to them. This conclusion, however, is not completely borne out by the Burma jades, of which one (No. 4) showed greater strength and the other (No. 1) less strength than either of the specimens numbered 2 and 3, tested parallel to the cleavage planes. The number of tests is insufficient to demonstrate this point with certainty, and the great difference in the strength of the China jades (Nos. 5 and 6) may be due to some cause other than the difference in the direction of the blows.

The most important fact brought out by the tests is the high resistance offered by jade to impact, the average for all the tests being 93 blows, whereas from the four specimens of slate tested the average was 16 blows, and from three specimens of granite 23 blows. The highest resisting power which has previously been obtained with this method of testing has been with 2 cm. cubes of diabase, of which one sustained 68 blows before fracture; but as this test was made on a much larger specimen than the standard used for the jades, the results are not directly comparable. It is certain, however, with a test-cube of the same size the diabase would not have shown so high a result.

A comparison of the strength of the different specimens shows a decided superiority of the Burma jade over the others; the number of test pieces, however, is not sufficient to determine the relative positions of the China and New Zealand specimens.

The Compression tests were made by Professor Ira Harvey Woolson of the Department of Mechanical Engineering at Columbia University, New York.

In addition to inch-cubes of the material already described as having been used in the impact tests (Nos. 13336, 13268, and 13030), Professor Woolson tested inch-cubes of two other specimens of jadeite from Burma, and two of nephrite from China (but probably of Turkistan origin); viz.:

No. 13102D, Crude jadeite from Burma ; specific gravity, 3.2466 ; hardness, 7 ; color, dark brownish-green on four sides of the cube, and yellowish-green on the other two sides.

No. 13215, Jadeite boulder from Burma ; specific gravity, 3.2176 ; hardness, 7 ; color, dead-white with bluish-green markings ; homogeneous and compact, showing the included crystals very clearly.

No. 13214, Fragment of a nephrite boulder from China, (probably Turkistan) ; specific gravity, 2.9825 ; hardness, 6.5 ; color, light sage-green ; very compact and homogeneous ; showing scarcely any stratification. A number of black metallic spots—probably chromic iron—present.

His report is as follows :

COMPRESSION TESTS ON JADE.

BY IRA HARVEY WOOLSON.

With the exception of the two preliminary tests made by Professor Jaczewsky on Siberian jade (already referred to), no attempts to determine scientifically the compressive strength of jade have ever been made. The results now to be given may therefore be styled unique and of unusual interest.

The tests were made on an Emery Hydraulic Testing-Machine, the most accurate testing-machine known, and in view of the interest attaching to the material were carried on with the utmost care.

The specimens were all inch-cubes, sawn to shape and rubbed to a smooth dull finish. So far as possible they were all tested on bed, that is, the load was applied at right angles to the bedding planes ; but in two specimens, Nos. 13215 and 13336, the stratification was not sufficiently distinct to make a positive determination. The compression faces were finished with much care and their contact with the steel compression plates of the testing machine made as perfect as possible. To insure still more perfect support and uniform distribution of load, a sheet of stiff blotting-paper was inserted between each face and the steel plate; experience has shown that this material has no effect except to improve the support. The lower plate of the machine was fitted with a spherical adjustment which made it possible to apply the load squarely to the two compression faces of the specimens, even though they might be slightly out of parallel.

In all cases except No. 13336 *bis* a compressometer was attached to the specimen, on a gauged length of $\frac{3}{4}$ of an inch, and the amount of compression measured in hundred-thousandths of an inch for each 1000 lbs. per square inch increment of load. On one specimen 80 readings were taken, on three others 75 readings each, while on one 54 and on another only 40 readings were obtained because the specimens failed at loads only slightly above these points.

Seven cubes in all were tested: Two of these were taken from the Burmese material No. 13336 of the Collection. The first of these, which had a flaw in one corner, measured 1.001″ x 1.013″ x 1.009″; area, 1.022 square inches. The load was applied to the apparent bedding of the material. When the load had reached 75,000 lbs. per square inch, the compressometer was removed, and the width was found to have increased from 1.013″ to 1.014″, and thickness from 1.009″ to 1.011″. The total compression in $\frac{3}{4}$″ at a pressure of 75,000 lbs. per square inch was .0027 inches = $\frac{36}{100}$ of 1 per cent. At 94,000 lbs. pressure a slight crack appeared on one corner, and the specimen suddenly failed with a sharp report at 94,450 lbs., breaking into numerous small fragments. Ultimate strength per square inch 92,416 lbs. Time required, 2 hours.

The second cube of No. 13336, which showed two flaws on one corner, measured 1.004″ x 1.021″ x 1.018″; area 1.039 square inches. As in the previous specimen, the load was applied at right angles to the apparent bedding. The specimen began to show white mottled spots on the exposed faces at 65,000 lbs. These gradually increased until crushing began. The first crack was observed when the applied load had reached 76,400 lbs., and at 79,180 lbs. the specimen failed suddenly with a sharp report, breaking into fine pieces, somewhat prismatic. The ultimate strength proved to be 76,208 lbs. per square inch. Time, 1½ hours. The compressometer was not used on this specimen.

No. 13268. A cube made from a nephrite boulder from China; of a greenish-gray color, and apparently very compact, with a few spots of what seemed to be manganous oxide. It measured 0.998″ x 1.016″ x 1.013″; area in square inches, 1.029. Measured at a load of 75,000 lbs. per square inch, and just before removing the compressometer, the width had increased from 1.016″ to 1.018″, and the thickness from 1.013″ to 1.015″. The total compression in $\frac{3}{4}$″ at a load of 75,000 lbs. per square inch was .0036″ = $\frac{4}{10}$ of 1 per cent. At 80,100 lbs. of applied load one corner flaked slightly, and at 94,500 lbs. the specimen failed suddenly with a sharp report, being completely pulverized. The ultimate strength per square inch proved to be 91,836 lbs. Time of test, 2 hours and 25 minutes.

No. 13030. A cube from a nephrite boulder from the West Island of New Zealand; cut almost horizontally across the schistose structure of the material; color, dark rich green; dimensions 0.955″ x 0.980″ x 0.972″; area in square inches, 0.952. When a load of 65,000 lbs. per square inch was reached, cleavage planes which showed in the original cube became whitish, and were decidedly white on one side at 75,000 lbs. per square inch. A few white cracks also were visible at this load, but no spalling or breaking occurred until failure. Measured at a load of 75,000 lbs. per square inch, just after the removal of the compressometer, the width was found to have increased from 0.980″ to 0.987″, and the thickness from 0.972″ to 0.975″. The total compression in $\frac{3}{4}$ of an inch at 75,000 lbs. load per square inch = .0037 inches, or $\frac{49}{100}$ of 1 per cent. The ultimate strength proved to be 92,332 lbs. per square inch, a pressure at which the specimen failed suddenly with a sharp report, the cube being reduced to sand and fine fragments. Time occupied in the experiment, $2\frac{1}{2}$ hours.

No. 13102D. A cube of crude jadeite from Burma, in parts coarsely granular ; color very light green in a white magna, showing large, apparently black patches in cloudy dark green ; dimensions, 0.945″ x 0.968″ x 0.981″; area, 0.949 square inches. The specimen, which was not very perfect, and seemed to be filled with cleavage planes or seams in various directions, failed suddenly with only a slight report, while the compressometer was still attached, at the maximum load of 38,934 lbs. The total compression in $\frac{3}{4}$″ at 40,000 lbs. load per square inch was 0.00075″ = $\frac{1}{10}$ of 1 per cent. (No. 13215, Burmese jadeite, when measured at the same load gave the same compression.) Ultimate strength of specimen, 41,000 lbs. per square inch. Time, 1 hour.

No. 13215. Cube cut from a jadeite boulder from Burma ; color, dead white, with bluish-green markings ; homogeneous and compact ; and clearly showing included crystals ; size 0.930″ x 0.946″ x 0.807″; area in square inches, 0.763. The specimen failed suddenly without report at a maximum applied load of 41,987 lbs., while the compressometer was still attached to it, so that no lateral deformations were measured. Compressometer readings were made on gauged length of $\frac{3}{4}$″ for each 1000 lbs. up to 55,000 lbs. per square inch. At 54,000 lbs. per square inch the total compression was 0.0012″ = $\frac{16}{100}$ of 1 per cent.; at 40,000 lbs. it equalled 0.00074″, or $\frac{1}{10}$ of 1 per cent. No. 13102D, measured at the same load, gave the same compression. At the crushing point the specimen broke in small fragments—somewhat prismatic. The ultimate strength was 55,000 lbs. per square inch. Time, 1 hour and 10 minutes.

No. 13214. Cube cut from a boulder from China (? Turkistan). The material was compact and homogeneous, and showed scarcely any stratification. A number of black metallic spots, probably chromic iron, present; color, light sage-green; dimensions 0.956″ x 0.957″ x 1.006″; area in square inches, 0.962. At 87,300 lbs. per square inch white spots began to appear beneath the surface of the specimen; while at 89,500 lbs. per square inch it had as a whole a mottled or cloudy appearance. With a maximum load of 91,600 lbs. it was suddenly shattered to fine bits, with a sharp report. Much sand produced. Ultimate strength 95,150 lbs. per square inch. Time, 2 hours. The compressometer was used and measurements taken on a gauged length of $\frac{3}{4}$″ for each 1000 lbs. of load up to 80,000 lbs. per square inch. At 75,000 lbs. the total compression per square inch = .00206″ = $\frac{27}{100}$ of 1 per cent. At 80,000 lbs. it was .00228″, or $\frac{3}{10}$ of 1 per cent.

SUMMARY OF COMPRESSION TESTS.

No.	Material	Maximum load in lbs.	Ultimate strength per sq. inch	Total compression at 75,000 lbs.	Percentage of compression	Remarks
				Inches		
13336	Jadeite	94,450	92,416	.0027	$\frac{36}{100}$ of 1%	
13336	"	79,180	76,208	*......	......	*Compression not measured
13268	Nephrite	94,500	91,836	.0030	$\frac{4}{10}$ of 1%	
13030	"	87,800	92,332	.0037	$\frac{49}{100}$ "	
13102D	Jadeite	38,934	41,000	.00075†	$\frac{1}{10}$ "	†Compression measured at 40,000 lbs.
13215	"	41,987	55,000	.0012‡	$\frac{16}{100}$ "	‡Compression measured at 54,000 lbs.
13214	Nephrite	91,600	95,150	.00206	$\frac{27}{100}$ "	
				.00228¶	$\frac{3}{10}$ "	¶Compression measured at 80,000 lbs.

From this it is seen that the crushing point of the specimens tested ranges from 41,000 lbs., jadeite, to 95,000 lbs., nephrite, per square inch, and it is probable that these figures may be accepted as typical. When compared with the values given in the following table for building-stone, steel, and cast iron, the average of many tests in all parts of the world, the greater tenacity of jade becomes very apparent.

Sandstone, . . .	5,000 to 15,000	lbs.	per	square	inch.
Limestone, . . .	7,000 " 20,000	"	"	"	"
Granite, . . .	15,000 " 35,000	"	"	"	"
Mild Steel, . . .	40,000 " 60,000	"	"	"	"
Medium Steel, . .	60,000 " 80,000	"	"	"	"
Cast Iron, . . .	60,000 " 80,000	"	"	"	"
JADE, . . .	41,000 " 95,000	"	"	"	"

It is true that special hard grades of steel and cast iron will stand much more than is indicated above, but it is scarcely fair to compare the strength of a mineral with the strength of iron metals.

A few isolated cases are on record where samples of very fine-grained granite, bluestone, or vitrified sandstone have withstood 40,000 to 44,000 lbs. per square inch, but these are rare exceptions. So far as known these tests prove this material to be by far the strongest of all the mineral kingdom, and that it possesses rare physical characteristics independent of its beauty and ornamental features.

The accompanying Tables show the physical properties determined by measurements of the deformations produced by successive loads of 1000 lbs. per square inch.

No. 13336.

Burmese Jadeite.

Area, 1.1042 sq. in.

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
500	.01840			
700	.01844	.00004		
1000	.01850	.00010	.00006	
2000	.01850	.00010		14,900,000?
3000	.01860	.00020	.00010	11,200,000
4000	.01866	.00026	.00004	11,500,000
5000	.01866	.00026		14,400,000
6000	.01871	.00031	.00005	14,500,000
7000	.01871	.00031		16,900,000
8000	.01871	.00031		19,300,000
9000	.01877	.00037	.00006	18,200,000
10000	.01877	.00037		20,200,000
11000	.01877	.00037		22,200,000
12000	.01877	.00037		24,300,000
13000	.01877	.00037		26,400,000
14000	.01883	.00043	.00006	24,400,000
15000	.01888	.00048	.00005	23,400,000
16000	.01888	.00048		25,000,000
17000	.01894	.00054	.00006	23,600,000
18000	.01894	.00054		25,000,000
19000	.01899	.00059	.00005	24,100,000
20000	.01899	.00059		25,400,000
21000	.01906	.00066	.00007	23,900,000
22000	.01906	.00066		25,000,000
23000	.01910	.00070	.00004	24,600,000
24000	.01910	.00070		25,700,000
25000	.01915	.00075	.00005	25,000,000
26000	.01920	.00080	.00005	24,400,000
27000	.01920	.00080		25,300,000
28000	.01925	.00085	.00005	24,700,000
29000	.01925	.00085		25,600,000
30000	.01925	.00085		26,500,000
31000	.01930	.00090	.00005	25,800,000
32000	.01930	.00090		26,600,000

No. 13336, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
33000	.01930	.00090		27,500,000
34000	.01930	.00090		28,400,000
35000	.01930	.00090		29,200,000
36000	.01935	.00095	.00005	28,400,000
37000	.01935	.00095		29,200,000
38000	.01935	.00095		30,000,000
39000	.01940	.00100	.00005	29,200,000
40000	.01940	.00100		30,000,000
41000	.01940	.00100		30,700,000
42000	.01945	.00105	.00005	30,000,000
43000	.01945	.00105		30,700,000
44000	.01950	.00110	.00005	30,000,000
45000	.01956	.00116	.00006	29,100,000
46000	.01961	.00121	.00005	28,500,000
47000	.01967	.00127	.00006	27,800,000
48000	.01972	.00132	.00005	28,000,000
49000	.01972	.00132		28,600,000
50000	.01978	.00138	.00006	27,200,000
51000	.01978	.00138		27,700,000
52000	.01978	.00138		28,200,000
53000	.01983	.00143	.00005	27,800,000
54000	.01989	.00149	.00006	27,200,000
55000	.01989	.00149		27,700,000
56000	.01994	.00154	.00005	27,300,000
57000	.01994	.00154		27,700,000
58000	.02000	.00160	.00006	27,200,000
59000	.02005	.00165	.00005	26,800,000
60000	.02010	.00170	.00005	26,400,000
61000	.02010	.00170		26,900,000
62000	.02016	.00176	.00006	26,400,000
63000	.02016	.00176		26,800,000
64000	.02022	.00182	.00006	26,300,000
65000	.02027	.00187	.00005	26,100,000
66000	.02033	.00193	.00006	25,600,000
67000	.02038	.00198	.00005	25,400,000
68000	.02049	.00209	.00011	24,400,000
69000	.02060	.00220	.00011	23,500,000

No. 13336, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
70000	.02072	.00232	.00012	22,700,000
71000	.02090	.00250	.00018	21,300,000
72000	.02096	.00256	.00006	21,000,000
73000	.02102	.00262	.00006	20,900,000
74000	.02108	.00268	.00006	20,700,000
75000	.02114	.00274	.00006	20,500,000
92416	Breaking	Load.		

No. 13268.

Chinese Nephrite.

Area, 1.029 sq. in.

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
700	.02220			
1000	.02230	.00010		7,500,000 ?
2000	.02270	.00050		3,000,000
3000	.02287	.00067	.00017	3,300,000
4000	.02294	.00074	.00004	4,050,000
5000	.02300	.00080	.00006	4,700,000
6000	.02307	.00087	.00007	5,200,000
7000	.02314	.00094	.00007	5,600,000
8000	.02320	.00100	.00006	6,000,000
9000	.02320	.00100		6,700,000
10000	.02326	.00106	.00006	7,000,000
11000	.02339	.00119	.00013	6,300,000 ?
12000	.02346	.00126	.00007	7,200,000
13000	.02353	.00133	.00007	7,300,000
14000	.02360	.00140	.00007	7,500,000
15000	.02360	.00140		8,000,000

No. 13268, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Ap. lied loads in lbs. per sq. inch.	C o m p resso-meter readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
16000	.02366	.00146	.00006	8,200,000
17000	.02372	.00152	.00006	8,400,000
18000	.02372	.00152		8,900,000
19000	.02378	.00158	.00006	9,000,000
20000	.02384	.00164	.00006	9,100,000
21000	.02384	.00164		9,600,000
22000	.02390	.00170	.00006	9,700,000
23000	.02397	.00177	.00007	9,700,000
24000	.02403	.00183	.00006	9,900,000
25000	.02403	.00183		10,200,000
26000	.02410	.00190	.00007	10,300,000
27000	.02420	.00190		
28000	.02416	.00196	.00006	10,700,000
29000	.02423	.00203	.00007	10,700,000
30000	.02423	.00203		11,100,000
31000	.02429	.00209	.00006	11,100,000
32000	.02435	.00215	.00006	11,200,000
33000	.02435	.00215		11,500,000
34000	.02440	.00220	.00005	11,600,000
35000	.02446	.00226	.00006	11,600,000
36000	.02446	.00226		11,900,000
37000	.02451	.00231	.00005	12,000,000
38000	.02457	.00237	.00006	12,000,000
39000	.02463	.00243	.00006	12,000,000
40000	.02468	.00248	.00005	12,100,000
41000	.02468	.00248		12,300,000
42000	.02477	.00257	.00009	12,300,000
43000	.02479	.00259	.00002	12,400,000
44000	.02479	.00259		12,700,000
45000	.02479	.00259		13,000,000
46000	.02485	.00265	.00006	13,000,000
47000	.02490	.00270	.00005	13,000,000
48000	.02495	.00275	.00005	13,100,000
49000	.02500	.00280	.00005	13,200,000
50000	.02500	.00280		13,400,000
51000	.02500	.00280		13,600,000
52000	.02500	.00280		13,900,000

No. 13268, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
53000	.02505	.00285	.00005	13,900,000
54000	.02511	.00291	.00006	13,900,000
55000	.02516	.00296	.00005	13,900,000
56000	.02522	.00302	.00006	14,000,000
57000	.02522	.00302		14,100,000
58000	.02528	.00308	.00006	14,100,000
59000	.02533	.00313	.00005	14,200,000
60000	.02533	.00313		14,300,000
61000	.02533	.00313		14,600,000
62000	.02539	.00319	.00006	14,600,000
63000	.02544	.00324	.00005	14,600,000
64000	.02550	.00330	.00006	14,600,000
65000	.02555	.00335	.00005	14,600,000
66000	.02555	.00335		14,700,000
67000	.02555	.00335		14,900,000
68000	.02560	.00340	.00005	15,000,000
69000	.02560	.00340		15,200,000
70000	.02566	.00346	.00006	15,200,000
71000	.02572	.00352	.00006	15,200,000
72000	.02577	.00357	.00005	15,200,000
73000	.02577	.00357		15,300,000
74000	.02583	.00363	.00006	15,300,000
75000	.02588	.00368	.00005	15,300,000
91836	Breaking	Load.		

No. 13030.

New Zealand Nephrite.

Area, .952 sq. in.

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
500	.00630			
800	.00650	.00020		3,000,000
1000	.00650	.00020		3,800,000
2000	.00665	.00035	.00015	4,300,000
3000	.00673	.00043	.00008	5,200,000
4000	.00677	.00047	.00004	6,400,000
5000	.00681	.00051	.00004	7,400,000
6000	.00683	.00053	.00002	8,500,000
7000	.00685	.00055	.00002	9,500,000
8000	.00689	.00059	.00004	10,200,000
9000	.00697	.00067	.00008	10,100,000
10000	.00698	.00068	.00001	11,000,000
11000	.00699	.00069	.00001	12,000,000
12000	.00700	.00070	.00001	12,800,000
13000	.00703	.00073	.00003	13,400,000
14000	.00704	.00074	.00001	14,200,000
15000	.00705	.00075	.00001	15,000,000
16000	.00706	.00076	.00001	15,800,000
17000	.00706	.00076		16,800,000
18000	.00707	.00077	.00001	17,500,000
19000	.00709	.00079	.00002	18,000,000
20000	.00710	.00080	.00001	18,700,000
21000	.00717	.00087	.00007	18,100,000
22000	.00720	.00090	.00003	18,300,000
23000	.00723	.00093	.00003	18,500,000
24000	.00730	.00100	.00007	18,000,000
25000	.00734	.00104	.00004	18,000,000
26000	.00737	.00107	.00003	18,200,000
27000	.00744	.00114	.00007	17,700,000
28000	.00747	.00117	.00003	17,900,000
29000	.00750	.00120	.00003	18,100,000
30000	.00755	.00125	.00005	18,500,000
31000	.00759	.00129	.00004	18,000,000
32000	.00763	.00133	.00004	18,000,000
33000	.00767	.00137	.00004	18,000,000

No. 13030, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
34000	.00770	.00140	.00003	18,200,000
35000	.00774	.00144	.00004	18,200,000
36000	.00786	.00156	.00012	17,300,000
37000	.00790	.00160	.00004	17,300,000
38000	.00790	.00160		17,800,000
39000	.00795	.00165	.00005	17,700,000
40000	.00799	.00169	.00004	17,700,000
41000	.00799	.00169		18,100,000
42000	.00803	.00173	.00004	18,200,000
43000	.00807	.00177	.00004	18,200,000
44000	.00816	.00186	.00009	17,700,000
45000	.00825	.00195	.00009	17,300,000
46000	.00830	.00200	.00005	17,200,000
47000	.00834	.00204	.00004	17,200,000
48000	.00839	.00209	.00005	17,200,000
49000	.00843	.00213	.00004	17,200,000
50000	.00847	.00217	.00004	17,200,000
51000	.00857	.00227	.00010	16,800,000
52000	.00861	.00231	.00004	16,800,000
53000	.00866	.00236	.00005	16,800,000
54000	.00871	.00241	.00005	16,800,000
55000	.00876	.00246	.00005	16,700,000
56000	.00881	.00251	.00005	16,700,000
57000	.00886	.00256	.00005	16,700,000
58000	.00891	.00261	.00005	16,800,000
59000	.00891	.00261		16,900,000
60000	.00896	.00266	.00005	16,900,000
61000	.00902	.00272	.00006	16,800,000
62000	.00902	.00272		17,100,000
63000	.00907	.00277	.00005	17,000,000
64000	.00913	.00283	.00006	16,900,000
65000	.00919	.00289	.00006	16,800,000
66000	.00924	.00294	.00005	16,800,000
67000	.00930	.00300	.00006	16,700,000
68000	.00935	.00305	.00005	16,700,000
69000	.00946	.00316	.00011	16,400,000
70000	.00952	.00322	.00006	16,300,000

No. 13030, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
71000	.00957	.00327	.00005	16,200,000
72000	.00976	.00346	.00019	15,600,000
73000	.00982	.00352	.00006	15,500,000
74000	.00994	.00364	.00012	15,300,000
75000	.01000	.00370	.00006	15,700,000
92332	Breaking	Load.		

No. 13102D.

Burmese Jadeite.

Area, .9496 sq. in.

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
500				
1000	.00228			
2000	.00232	.00004		37,500,000
3000	.00238	.00010	.00006	22,500,000
4000	.00241	.00013	.00003	23,000,000
5000	.00241	.00013		28,800,000
6000	.00246	.00018	.00005	25,000,000
7000	.00250	.00022	.00004	23,900,000
8000	.00250	.00022		27,300,000
9000	.00250	.00022		30,700,000
10000	.00250	.00022		34,100,000
11000	.00250	.00022		37,500,000
12000	.00250	.00022		41,000,000
13000	.00255	.00027	.00005	36,200,000
14000	.00255	.00027		39,000,000
15000	.00255	.00027		41,700,000
16000	.00260	.00032	.00005	37,500,000

No. 13102D, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
17000	.00260	.00032		39,800,000
18000	.00265	.00037	.00005	36,500,000
19000	.00270	.00042	.00005	34,000,000
20000	.00270	.00042		35,700,000
21000	.00275	.00047	.00005	33,500,000
22000	.00275	.00047		35,100,000
23000	.00275	.00047		36,700,000
24000	.00279	.00051	.00004	35,300,000
25000	.00279	.00051		36,800,000
26000	.00279	.00051		38,300,000
27000	.00279	.00051		39,700,000
28000	.00284	.00056	.00005	37,500,000
29000	.00284	.00056		38,800,000
30000	.00284	.00056		40,100,000
31000	.00284	.00056		41,500,000
32000	.00284	.00056		42,800,000
33000	.00284	.00056		44,200,000
34000	.00284	.00056		45,500,000
35000	.00284	.00056		47,000,000
36000	.00289	.00061	.00005	44,200,000
37000	.00294	.00066	.00005	42,100,000
38000	.00294	.00066		43,200,000
39000	.00298	.00070	.00004	41,800,000
40000	.00303	.00075	.00005	40,000,000
	.00324	.00096	.00021	32,000,000
41000	Breaking	Load.		

No. 13215.

Burmese Jadeite.

Area, .7634 sq. in.

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
500	.01120			
1000	.01130	.00010		7,500,000
2000	.01134	.00014	.00004	10,700,000
3000	.01137	.00017	.00003	13,200,000
4000	.01137	.00017		17,600,000
5000	.01141	.00021	.00004	17,900,000
6000	.01141	.00021		21,400,000
7000	.01145	.00025	.00004	21,000,000
8000	.01149	.00029	.00004	20,700,000
9000	.01149	.00029		23,200,000
10000	.01149	.00029		25,800,000
11000	.01153	.00033	.00004	25,000,000
12000	.01153	.00033		27,300,000
13000	.31153	.00033		29,600,000
14000	.01153	.00033		31,800,000
15000	.01153	.00033		34,100,000
16000	.01153	.00033		36,400,000
17000	.01157	.00037	.00004	34,500,000
18000	.01157	.00037		36,500,000
19000	.01157	.00037		38,500,000
20000	.01161	.00041	.00004	36,600,000
21000	.01166	.00046	.00005	34,300,000
22000	.01166	.00046		35,900,000
23000	.01166	.00046		37,500,000
24000	.01166	.00046		39,100,000
25000	.01166	.00046		40,700,000
26000	.01170	.00050	.00004	39,000,000
27000	.01170	.00050		40,500,000
28000	.01174	.00054	.00004	38,900,000
29000	.01174	.00054		40,200,000
30000	.01178	.00058	.00004	38,800,000
31000	.01178	.00058		40,000,000
32000	.01182	.00062	.00004	38,700,000
33000	.01182	.00062		39,900,000
34000	.01182	.00062		41,100,000

No. 13215, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
35000	.01186	.00066	.00004	39,800,000
36000	.01190	.00070	.00004	38,600,000
37000	.01190	.00070		39,600,000
38000	.01190	.00070		40,700,000
39000	.01194	.00074	.00004	39,500,000
40000	.01194	.00074		40,500,000
41000	.01198	.00078	.00004	39,400,000
42000	.01198	.00078		40,400,000
43000	.01198	.00078		41,700,000
44000	.01202	.00082	.00004	40,300,000
45000	.01202	.00082		41,200,000
46000	.01207	.00087	.00005	39,600,000
47000	.01211	.00091	.00004	38,700,000
48000	.01211	.00091		39,600,000
49000	.01216	.00096	.00005	38,300,000
50000	.01216	.00096		39,000,000
51000	.01216	.00096		39,800,000
52000	.01216	.00096		40,600,000
53000	.01220	.00100	.00004	39,700,000
54000	.01238	.00118	.00018	34,300,000
* 55000	.01328	.00208	.00090	19,800,000
	* Breaking	Load.		

No. 13214.
Chinese Nephrite.
Area, .9627 sq. in.

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
500	.02490			
600	.02495	.00005		9,000,000
700	.02500	.00010	.00005	5,200,000
800	.02500	.00010		6,000,000
900	.02505	.00015	.00005	4,500,000
1000	.02505	.00015		5,000,000
2000	.02511	.00021	.00006	7,100,000
3000	.02517	.00027	.00006	8,300,000
4000	.02522	.00032	.00005	9,400,000
5000	.02522	.00032		11,700,000
6000	.02528	.00038	.00006	11,800,000
7000	.02528	.00038		13,800,000
8000	.02528	.00038		15,700,000
9000	.02528	.00038		17,800,000
10000	.02528	.00038		19,700,000
11000	.02533	.00043	.00005	19,400,000
12000	.02533	.00043		20,900,000
13000	.02533	.00043		22,600,000
14000	.02533	.00043		24,400,000
15000	.02533	.00043		26,200,000
16000	.02539	.00049	.00006	24,500,000
17000	.02539	.00049		26,000,000
18000	.02544	.00054	.00005	25,000,000
19000	.02544	.00054		26,400,000
20000	.02544	.00054		27,800,000
21000	.02550	.00060	.00006	26,300,000
22000	.02550	.00060		27,500,000
23000	.02550	.00065	.00005	26,500,000
24000	.02550	.00065		27,700,000
25000	.02550	.00065		28,900,000
26000	.02560	.00070	.00005	27,800,000
27000	.02560	.00070		28,900,000
28000	.02560	.00070		30,000,000
29000	.02566	.00076	.00006	28,600,000
30000	.02566	.00076		29,600,000

No. 13214, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
31000	.02566	.00076		30,600,000
32000	.02572	.00082	.00006	29,300,000
33000	.02577	.00087	.00005	28,400,000
34000	.02583	.00093	.00006	27,400,000
35000	.02588	.00098	.00005	26,800,000
36000	.02588	.00098		27,500,000
37000	.02588	.00098		28,300,000
38000	.02594	.00104	.00006	27,400,000
39000	.02599	.00109	.00005	26,800,000
40000	.02599	.00109		27,500,000
41000	.02599	.00109		28,200,000
42000	.02605	.00115	.00006	27,400,000
43000	.02605	.00115		28,000,000
44000	.02605	.00115		28,600,000
45000	.02605	.00115		29,300,000
46000	.02605	.00115		29,900,000
47000	.02610	.00120	.00005	29,400,000
48000	.02615	.00125	.00005	29,600,000
49000	.02620	.00130	.00005	28,200,000
50000	.02620	.00130		28,800,000
51000	.02620	.00130		29,400,000
52000	.02620	.00130		29,900,000
53000	.02625	.00135	.00005	29,400,000
54000	.02630	.00140	.00005	28,900,000
55000	.02630	.00140		29,400,000
56000	.02635	.00145	.00005	29,000,000
57000	.02640	.00150	.00005	28,500,000
58000	.02645	.00155	.00005	28,000,000
59000	.02650	.00160	.00005	27,600,000
60000	.02655	.00165	.00005	27,300,000
61000	.02659	.00169	.00004	27,000,000
62000	.02664	.00174	.00005	26,700,000
63000	.02669	.00179	.00005	26,400,000
64000	.02674	.00184	.00005	26,100,000
65000	.02674	.00184		26,400,000
66000	.02678	.00188	.00004	26,300,000
67000	.02680	.00190	.00002	26,400,000

No. 13214, *Continued.*

LOADS AND CORRESPONDING DEFORMATIONS.

Applied loads in lbs. per sq. inch.	Compressometer readings in inches.	Change of length in inches.		Modulus of elasticity.
		Actual.	Difference.	
68000	.02683	.00193	.00003	26,500,000
69000	.02684	.00194	.00001	26,600,000
70000	.02686	.00196	.00002	26,800,000
71000	.02687	.00197	.00001	27,000,000
72000	.02687	.00197		27,400,000
73000	.02687	.00197		27,800,000
74000	.02692	.00202	.00005	27,500,000
75000	.02696	.00206	.00004	27,300,000
76000	.02701	.00211	.00005	27,000,000
77000	.02705	.00215	.00004	26,800,000
78000	.02710	.00220	.00005	26,600,000
79000	.02714	.00224	.00004	26,400,000
80000	.02718	.00228	.00004	26,300,000
95150	Breaking	Load.		

Amount of Deformation.—On comparing the columns of "Differences" in the tables given above, it will be noted that the amount of compression for each additional load of 1000 lbs. per square inch of area was very uniform throughout the whole set of tests. With few exceptions the maximum variation for the whole 400 observations taken was about .0001 of an inch, and the majority of the variations were within .00003 of an inch. This uniformity is slightly more apparent in the tests of nephrite than in jadeite.

In many instances, particularly with the jadeite, several increments of load would be added before any additional increase in deformation would be observed. In this respect it was more erratic than the nephrite. However, considering the very small value of these measurements and the fact that the specimens were not duplicates, the results are really quite wonderful. Attention must also be called to the fact that all the variation recorded is not due to deformation of the specimen. A certain proportion must be charged to unavoidable errors in reading the instrument, and a considerable portion to errors in the instrument itself. The Olsen compressometer used was the only one obtainable suited for so short a gauged length as $\frac{3}{4}$ of an inch. It read directly to only $\frac{1}{10000}$ (.0001) of an inch, and smaller values were estimated. The instrument was not as accurate as claimed by its maker, though by carefully standardizing, and obtaining its errors for the range over which it was used, it was possible, by applying corrections, to get quite accurate observations. An initial load of 500 to 1000 lbs. per square inch was applied before readings were begun, and most of the records are not to be fully depended upon until a load of 2500 lbs. per square inch has been reached. By that time specimen and instrument have settled to a rigid bearing and the readings become logical.

The total amount of compression as expressed in percentage of the gauged length of $\frac{3}{4}$ of an inch is also quite uniform. On the four specimens where measurements were obtained at loads of 75,000 lbs. per square inch, the amounts of compression were practically $\frac{5}{10}$, $\frac{3}{10}$, $\frac{4}{10}$, and $\frac{4}{10}$ of 1 per cent—a variation of only $\frac{2}{10}$ of 1 per cent. in all. With the two jadeites from Burma, which broke at 40,000 lbs. and 55,000 lbs. per square inch respectively, measurements made at 40,000 lbs. per square inch on each give exactly the same amount of compression; viz., $\frac{1}{10}$ of 1 per cent.

Numerous attempts were made to determine if permanent set remained after the application and removal of certain definite loads, but the amounts were so small, if any really existed, they were beyond the capacity of the instrument to measure accurately, so the plan was abandoned.

Specimens Nos. 13336, 13268, and 13030 were measured laterally while sustaining a load of 75,000 lbs. per square inch, and these dimensions were found to have increased in proportion as the vertical dimensions had decreased. With one exception (which may have been an error in reading), this expansion in each direction was from $\frac{1}{2}$ to $\frac{2}{3}$ of the total compression which the cube had suffered owing to the load it was supporting.

Elastic Limit—With the possible exceptions of Nos. 13102D and 13215, none of the specimens showed any clearly defined Elastic Limit under the loads for which deformations were measured. The two exceptions crushed before the instrument was removed, so deformation readings were taken up to the point of failure. In these two instances there is a large increase in the amount of compression just previous to the failure (see Plate of Stress-Diagrams) and would seem to indicate an Elastic Limit, though the point is so near the breaking load it is quite probable that final disintegration had begun.

Modulus of Elasticity.—The modulus of elasticity was calculated for each deformation measured. In computing this the well-known formula $E = \frac{p}{d}$ was employed, in which

E = modulus
p = unit load
d = unit deformation

It will be observed from the tables that the modulus of elasticity has a marked variation for the different specimens, and for different loads on the same specimen, but this is to be expected with such material. It is well known that the modulus of elasticity of stone is quite variable, and increases with increase of load over quite large ranges of application, often differing by several millions in value. This characteristic is very marked in these tests, but as a whole the results are surprisingly regular when one takes into consideration the widely varying character of the specimens, the very small length measured, on account of which a slight variation in the fourth decimal place of measurement would make a difference of hundreds of thousands in calculating the value of the modulus.

The varying value of the modulus for each specimen are clearly shown in the accompanying diagram, where all the moduli for each test were plotted to scale, and the average curves drawn.

In all cases the modulus gradually increased with the load; sometimes this continued to the point where the instrument was removed, as in the nephrite from China, No. 13268; sometimes it rose to a maximum and practically held there, with moderate fluctuations for some time, then reduced slightly as in the case of the New Zealand nephrite No. 13030, and the Chinese nephrite No. 13214, while in the case of the Burmese jadeite No. 13336 it rose to a maximum in the same way, then took a decided fall with gradual regularity.

The two jadeites from Burma, No. 13215 and No. 13102D, both crushed while the compressometer was still attached, and they both show a sharp falling off of the modulus during the application of the last few thousand pounds of load. This was undoubtedly due to incipient failure of the specimen. The former—No. 13215—gives a very regular curve, but the curve of the latter is exceedingly erratic in its character, for which no cause is apparent. Probably due to errors in reading the instrument.

The most remarkable feature of these figures, and the one which shows more clearly than anything else the wonderful tenacity and elasticity of this rare mineral, is the very high value which the modulus attains.

The minimum value is 3,000,000 and the highest 47,000,000. Four specimens gave a maximum of over 30,000,000, and for No. 13268 (the lowest record) the maximum was 15,000,000.

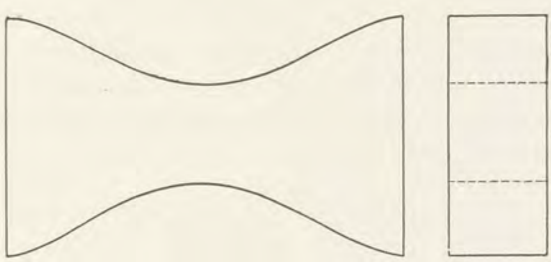
The extraordinary character of these figures will be best understood by reference to the following table, giving the approximate values of the modulus of elasticity for various well-known materials as determined by United States Government tests:

Steel, ...	28,000,000 to 30,000,000
Cast Iron, ...	12,000,000 " 27,000,000
Marble, ...	6,000,000 " 14,000,000
Blue Stone, ...	4,000,000 " 9,000,000
Granite, ...	2,000,000 " 9,000,000
Limestone, ...	3,000,000 " 5,000,000
Sandstone, ...	1,000,000 " 5,000,000
JADE, ...	3,000,000 " 47,000,000

The figures given for stone are considerably higher than those given by Professor Bauschinger from investigations on Bavarian stone.

TENSION TESTS.

These also were made by Professor Woolson with the same Emery Hydraulic Testing-Machine, and on specimens of the carefully selected and typical material already described as having been used in the other tests; viz.: 13336, jadeite from Burma; 13268, nephrite from China; and 13030, nephrite from New Zealand. Only one specimen of each was tested. They were of the shape and size shown in the annexed diagram.



The results are here tabulated :

Material..........	Jadeite	Nephrite	Nephrite
Source...........	Burma	China	New Zealand
No. on Specimen..	13336	13268	13030
Thickness.........	.570 inches	.505 inches	.517 inches
Average width at Fracture........	.564 inches	.540 inches	.700 inches
Area at Fracture ..	.265 sq. inches	.270 sq. inches	.362 sq. inches
Maximum Load...	1340 lbs.	1620 lbs.	1970 lbs.
Strength per sq. inch..........	5056 lbs.	5959 lbs.	5442 lbs.
Character of Fracture............	Square across	Somewhat ragged and at an angle	Quite irregular and ragged
Time of Test......	10 minutes	8 minutes	11 minutes

REMARKS : Seams in structure of Nos. 13268 and 13030 turned white when nearing the maximum load.

At a pull of 1920 lbs. the first crack occurred in No. 13030, and the specimen opened on one side.

The figures are very uniform, but are in no way as striking as the compression tests. The specimens were so short it was impossible to attach an instrument for measuring the deformation, so the ultimate strength was the only result obtained.

The great cohesive power of jade is very clearly shown by these tests of Woolson and Page. It is this wonderful resistance to stresses of every kind which conduces to the enduring quality of the mineral and makes it possible to carve it into the most delicate forms and impart to it such a high polish. Crystals of diopside, tremolite, and actinolite, the equivalents of the jade minerals in composition and hardness, possess none of the great tenacity which isolates nephrite and jadeite. After what has been said above, however, under the head of Structure, it is not difficult to understand that this great difference in cohesiveness is to be traced to the fibrous character of jade, the individuals which compose the mass being so compactly felted, woven, and twisted together that the whole possesses a power of resistance to fracture or to cutting far above that of the individuals themselves.

It is said of nephrite, as of almost every rock or mineral that is mined, that when first taken from the mine it is susceptible of being much more readily worked than later. There is a possibility that while it still contains a little quarry-water it may be a trifle more readily worked, but this has never been proved. Indeed, it is the difficulty of quarrying jade that impels the quarry-men of Burma to resort to the use of fire in detaching the jade mass from its bed. This difficulty was well illustrated in the writer's experience at the Jordansmühl quarry in April, 1899, when an attempt was made by drilling and blasting to remove the large block of nephrite weighing 2140 kilogrammes, now in the Bishop Collection. After a few blows on the head of the drill the point broke off, much to the surprise of the workmen, and the blasting had to be abandoned.

FRACTURE.

The fibrous structure which gives to the jade minerals their exceptional tenacity is again expressed in their mode of fracture. Both jadeite and nephrite possess a very perfect cleavage parallel to the prismatic planes of their crystals ; but as a rule the individuals are so small in both minerals that these cleavages are imperceptible and the fracture surface is very uneven, splintery, and as though dusted over with minute slivers of the substance, the roughness being readily felt if the finger be drawn across the surface. It may best be likened to the surface of broken horn.

This type of fracture is, however, particularly characteristic of nephrite. The more granular jadeite, especially that of coarser grain, breaks with a distinctly granular fracture often not unlike that of marble—the cleavage of each grain being visible in the numerous glistening facets that stud the surface. But even this granular fracture-surface is more or less rough and splintery, thus testifying to the tenacity with which the particles cling to one another.

HARDNESS.

Hardness, or the degree to which a substance resists abrasion, is one of the simplest and one of the most practical means of distinguishing minerals, and especially in distinguishing jadeite from nephrite. It has been found that the hardness of pure nephrite is quite constant at 6.5 of the Mohs scale, or that of microcline feldspar, *i. e.*, it can be scratched by quartz, but will not scratch quartz; whereas jadeite when pure is very constant at 7 (the hardness of rock-crystal), but it can be scratched by agate or chalcedony, which are a trifle harder than the crystalline varieties of quartz (rock-crystal and amethyst). Consequently jadeite will scratch nephrite, especially when it is polished. If, therefore, a slab of polished nephrite be plainly scratched by a jade mineral, the latter cannot be nephrite and may be classed as jadeite. This, however, is true only of pure jadeite and pure nephrite. Errors may arise from the admixture of other minerals, in greater or smaller quantities. In some pieces these can be detected by the naked eye, or with the aid of a pocket lens, but can most surely be detected and identified by microscopic examination of thin sections.

The hardness, according to the Mohs scale, of every piece in the Bishop Collection was determined by the present writer, by the methods common among mineralogists, and by means of finely pointed triers made of the following minerals:

Topaz, with a hardness of 8
Quartz, with a hardness of 7
Microcline feldspar, with a hardness of 6.5
Orthoclase feldspar, with a hardness of 6
Apatite, with a hardness of 5

To corroborate the results thus obtained and for purposes of comparison, a set of six additional triers was made from typical pieces of jadeite and nephrite in the Collection. These, like the five already mentioned, consisted of small prismatic sections, 4 to 5 mm. in breadth, and 10 to 20 mm. in length, pointed at each end. They were as follows:

13210	Crude jade from	Silesia,	No. 1—	Hardness	6.5	Mohs	scale
13211	" " "	Siberia,	" 2—	"	6.5	"	"
13030	" " "	New Zealand,	" 3—	"	6.5	"	"
13267	" " "	Burma,	" 4—	"	7	"	"
13268	" " "	China,	" 5—	"	6.5	"	"
13215	" " "	Burma,	" 6—	"	7	"	"

The triers were held firmly in the hand and then steadily drawn across the specimen to be tested for a distance of usually not more than 2 to 5 mm. The trier of the lowest hardness was first used, and then the next higher in regular succession until a scratch could be obtained, and owing to the extreme fineness of the points so delicate was this scratch that it was scarcely discernible by the naked eye. Indeed, in many cases it was necessary to use a pocket lens. In almost every instance the result was obtained with little difficulty, for even the mineralogical pieces had been polished on one side to show more clearly the color of a polished surface as well as that of the natural fracture or cleavage, and every archæological object had either a polished or a smooth surface. Nephrite was not affected by orthoclase feldspar (unless part of it was decomposed), it was scarcely marked by microcline feldspar, but could readily be scratched by quartz. Jadeite was not affected by microcline feldspar, scarcely by quartz, but markedly by chalcedony and agate points, which, although quartz, are slightly harder; and of course the jadeite of Burma scratched the nephrite from Silesia, Siberia, and New Zealand.

In addition to these tests, 16 pieces were selected to be tested by the Microsclerometer, the ingenious instrument invented by Dr. Thomas Augustus Jaggar, Jr., of Harvard University, whose results, however, are stated according to a new scale in which corundum (corresponding to 9 in the

Mohs scale) has an empirical value of 1000 assigned to it. His report is as follows :

MICROSCLEROMETER TESTS OF HARDNESS.

BY THOMAS AUGUSTUS JAGGAR, JR.

The only accurate mechanical tests of the hardness of jade that have been made, so far as known to the writer, are those by Martens (*Zeitschr. für Ethnologie*, Vol. XXIV., p. 248, 1892), for use intesting the hardness of metal in the Technical High School at Charlottenburg, Prussia. The mean width of scratch made by a diamond point of known dimensions, under constant weights, is taken as the determinant of relative hardness. A cone-shaped cut diamond of 90° angular cross-section, is held, point downward, in the end of a balance arm ; a polished surface of the mineral is drawn under this point on a sliding carriage, and scratches are so produced under weights varying from 10 to 30 grammes. The mean width of scratch (b) for 20 grammes is taken from direct readings under that weight, and the mean of weights greater and less (10, 15, 25, and 30 grammes). The measurement of width of scratch is made with the microscope, using the ocular screw-micrometer and the Zeiss B objective (0.1 mm. equal to 7.382 rotations (R) of micrometer screw). Three faces of the nephrite were cut in different directions on the same specimen, and uniformly polished, and scratches were made in two directions at right angles to each other on each face. The reciprocal values of the width of scratch (in mm.) are given as hardness grades. Unfortunately no tests with the Mohs scale are recorded as having been made by this method, and we have only metals for comparison. The following table shows the values obtained for this specimen of nephrite :

Face	Direction of scratch	Mean width of scratch b, expressed in rotations R	Hardness $H=1/b\times7.382/0.1$
I	1 a	0.530	139
	1 b	0.352	210
II	2 a	0.394	187
	2 b	0.406	182
III	3 a	0.362	204
	3 b	0.344	214
Steel, blue tempered		0.465	159
Steel, yellow tempered		0.386	191

In the following pages are recorded the results of tests made with the microsclerometer, for a full description of which see the *American Journal of Science*, Vol. IV., December, 1897, and *Zeitschrift für Krystallographie* etc., XXIX Bd., 3rd Heft, p. 262. The object of this instrument, like that of Martens, is to provide a precise method of measuring the resistance of a smooth surface of a substance to abrasion by a diamond point.

The principle of the instrument is as follows: A diamond point of constant dimensions is rotated on an oriented mineral section under uniform rate of rotation and uniform weight to a uniform depth. The number of rotations of the point, a measure of the duration of the abrasion, varies as the resistance of the mineral to abrasion by diamond: this is the property measured. The instrument consists of the following parts,

(1) A standard and apparatus for adjusting to microscope;
(2) A balance beam and its yoke;
(3) A rotary diamond in its end;
(4) Apparatus for rotating uniformly;
(5) Apparatus for recording rotations;
(6) Apparatus for locking and releasing;
(7) Apparatus for recording depth;

and it admits of measurement with any one of the four variables, rate, weight, depth, or duration. The last has been found most practical because it gives the highest values and hence admits of the most delicate gradation.

For the tests with jade the diamond point was perfectly centred so that its action was that of a drill. The micrometer scale was arranged parallel to a cross-hair of the ocular, set in the 45° position from lower right-hand quadrant to upper left, and the inclination of the scale was so adjusted that the three scale divisions nearest the centre should record a change of focus representing a boring to a depth of 15 μ. It is important that these focal measurements be read always on the same part of the field of the ocular, as there is considerable variation in different parts, due to aberration. It is also necessary to adopt a uniform criterion of focal perfection, though the sharp focus is more easily read on a fine scale ($\frac{1}{100}$ mm.) highly inclined, than on the coarse one ($\frac{1}{20}$) formerly used. With a little practice the depth may be accurately read to within .0005 mm. of $\frac{1}{2}$ μ. The rate adopted for these tests was 10 revolutions of the diamond per second, and the weight used was 40 grammes. Polished sections of each specimen, averaging 0.4 mm. thick, were made and mounted on glass. An interesting check on the results attained was furnished by the degree of polish taken by different slides, and sometimes by different parts of the same preparation. As shown by Behrens (*Anleitung zür Mikrochemische Analyse*, 1895) the harder portions take the higher polish. Where more than one value for the same preparation is given in the following pages, the reference is to different parts of the same surface. Under a high power in the microscope the borings show an outer ring and a central pit; this is due to the fact that the diamond point, microscopically, is not a perfect pyramidal point, but is a minute nipple surmounting edges which diverge at a wider angle; the nipple bores the core and when the edges are reached the outer ring is abraded; the boring may thus be described as somewhat funnel-shaped, steep about the centre and flaring above. In accordance with this irregularity in the shape of the point, it is found that the downward movement of the micrometer per unit of depth is much more rapid at the beginning of a test than toward the end, when the retardation is very great after the first nipple tip is passed. The borings are seen to be perfectly clean, with the filings usually piled in a ring about the periphery. Slight sources of error in this series of tests are irregularities of rate and of initial surface and texture of preparation ; all results are averaged from at least three tests with each preparation. Uniformity of results was neither expected nor attained with jade surfaces, as the texture is extremely various and the substance is usually both mineralogically a mixture, and chemically impure. Constant results can be expected only from definite crystals of uniform composition and on a surface of known orientation relative to crystallographic form.

As a basis for comparison special tests with the harder minerals of the Mohs scale were made by exactly the same procedure as was used throughout for the series of jade specimens, and gave the results shown below ; the hardness value is expressed in all cases with reference to a value for Corundum of 1000. It will be seen that the number of rotations of the diamond point, under 40 grammes weight, at the rate of ten rotations per second, to a depth of 15μ, on a corundum cleavage surface, was 25,814 ; if we give this mineral the empirical value of 1000 the corundum unit becomes 25,814. Each value as expressed in rotations of the boring point, for other minerals, is divided by this unit.

	Rotations	Hardness
Corundum		
Cleavage rhombohedron,	25814.00	1000
Topaz		
Basal,	6113.66	236.8
Quartz		
Average of prism and basal sections,	1525.66	59.1

In the following description of tests with specimens of nephrite and jadeite, the specific gravity, color, chemical characteristics, and petrographical peculiarities are appended in each case for comparison. The specimens are arranged in the order of increasing hardness.

13251. Lake-dweller's hatchet from Lake Constance, showing influence of heat, "*burnt jade*"; specific gravity, 2.9035; color, ashy-gray; nephrite,—fibrous.

Petrography: In this thin section there is a faint suggestion of the patches derived from previous pyroxene, but the amphibole fibres are in a confused aggregation, with occasionally longer streaks of nearly parallel fibres. There is a yellowish stain in part of the section which seems to be occasioned by hydrous oxide of iron. A brown mineral in thin plates resembles mica. No polish.

Hardness: Too soft for these tests. About like fluorite in its action, the diamond bores through to the glass at once. Possibly the preparation is too thin. The material is softer, however, than any other in the collection examined.

13210. Crude jade from Jordansmühl, Silesia, Prussia; specific gravity, 2.9451; percentage of silica, 54.44; color, spinach-green, unevenly blended with black; nephrite.

Petrography: Numerous compact prisms of amphibole with marked microstructure. The prisms grade into fibres, are in parallel groups, and cross each other. No polish; fibrous in appearance.

Hardness:

	Revolutions		Hardness	
(1)	333.8	=	12.9	
(2)	87.5	=	3.3	narrow soft streak.

Remarks: Tests were made in lines across different parts of the slide, giving the following results: 1st line—344, 496, 244, 341. Second line—112, 63, 244.
soft area

13267. Fragment of boulder from Burma; specific gravity, 3.1223; percentage of silica, 57.36; color, lettuce-green.

Analysis shows an intermediate composition between jadeite and nephrite, with alumina 10, magnesia 12, and soda 1. This is borne out by the specific gravity.

Petrography: Classed as a mixture of jadeite and amphbole; the prisms acicular, and fibrous. Amphibole pale green and pleochroic.

Hardness:

Revolutions		Hardness
624.5	=	24.2

Remarks: Slide is irregularly polished, as though portions were harder, and this is confirmed by one abnormally hard reading as shown in following readings across slide: 557, 487, 587, 1403, 218, 495. This accords with the probability of the mass being a mixture of nephrite with a little of the harder jadeite.

13223. Hatchet from Neufchâtel, Switzerland; specific gravity, 3.0034; percentage of silica, 55.49; color, light olive-green. Composition of normal nephrite—high magnesia and lime.

Petrography: Most extreme case of a nephrite with parallel fibres, with striations that seem to be due to twinning parallel to orthopinacoid. Brown and white fibre zones.

Hardness:

Revolutions		Hardness	
695.5	=	26.9	average
869.	=	33.6	brown zone
522.	=	20.2	white zone.

Remarks: Readings 447, 597 white; 661, 1077 brown.

13214. Chinese boulder; specific gravity, 2.9825; percentage of silica, 58.59; color, light sage-green; nephrite.

Analysis, quite normal, high in magnesia and lime.

Petrography: A few fragments of jadeite remain; the mass of the rock consisting of amphibole fibres, that in places reach the size of compact crystals.

Hardness:

Revolutions		Hardness
694.66	=	26.9

Remarks: Readings 667, 716, 701.

13211. Part of boulder from Belaja River, near Irkutsk; specific gravity, 3.0138; percentage of silica, 57.65; color, brilliant seaweed-green; nephrite, very high in calcium.

Petrography: Mottled patches map out the former pyroxene crystals, now altered to long streaks of parallel fibres of nephrite.

Hardness:

	Revolutions		Hardness
	750.5	=	29.0
soft area =	458.	=	17.7

Remarks: 441, 475, 688, 830, 799, 685.
soft area

13268. Small boulder of white Chinese jade; specific gravity, 2.9690; percentage of silica, 57.43; color, greenish-gray; the surface incrusted with a patina of many shades from black to light brown. Nephrite, normal analysis, with high magnesia.

Petrography: Coarse mottled patches representing the areas of original jadeite crystals, now altered to fan-like and spherulitic bundles of nephrite fibres. Other bundles in cross-section. Thus a close, but coarse, mesh of fibres.

Hardness:

Revolutions		Hardness
768.66	=	29.7

Remarks: Readings 832, 770, 704.

13262R. White medallion, formerly part of a sceptre; specific gravity, 2.9510; percentage of silica, 57.77; color, opalescent white; normal nephrite composition.

Petrography: Large patches consisting of a microscopic aggregation of fibres of colorless amphibole that extinguish light between crossed nicols; these patches correspond to the originally twinned jadeite. There is also a mottling similar in size to that noticed in the large crystals of jadeite where it was the result of strain.

Hardness:

Revolutions		Hardness
1437.66	=	55.6

Remarks: Constant readings—1462, 1398, 1453. The sudden jump to double former hardness values should be noted.

3095. Jadeite from Burma; specific gravity, 3.3287; color, emerald-green blending into lighter tints; no analysis.

Petrography: A fibrous modification of jadeite which might almost be mistaken for fibrous amphibole.

Hardness:

Revolutions		Hardness
1649.25	=	63.8 (average of four best readings).

Remarks: Preparation has deep green and white portions. The readings obtained were not uniform: 1371, 718, 1727, 1971, 1528.
(1371, 718 — white; 1727, 1971 — green)

13207. Green stone chisel, said to be from Siberia, but purchased in the City of Mexico; specific gravity, 2.9673; color, spinach-green venated with black; no analysis; nephrite.

Petrography: Confused amphibole fibres.

Hardness:

Revolutions		Hardness	
1432.	=	55.4	
974.33	=	37.7	average 3 softest parts
1889.66	=	73.2	" 3 hard parts.

Remarks: There are considerable variations in the hardness in different parts of the surface of the section. Readings, 1466, 803, 1171, 1835, 2368, 949. This diversity of values in the same preparation is more noticeable in the harder specimens, and is probably due to an admixture of secondary nephrite with some original jadeite.

13216. Hatchet from New Caledonia; specific gravity, 2.9311; percentage of silica, 52.60; color, dark brown with veins and lines of lighter shades; normal nephrite.

Petrography: Uniform mixture of amphibole fibres in divergent clusters sometimes almost spherulitic, without any special trace of original jadeite.

Hardness: Gave very diverse results in different tests, and the cause of these differences does not appear. The preparation is rather thin, and this may affect results. In a first set of tests the mineral showed extraordinary hardness, almost equal to corundum; in a later series it showed a moderate hardness. It is possible that the first results were influenced by some accident in the manipulation of the instrument.

		Revolutions		Hardness
1st series	—	20069.5	=	777.4
2nd "	—	2095	=	81.1

13086. Adze from New Zealand; specific gravity, 3.2663; percentage of silica, 54.19; color, pear-leaf green, with lighter shades interspersed, and upon the rougher surface brown oxidation.

Analysis: That of nephrite, with high magnesia and lime.*

* In regard to this specimen see Penfield's *Chemical Notes*, on a later page.—*Note by Editor.*

Petrography: Probably impurities account for the abnormally high specific gravity; consists of minute fibres and particles with banded structure; small opaque spots, and crystals of a reddish-brown isotropic mineral, surrounded by a white opaque substance—probably perovskite. This would account for the added weight.

Hardness:

Revolutions		Hardness
2544.5	=	98.5

Remarks: Readings, 1382, 2217, 2611, 3135, 3377. Showed a singularly regular increase in hardness across the preparation in one direction.

13030. Piece of natural jade from New Zealand; specific gravity, 3.0122; percentage of silica, 57.78; color, dark rich green mottled with lighter tones; nephrite in composition, considerable iron, and alkali strong.

Petrography: Laminated fibres of nephrite with indications of crushing and dynamic metamorphism.

Hardness:

Revolutions		Hardness
2754.4	=	106.7

Remarks: Readings across preparation at distance of 0.3 mm. gave as follows: 2612, 4171, 2741, 701, 960, 2458, 1790. Thus the readings differ
soft area
considerably, and a soft area is shown at one point.

13266. Prehistoric Chinese celt; specific gravity, 2.9506; percentage of silica, 52.98; color, dark brown of various tints, grading to pale yellowish-brown and mingled with shades of gray; nephrite, excessively high in magnesia—(25.49 per cent.).

Petrography: A mixture of jadeite and nephrite, the latter derived from the former; the mass is of nephrite fibres that sometimes reach the size of compact crystals. A small amount of colorless jadeite occurs in fan-shaped aggregates.

Hardness:

	Revolutions		Hardness
On portions that have taken polish,	3963.	=	153.4
On portions that have not taken polish,	2050.	=	79.4
General average,	2861.2	=	111.2

Remarks: Readings, 3700, 1317, 2542, 2122, 2219, 3710, 4419. It is probable that the polished patches contain more jadeite, and the matt portions nephrite; variations are also to be expected from differently oriented crystals. Note similarity of values in 1st and 6th readings.

13215. Piece of boulder of jadeite from Burma; specific gravity, 3.2176; percentage of silica, 58.41; color, white mingled with a bluish-green. Jadeite, very high in alumina and soda, with only a little over 1 per cent. each of magnesia and lime.

Petrography: Characteristic jadeite. Aggregate of crystals, sometimes long prisms. A colorless mineral acts as cement or matrix for the jadeite crystals, which may be analcite.

Hardness:

	Revolutions		Hardness
General average,	2024.4	=	78.4
Homogeneous polished jadeite,	3353.5	=	129.9

Remarks: The preparation showed high polish; the two highest values, from which the last figure above given was obtained, were clean small borings remote from any cleavage cracks, which are present in most of the other borings. Readings, 1066, 1696, 1410, 1657, 2473, 1635, 4234.

13102C and D. Two fragments of jadeite slabs cut from a boulder or weathered mass of Burmese jadeite: specific gravity, 3.2578, and 3.2466, respectively; percentage of silica, 57.54 (average of three analyses of 13102C); coarsely granular;

color, lavender, clouded with bright lettuce-green and dead black.

Hardness :

Revolutions		Hardness
3802	=	147.2

Remarks : Highly polished; some portions smoother, others dark and cleaved. The latter give the lowest readings, 5508, 5901, 2185, 2380, 3343, 3498. Note the three sets of two like values each. Does this mark separate crystals?

SUMMARY.

No.	Name	Specific gravity	Silica	Hard-ness	Color	Remarks
13251	Nephrite	2.9035	....	Soft	Gray	Burnt jade, matt
13210	"	2.9451	54.44	12.9	Green	A soft area, matt
13267	" ?	3.1223	55.92	24.2	"	Irregular polish and hardness
13214	"	2.9825	58.59	26.9	"	Some jadeite present
13223	"	3.0034	55.48	26.9	"	Hard and soft zones
13211	"	3.0138	57.65	29.0	"	A soft area
13268	"	2.9690	57.43	29.7	Gray-green	
13207	" ?	2.9673	....	55.4	Green	H. very variable
13262R	"	2.9510	57.77	55.6	White	H. uniform
3095	Jadeite ?	3.3287	....	63.8	Light green	H. not uniform
13216	Nephrite	2.9311	52.60	81.1	Brown	A first set of tests gave extraordinary H. = 777.4
13086	"	3.2663	54.19	98.5	Green	Impure
13030	"	3.0122	57.78	106.7	"	H. not uniform
13266	Mixed	2.9506	52.98	111.2	Brown	Irregular; variable hardness
13215	Jadeite	3.2176	58.41	129.9	White	Reading given is pure jadeite; average is much lower = 78.4
13102C	Jadeite	3.2466	57.49	147.2	Lavender, green & black	Variable H.; irregular polish
....	Corundum	....	....	1000.		
....	Topaz	....	....	236.8		
....	Quartz	....	....	59.1		

The tabulated results of these hardness tests on specimens of jadeite and nephrite show clearly that in most cases we have to do with mixtures. The harder members show great variations in a single specimen, indicating the presence of secondary nephrite. It is clear that the color and amount of silica present are quite independent of the hardness. The specific gravity, also, shows great irregularities, and is probably affected by impurities, largely in the form of iron oxides. In general the specific gravity increases with the hardness, and both vary directly with the mineral composition ; both increase with the quantity of original jadeite which persists in the specimen, and decrease as secondary nephrite increases. The actual mean hardness of pure jadeite is probably not far from the value given for No. 13215, viz., 129.9, referred to a Corundum standard of 1000. From these tests it is not possible to state accurately the mean hardness of nephrite, as a smooth crystal surface of the mineral is not obtainable, and its varying fibrous texture influences widely the results. The values given for Nos. 13262R and 13207, namely about 55, represent an approximate mean for nephrite, or less than one-half the value given for jadeite. Thus jadeite as far as these tests are concerned, stands nearly midway between quartz and topaz, and nephrite is not quite as hard as quartz. No. 3095 is labelled "jadeite," but no analysis or petrographic description of this specimen was seen by the writer, and while the specific gravity is high, we are inclined to attribute this to impurities ; in any case, the hardness, as determined by these tests, is that of nephrite.

SPECIFIC GRAVITY.

The density, or specific gravity, of jade offers a comparatively simple problem for study. In jadeite we have a pyroxene, and in nephrite a member of the parallel amphibole series. In general terms, other factors being equal, the pyroxenes are higher in specific gravity than the amphiboles, and the difference is well beyond the range of experimental errors. The mean density of nearly 500 nephrites, according to the figures given elsewhere, is 2.95+. That of about 100 jadeites is 3.32+, and that of 6 chloromelanites is 3.40+. Chloromelanite is essentially a jadeite containing a larger proportion of iron compounds, and to that cause mainly its higher specific gravity is due. The table which is given lower down well shows the range of variation in each group of jade.

The determination of the density or specific gravity of every piece in the Collection that was not inseparably mounted in wood or metal was kindly undertaken by Professor William Hallock, of the Department of Physics in Columbia University, New York ; and his account of his methods, and of the special devices employed by him, is here given in full.

PROFESSOR HALLOCK'S ACCOUNT OF HIS WORK.

The determination of the density of a large number of such objects as are brought together in this wonderful Collection of Jades, and especially of large finely sculptured pieces, presents two problems of novel interest: first, the handling of a single piece weighing as much as 60 kilogrammes (132 pounds), several weighing from 5 to 15 kilogrammes (10 to 30 pounds); and secondly, a very large number of smaller articles.

Apparently no one has heretofore attempted to determine, by immersion, the density of an object weighing more than a few pounds, and indeed there has been little or no necessity for such a determination, since it is but rarely that a heavier specimen is sufficiently homogeneous to make its density of interest, and if it were, a piece could be knocked off for examination; but one cannot knock off a piece of an absolutely unique carved jade jardinière.

For the examination of the heavy articles a Kohlbusch bullion balance of 30 kilogrammes' (1000 ounces) capacity was used; two other Kohlbusch balances for moderate load, and a Becker analytical balance, were employed for the smaller articles, as the case required. For the great jardinière with its mass of 60 kilogrammes, double the load of our largest balance, a special device had to be invented. It consisted of an auxiliary lever, or balance-arm, having three parallel steel knife-edges, one under each end and one on top about one-fourth the length from one end. The knife-edge under the short end rested upon a plate of glass mounted upon a wooden trestle, the knife-edge under the long end of the bar rested upon a plate of glass lying on the centre of the left-hand scale-pan. Upon the third knife-edge rested a plate of glass under a yoke, from which depended a hook upon which the object to be weighed could be hung. By placing a 10-kilogramme weight upon this hook it was possible to weigh the pressure upon the scale-pan and thus determine accurately the ratio of the lever arms. Hanging the jardinière upon the hook its weight in air was observed, and then placing around it a tank of water it was possible to determine its weight when immersed in water, these two weights enabling one to calculate the density. The system is more efficient and convenient when the vertical plane through the balance beam and that through the auxiliary beam are approximately at right angles to each other.

The other pieces of over one kilogramme mass were placed upon the pan of a suitable balance and weighed, one after another. Then replacing the ordinary pan of the balance with a skeleton pan hanging upon a single fine wire in a tank of water, the same articles were weighed in water.

A great number of the articles under one kilogramme in mass (over 500) were determined upon a special form of balance constructed for the work. The left pan was removed and in its stead was placed a two-story pan; the upper one hanging directly on the beam, and the lower one hanging by a single fine wire from a hook under the upper pan. The lower pan was entirely submerged in a jar of water, only the suspending wire passing through the surface. Under these conditions the balance is counterpoised and adjusted and is then ready for the day's use. It must, however, be readjusted from time to time, on account of the varying temperature and level of the water. This arrangement is very convenient and enables one to determine densities very easily, rapidly, and withal accurately. The object is placed in the upper pan and weighed in air, then upon the lower pan and weighed in water, and all is finished. In the latter part of the investigation a similar two-story pan was fitted to all the balances. Any difficulty arising from the capillary action of the surface of water where the wire passes through is readily eliminated by making small waves on the water; for example, by tapping on the tank, or by putting the tip of the finger into the water while the weighing is going on.

In all cases the article was first wetted with alcohol, then washed in an auxiliary tank of water, and then placed on the lower pan in the weighing tank; in this way it was possible to ensure perfect wetting and the entire elimination of all air films and bubbles. In certain special cases where the article was slightly porous, it was weighed in water several times after periods of soaking ranging from a few hours to several days. The formula used to calculate the results is the usual one to be found in any reliable text-book:

$$D = \frac{M}{W} (Q - L) + L,$$

in which D is the density or specific gravity.
M is the apparent weight of the body in air.

W is the apparent loss in weight of the body when suspended in water.

Q is the density of the water in which the object is weighed.

L is the density of the air at the temperature and barometric pressure existing during the weighings. In practice it is sufficiently accurate to assume $L = 0.0012$.

This formula is rigidly correct, and allows for the buoyant effect of the air upon the weights as well as upon the object.

The object is weighed in air and this weight is M; it is then weighed while submerged in water whose temperature is noted; this weight in water subtracted from the weight in air gives W, the loss in weight due to the buoyant effect of the water; Q is obtained from a table giving the density of water at different temperatures.

The specific gravity of over 1000 separate pieces, with a density of 2.9 and over, was determined by Professor Hallock. The figures given below are based on the first 598 of these, and may be accepted as typical of all.

Of the 598 specimens	6 were	Chloromelanites
	101	Jadeites
	491	Nephrites

From 2.9 up to 3.0	417	pieces	averaged	2.9389	(Nephrite)
3.0 " " 3.2	74	"	"	3.0159	(Nephrite)
3.2 " " 3.34	101	"	"	3.3152	(Jadeite)
3.34 upward	6	"	"	3.4039	(Chloromelanite)

Taking the nephrites all together the average is 2.9505; the jadeites and chloromelanites together show an average of 3.3202.

Jadeites.

6 Chloromelanites average 3.4039

43 pieces have a specific gravity of	3.33+	(average 3.3351)
27	3.32+	(" 3.3252)
8	3.31+	(" 3.3182)
4	3.30+	(" 3.3041)
19	3.20+	(" 3.2527)

Nephrites.

3 pieces have a specific gravity of	3.10+	(average 3.1311)
71	3.00+	(" 3.0109)
34	2.99+	(" 2.9945)
28	2.98+	(" 2.9843)
45	2.97+	(" 2.9748)
69	2.96+	(" 2.9642)
145	2.95+	(" 2.9545)
65	2.94+	(" 2.9461)
24	2.93+	(" 2.9356)
4	2.92+	(" 2.9256)
1	2.91+	(" 2.9171)
2	2.90+	(" 2.9035)

491 nephrites average 2.9505

When we study the individual specimens in detail, many differences of density appear; but in most cases they are easily intelligible. In the less pure jadeites and in all the nephrites we have to deal with salts of lime and magnesia, which replace each other in varying proportions. An increase in magnesia tends to raise density, and an increase in lime to lower it. If, however, the lime in a specimen represents a pyroxene, as in No. 13086, the density will be higher than in an amphibole of similar composition. Iron increases density very perceptibly; water, on the other hand, is a depressing agent. Again, an admixture of a lighter mineral diminishes specific gravity; as in No. 13215, a mixture of jadeite and analcite of density 3.2176, and in No. 13193, a jadeite and albite mixture of density 2.8345. In short, the specific gravity of a given sample depends upon many factors, which often operate in different directions; but as we approach the typical minerals in their greatest purity remarkably constant and uniform values appear. The statistical table shows how close the determinations run together, and indicates a remarkable uniformity in this particular. In most cases density alone will distinguish between jadeite and nephrite, but the first species contaminated by a lighter impurity may even fall below a nephrite which happens to be rich in iron.

SONOROUSNESS.

The resonant character of jade has long been known to the Chinese, and regarded by them as a sure sign of the genuineness of the material, when found united with translucency and the proper color. "Sounding-stones," and stones for polishing them, are mentioned in the earliest historical records of China—twenty-three centuries B. C.—as tribute to be furnished by certain provinces, after the waters of the great Chinese flood had been regulated and drained off by Yu the Great, and the empire resurveyed by him.*

Confucius played on the "musical-stone," and we find frequent reference to it in the early classical literature of the country. "Full indeed is the heart of him who beats the musical-stone like that" was the remark of a passing peasant as Confucius—the sage, and disappointed reformer—then a sojourner in the principality of Wei, sought solace in the tinkle of the sounding-stone as he bewailed the degeneracy of his times and the non-success of his teachings.

The *Book of Poetry*, a collection of odes ranging in date from 1765 B. C. to the sixth century B. C., refers to the "musical-stone" in connection with the mouth-organ, the flute, and the drum; and in one of the odes whose theme was ceremonial music, we are told that

> "When the bells and drums sound in harmony
> And the sounding-stones and flutes blend their notes,
> Abundant blessing is sent down."

These musical-stones were of various kinds:

(1) The "single-stone," used "to receive the sound" at the end of a line, as in chanting a ceremonial hymn.

*See the *Shoo King*, Vol. III. pt. i. p. 121, in Legge's *Chinese Classics* (London and Hongkong, 1865).

(2) A series of sixteen, all of the same size and shape, but differing in thickness, forming the "stone chime," used in court and religious ceremonies.

(3) A series of twelve to twenty-four pieces carved into fantastic shapes forms what is called the "singers' chime."

Jade was the material best adapted for musical uses, but we are told in the books that other stones were also in use, especially a kind of black calcareous stone which was more easily worked than jade.*

The common form of the musical stones composing the stone chime is that of an undecorated obtuse-angled carpenter's square with unequal arms, the longer—that usually beat—measuring 1.8 feet and the shorter, 1.35 feet.

The Bishop Collection possesses several specimens of the decorated kind. Two of these (Nos. 3255 and 13,141) and a number of bowls and other objects, twenty-one in all, were selected for a series of special sound-tests by Professor Hallock of Columbia University, and his report, preceded by a description of the specimens tested, is now given in full.

TWENTY-ONE JADE OBJECTS TESTED FOR SONOROUSNESS.

No. 3176 A graceful ju-i sceptre of beautifully compact and pure nephrite ; 46.4 cm. long ; 11 cm. broad; and 1.3 cm. thick ; weight, 33.792 oz.; specific gravity, 2.9620 ; broad oval head of four-lobed outline, carved in relief ; an incised inscription on the stem.

Nos. 3098 A pair of plain rice-bowls of jadeite, 8 cm. in height and 3262 17.2 cm. in diameter ; specific gravity of No. 3098, 3.3376 ; of No. 3262, 3.3364 ; weight of 3098, 14.873 oz.; weight of 3262, 12.617 oz.

No. 3091 A bowl of remarkably pure jadeite, carved in slight relief, and known as a "camphor bowl" because of its resemblance in color and texture to lump-camphor, showing a translucent ground, thickly interspersed with clouds of opaque white ; height 5.5 cm.; diameter, 16.5 cm.; weight, 11.415 oz.; specific gravity, 3.3374. It is so translucent in parts that print in contact with it can be read through it.

* See *Chinese Music*, by J. A. Van Aalst, published by the Imperial Maritime Customs of China (Shanghai, 1884).

No. 3105 A small circular fluted dish of translucent, homogeneous and compact nephrite, modelled after the conventional chrysanthemum-pattern ; 3.5 cm. in height, and 16.6 cm. in diameter ; weight 7.591 oz., specific gravity, 2.9673.

No. 3103 A rice-bowl of remarkably fine-grained, translucent, homogeneous and compact nephrite, with a low foot cut in scallop fashion, and a double band of vertical flutings convex without and concave within. Height 5 cm. ; diameter 12 cm.; weight 5.344 oz. ; specific gravity 2.9492.

No. 3092 A highly polished nephrite bowl of remarkably pure material, and of almost egg-shell thinness, fluted into eight slightly bulging lobes, and poised upon a circular rimmed foot, and provided with handles carved in openwork with a spiral ornament. Height, 5.7 cm., diameter, 13.0 cm. ; weight, 6.204 oz.; specific gravity, 2.9506.

No. 3101 A small teacup of exceedingly pure and transparent jadeite, with a circular rim round the foot, and a slightly etched design on the outside. Height, 4.5 cm. ; diameter, 10.5 cm. ; weight, 3.152 oz. ; specific gravity, 3.3374.

No. 3106 A small polished bowl without decoration or carving except an incised inscription underneath. The material is nephrite, translucent, compact, and remarkably homogeneous in its texture. Height, 6.5 cm.; diameter, 14.3 cm.; weight, 10.293 oz. ; specific gravity, 2.9809.

No. 13097D A small round saucer-like dish with three rings of flutings surrounding a convex button-shaped middle engraved with cross lines. The nephrite is translucent, very compact and homogeneous, with inclusions of a black metallic substance—probably chromite. Height, 3.5 cm. ; diameter, 15.9 cm. ; weight, 7.216 oz. ; specific gravity, 2.9915.

No. 13094 A round saucer-like dish, finely fluted in three concentric rings encircling a round, nearly flat, cross-hatched centre. The nephrite is translucent, and very hornlike in its general texture. Height, 3.8 cm.; diameter, 16.1 cm.; weight, 7.415 oz.; specific gravity, 2.9968.

No. 3171 A large round dish of flattened saucer-like form, plain inside but covered outside with a carved decoration in slight relief. The nephrite is translucent, homogeneous and compact, and shows a number of inclusions. Height, 2.5 cm., diameter, 27.6 cm. ; weight, 20.024 oz.; specific gravity, 2.9757.

No. 3129 A shallow undecorated bowl with flat base ; of translucent, homogeneous, and compact Siberian nephrite. Height, 3.3 cm., diameter 12.2 cm.; weight, 5.425 oz.; specific gravity, 3.0154.

No. 3060 A large flaring bowl with circular rimmed foot, of the variety of nephrite styled "puddingstone jade." Height, 7.3 cm.; diameter, 20.3 cm.; weight, 17.448 oz.; specific gravity, 3.0034.

No. 3023 A large round saucer-shaped dish, of conventional chrysanthemum design, carved out of the "melting snow and moss" variety of jadeite, so called from its general aspect. It is carved outside with a double ring of flutings, and inside with six concentric rings of florets or petals. Height, 4.7 cm.; diameter, 29.4 cm.; weight, 50.116 oz.; specific gravity, 3.3363.

No. 3090 A large undecorated bowl of nephrite, which shows a marked horizontal stratification, as indicated by numerous inclusions of a black metallic mineral—probably chromite. Height, 9.2 cm., diameter, 16.8 cm.; weight, 12.429 oz.; specific gravity, 2.9499.

No. 3232 A jadeite rice-bowl of beautifully translucent, homogeneous and compact texture, and so thin that print can be read through it at a distance of 3 to 4 mm. The color is somewhat poetically but accurately described as suggesting "bits of moss entangled in melting snow." Height, 7.75 cm.; diameter, 18.45 cm.; weight, 13.716 oz.; specific gravity, 3.3385.

No. 3026 A large round saucer-shaped dish of very translucent, homogeneous nephrite, carved in relief with scrolls on the exterior, and polished to an exquisite thinness. Height, 6.2 cm.; diameter, 28.5 cm.; weight, 19.627 oz.; specific gravity, 2.9939.

No. 3255 A "musical stone" in the form of a broad obtuse-angled band, carved in relief, with total length of 22.2 cm., a width of 10.8 cm., and thickness of 0.6 cm.; weight, 9.811 oz.; specific gravity, 2.9787. Translucent and compact nephrite of very sinewy structure.

No. 13141 A small carved "musical stone," having the outline of a fish with bowed back, thus approaching the angular shape of a regulation hanging musical-stone with unequal arms. Total length, 24.0 cm.; breadth, 13.6 cm.; thickness, 0.9 cm.; weight, 12.432 oz.; specific gravity, 3.3369. Translucent, homogeneous and compact jadeite.

No. 3075 A finely polished ruler or bar of translucent New Zealand nephrite; of square section, 31.7 cm.; long, and 1.25 cm. thick; weight, 5.008 oz.; specific gravity, 3.0108.

TESTS ON THE SONOROUSNESS OF JADE.

BY PROFESSOR WILLIAM HALLOCK.

Owing to the high modulus of elasticity and the extreme compactness of jade it possesses the property of emitting a very clear tone when struck, and of maintaining the tone for a comparatively long time. The tones are of the pure quality, usually described as "bell tones," or "as clear as silver," or as "silvery tones." This is undoubtedly due to the fact that the tones are often simple or "pure," unaccompanied by any overtones; in other cases where the tone is complex the relation of the partial tones to each other is that of some of the principal harmonious chords, as for example the major third-fifth-chord (*c e g*), or the same diminished (*c e flat g*), etc.

Owing to a lack of perfect symmetry in either thickness or quality of material, the jades, like bells in general, emit a tone that varies in intensity rhythmically, giving rise to what the physicist calls "beats," and what is called "tremolo" in the organ and the voice, and "throbbing" in bells. If these are not too frequent, not more than eight or ten per second, they lend a peculiar charm to the tones, but when they become more rapid they produce a very disagreeable roughness, or discord, in the tone.

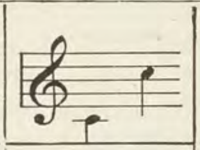
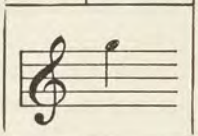
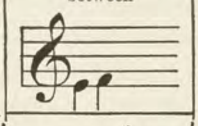
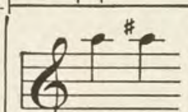
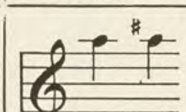
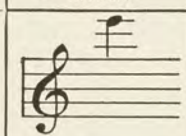
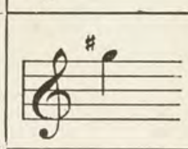
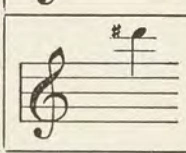
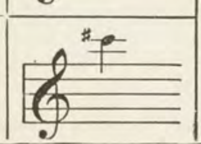
Each of the bowls, plates, saucers, and similar articles might be made the subject of an elaborate acoustic investigation, but the score reproduced below will serve to give an idea of the range and peculiarities of the tones represented.

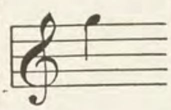
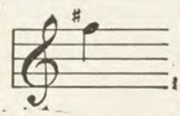
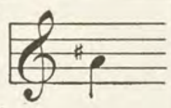
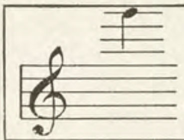
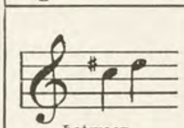
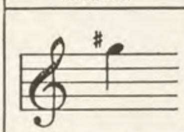
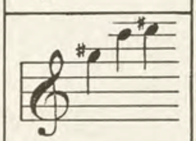
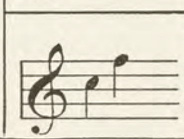
In order to determine the rate of vibration, and possibly the components of the tones, recourse was had to the method of photographing a small gas flame which was controlled by the motions of the particular bowl or object under study.

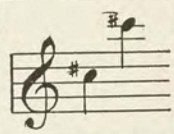
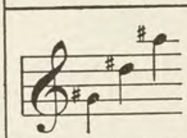
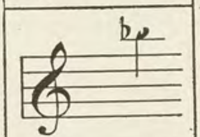
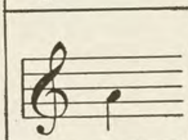
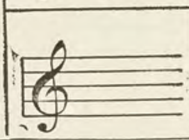
Gas on its way to a small pointed-flame burner is made to pass through a little box which is provided with a cover of very thin india rubber. This cover rests against the edge of the bowl, and thus the vibrations of the bowl are transferred to the gas, and thereby to the little flame. The flame is photographed upon a plate that is moving sideways, so that each jump of the flame falls upon a different part of the plate, and the resulting picture looks very much like the teeth of a saw. A similar arrangement resting against a standard electrically-driven tuning fork gives another series of teeth, from which the rate of motion of the plate is computed.

The quality of the tone depends upon the character of the blow, and where it strikes the piece ; this is of course due to development of tones higher than the fundamental, either alone or along with the fundamental in varying relative intensities. In these experiments the bowls were struck with a soft wooden hammer, on their extreme edges, the blow being as *staccato* as possible, the bowl being so supported as not to interfere with its free vibration.

The following table gives the rate of vibration of the fundamental tone, the combination of tones, if present, the number of beats per second, and the duration of the tone after a moderately strong blow.

Number	Position on treble clef	Fundamental vibrations per second	Ratio of tones	Beats per second	Duration of tone
3176		256	1:2	0	5 seconds
3098		776	1	0	3 seconds
3262	between 	667	1	0	3 seconds
3091	 between	897	1	3½	6½ seconds
3105	 between	902	1	4	6 seconds
3103		1307	1	0	2 seconds
3092		809	1	0	5 seconds
3101		1216	1	3½	5 seconds
3106		1105	1	4	3 seconds

Number	Position on treble clef	Fundamental vibrations per second	Ratio of tones	Beats per second	Duration of tone
13097D		768	1	too fast	3 seconds
13094		740	1	too fast	2 seconds
3171		456	1	0	12 seconds
3129		1587	1	0	3 seconds
3060	 between	562	1	0	4 seconds
3023		810	1	3	5 seconds
3090		total 1344	4:5	too fast	5 seconds
3232		total 1245	4:5:6	3–4	8 seconds
3026		total 692	3:4	2	18 seconds

Number	Position on treble clef	Fundamental vibrations per second	Ratio of tones	Beats per second	Duration of tone
3255		total 1126	1:2	0	5 seconds
13141		total 908	2:3:4	0	7 seconds
3075		947	[3:5:7:9] theoretically	0	5 seconds
Standard of pitch used		435 complete vibrations per second			
					

THE CHEMICAL CONSTITUTION OF JADE.

BY F. W. CLARKE.

A study of the chemical constitution of jadeite and nephrite opens up a variety of interesting and curious questions, some of which have a bearing upon problems lying beyond the limits of mineralogy. From Iddings' observations it seems probable that nephrite is sometimes derived from pyroxenes by a process of alteration. He describes, first, jadeites pure and simple ; then come jadeites containing traces of amphibole, then with much amphibole, then nehprites containing residual jadeite, then nephrites with the slightest possible remnants of jadeite, and finally nephrite alone. The series is continuous, and in it no sharp breaks appear. Now, as has already been shown, the pyroxenes have higher specific gravity than the corresponding amphiboles. The change from one series to another therefore, as a consequence of diminished density, implies increase of volume; and this, in the interior of a rock mass, involves the generation of pressure. In other words, the production of the amphibole from the pyroxene takes place under more than the normal pressure of the superincumbent rocks, and it is possible that this fact may account to some extent for the remarkable compactness and tenacity of the product. Another consequence is deducible from the phenomena—namely, that the molecular weight of the pyroxene is greater than that of the amphibole ; the one molecule being probably a polymer of the latter. Greater density implies greater complexity of molecule, and the change from one to the other represents a breaking down of the more complex into the simpler. Ordinarily, but on quite superficial grounds, the amphibole molecules have been regarded as heavier than the molecules of pyroxene, but all the valid evidence indicates that the reverse proposition is true. To this subject I shall recur later.

Another class of problems is suggested by the impurities in jade, or rather by its mixture with other minerals. For example, No. 13193, a mask from Mexico, is shown by Penfield and Iddings to be a mixture of jadeite and albite. No such mixture has been observed among the Oriental jades, and it therefore becomes more than probable that the Mexican mineral is indigenous. To mineralogists this will seem to be a very simple and obvious matter; but the fact that jadeite has not been reported as found at any Mexican locality *in situ* has led some anthropologists to assume that the American material was derived from an Asiatic source through some prehistoric channel of communication. A fuller study study of jadeite from Mexico and Central America might reveal still other differences, and so dispose of the anthropological speculation forever.

Still another highly suggestive specimen is No. 13215, from Burma, a mixture of jadeite and analcite with a trace of diopside. Between jadeite, analcite, and the ferric equivalent of jadeite, acmite, there are relations of decidely important character. The empirical formulæ of the three minerals are as follows:

Acmite,	$Na\ Fe\ Si_2O_6$
Jadeite,	$Na\ Al\ Si_2O_6$
Analcite,	$Na\ Al\ Si_2O_6\ H_2O$

That is, empirically analcite has the composition of jadeite plus one molecule of water. Fused jadeite has the properties of fused analcite, and in Norway pseudomorphs of analcite after acmite have been observed by Brögger. A relationship between the species is evident; but upon closer scrutiny it becomes more complex than it at first appears to be. Let us study the molecular volumes of the three minerals, the molecular volume being the quotient obtained upon dividing the molecular weight by the specific gravity.

	Molecular weight	Specific gravity	Molecular volume
Acmite,	231.8	3.50	66.2
Jadeite,	202.9	3.30	61.5
Analcite,	221.0	2.25	98.2

Here we find acmite and jadeite near together, while analcite gives a volume one-half greater. Between jadeite and analcite there is a difference in volume of 36.7 units, whereas the molecular volume of water alone, in the form of ice, is only 19.5. That is, a molecule of jadeite plus a molecule of ice would have a volume of only about 81.0 units, as against the 98.2 found. In short, a change from jadeite to analcite, if such a change occurred, would involve a very perceptible increase in volume over the sum of the two component parts, and this indicates that the simple molecular weights which we have taken are really submultiples of the true values. The jadeite and acmite molecules are polymers of the anhydrous analcite molecule, and the alteration of one mineral into the other, as in the change from pyroxene to amphibole, means a breaking down from a higher molecular weight into a lower, and the same breaking down occurs when jadeite is fused. Jadeite itself is hardly, if at all, attacked by aqueous hydrochloric acid; but after fusion that reagent decomposes it readily. Analcite, whether natural or fused, is also easily decomposed by hydrochloric acid; and Lemberg has shown that the two minerals after fusion have become identical. This conclusion, together with that derived from a comparative study of the pyroxenes and amphiboles, bears directly upon the investigation of their chemical structure.

Now, leaving out of account all pseudo-jades, such as pectolite, fibrolite, or saussurite, and also neglecting all mixtures of minerals other than pyroxenes or amphiboles with jadeite or nephrite, let us consider the chemical formulæ of both species.

The simplest empirical formulæ are as follows:

Pyroxenes	:	Jadeite,	$Na\ Al\ Si_2O_6$
	:	Acmite,	$Na\ Fe\ Si_2O_6$
	:	Diopside,	$Ca\ Mg\ Si_2O_6$

Acmite and diopside are both identified by Penfield as isomorphously commingled with the normal jadeite.

Amphiboles:	Tremolite,	$Ca\ Mg_3Si_2O_6$
:	Actinolite,	$Ca\ (Mg\ Fe)_3\ Si_2O_6$
:	Glaucophane,	$Na\ Al\ (Fe\ Mg)\ Si_3O_9$
:	Riebeckite,	$Na_2Fe'''_2Fe''\ Si_5O_{15}$

Normal nephrite approximates to tremolite or actinolite; but the glaucophane and riebeckite both appear in Penfield's discussion of certain analyses.

In all of the foregoing molecules the ratio of silicon to oxygen is 1 : 3, the ratio of a metasilicate. But a full discussion of the jadeite analyses shows that this ratio is sometimes exceeded and to an extent which cannot be accounted for by the natural errors of experiment. This excess probably indicates the presence of a molecule represented by the generalized formula $Al_2Mg\ Si\ O_6$; a compound which is not known in the free state, but which is well recognized in all the best theoretical interpretations of the amphiboles and pyroxenes. In jade it is small in amount, and for most purposes it may be neglected; but in augite, one of the most important pyroxenes, its presence seems to be very evident. In this connection it is mentioned simply as one link in a chain of evidence as to the nature of the substances under consideration.

It has already been shown that the pyroxene molecules are more condensed than those of the amphibole group; and this may be more clearly brought out by a further study of the molecular volumes. Taking the empirical formulæ as indicating for each mineral the minimum possible molecular weight, let us make the comparison here suggested.

	Mol. Wt.	Sp. Gr.	Mol. Vol.	Mean Volume
Jadeite,	202.9	3.30	61.5	61.5
Acmite,	231.8	3.50	66.2	66.2
Diopside,	217.1	3.20	67.8	67.8

The three pyroxenes run pretty well together; part of the difference being due to the fact that the ideally pure molecules were not used for the specific gravity determinations. Now let us pass on to the amphiboles.

	Mol. Wt.	Sp. Gr.	Mol. Vol.	Mean Volume
Tremolite,	418.5	2.94	142.4	71.2
Glaucophane,*	314.2	3.10	101.4	67.6
Riebeckite,	596.0	3.40	175.3	70.1

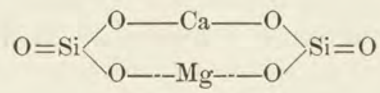
The last column gives the volume proportional to Si_2O_6; a factor which occurs once in the pyroxenes, twice in tremolite, one and a half times in glaucophane, and two and a half times in the empirical riebeckite formula. This column reduces all the minerals to a common denominator, and renders a comparison possible. From it we see that the pyroxenes and amphiboles are near each other in molecular volume, but that the amphiboles tend to run perceptibly higher. In other words, the amphibole molecules are less condensed, and therefore occupy more volume, than the molecules of pyroxene. Or, to state the result in still another form, the pyroxenes, atom for atom, represent the larger weight of matter in the unit volume of space. The true molecular weights are multiples of the empirical values, and those of the pyroxenes are the greater.

This view as to the molecular magnitudes under consideration is diametrically opposed to the most commonly accepted opinions. The latter take the simplest empirical formulæ alone, and as many amphiboles are representable only by relatively high expressions, these are regarded as indicating greater molecular weights. The supposed simplicity of the pyroxenes, however, is apparent rather than real, and disappears when all of the evidence is considered in all of its bearings. A mineral cannot be properly studied by itself alone; it must be interpreted with relation to other species; from some of which it may be derived, or into which it may alter. These relations must be expressed in its formula before the latter can be regarded as fully established. An empirical formula represents composition only; a structural formula takes into account molecular weight and relationship to other compounds also. The one is simple, the other may be complex; but that is best which best fulfils its purpose

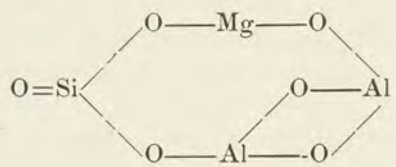
* Computed with Mg : Fe :: 2 : 1.

and symbolizes the largest number of facts. Among the various formulæ which have been proposed for pyroxenes and amphiboles, what system best satisfies all the conditions? That is the problem now to be considered.

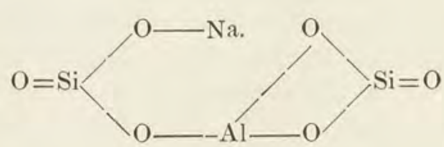
According to the current and more commonly accepted opinions, both groups of minerals are salts of metasilicic acid, and the simple empirical formulæ are merely re-stated in structural form. On this basis diopside becomes



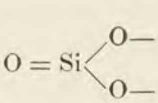
and the molecule $Al_2\ Mg\ Si\ O_6$ is written



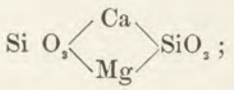
These expressions indicate a simple relationship in form, and by comminglings of the two types a large number of pyroxenes are expressible. On a similar plan jadeite may be given the structure

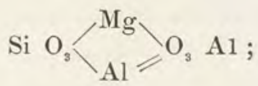


and here again the superficial resemblance is apparent. For convenience these formulæ can be put in more condensed form, the metasilicate group

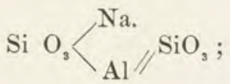


being written SiO_3, and then the expressions become



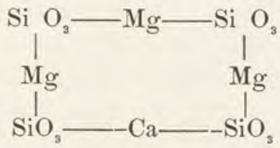


and

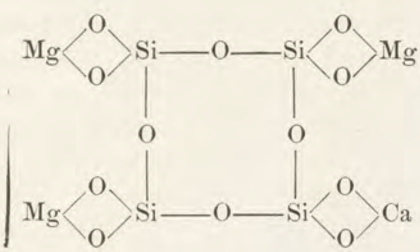


a plan which is easier for the eye and which avoids repetition of symbols.

On similar lines tremolite may be written also as a metasilicate



or as a salt of the more complex acid $H_8 Si_4 O_{12}$. In the latter case its structures is indicated thus :



the eight hydrogen atoms of the acid being replaced by the four bivalent atoms of magnesium and calcium. These expressions for tremolite are well enough so far as they go ; but the other amphiboles, such as glaucophane and riebeckite, are difficult to adjust with them. Partial evidence may well be easier to interpret than complete evidence.

Going beyond the empirical formulæ as a basis for study, a clue to the condition of jadeite is found in the properties of another pyroxene, the mineral spodumene. This species, with jadeite and acmite, forms a well defined series of compounds, whose empirical formulæ are as follows:

Spodumene,	$Li\ Al\ Si_2O_6$
Jadeite,	$Na\ Al\ Si_2\ O_6$
Acmite,	$Na\ Fe\ Si_2O_6$

Spodumene, then, resembles jadeite, except that it contains lithium instead of sodium. In form and density the species are closely allied, and the evidence obtained by the study of one probably applies to all three. The molecular magnitudes should be strictly similar.

It so happens that the alteration products of spodumene have been very thoroughly studied; and their investigation has shed much light upon the character of the mineral. It takes up soda quite easily, probably from percolating waters, and becomes transformed into a mixture of albite and eucryptite, which may be compared with the original spodumene thus:

Spodumene,	Sp. Gr.	3.15	$Li\ Al\ Si_2O_6$
Eucryptite,	" "	2.67	$Li\ Al\ Si\ O_4$
Albite,	" "	2.62	$Na\ Al\ Si_3O_8$

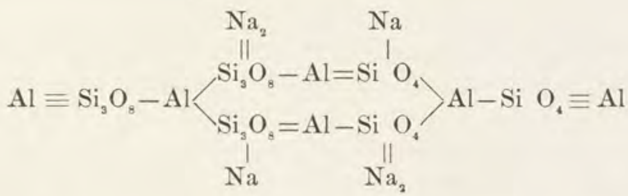
Both eucryptite and albite are much lower in density than spodumene, and their molecular complexity should therefore, in all probability, be less. In order to effect this change, the molecular weight must be at least double that indicated by the empirical formula, and then it become $Li_2\ Al_2\ Si_4O_{12}$ or possibly greater. This expression is a minimum. Eucryptite in turn alters into muscovite mica, of which the simplest formula is $Al_3\ KH_2\ Si_3O_{12}$, and to satisfy this condition the eucryptite formula must be trebled. This consideration, taken in connection with the albite and the spodumene goes to show that the latter mineral must be given a formula six times greater than the original expression, and so it becomes $Li_6\ Al_6\ Si_{12}O_{36}$. The formulæ for jadeite and acmite must be treated in the same way, and the final result for jadeite is

$$Na_6\ Al_6\ Si_{12}O_{36}.$$

Does this represent a metasilicate, or is the metasilicate ratio Si : O_3 only apparent? Just as spodumene alters into albite and eucryptite, so jadeite should alter into albite and nepheline $(Na\ Al\ SiO_4)_3$; and the splitting up would be according to the equation

$$\underset{\textit{Jadeite}}{Na_6\ Al_6\ Si_{12}O_{36}} = \underset{\textit{Albite}}{Na_3\ Al_3\ Si_9O_{24}} + \underset{\textit{Nepheline}}{Na\ Al_3\ Si_3O_{12}}.$$

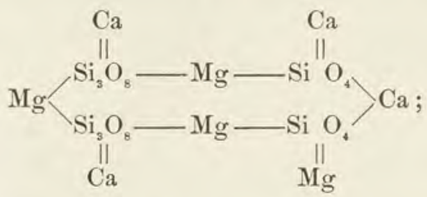
Albite is a derivative of trisilicic acid, $H_4\ Si_3O_8$; and nepholine is a salt of orthosilicic acid, $H_4\ SiO_4$. When ortho- and tri-silicates are commingled, ratios like those of the metasilicates are produced; for $H_4\ SiO_4 + H_4\ Si_3O_8 = H_8\ Si_4O_{12}$, and the latter as a mixture would exactly represent four molecules of metasilicic acid, $H_2\ SiO_3$. Such mixtures are common among minerals, especially in the feldspar, scapolite, and mica groups; and the possibility of a similar occurrence must be considered here. The radicles SiO_4 and Si_3O_8 seem to be equivalent to each other; and on this supposition the formula $Na_6\ Al_6\ Si_{12}O_{36}$ may be written structurally,



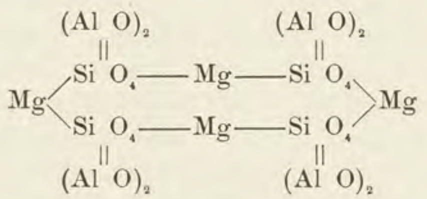
Such a molecule as this could split directly into the two molecules $Al_3\ Na_3\ (Si_3O_8)_3$, (albite), and $Al_3\ Na_3\ (SiO_4)_3$, (nepheline); and it seems to satisfy all of the conditions imposed by the different phases of the problem.

The unification of the other pyroxene formulæ with this new formula for jadeite now becomes a very simple matter. Diopside, Mg Ca Si_2O_6, becomes $Mg_4\ Ca_4\ Si_8O_{24}$; and the hypothetical compound Al_2 Mg SiO_6 is also quadrupled. In diopside a mixed ortho- and tri-silicate is assumed; and in the other compounds we have a basic ortho-silicate containing the well recognized univalent radicle Al O. Two

Al O groups are structurally equivalent to one atom of calcium or magnesium. We thus have, for diopside

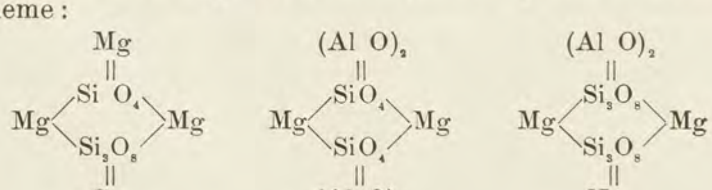


and for the other molecule, the structure



All of the other pyroxenes are capable of similar interpretations; and thus the entire group is reduced to one general type of constitution. No other mode of interpretation hitherto proposed is equally general.

For the amphiboles, a similar treatment is possible; and they too can be regarded as mixed ortho- and tri-silicates; the apparent metasilicate ratios being apparent only. Nephrite, it will be remembered, approximates to tremolite and actinolite, but its molecule is less complex than that of jadeite, and is formed by a lower degree of condensation. In the amphiboles we also find admixtures of a compound $Al_2 Mg SiO_6$, which is not known by itself; and this, as in the case of the pyroxene is covered by the following scheme:



Tremolite $(Mg\ Al_2\ Si\ O_6)_2$ *Glaucophane*

Riebeckite and crocidolite are possibly the equivalents of glaucophane, with ferric iron replacing aluminium, and ferrous iron in place of magnesium. But their analyses vary too widely to admit of any final conclusion upon this point. The empirical formula used for riebeckite in the preceding pages is merely the formula which is commonly assumed; but which does not fit the analytical data at all closely.

To sum up: the formulæ here developed represent the known relations between the pyroxene and the amphiboles in general, and between jadeite and nephrite in particular. They cover the evidence so far as evidence exists; but they may not be final. A formula is merely a symbol for expressing facts; and new facts may compel the abandonment of one symbol for another of broader scope. Written in structural form they bring evidence more clearly before the eye, and they suggest investigations through which more truth may become attainable. That function, the function of suggestiveness, is one of their chief values.

THE CHEMICAL ANALYSES.

For the purposes of the investigation begun by Mr. Bishop some three score chemical analyses were made from typical specimens in his Collection. This analytic work was carried out by Mr. Percy T. Walden, and later by Dr. Harry W. Foote, both of the Sheffield Scientific School at Yale University, under the direct supervision of Mr. S. L. Penfield, Professor of Mineralogy at Yale. Of the total number of analyses several were merely qualitative, and others quantitative for the alkali metals only, and these are not here recorded. The others are given below in tabular form, and are considered in detail, with descriptions of the several specimens, and reductions and notes by Clarke and Penfield. The jadeites, in the order of their purity come first; the nephrites similarly arranged come next, and lastly, those specimens, only two in number, which, though not strictly jade, are so closely connected with it that they are allowed to stand.

The method of analysis used was that almost universally adopted for silicate analyses of this character.

Water was determined by igniting about one gramme of the air-dry material over a blast-lamp. The residue from the water determination was fused with sodium carbonate, extracted with water, acidified with hydrochloric acid, evaporated to dryness, and the silica filtered off. The filtrate was again evaporated to remove the last trace of silica, which was added to the first, and the whole ignited to constant weight, and silica determined by loss on evaporation with hydrofluoric acid.

Iron and alumina were precipitated in the filtrate from the silica, and the precipitate was dissolved in nitric acid, reprecipitated to ensure purity, and ignited to constant weight over a blast-lamp. The residue of Fe_2O_3 and Al_2O_3 was dissolved by means of a potassium bisulphate fusion, the fusion being soaked out in water containing sulphuric acid. If a trace of silica were found at this point, it was added to the silica previously obtained. The total iron was then found by reducing the hot sulphate solution with hydrogen sulphide and titrating with potassium permanganate.

The two filtrates from the iron and alumina precipitation were concentrated and calcium was precipitated as oxalate. When more than a very few per cent. was present it was dissolved and reprecipitated, being weighed as oxide.

In the filtrate, magnesia was precipitated as ammonium magnesium phosphate, and the first precipitate was always dissolved and reprecipitated to ensure purity. It was weighed as $Mg_2P_2O_7$.

Ferrous iron was determined by titration with potassium permanganate, after solution of the mineral in hydrofluoric acid in an atmosphere of Co_2.

Alkalis were determined by a Smith fusion with calcium carbonate and ammonium chloride, being separated from each other by platinum solution.

TABULAR STATEMENT OF ANALYSES OF JADE MADE FOR MR. HEBER R. BISHOP, FROM SPECIMENS IN HIS COLLECTION.

	NUMBER	Silica SiO_2	Titanic Oxide TiO_2	Alumina Al_2O_3	Chromic Oxide Cr_2O_3	Ferric Oxide Fe_2O_3	Ferrous Oxide FeO	Manganese Oxide MnO	Magnesia MgO	Lime CaO	Soda Na_2O	Potassa K_2O	Water H_2O	TOTAL
I......	13206B	57.60	..	25.75	..	..	..	trace	0.13	0.58	13.31	2.20	0.25	99.82
II......	13323	58.80	..	25.37	..	0.33	..	..	0.25	0.58	14.65	0.05	0.14	100.17
III......	13243	58.69	..	25.56	..	..	..	trace	0.11	0.58	13.09	1.54	0.17	99 74
IV......	3127	58.93	0.15	25.39	..	..	..	trace	0.29	0.72	12.90	1.63	0.23	100.24
V......	13336	58.58	..	23.71	..	0.51	0.24	..	1.35	1.67	13.80	trace	0.30	100.16
VI......	13102C	57.45	..	21.94	..	0.91	..	trace	3.96	3.10	12.13	..	0.79	100.28
VII	13102C	57.79	..	21.40	..	0.80	..	trace	4.72	3.06	12.36	..	0.76	100.89
VIII......	13102C	57.49	..	21.56	..	1.05	..	trace	4.79	2.90	11.98	..	0.45	100.22
IX	13255	58.40	..	27.05	..	..	..	trace	0.57	0.65	11.37	2.20	0.18	100.42
X......	3248	58.48	..	23.57	..	1.68	..	trace	1.33	1.62	10.33	3.09	0.16	100.26
XI......	13195	59.02	..	24.88	..	1.23	0.28	0.19	1.10	1.15	11.21	1.34	0.07	100.47
XII......	13242	56.69	..	20.46	..	4.49	0.75	trace	1.64	3.28	11.65	1.15	0.48	100.59
XIII......	13249	56.08	..	19.05	..	3.76	2.26	..	2.08	4.94	11.61	0.26	0.18	100.22
XIV......	13215	58.41	..	24.64	..	0.67	..	..	1.24	1.43	12.76	0.58	1.19	100.92
XV......	13267	57.36	..	14.01	..	1.37	0.79	..	11.07	1.91	11.32	0.53	1.55	99.91
XVI......	13193	63.47	..	20.76	..	1.27	..	trace	11.11	1.16	11.98	0 34	0.36	100.45
XVII......	13200	57.37	..	1.03	..	— 0.78 —		trace	23.96	13.03	undet.	undet.	3.63	99.80
XVIII......	13334	57.09	..	0.53	..	0.81	3.98	..	22.28	11.75	0.21	..	3.57	100.22
XIX......	13335	57.02	..	0.70	..	1.04	4.33	..	21.56	12 63	0.22	..	3.01	100.51
XX	13122	56.70	..	2.01	..	..	5.09	..	21.91	12.12	0.14	..	2.56	100.53
XXI.. ..	13205	57.02	..	1.05	..	— 1.10 —		trace	23.01	14.77	undet.	undet.	3.00	99.95
XXII......	13262E	57.38	..	0.83	..	1.71	trace	trace	23.37	13.14	0.33	..	3.51	100.27
XXIII......	3185	54.44	..	0.82	..	0.38	0.34	trace	25.88	13.70	0.70	0.54	3.48	100.28
XXIV......	3121	57.28	..	1.46	..	0.56	1.19	0.28	20.88	13.15	2.61	1.23	1.79	100.43
XXV......	13223	55.48	..	0.89	..	0.90	3.47	trace	22.69	12.89	0.80	0.44	3.12	100.68
XXVI......	13262R	57.77	..	2.50	..	2.76	..	trace	20.91	13.61	trace	trace	3.52	101.07

TABULAR STATEMENT OF ANALYSES OF JADE MADE FOR MR. HEBER R. BISHOP, FROM SPECIMENS IN HIS COLLECTION.

(Continued.)

	NUMBER	Silica SiO_2	Titanic Oxide TiO_2	Alumina Al_2O_3	Chromic Oxide Cr_2O_3	Ferric Oxide Fe_2O_3	Ferrous Oxide FeO	Manganese Oxide MnO	Magnesia MgO	Lime CaO	Soda Na_2O	Potassa K_2O	Water H_2O	TOTAL
XXVII..	13248	58.66	..	0.50	..	1.76	3.48	0.02	22.43	13.34	0.48	0.10	0.12	100.89
XXVIII..	3125	55 51	..	1.72	..	1.33	7.69	..	18.80	13.17	0.41	..	1.82	100.45
XXIX..	13118	58.14	..	0.98	..	3.39	0.85	0.22	22.38	12.53	0.36	..	1.69	100.54
XXX..	13214	58.59	..	2.33	..	0.97	0.11	0.35	22.30	12.41	0.98	0.21	1.54	99.79
XXXI..	3136	56.66	..	2.74	..	0.56	0.51	trace	23.42	12.52	1.16	..	2.23	99.80
XXXII..	13192H	57.82	..	1.14	..	4.10	..	trace	20.49	13.93	0.31	..	3.08	100.87
XXXIII..	3156	57.89	..	1 99	..	1.36	..	trace	20.74	12.60	2.06	..	3.38	100.02
XXXIV..	13233	57.19	..	2 24	..	1.60	1.10	trace	21.97	13.16	0.20	1.44	1.82	100.72
XXXV..	3148	57.46	..	2.70	..	0.83	..	trace	20.87	12.49	1.79	1.64	2.71	100.49
XXXVI..	13246	55.96	..	2.33	..	4.28	..	trace	20.35	13.49	0.51	trace	2.72	99.64
XXXVII..	13095	57.42	..	2.66	..	1.31	1.78	0.28	14.30	16.19	1.93	..	3.69	99.56
XXXVIII..	13030	57.78	..	2.35	..	1.60	2.83	..	14.80	15.02	1.63	1.00	2.75	99.76
XXXIX..	13088	56.41	..	0.91	..	3.84	1.92	0.15	19.09	12.81	2 64	..	2.56	100.33
XL..	13006	56.63	..	2.14	..	3.99	..	..	21.69	13.41	0.20	0.69	1.67	100.42
XLI..	3246	56.91	..	2.84	..	1.56	..	trace	21.82	11.56	1.62	1.19	3.07	100.57
XLII..	13211	57.65	..	1.06	..	4.93	0.11	..	14.95	16.05	2.38	0.93	2.46	100.52
XLIII..	13268	57.43	..	3.14	..	1.88	0.47	trace	19.68	12.04	2.87	..	2.61	100.12
XLIV..	13008	56.83	..	5.33	..	0.46	..	trace	19.38	13.11	2.25	..	3.44	100.80
XLV..	13212	58.04	..	2.23	..	4.64	0.16	0.38	14.50	12.68	4.83	0.39	2.83	100.68
XLVI..	13007G	56.13	..	5.06	..	2.12	1.01	trace	19.20	11.88	1.19	1.90	2.29	100.78
XLVII..	13216	52.60	..	1.45	..	2.10	2.14	0.10	23.06	12.72	0.93	0.57	3.62	99.29
XLVIII..	13266	52.98	..	1.79	..	0.05	0.46	0.05	25.49	13.39	1.11	0.71	3.50	99.53
XLIX..	13210	54.44	..	5.92	..	3.72	2.56	0.22	16.79	7.51	4.64	0.28	4.12	100.20
L..	13005	51.33	..	18.31	..	8.08	..	..	4.05	11.34	5.76	0.55	0.76	100.18
LI..	13086	54.19	..	3.48	..	1.79	..	trace	14.58	24.03	0.88	..	0.65	99.60

THE SPECIMENS ANALYZED.

13206B. *Fragment* of an ornamental medallion from China. Specific gravity 3.3303; hardness, 7; translucent Burmese jadeite, with remarkably perfect crystalline structure. *Color*, "Melting snow."

Microstructure: This is the coarsest-grained variety examined by Iddings. It is an aggregate of colorless crystals that can be seen without the aid of a lens, the largest being 3 mm. long. The size of the crystals varies greatly, from that just mentioned to microscopic dimensions, all mingled without definite arrangement or any suggestion of a porphyritic structure. The substance of the jadeite is very pure and free from inclusions in most crystals. A few show specks that seem to be incipient decomposition. These are not twinned.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R_2''' R'' (SiO_3)_4$
Silica,	57.60	57.26	.34
Alumina,	25.75	24.50	.14
Magnesia,	.13		
Lime,	.58		.07
Soda,	13.31	13.31	
Potash,	2.20	2.20	
Water,	.25		
	99.82	97.27	.55

Jadeite,	97.27	
$R_2''' R'' (SiO_3)_4$,	.55	
	97.82	
Alumina	1.11	unaccounted for.
Magnesia,	.13	unaccounted for.
Lime,	.51	unaccounted for.
Water,	.25	unaccounted for.
	99.82	

13323. *Fragment* of raw jade from Tibet. Specific gravity, 3.3359; hardness 7.; of translucent, homogeneous and compact material with a decided granular crystalline structure. *Color*, lavender, with opaque white snow-like patches.

Microstructure: Almost pure jadeite, almost colorless in thin section, with a whitish tinge. It is traversed by numerous irregular cracks as though the rock had been subjected to crushing. There are minute colorless veins crossing the section independent of the cracks. They are made up of larger crystals of the same mineral as the mass. The whole is an aggregation of irregularly-shaped crystals of jadeite, the majority of which are very minute and do not exhibit crystallographic outlines. Scattered through it are microscopically small opaque specks, usually with irregular outline, whose exact character cannot be determined. They are probably magnetite. There are also small crystals of a colorless mineral with index of refraction slightly higher than that of the surrounding jadeite, and having a double refraction about half as great as that of jadeite. It appears to be either a tetragonal or orthorhombic mineral having the axis of greatest elasticity parallel to the length of the prism. It is so filled with inclusions of jadeite that good interference figures could not be obtained, and hence its uniaxial or biaxial character could not be determined. It is therefore not possible to state its mineral character. The most probable assumption is that it is andalusite. The quantity is not large, so that its presence does not materially affect the character of the rock.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R'''_2 R'' (SiO_3)_4$
Silica,	58.80	56.85	1.95
Alumina,	25.37	24.16	.83
Ferric oxide,	.33		
Magnesia,	.25		.25
Lime,	.58		.11
Soda,	14.65	14.65	
Potash,	.05	.05	
Water,	.14		
	100.17	95.71	3.14

Jadeite,	95.71	
$R'''_2 R'' (SiO_3)_4$,	3.14	
	98.85	
Alumina,	.38	unaccounted for.
Ferric oxide,	.33	
Lime,	.47	
Water,	.14	
	100.17	

13243. *Fragment* of jadeite pendant from China. Specific gravity 3.3287; hardness, 7; wholly jadeite, evidently from Burma, with no other mineral. The crystals are all quite small, grading from 0.8 mm. to microscopic. There is a slight central clouding in some crystals and a small amount of crushing. *Color*, white with emerald-green in part.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R'''_2 R'' (SiO_3)_4$
Silica,	58.69	54.59	3.06
Alumina,	25.56	23.20	1.30
Magnesia.	.11		.11
Lime,	.58		.58
Soda,	13.09	13.09	
Potash,	1.54	1.54	
Water,	.17		
	99.74	92.42	5.05

Jadeite,	92.42	
$R'''_2 R'' (SiO_3)_4$,	5.05	
	97.47	
Excess silica,	1.04	unaccounted for.
" alumina,	1.06	
" water,	.17	
	99.74	

3127. *Vase* in the form of blossoming plum-tree trunk, China. Specific gravity, 3.3316; hardness, 7; of translucent, homogeneous, and compact material, remarkable for its color. *Color*, various shades of blue, with brown (almost amber-colored) staining in parts.

Microstructure: an aggregate of lath-shaped jadeite crystals with jagged outline and somewhat parallel arrangement. In places they are very minute and carry longer crystals of jadeite with no optical distinction; or, in other words, they give no evidence of having been strained. Part of the rock, however, shows signs of having been crushed and dragged. There is a little colorless mineral supposed to be albite.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R'''_2 R'' (SiO_3)_4$
Silica,	58.93	54.10	4.83
Alumina,	25.39	22.99	2.05
Titanic oxide,	.15		
Manganous oxide,	trace		
Ferric oxide,	trace		
Ferrous oxide,	trace		
Magnesia,	.29		.29
Lime,	.72		.72
Soda,	12.90	12.90	
Potash,	1.63	1.63	
Water,	.23		
	100.24	91.62	7.89

Normal jadeite,	91.62	
Pseudo- "	7.89	
	99.51	
Excess alumina,	.50	unaccounted for.
" water,	.23	unaccounted for.
	100.24	

13336. **Fragment* of boulder from Burma. Specific gravity, 3.3122; hardness, 7; homogeneous and compact. *Color*, greenish blue-white, with dark green veinings.

Microstructure: a comparatively coarse-grained aggregation of jadeite crystals, the larger of which are 0.6 mm. in diameter. The rock is colorless in thin section, with small spots of clouded material. It is almost wholly jadeite, the clouded matter being indeterminable and presumably the beginnings of decomposition. The grains or anhedrons of jadeite are irregular and of various sizes. In some cases the prismatic cleavage is distinct. Areas that appear as one crystal often prove to be compounded of many individuals when seen between crossed nicols. The variations in grain and the curving of some cleavage lines, the mottling of the larger crystals when viewed between crossed nicols indicating strains and the first stages of granulation, together with the streaked arrangement of the smaller anhedrons, prove that the rock had been subjected to forces that crushed it to some extent. In places there are patches of a colorless mineral with lower index of refraction than that of jadeite, and with the double refraction and polysynthetic twinning of plagioclase feldspar. It acts as a matrix in which small prisms of jadeite lie at all positions, and against which the jadeite is automorphic. It exhibits no signs of alteration, whether of decomposition or of crushing. These facts point to its being of later origin than the dynamic metamorphism of the rock. But the areas of feldspar are so small that the evidence is not conclusive, and they may possibly have been formed when the jadeite crystallized. They certainly formed after the adjacent and enclosed jadeite crystallized. The chemical analysis given below shows that the mass is slightly higher in silica than if it consisted wholly of pyroxene. And a calculation of the possible mineral constituents based on a knowledge of the presence of feldspar shows that the material analyzed probably consisted of

Jadeite,	86.15	per cent. by weight.
Diopside,	6.17	" " " "
$R''_2 R SiO_6$,	2.05	" " " "
Albite,	4.89	" " " "
Anorthite,	.56	" " " "
	99.82	

The feldspar would have the composition $Ab_9\ An_1$, that is, oligoclase-albite.

The analysis by Foote, with reduction by Clarke, is as follows:

		Jadeite	R''_2 Ca SiO_6	Nephrite
Silica,	58.58	53.42	.79	4.24
Alumina,	23.71	22.70	1.01	
Ferric oxide,	.51		.51	
Ferrous "	.24			.24
Magnesia,	1.35			1.35
Lime,	1.67		.73	.94
Soda,	13.80	13.80		
Water,	.30			.30
	100.16	89.92	3.04	7.07

Jadeite,	89.92
R''_2 Ca SiO_6,	3.04
Nephrite,	7.07
Excess silica,	.13
	100.16

Or is it a pyroxene near diopside?

13102C. *Slab* of crude jade from Upper Burma. Specific gravity, 3.2578; hardness, 7; of subtranslucent material, coarsely granular in structure, with apparent radiated reflections from 1 to 4 mm. in diameter, an admirable example of unaltered original pyroxene mineral. *Color*, lavender, clouded with bright lettuce-green and dead black.

Three analyses by Walden, with reduction by Penfield of the analysis of the mixture, are as follows:

	Lavender	Green	Mixture
Silicia,	57.79	57.49	57.45
Alumina,	21.40	21.56	21.94
Ferric oxide,	.80	1.05	.91
Ferrous oxide,	.....	.....	.....
Manganous oxide,	trace	trace	trace
Magnesia,	4.72	4.79	3.96
Lime,	3.06	2.90	3.10
Soda,	12.36	11.98	12.13
Potash,	.....	.....	.....
Water,	.76	.45	.79
	100.89	100.22	100.28

	Diopside $Ca\ Mg\ (SiO_3)_2$	Jadeite $Na\ Al\ (SiO_3)_2$	Jadeite Cal. to 100 %	Jadeite Theory
Silica,	7.80	49.65	57.88	59.40
Alumina,		21.94	26.24	25.25
Ferric oxide,		.91		
Magnesia,	3.00	.96		
Lime,	3.10			
Soda,		12.13	15.88	15.35
Potash,				
Loss on ignition,				
	13.90	85.59	100.00	100.00

13255. *Plate*, from China. Specific gravity, 3.3373 ; hardness, 7; of translucent, very compact, and homogeneous material in which by the aid of a pocket lens the crystals can be clearly seen ; remarkably perfect and sharply resonant. *Color*, whitish, with green patches.

Microstructure: wholly jadeite without other mineral, with a slight central clouding in some crystals, and a small amount of crushing. The crystals are all quite small.

The analysis, with reduction by Clarke, is as follows :

		Jadeite	$R'''_2\ R''\ (SiO_3)_4$
Silica,	58.40	49.63	6.21
Alumina,	27.05	21.09	2.64
Magnesia,	.57		.57
Lime,	.65		.65
Soda,	11.37	11.37	
Potash,	2.20	2.20	
Water,	.18		
	100.42	84.29	10.07

Normal jadeite,	84.29	
Pseudo- "	10.07	
	94.36	
Excess alumina,	3.32	unaccounted for.
" silica,	2.56	unaccounted for.
" water,	.18	unaccounted for.
	100.42	

3248. *Bowl*, from China. Specific gravity, 3.3394; hardness, 7; of translucent, homogeneous, coarsely crystalline material. *Color*, sea-green, with opaque frosted aspect.

Microstructure: Many large crystals of jadeite up to 3 mm. in diameter, undulatory extinction is pronounced, and the rock has evidently been subjected to great strains. Many of the jadeite aggregates are arranged in optical fields often resembling sections of mica. Fine fragments and fibres of jadeite occur in veins and act as a cement.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R'''_2 R'' (SiO_3)_4$
Silica,	58.48	47.85	10.12
Alumina,	23.57	20.34	3.23
Ferric oxide,	1.68		1.68
Magnesia,	1.33		.53
Lime,	1.62		1.62
Soda,	10.33	10.33	
Potash,	3.09	3.09	
Water,	.16		
	100.26	81.61	17.18

Jadeite,	81.61	
$R'''_2 R'' (SiO_3)_4$,	17.18	
	98.79	
Magnesia,	.80	unaccounted for.
Silica,	.51	unaccounted for.
Water,	.16	unaccounted for.
	100.26	

K is regarded as replacing Na in jadeite. The other molecule is a jadeite-acmite with lime and magnesia in place of alkalies. Penfield includes it with the jadeite, as is proper.

13195. Small *saucer-shaped dish*, from China. Specific gravity, 3.3381; hardness, 7; of translucent, homogeneous, and compact material. *Color*, white, blended with emerald-green.

Microstructure: an aggregate of jadeite crystals all of which are quite small, grading to microscopic, the longest being about 0.8 mm. The lamination is due to the nearly parallel arrangement of some prisms, and to the alternation of layers of coarser and finer grains. The rock is very fresh and pure without other constituent minerals, and there is little or no sign of decomposition or alteration by dynamic forces.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R''_2 R'' (SiO_3)_4$
Silica,	59.02	46.80	12.22
Alumina,	24.88	19.89	4.99
Ferric oxide,	1.23		.33
Ferrous oxide,	.28		.02
Manganous oxide,	.19		.19
Magnesia,	1.10		1.10
Lime,	1.15		1.15
Soda,	11.21	11.21	
Potash,	1.34	1.34	
Water,	.07		
	100.47	79.24	20.00

Normal jadeite,	79.24	
Pseudo- "	20.00	
	99.24	
Ferric oxide,	.90	unaccounted for.
Ferrous "	.26	
Water,	.07	
	100.47	

13242. *Celt*, from Mexico. Specific gravity, 3.3034; hardness, 7; typical chloromelanite, showing on cut edges a very compact crystalline structure with occasional white markings and veinings which are also visible on the weathered surface. At the lower end there is a cavity 17 mm. long by 6 in width, and more than a dozen smaller ones in various parts, filled with a hard, compact white substance which effervesces readily on the application of hydrochloric acid, proving it to be calcite which deposited after the object had been lost or buried in some limestone strata, or a limestone cave. *Color*, black with a greenish tint.

Microstructure: an aggregate of small jadeite crystals with a few larger ones of irregular shape, parts of some of them being pale-green. The mass is streaked with greenish dark-colored specks which appear under the microscope as opaque particles crowded together in the larger jadeite crystals as products of alteration. There are also rather numerous patches of a colorless undeterminable mineral, and small somewhat lenticular bluish-green crystals which suggest glaucophane.

The analysis, with reduction by Penfield, is as follows:

		Diopside $Ca(MgFe)(SiO_3)_2$	Acmite $NaFe(SiO_3)_2$	Jadeite $NaAl(SiO_3)_2$	Jadeite Cal. to 100%	Jadeite Theory
Silica,	56.69	4.98	6.72	44.99	57 85	59.40
Alumina,	20.46			20.46	26.31	25.25
Ferric oxide,	4.49		4.49			
Ferrous oxide,	.75	.75				
Magnesia,	1.64	1.28		.36		
Lime,	3.28	2.29		.99		
Soda,	11.65		1.74	9.91	15.84	15.35
Potash,	1.15			1.15		
Loss on ignition,	.48					
	100.59	9.30	12.95	77.86	100.00	100.00

13249. *Hatchet* from the lake-dwellings of Neufchâtel, Switzerland. Specific gravity, 3.3745; hardness, 7; opaque, very compact in texture, with a weathered spot at the upper end. *Color*, dark green, almost black.

Microstructure: very small irregularly shaped crystals or grains of colorless jadeite and also pale green amphibole, with a crudely parallel orientation, producing a lamination or fibration of the mass. This is further emphasized by streaks of minute grains of an almost colorless mineral with high index of refraction, and with the characteristics of zircon. There is also a little iron oxide, probably magnetite in irregularly shaped grains.

The analysis, with reduction by Clarke, is as follows :

		Jadeite	Fe''_2 Ca SiO_6	Magnetite	Nephrite
Silica,	56.08	44.95	1.04		8 91
Alumina,	19.05	19.05			
Ferric oxide,	3.76		2.82	.94	
Ferrous oxide,	2.26			.42	1.84
Magnesia,	2.08				2.08
Lime,	4.94		.96		3.98
Soda,	11.61	11.61			
Potash,	.26				
Water,	.18				
	100.22	75.61	4.82	1.36	16.81

Jadeite,	75.61	
Fe''_2 Ca SiO_6,	4.82	
Magnetite ?	1.36 ?	
Nephrite,	16.81	
	98.60	
Silica,	1.18	unaccounted for.
Potash,	.26	unaccounted for.
Water,	.18	unaccounted for.
	100.22	

13215. *Fragment* of boulder from Burma. Specific gravity, 3.2176 ; hardness, 7.; of coarsely granular structure. On broken surfaces the outlines of many of the pyroxene crystals are clearly visible. On cut surfaces the reflections resemble the frosted appearance of galvanized iron. *Color*, white, with bluish-green.

Microstructure : an aggregation of irregularly shaped crystals of nearly colorless jadeite, with many cracks which follow the outlines of the crystals, the prismatic cleavage, and a transverse parting, probably basal. In places the pyroxene crystals become long prisms and lie at all angles, sometimes grouped in fan-like aggregation-bundles. In several places they lie embedded in a colorless mineral which acts as a matrix for the pyroxene crystals. In these they have sharply defined crystal forms. This colorless matrix appears to consist of relatively large individuals, not an aggregate of small ones. It has a low index of refraction, and very low double refraction and shows some polysynthetic lamellæ. Its exact nature is not determinable by optical means alone. It is possibly analcite. The analysis, with reduction by Penfield, is as follows :

		Diopside $CaMg(SiO_3)_2$	Analcite $NaAl(SiO_3)_2+H_2O$	Jadeite $NaAl(SiO_3)_2$	Jadeite Cal. to 100%	Jadeite Theory
Silica,	58.41	1.50	15.84	41.07	58.37	59.40
Alumina,	24.64		6.73	17.91	26.05	25.25
Ferric oxide,	.67			.67		
Magnesia,	1.24	.52		.72		
Lime,	1.43	.67		.76		
Soda,	12.76		4.09	8 67	15.58	15.35
Potash,	.58			.58		
Loss on Ignition,	1.19		1.19			
	100.92	2.69	27.85	70.38	100.00	100.00

13267. *Fragment* of boulder from Burma. Specific gravity, 3.1223 ; hardness, 7. ; of subtranslucent material, with a crystalline, interwoven structure of interlacing patches of an intense emerald-green and an almost white mineral. *Color*, lettuce-green.

Microstructure: The prisms are acicular and fibrous. There is more of an approach to streaked or parallel fibrous structure, though the needles cross one another at various angles. The amphibole has a pale green color in thin section, the crystals being pleochroic, yellowish-green parallel to the prism axis and bluish-green at nearly right angles. It is a mixture of jadeite and amphibole in the proportion of three to two, and consists of very minute fibres with a preponderating parallel arrangement, producing a more or less pronounced fibration or lamination in the rock.

The analysis by Foote, with reduction by Clarke, gave the following results:

		Jadeite	Acmite	Amphibole	Reduced	Calculated
Silica,	57.36	33.16	2.05	22.15	58.74	58.39
Alumina,	14.01	14.01				
Ferric oxide,	1.37		1.37			
Ferrous "	.79			.79		
Magnesia,	11.07			11.07	34.13	34.07
Lime,	1.91			1.91		
Soda,	11.32	8.51	.57	2.24	6.86	7.54
Potash,	.53			.53		
Water,	1.55			.10	.27	
	99.91	55.68	3.99	38.79	100.00	100.00

Amphibole,	38.79
Jadeite,	55.68
Acmite,	3.99
Excess water,	1.45
	99.91

The amphibole is unusual. In the reduced column Fe and Ca are reduced to terms of Mg, and K to Na, then all to 100 per cent. The calculated column is computed for $Na_2Mg_7(SiO_3)_8$

This amphibole may be new.

13193. *Mask*, from Mexico. Specific gravity, 2.8320; hardness, 7.; subtranslucent, fairly compact granular material.

Color, light emerald-green and gray, with seams of gray-brown, and light green on the back.

Microstructure: irregularly shaped crystals of jadeite scattered through albite, which forms interlocking crystals of variable size, some individuals inclosing a number of crystals of jadeite. The albite is pure and fresh and exhibts a characteristic cleavage and optical properties. Twinning in polysynthetic lamellae is developed to only a limited extent. Many crystals are not twinned. Apparently the jadeite and albite crystallized at the same time.

The analysis, with reduction by Penfield, is as follows:

		Nephrite $CaMg(SiO_3)_2$	Jadeite $NaAl(SiO_3)_2$	Albite $NaAlSi_3O_8$	Theoretical comparison of a mixture of		
					Nephrite	Jadeite	Albite
Silica,	63.47	2.20	28.80	32.47	2.17	28.87	32.48
Alumina,	20.76		11.53	9.23		12.45	9.20
Ferric oxide,	1.27		1.27				
Magnesia,	1.11	1.11			1.08		
Lime,	1.16	.50	.66		.50		
Soda,	11.98		6.63	5.35		7.46	5.81
Potash,	.34			.34			
Water,	.36						
	100.45	3.81	48.89	47.39	3.75	48.76	47.49

The analysis indicates the presence of a little nephrite.

13200. Part of a *Kuei* or Sceptre, from China. Specific gravity, 2.9430; hardness, 6.5; a tomb piece. *Color*, light grayish-yellow with a rich brown dead oak-leaf coloring due to oxidation while buried in the ground, the general effect reminding one of a stained meerschaum pipe.

Microstructure: consists of minutely fibrous amphibole, and considerable compact amphibole in irregularly-shaped crystals, in clusters and streaks through the rock. There are also remnants of small jadeite crystals in aggregations and streaks and sometimes in spherulitic clusters.

The analysis, with reduction by Clarke, is as follows:

		Doubtful	Nephrite
Silica,	57.37	.58	56.79
Alumina,	1.03	1.03	
Iron oxides,	.78	.78	
Magnesia,	23.96		23.96
Lime,	13.03		13.03
Alkalies,	undet	?	
Water,	3.63	1.57	2.06
	99.80	3.96	95.84

Iddings' work shows that the material was once jadeite, but is mainly altered to amphibole. The alumina corresponds to about 4 per cent. jadeite.

13334. *Fragment of crude nephrite* from Jade Mountain, Alaska. Specific gravity, 2.9487; hardness, 5.5; structure strongly foliated, and in part fine-grained, compact, and tenacious. One end is altered to a white almost steatitic mass with a hardness of not over 2, suggesting weathering or fire-mining. *Color*, sage-green.

Microstructure: an aggregation of extremely fine fibres that lie parallel to one another and have been bent into contorted and crenulated bands. There is some clouding of the material which is white by incident light, and yellowish by transmitted light. In places the fibres are less crinkled and the substance is nearly transparent, and the double refractions are more uniform as shown by the interference colors, but there is some mottling. The thin section cut across the fibres shows less crinkling and a less fibrous texture, and indicates that the fibres are flattened or bladed. Very free from inclusions of other minerals.

The chemical analysis by Foote, and reduction by Clarke gave the following:

		Jadeite	$R''_2 CaSiO_6$	Nephrite
Silica,	57.09	.81	.41	55.87
Alumina,	.53	.34	.19	
Ferric oxide,	.81		.81	
Ferrous "	3.98			3.98
Magnesia,	22.28			22.28
Lime,	11.75		.38	11.37
Soda,	.21	.21		
Water,	3.57			2.08
	100.22	1.36	1.79	95.58

Nephrite,	95.58
Jadeite,	1.36
R''_2 Ca SiO_6	1.79
Excess water,	1.49
	100.22

Nephrite = $H_4\ Ca_4\ (MgFe)_{12}(SiO_3)_{18}$

13335. *Crude Fragment* from the Jade Mountain, Alaska. Specific gravity, 2.9604; hardness, 6.5. The specimen shows contact markings with slight traces of slickensides, is closely foliated in part, enclosing rounded protuberant masses in the foliation. It is stained more or less with small brownish spots which are probably the alteration of some included mineral. *Color*, olive-green; grayish-green on fractured surfaces.

Microstructure: confused fibres of amphibole, extremely minute, crinkled and contorted in some places, in streaks of parallel fibres in others. The fibres are so minute that they overlie one another in the thin section and produce aggregate polarizations between crossed nicols. It is traversed by short crooked cracks containing dark coloring matter. The nephrite is stained yellow with streaks of brown.

The chemical analysis by Foote, with reduction by Clarke, is as follows:

		Jadeite	R''_2 Ca SiO_6	Nephrite
Silica,	57.02	.85	.58	55 59
Alumina,	.70	.36	.34	
Ferric oxide,	1.04		1.04	
Ferrous "	4.33			4.33
Magnesia,	21.56			21.56
Lime,	12.63		.54	12.09
Soda,	.22	.22		
Water,	3.01			2.00
	100.51	1.43	2.50	95.57

Nephrite,	95.57
Jadeite,	1.43
R'''_2 Ca SiO_6	2.50
Excess water,	1.01
	100.51

13122. *Knife* from British Columbia. Specific gravity, 2.9987; hardness, 6.5; of translucent and very compact material, showing, where sawn, a very characteristic splintery structure. *Color*, spinach-green, black venation.

Microstructure: a confused aggregation of amphibole fibres, with occasional longer streaks of nearly parallel fibres, and a faint suggestion of patches derived from previous pyroxene.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	Al_2 Ca SiO_6	Nephrite
Silica,	56.70	.55	1.05	55.10
Alumina,	2.01	.23	1.78	
Ferric oxide,	.....			
Ferrous "	5.09			5.09
Magnesia,	21.91			21.91
Lime,	12.12		.98	11.14
Soda,	.14	.14		
Water,	2.56			1.81
	100.53	.92	3.81	95.05

Nephrite,	95.05
Jadeite,	.92
Al_2 Ca SiO_6	3.81
Excess water,	.75
	100.53

Nephrite = H_4 Ca_4 $(MgFe)_{13}(SiO_3)_{19}$

13205. *Thumb-ring* from China. Specific gravity, 2.9896; hardness, 6.5; horny, compact, with scattered fragmentary highly striated crystals of colorless jadeite. *Color*, olive-gray, clouded and veined with brown and black.

The analysis, with reduction by Clarke, is as follows:

			Jadeite	Nephrite
Silica,	57.02		2.47	54.55
Alumina,	1.05		1.05	
Ferric oxide, } Ferrous " }	1.10			.55 ? .50 ?
Magnesia,	23.01			23 01
Lime,	14.77			14.77
Alkalies,	undet	Na_2O	.63?	
Water,	3.00			.95
	99.95		4.15	94.33

Nephrite,	94.33
Jadeite,	4.15
Excess water,	2.03
	100.53

Jadeite is assumed to be proportional to alumina, and the undetermined soda is calculated to correspond. Ferrous and ferric oxide not separated by the analyst.

13262E. *Fragment* of oblong medallion from China. Specific gravity, 2.9546; hardness, 6.5; of very pure, translucent, and compact material, with splintery fracture. *Color*, sage-green.

Microstructure: There is a faint suggestion of patches derived from a previous pyroxene, but the amphibole fibres are in confused aggregation with occasional longer streaks of nearly parallel fibres.

The analysis, with reduction by Clarke, is as follows:

		Jadeite?	R'''_2 Ca SiO_6	Nephrite
Silica,	57.38	1.28	.81	55.29
Alumina,	.83	.54	.29	.
Ferric oxide,	1.71		1.71	
Magnesia,	23.37			23.37
Lime,	13.14		.76	12.36
Soda,	.33	.33		
Water,	3.51			1.79
	100.27	2.15	3.57	92.83

Nephrite,	92.83
Jadeite?	2.15
R'''_2 Ca SiO_6,	3.57
	98.55
Excess water,	1.72
	100.27

3185. *Little figure* from China. Specific gravity, 2.9490 ; hardness, 6.5 ; of translucent, homogeneous, and compact material, in which are seen by transmitted light some subtranslucent inclusions, evidently another form of nephrite. *Color*, yellow, with a greenish tint.

The analysis, with reduction by Clarke, is as follows :

		$R''_2 Ca SiO_6$	Serpentine	Nephrite
Silica,	54.44	.62	.84	52.98
Alumina,	.82	.82		
Ferric oxide,	.38	.38		
Ferrous "	.34			.34
Magnesia,	25.88		.84	25.04
Lime,	13.70	.58		13.12
Soda,	.70			.70
Potash,	.54			.54
Water,	3.48		.25	
	100.28	2.40	1.93	92.72

Nephrite,	92.72
Serpentine,	1.93
$R''_2 Ca SiO_6$,	2.40
Excess water,	3.23
	100.28

The low silica indicates serpentine. Without it bases are in excess of silica.

3121. *Vase* from China. Specific gravity, 2.9513; hardness, 6.5 ; of translucent, compact material, the sinewy texture of which is well shown by transmitted light. *Color*, white, with very light greenish tint.

The analysis, with reduction by Clarke, is as follows :

		Jadeite?	Acmite?	Nephrite
Silica,	57.28	3.43	.84	53.01
Alumina,	1.46	1.46		
Ferric oxide,	.56		.56	
Ferrous "	1.19			1.19
Manganous "	.28			.28
Magnesia,	20.88			20.88
Lime,	13.15			13.15
Soda,	2.61	.88	.22	1.51
Potash,	1.23			1.23
Water,	1.79			1.23
	100.43	5.77	1.62	92.48

Nephrite,	92.48
Jadeite,	5.77
Acmite,	1.62
Excess water,	.56
	100.43

Here the excess of alkalies replaces magnesia in the nephrite.

13223. *Hatchet* from the lake-dwellings at Neufchâtel, Switzerland. Specific gravity, 3.0034; hardness, 6.5; of subtranslucent material, with a compact, interwoven, laminated structure made up of so many fine laminæ that a beautiful sheen is seen transversely across the left side. *Color*, light olive-green.

Microstructure: the rock gives evidence of having been crushed or dragged, and the structure indicates a high degree of dynamic metamorphism. The fibres are almost perfectly parallel, with striations that seem to be due to twinning parallel to the orthopinacoid. The structure resembles that of silicified wood in longitudinal section.

The analysis, with reduction by Clarke, is as follows:

		$Na\,Al\,Si_2O_6$	$Na\,Fe\,Si_2O_6$	Nephrite
Silica,	55.48	1.91	1.35	52.22
Alumina,	.89	.89		
Ferric oxide,	.90		.90	
Ferrous "	3.47			3.47
Magnesia,	22.69			22.69
Lime,	12.89			12.89
Soda,	.80	.49	.31	
Potash,	.44		.06	.38
Water,	3.12			.44
	100.68	3.29	2.62	92.09

Nephrite,	92.09
$Al\,Na\,Si_2O_6$,	3.29
$Fe\,Na\,Si_2O_6$,	2.62
Excess water,	2.68
	100.68

13262R. *Broken medallion*, China. Specific gravity, 2.9510; hardness, 6.5; compact, homogeneous, splintery structure; apparently no inclusions. *Color*, white.

Microstructure: a microcrystalline to micro-cryptocrystalline aggregation of fibres of colorless amphibole that extinguish light between crossed nicols in irregular patches, showing that the original rock was a coarse-grained jadeite.

The analysis, with reduction by Clarke, is as follows:

		$Al_2\ Ca\ SiO_6$	$Fe_2\ Ca\ SiO_6$	Nephrite
Silica,	57.77	1.47	.91	55.39
Alumina,	2.60	2.50		
Ferric oxide,	2.76		2.43	
Magnesia,	20.91			20.91
Lime,	13.61	1.37	.85	11.39
Water,	3.52			3.52
	101.07	5.34	4.19	91.21

Nephrite,	91.21
$Fe_2\ Ca\ SiO_6$	4.19
$Al_2\ Ca\ SiO_6$,	5.34
Excess Fe_2O_3,	.33
	101.07

Computation uncertain. Absence of alkalies seems to render the hornblendic molecule R_2 Ca SiO_6 necessary. The summation of the analysis is not good.

13248. *Hatchet* from the Swiss lake-dwellings. Specific gravity, 2.9836; hardness, 6.5; two sides flat and free from stains, two stained to some depth. *Color*, light green.

Microstructure: Fibres parallel, slightly curved; the laminated structure is strongly marked and accompanied by crooked cracks. It has the appearance of having been crushed or dragged, and the structure indicates a high degree of dynamic metamorphism.

The analysis, with reduction by Clarke, is as follows:

		Acmite	$R''_2\ (SiO_3)_3$	Nephrite
Silica,	58.66	1.86	1.46	51.25
Alumina,	.50		.50	
Ferric oxide,	1.76	1.24	.52	
Ferrous "	3.48			3.48
Manganous "	.02			.02
Magnesia,	22.43			22.43
Lime,	13.34			13.34
Soda,	.48	.48		
Potash,	.10			
Water,	.12			.12
	100.89	3.58	2.48	90.64

Nephrite,	90.64	
Acmite?	3.58	
$R'''_2 (SiO_3)_3$	2.48	This nephrite carries an excess of silica over bases.
	96.70	
Excess silica,	4.09	
" potash,	4.10	
	100.89	

3125. *Sword-guard* from India. Specific gravity, 3.0783; hardness, 6.5; of subtranslucent, very homogeneous and remarkably compact material with a vein-like fracture running parallel with the width of the guard. *Color*, very dark greenish-black.

Microstructure: a nearly uniform mixture of amphibole fibres in fan-shaped divergent clusters sometimes approaching a spherulitic arrangement.

The analysis, with reduction by Clarke, is as follows:

		Jadeite ?	$R'''_2 (SiO_3)_3$	Nephrite
Silica,	55.51	1.59	4.35	49.57
Alumina,	1.72	.67	1.05	
Ferric oxide,	1.33		1.33	
Ferrous "	7.69			7.69
Magnesia,	18.80			18.80
Lime,	13.17			13.17
Soda,	.41	.41		
Water,	1.82			.55
	100.45	2.67	6.73	89.78

Nephrite,	89.78	The excess of alumina and ferric oxide over jadeite is reckoned as the silicate $(Al\ Fe)_2 (SiO_3)_3$. This may be regarded also as part of the nephrite.
Jadeite,	2.67	
$R'''_2 (SiO_3)_3$,	6.73	
Excess water,	1.27	
	100.45	

13118. *Slab* from New Zealand. Specific gravity, 3.0103; hardness, 6.5. This is a section of a boulder with part of the weathered surface still remaining at one end. It is remarkably free from metallic inclusions of every kind, is highly translucent, compact, and homogeneous, admitting of a very high polish. *Color*, brilliant seaweed-green.

Microstructure: Fibres in parallel, sometimes in curved, arrangement, with a parallel or laminated structure, strongly marked, and often accompanied by crooked cracks. The rock appears to have been crushed or dragged, and the structure indicates a high degree of dynamic metamorphism.

The analysis, with reduction by Clarke, is as follows:

		$Al\,Na\,Si_2O_6$	$(Al\,Fe)_2\,(SiO_3)_3$	Nephrite
Silica,	58.14	1.40	4.50	52.24
Alumina,	.98	.59	.39	
Ferric oxide,	3.39		3.39	
Ferrous "	.85			.85
Manganous "	.22			.22
Magnesia,	22.38			22.38
Lime,	12.53			12.53
Soda,	.36	.36		
Water,	1.69			1.30
	100.54	2.35	8.28	89.52

Nephrite,	89.52	
$Al\,Na\,Si_2O_6$,	2.35	Nephrite =
$R'''_2\,(SiO_3)_3$,	8.28	$H_2Ca_3Mg_8\,(SiO_3)_{12}$ or
Excess water,	.39	$Ca\,(H_2Mg)_3\,(SiO_3)_4$
	100.54	

13214. *Fragment* of boulder from river-bed, China. Specific gravity, 2.9825; hardness, 6.5. Translucent, compact, splintery structure, with very fine grained texture on cut surfaces. One-half of the mass has been polished by attrition in the river, and stained by oxidation of iron and other minerals. *Color*, light sage-green.

Microstructure: a confused aggregate of amphibole fibres that in places reach the size of compact crystals, with a few fragments of jadeite remaining.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R''_2(SiO_3)_3$	Nephrite
Silica,	58.59	4.33	1.95	52.31
Alumina,	2.33	1.84	.49	
Ferric oxide,	.97		.97	
Ferrous "	.11			.11
Manganous"	.35			.35
Magnesia,	22.30			22.30
Lime,	12.41			12.41
Soda,	.98	.98		
Potash,	.21	.21		
Water,	1.54			1.54
	99.79	7.36	3.41	89.02

Nephrite,	89.02	
Jadeite,	7.36	Nephrite =
$R''_2(SiO_3)_3$,	3.41	$Ca(H_2Mg)_3(SiO_3)_4$
	99.79	

3136. *Screen-picture* from China. Specific gravity, 2.9609; hardness, 6.5; translucent, compact, homogeneous, with white mottlings or inclusions that are almost opaque and are evidently nephrite. *Color*, white, with light greenish tint.

Microstructure: clearly the result of amphibolic alteration of jadeite. The rock consists of microcrystalline to microcryptocrystalline aggregations of fibres of colorless amphibole that extinguish light between crossed nicols in irregular patches, some of which are banded in parallel lines. These correspond to the originally twinned pyroxenes. In places the amphibole is in compact crystals. A few small clouded spots appear to be impure muscovite.

The analysis, with reduction by Clarke, is as follows:

		Jadeite	$R''_2 Ca SiO_6$	Nephrite
Silica,	56.66	4.49	.70	51.47
Alumina,	2.74	1.91	.83	
Ferric oxide,	.56		.56	
Ferrous "	.51			.51
Magnesia,	23.42			23.42
Lime,	12.52		.65	11.87
Soda,	1.16	1.16		
Water,	2.23			.93
	99.80	7.56	2.74	88.20

Nephrite,	88.20	Nephrite = $H_2Ca_4\ Mg_{11}(SiO_3)_{16}$ or $Ca_2\ (H_2Mg)_3(SiO_3)_4$.
Jadeite,	7.56	
R''_2 Ca SiO_6,	2.74	
Excess water,	1.30	
	99.80	

13192H. *Medallion* with carving of dragon-heads, China. Specific gravity, 2.9706 ; hardness, 6.5 ; remarkably pure and homogeneous, exhibiting a characteristic splintery fracture when broken. *Color*, white, with milky tint.

Microstructure: considerable parallelism is seen in the fibres in places, and there are traces of the original pyroxenic grains in the arrangement of the fibres. Prismatic crystals of amphibole are abundant, and lie in several directions.

The analysis, with reduction by Clarke, is as follows :

		Jadeite	$R''_2\ (SiO_3)_3$	Nephrite
Silica,	57.82	1.20	5.72	50.90
Alumina,	1.14	.51	.63	
Ferric oxide,	4.10		4.10	
Magnesia,	20.49			20.49
Lime,	13.93			13.93
Soda,	.31	.31		
Water,	3.08			1.57
	100.87	2.02	10.45	86.89

Nephrite,	86.89	State of iron uncertain. If ferrous the summation would be 0.41 lower, and better. Nephrite would then be about 7 per cent. higher.
$R''_2\ (SiO_3)_3$,	10.45	
Jadeite,	2.02	
Excess water,	1.51	
	100.87	

3156. *Vase* from China. Specific gravity, 2.9539; hardness, 6.5 ; of a translucent, homogeneous and compact material with several inclusions, 2 to 3 mm. in width, of a delicate grayish-brown color. *Color*, white, with very light greenish tint.

Microstructure : a uniform aggregation of minute fibres. In the finer-grained portion are groups of compact amphiboles yielding fan-shaped sections.

The analysis, with reduction by Clarke, is as follows:

		$Al\,Na\,Si_2O_6$	$Fe\,Na\,Si_2O_6$	Nephrite
Silica,	57.89	4.68	2.04	51.17
Alumina,	1.99	1.99		
Ferric oxide,	1.36		1.36	
Magnesia,	20.74			20.74
Lime,	12.60			12.60
Soda,	2.06	1.21	.53	.32
Water,	3.38			1.87
	100.02	7.88	3.93	86.70

Nephrite,	86.70
$Al\,Na\,Si_2O_6$,	7.88
$Fe\,Na\,Si_2O_6$,	3.93
Excess water,	1.51
	100.02

13233. *Hatchet* from the lake-dwellings of Neufchâtel, Switzerland. Specific gravity, 3.0118; hardness, 6.5; material very compact and subtranslucent. *Color*, light olive-green.

Microstructure: parallel fibres, sometimes in a slightly curved arrangement, with a parallel or laminated structure strongly marked, and accompanied by crooked cracks. There is every appearance of the rock having been crushed or dragged and the structure indicates a high degree of dynamic metamorphism.

The analysis, with reduction by Penfield, is as follows:

		Glaucophane and Riebeckite	Nephrite $R\,SiO_3$	Unaccounted for	Nephrite re-calculated	Theory
Silica,	57.19	7.44	49.75		57.35	57.69
Alumina,	2.24	2.24				
Ferric oxide,	1.60	1.60				
Ferrous "	1.10		1.10			
Magnesia,	21.97		21.97		28.32	28.85
Lime,	13.16	.73	12.43		14.33	13.46
Soda,	.20	.20				
Potash,	1.44	1.44				
Water,	1.82		.90	0.92		
	100.72	13.65	86.15	0.92	100.00	100.00

3148. *Sculptured rock-mass*, from China. Specific gravity, 2.9549 ; hardness, 6.5 ; a very large piece of remarkably pure material. *Color*, white, with light-greenish tint.

Microstructure : a microcrystalline to microcryptocrystalline aggregation of colorless fibres and flakes or scales, having a confused arrangement which in places approaches a more definite grouping, in which the fibres lie in several directions. In each of these directions the fibres are approximately parallel and slightly curving, so that the streaks or bands of fibres extinguish the light simultaneously between crossed nicols. The polarizing colors of these minute fibres are grays of the first order. They grade into thicker and more compact crystals with higher interference colors. Throughout this mass are scattered fragmentary crystals of colorless jadeite, which is distinguished from the amphibole by its higher refraction. The double refraction is also higher. Its prismatic cleavage is also characteristic. A lamellar twinning is present and in places is curved, and apparently the result of strain. The amphibole is compact in some cases and fibrous in others. The transition is into compact amphibole which frays out into curved fibres at the ends. It is evident that the fibrous amphibole composing this rock has been derived from colorless pyroxene or jadeite remnants of which still exist in the rock.

The analysis, with reduction by Clarke, is as follows :

		Jadeite	Fe (NaK) Si_2O_6	Nephrite
Silica,	57.46	6.36	1.25	49 85
Alumina,	2.70	2.70		
Ferric oxide,	.83		.83	
Magnesia,	20.87			20.87
Lime,	12.49			12.49
Soda,	1.79	1.64	.15	
Potash,	1.64		.26	1.28
Water,	2.71			1.28
	100.49	10.70	2.49	85.87

Nephrite,	85.87	
Jadeite,	10.70	Nephrite =
Acmite ?	2.49	$Ca(H_2Mg)_3(SiO_3)_4$ approx.
Excess water,	1.43	
	100.49	

13246. *Slab* from jade boulder, Siberia. Specific gravity, 3.0070; hardness, 6.5. Highly translucent, very compact and homogeneous, with characteristic splintery fracture. *Color*, seaweed-green, with clouds of brown.

Microstructure: a nearly uniform mixture of amphibole fibres in fan-shaped, divergent clusters; sometimes approaching a spherulitic arrangement.

The analysis, with reduction by Clarke, is as follows:

		$Al\,Na\,Si_2O_6$	$R'''_2\,Ca\,SiO_6$	Nephrite
Silica,	55.96	1.97	2.43	51.56
Alumina,	2.33	.84	1.49	
Ferric oxide,	4.28		4.12	
Magnesia,	20.35			20.35
Lime,	13.49		2.26	11.23
Soda,	.51	.51		
Water,	2.72			2.72
	99.64	3.32	10.30	85.86

Nephrite,	85.86	
$Al\,Na\,Si_2O_6$	3.32	
$R'''_2\,Ca\,SiO_6$	10.30	Here, unless the iron oxide is in error, the hornblendic molecule $R'''_2\,Ca\,SiO_6$ seems to be necessary.
	99.48	
Excess Fe_2O_3,	.16	
	99.64	

13095. *A small saucer-shaped dish*, from China (one of a pair). Specific gravity, 2.9758; hardness, 6.5; of translucent, homogeneous and very compact material, with a mottling throughout part of it of a trifle more opaque and slightly darker substance, probably nephrite, and an inclusion in one part of a most pronounced crystalline structure that may be a remnant of former jadeite. A few microscopic flakes of colorless mica are present. *Color*, sage-green.

The analysis by Walden, with reduction by Clarke, is as follows :

		Jadeite	Acmite	Nephrite
Silica,	57.42	5.49	1.96	49.97
Alumina,	2.66	2.35		.31
Ferric oxide,	1.31		1.31	
Ferrous "	1.78			1.78
Manganous oxide,	.28			.28
Magnesia,	14.30			14.30
Lime,	16.19			16.19
Soda,	1.93	1.42	.51	
Water,	3.69			2.68
	99.56	9.26	3.78	85.51

Nephrite,	85.51
Jadeite,	9.26
Acmite,	3.78
Excess Water,	1.01
	99.56

The nephrite is distinctly hydrous, and the excess of lime over magnesia in it indicates its pyroxenic origin.

13030. *Fragment* of a water-worn boulder, New Zealand. Specific gravity, 3.0122 ; hardness, 6.5 ; translucent, very compact, and homogeneous, admitting of a high polish ; with transverse fracturing and laminæ parallel to the flat length of the mass.

Microstructure : fibres parallel, sometimes in curved arrangement with a parallel or laminated structure strongly marked and often accompanied by crooked cracks. The rock appears to have been crushed or dragged, and the structure indicates a high degree of dynamic metamorphism. *Color*, rich dark green.

The analysis, with reduction by Penfield, is as follows :

		Glaucophane $Na_2 Al_2 (SiO_3)_4$	Riebeckite $Na_2 Fe_2 (SiO_3)_4$	Nephrite $R SiO_3$	Nephrite cal. to 100%	Theory
Silica,	57.78	5.52	2.40	49.86	57.62	57.69
Alumina,	2.35	2.35				
Ferric oxide,	1.60		1.60			
Ferrous "	2.83			2.83		
Magnesia,	14.80			14.80	25.15	28.85
Lime,	15.02			15.02	17.33	13.46
Soda,	1.63	1.01	0.62			
Potash,	1.00	.66				
Water,	2.75			2.45		
	99.76	9.54	4.62	84.96	100.00	100.00

Unaccounted for : Potash 0.34 ; water 0.30 = 0.64.

13088. *Fragment* of boulder from New Zealand. Specific gravity, 3.0000 ; hardness, 6.5 ; translucent, compact, homogeneous. The tough, splintery character of the material is very apparent in many places. A number of the original boulder surfaces are still unworked. *Under the microscope* there is a faint suggestion of the patches derived from previous pyroxene, but the amphibole fibres are in a confused aggregation, with occasionally longer streaks of nearly parallel fibres. *Color*, spinach-green with patches of olive-green.

The analysis, with reduction by Clarke, is as follows:

		$Na\,Al\,Si_2O_6$	$Na\,Fe\,Si_2O_6$	Nephrite
Silica,	56.41	2.14	5.76	48.51
Alumina,	.91	.91		
Ferric oxide,	3.84		3.84	
Ferrous "	1.92			1.92
Manganous oxide,	.15			.15
Magnesia,	19.09			19.09
Lime,	12.81			12.81
Soda,	2.64	.55	1.49	.60
Water,	2.56			1.15
	100.33	3.60	11.09	84.23

Nephrite,	84.23
$Na\,Al\,Si_2O_6$,	3.60
$Fe\,Al\,Si_2O_6$,	11.09
Excess Water,	1.41
	100.33

13006. *Slab*, New Zealand. Specific gravity, 3.0019; hardness, 6.5 ; translucent, homogeneous, compact in structure ; filled with splintery veinings and fractures. *Color*, pea-green.

Microstructure: fibres in parallel, sometimes curved, arrangement, with a strongly marked parallel or laminated structure. The rock gives evidence of having been crushed or dragged, and the structure indicates a very high degree of dynamic metamorphism.

The analysis, with reduction by Clarke, is as follows:

		Al (NaK) Si_2O_6	$R''_2 (SiO_3)_3$	Nephrite
Silica,	56.63	2.49	6.40	47.74
Alumina,	2.14	1.06	1.08	
Ferric oxide,	3.99		3.99	
Magnesia,	21.69			21.69
Lime,	13.41			13.41
Soda,	.20	.20		
Potash,	.69	.69		
Water,	1.67			.26
	100.42	4.44	11.47	63.10

Nephrite,	83.10
$R''_2 (SiO_3)_3$,	11.47
Al $R' Si_2O_6$,	4.44
Excess water,	1.41
	100.42

K is equivalent to Na, and is put in the glaucophane-like molecule. State of iron doubtful. In a pea-green jade it should be mainly ferrous.

3246. *Wine-jug* from China; a tomb piece. Specific gravity, 2.9243; hardness, 6.5. *Color*, light gray, changed in part by oxidation to a darker gray, with brownish hues, and seams and fractures of dead oak-leaf color.

Microstructure: a microcrystalline to microcryptocrystalline aggregation of fibres of colorless amphibole that extinguish light between crossed nicols in irregular patches, some of which are banded in parallel lines. These patches correspond to the originally twinned pyroxene. In places the amphibole is in compact crystals. There is also a mottling similar to that noticed in the large crystals of jadeite where it was the result of strain.

The analysis, with reduction by Clarke, is as follows:

		Jadeite, etc.	Nephrite
Silica,	56.91	9.17	47.74
Alumina,	2.84	2.84	
Ferric oxide,	1.56	1.56	
Magnesia,	21.82		21.82
Lime,	11.56		11.56
Soda,	1.62	1.62	
Potash,	1.19	1.17	
Water,	3.07		.49
	100.57	16.36	81.61

Nephrite,	81.61	The pyroxene molecule here represents jadeite, Al Na Si_2O_6, and acmite, Fe Na Si_2O_6, with potassium partly replacing sodium.
R‴R′ Si_2O_6	16.36	
Excess water,	2.58	
	100.55	

.02 K_2O unaccounted for.

13211. *Fragment* of boulder, Siberia. Specific gravity, 3.0138 ; hardness, 6.5 ; part of the original surface of what was a water-worn boulder. Translucent, showing on sawed surface a remarkably homogeneous and compact texture. On the fractured surfaces very splintery, in some parts almost fibrous. A few included crystals of a black metallic substance, apparently chromic iron. *Color*, brilliant seaweed-green.

Microstructure : there are mottled patches, but the mottling is so coarse that the details of it can be seen. It consists of fanlike bundles of fibres crossing one another in two or more directions, sometimes producing spherulitic aggregates with four long arms. In other places the fibres are arranged in lines of lenticular or spindle-shaped bundles, which produce curving lines. Between the latter are fibres in other orientations, probably bundles seen in cross-section. This appears to be the same structure that produces the mottling in the finer-grained forms. The long streaks of parallel fibres are very marked.

The analysis, with reduction by Penfield, is as follows:

		Glaucophane $Na_2Al_2(SiO_3)_4$	Riebeckite $Na_2Fe_2(SiO_3)_4$	Nephrite $R\,SiO_3$	Nephrite Cal. to 100%	Theory
Silica,	57.65	2.40	7.44	47.81	56.76	57.69
Alumina,	1.06	1.06				
Ferric oxide,	4.93		4.93			
Ferrous "	.11			.11		
Magnesia,	14.95			14.95	24.19	28.85
Lime,	16.05			16.05	19.05	13.46
Soda,	2.38	.62	1.76			
Potash,	.93		.28			
Water,	2.46			2.42		
	100.52	4.08	14.41	81.34	100.00	100.00

Unaccounted for : Potash 0.65 ; water 0.04 = 0.69.

13268. *Boulder* from river-bed, China. Specific gravity, 2.9690 ; hardness, 6.5 ; exterior worn down by attrition, and though stained black and brown exteriorly the inner surface is practically unaltered. *Color*, greenish-gray.

Microstructure : the once coarse-grained aggregate of pyroxene crystals is perfectly mapped out by patches of similarly oriented amphibole fibres arranged in a direction corresponding to the twinned positions of the pyroxene lamellæ, with patches of mottling so coarse that the details of the structure can be seen. It consists of fanlike bundles of fibres crossing one another in two or more directions, sometimes producing spherulitic aggregates, with four long arms. In other places the fibres are arranged in lines of lenticular or spindle-shaped bundles which produce curving lines. Between the latter are fibres in other orientations, probably bundles seen in cross-section. This appears to be the same structure that produces the mottling in the finer-grained forms.

The analysis, with reduction by Clarke, is as follows :

		Jadeite	Acmite	Nephrite
Silica,	57.43	7.39	2.82	47.22
Alumina,	3.14	3.14		
Ferric oxide,	1 88		1.88	
Ferrous "	.47			.47
Magnesia,	19.68			19.68
Lime,	12.04			12.04
Soda,	2 87	1.91	.73	.23
Water,	2 61			1.26
	100.12	12.44	5.43	80.90

Nephrite,	80.90
Jadeite,	12.44
Acmite,	5.43
Excess water,	1.35
	100.12

13008. Small *round dish* from China. Specific gravity, 2.9564 ; hardness, 6.5 ; of translucent, homogenous, and compact material, in which a fine camphor-like, apparently crystalline structure is seen that may possibly be due to traces of the former jadeite; and the *microscopic examination* bears out this observation. The coarse-grained aggregate of pyroxene crystals is perfectly mapped out by the patches of similarly oriented amphibole fibres, arranged in a direction corresponding to the twinned positions of the pyroxene lamellæ. *Color*, white, with light creamy tint.

The analysis by Walden, with reduction by Clarke, gave the following:

		Jadeite	Al_2CaSiO_6	Nephrite
Silica,	56.83	8.71	1.11	47.01
Alumina,	5.33	3.70	1.63	
Ferric oxide,	.46		.46	
Magnesia,	19.38			19.38
Lime,	13.11		1.03	12.08
Soda,	2.25	2.25		
Water,	3.44			1.50
	100.80	14.66	4.23	79.97

Nephrite,	79.97
Jadeite,	14.66
Al_2CaSiO_6,	4.23
Excess water,	1.94
	100.80

13212. *Fragment* of boulder from Turkistan. Specific gravity, 3.0033; hardness, 6.5. *Color*, seaweed-green.

Microstructure: a mixture of amphibole fibres in fan-shaped, divergent clusters sometimes approaching a spherulitic arrangement, as in No. 13216. Some of the bundles, however, are longer and larger, and needles of compact amphibole are sparingly present.

The analysis, with reduction by Clarke, is as follows:

		$AlNaSi_2O_6$	$FeNaSi_2O_6$	Nephrite
Silica,	58.04	5.24	6.96	45.84
Alumina,	2.23	2.23		
Ferric oxide,	4.64		4.64	
Ferrous "	.16			.16
Manganous oxide,	.38			.38
Magnesia,	14.50			14.50
Lime,	12.68			12.68
Soda,	4.83	1.35	1.80	1.68
Potash,	.39			.39
Water,	2.83			2.51
	100.68	8.82	13.40	78.14

Nephrite,	78.14	The nephrite contains water and alkalies replacing magnesia. The iron determination may be doubtful.
Fe Na Si_2O_6,	13.40	
Al Na Si_2O_6,	8.82	
Excess water,	.32	
	100.68	

13007G. *Fragment* of worked nephrite from China. Specific gravity, 2.9680 ; hardness, 6.5 ; translucent, compact, splintery structure with veinings of darker material, and inclusions of some other dark, almost black mineral. *Color*, spinach-green, with russet veinings.

Microstructure : a confused aggregation of amphibole fibres, with occasional longer streaks of nearly parallel fibres and a faint suggestion of patches derived from pyroxene. The texture varies from place to place. Some of it is extremely fine-grained ; in other places it is in patches of coarser grain.

The analysis, with reduction by Clarke, is as follows :

		$R'''R'\ Si_2O_6$	$R'''_2\ Ca\ SiO_6$	Nephrite
Silica,	56.13	9.46	1.40	45.27
Alumina,	5.06	4.02	1.04	
Ferric oxide,	2.12		2.12	
Ferrous "	1.01			1.01
Magnesia,	19.20			19.20
Lime,	11.88		1.31	10.57
Soda,	1.19	1.19		
Potash,	1.90	1.90		
Water,	2.29			1.29
	100.78	16.57	5.87	77.34

Nephrite,	77.34
$R'''R'\ Si_2O_6$,	16.57
$R'''_2\ Ca\ SiO_6$,	5.87
Excess water,	1.00
	100.78

13216. *Hatchet* from New Caledonia. Specific gravity, 2.9311 ; hardness, 6.5 ; polished all over except in two places where the weathered surface of the original boulder is visible. *Color*, dark-brown, with veins and lines of lighter shades.

Microstructure: a nearly uniform mixture of amphibole fibres, in fan-shaped, divergent clusters, sometimes approaching a spherulitic arrangement.

The analysis, with reduction by Clarke, is as follows:

		Al Na Si_2O_6	Fe R′ Si_2O_6	Serpentine	Nephrite
Silica,	52.60	3.40	1.62	4.92	42.66
Alumina,	1.45	1.45			
Ferric oxide,	2.10		1.08		
Ferrous "	2.14				2.14
Manganous oxide,	.10				.10
Magnesia,	23.06			4.92	18.14
Lime,	12.72				12.72
Soda,	.93	.88	.05		
Potash,	.57		.57		
Water,	3.62			1.48	
	99.29	5.73	3.32	11.32	75.76

Nephrite,	75.76	
Serpentine,	11.32	Silica in nephrite 0.05% too low.
Al Na Si_2O_6,	5.73	
Fe R′ Si_2O_6,	3.32	
	96.13	
Ferric oxide,	1.02	unaccounted for.
Water,	2.14	
	99.29	

13266. Large flat *carved celt* from China. Specific gravity, 2.9506; hardness, 6.5; a confused aggregate of amphibole fibres, with a small amount of colorless jadeite in fan-shaped aggregates. *Color*, dark brown of various shades.

Analysis, with reduction by Clarke, is as follows:

		Jadeite ?	Serpentine ?	Nephrite
Silica,	52.98	4.25	9.48	39.25
Alumina,	1.79	1.79		
Ferric oxide,	.05			
Ferrous oxide,	.46			.46
Manganous oxide,	.05			.05
Magnesia,	25.49		9.48	16.01
Lime,	13.39			13.39
Soda,	1.11	1.11		
Potash,	.71			.71
Water,	3.50		2.84	
	99.53	7.15	21.80	69.87

Nephrite,	69.87	
Serpentine,	21.80	
Jadeite,	7.15	
	98.82	
Ferric oxide,	.05	unaccounted for.
Water,	.66	
	99.53	

13210. *Fragment* of crude jade from Jordansmühl, Silesia. Specific gravity, 2.9451; hardness, 6.5; translucent, very compact, tough splintery texture, breaking into irregular horn-like fractures. *Color*, spinach-green, with black.

Microstructure: numerous compact prisms of amphibole which grade into fibres, are in nearly parallel groups and cross one another in several directions.

The analysis, with reduction by Clarke, is as follows:

		$Al\,Na\,Si_2O_6$	$Fe\,Na\,Si_2O_6$	Nephrite
Silica,	54.44	13.93	4.82	35.69
Alumina,	5.92	5.92		
Ferric oxide,	3.72		3.15	
Ferrous oxide,	2.56			2.56
Manganous oxide,	.22			.22
Magnesia,	16.79			16.79
Lime,	7.51			7.51
Soda,	4.64	3.60	1.04	
Potash,	.28		.28	
Water,	4.12			.04
	100.20	23.45	9.29	62.81

Nephrite,	62.81	Al and Fe probably in glaucophane and riebeckite molecules respectively.
$Fe\,Na\,Si_2O_6$,	9.29	
$Al\,Na\,Si_2O_6$,	23.45	
	95.55	
Ferric oxide,	.57	unaccounted for.
Water,	4.08	
	100.20	

13086. *Adze*, New Zealand. Specific gravity, 3.2663; hardness, 6.5; of compact, schistose, horny structure, showing black grains of chromic iron. *Color*, pear-leaf green.

Microstructure: very minute particles and fibres with a preponderating parallel arrangement, with banded structure, some bands being clouded, others transparent. There are small opaque spots that are green by incident light, and irregularly shaped crystals of a reddish-brown isotropic mineral probably perovskite, which is surrounded by a white opaque substance resembling leucoxene.

Analysis by Walden, with reduction by Penfield, is as follows:

		Jadeite-like Mineral	Diopside Ca Mg $(SiO_3)_2$	Diopside Cal. to 100%	Diopside Theory
Silica,	54.19	10.80	43.39	54.06	55.57
Alumina,	3.48	3.48			
Ferric oxide,	1.79	1.79			
Magnesia,	14.58		14.58	19.16	18.51
Lime,	24.03	1.74	22.29	27.77	25.92
Soda,	.88	.88			
Water,	.65				
	99.60	18.69	80.26	100.00	100.00

13005. *Axe* from the lake-dwellings at Neufchâtel, Switzerland. Specific gravity, 3.0919; hardness, 6.5; the material exhibits a twinned horny structure. *Color*, very dark green almost black.

Microstructure: consists mainly of amphibole in minute, irregularly shaped crystals, and some larger ones that exhibit distinct green color, with pleochroism from yellowish- to bluish-green. In places the amphibole occurs in distinct prismatic crystals, with the prism faces and cleavage well developed. Between these minute crystals is a colorless mineral with lower refraction and low double refraction, of very pure substance, suggesting quartz. It is wholly allotriomorphic, or interstitial, acting as a cement for the other minerals. Though in very small areas, it is very widely scattered through the rocks and is present in considerable quantity for an accessory mineral. Scattered through the rock in much greater quantity are small particles of an almost colorless mineral whose form and optical properties correspond to those of klinozoisite. It constitutes about 40% of the rock. With it is associated a small amount of epidote, distinguished by its yellow color in thin sections. There are a few small crystals of colorless garnet, and small, irregularly shaped grains of a highly refracting yellowish mineral, possibly titanite, with attached grains of magnetite.

Analysis, with reduction by Penfield, is as follows:

		Glaucophane			Epidote	Quartz
		$NaAl(SiO_3)_2$.	$NaFe(SiO_3)_2$.	$(MgCa)SiO_3$.	$HCa_2Al_3Si_3O_{13}$.	
Silica, SiO_2,	51.31	11.76	12.00	7.92	15.48	4.17
Alumina, Al_2O_3,	18.31	5.00			13.31	
Ferric ox., Fe_2O_3,	8.08		8.08			
Magnesia, MgO,	4.05			4.05		
Lime, CaO,	11.34			1.71	9.63	
Soda, Na_2O	5.76	2.66	3.10			
Potash, K_2O,	.55	.55				
Water, H_2O,	.76				.76	
	100.18	19.97	23.18	13.68	39.18	4.17

CHEMICAL NOTES.

BY S. L. PENFIELD.

JADEITE.

In its chemical nature jadeite is a silicate of sodium and aluminium, and the formula assigned to it is $Na\,Al\,(SiO_3)_2$. The theoretical composition of the ideally pure mineral is as follows:

Silica,	SiO_2,	59.40 %
Alumina,	Al_2O_3,	25.25
Soda,	Na_2O,	15.35
		100.00

An examination of the jadeite analyses given above indicates that although silica, alumina, and soda are the essential constituents, small amounts of other substances are always present. The silica maintains a fairly uniform percentage, close to that demanded by the theory. The same is true of the alumina, although it falls below the theory when ferric oxide, Fe_2O_3, is present. This latter oxide plays the same rôle in chemical compounds as alumina, and has, therefore, the property of replacing alumina in complex mineral substances. Or it may be considered that the jadeite molecule Na Al $(SiO_3)_2$ is replaced in part by the isomorphous ægerite molecule Na Fe $(SiO_3)_2$. When the percentages of soda are considered it will be observed that the amounts fall considerably below the theory. These deficiencies are largely made up by potash, K_2O, which may replace soda, since it is similar to it in its chemical relations, but still there is a deficiency of the combined alkalies, soda plus potash. The rôle played by the small amounts of lime, CaO, and magnesia, MgO, is somewhat questionable. Together they combine with silica to form a variety of pyroxene known as diopside, Ca Mg $(SiO_3)_2$, and the presence of varying amounts of this silicate with jadeite might be expected. The analyses, however, indicate that the diopside molecule usually is not present, for it contains no alumina, and its presence with jadeite would be indicated by a lowering of the percentage of alumina. In some complex silicates lime, CaO, and magnesia, MgO, play the same rôle as the alkalies Na_2O and K_2O, and it would seem from the analyses of jadeite in the Collection that the small amounts of these oxides act like the potash in replacing soda. The traces of ferrous oxide, FeO, and loss on ignition (probably water) may be disregarded in considering the composition of jadeite.

In order to show that ferric oxide replaces alumina, and that potash, lime, and magnesia replace soda, the analyses have been modified by substituting for Fe_2O_3 an amount of Al_2O_3 equivalent to it, and for K_2O, CaO, and MgO their equivalent of Na_2O, and then calculating to 100 per cent. The recalculated analyses can thus be compared with the theoretical composition of jadeite, and it will be observed that the agreement is very satisfactory :

	I	II	III	IV	V
Number	3248	13195	13255	13206B	13243
Specific gravity,	3.3394	3.3381	3.3373	3.3303	3.3287
Silica, SiO_2,	58.48	59.02	58.40	57.60	58.69
Alumina, Al_2O_3,	23.57	24.88	27.05	25.75	25.56
Ferric oxide, Fe_2O_3,	1.68	1.23	....	....	....
Magnesia, MgO,	1.33	1.10	.57	.13	.11
Lime, CaO,	1.62	1.15	.65	.58	.58
Soda, Na_2O,	10.33	11.21	11.37	13.31	13.09
Potash, K_2O	3.09	1.34	2.20	2.20	1.54
Ferrous oxide, FeO,	....	.28	....	....	....
Manganous oxide, MnO,		.19			
Loss on ignition, H_2O,	.16	.07	.18	.25	.17
	100.26	100.47	100.42	99.82	99.74

The analyses, after making the substitutions, and after recalculating to 100 per cent., are as follows:

	I	II	III	IV	V	
Silica,	58.48	59.02	58.40	57.60	58.69	
Alumina,	24.59	25.59	27.05	25.75	25.56	
Soda,	16.22	15.01	14.34	15.54	14.88	
	99.29	99.62	97.79	98.89	99.13	Theory for Jadeite $NaAl(SiO_3)_2$
Silica,	58.90	59.25	58.52	58.25	59.20	59.40
Alumina,	24.77	25.69	27.12	26.04	25.79	25.25
Soda,	16.33	15.07	14.36	15.71	15.01	15.35
	100.00	100.00	100.00	100.00	100.00	100.00

It may thus be concluded that potash, K_2O and small amounts of lime, CaO, and magnesia, MgO, may replace soda in jadeite.

Mixture of jadeite with other materials.

The analyses indicate that there are in the Collection a few specimens which are mixtures of jadeite with other minerals. Some of these are isomorphous mixtures of the different members of the pyroxene group, jadeite, ægerite, and diopside, and in one sense these are not mixtures, since the different molecules can combine together into a homogeneous crystal. In other cases the material is an intergrowth of different minerals.

Pyroxene—Essentially jadeite.

No. 13242. The existence of a rather large amount of ferric oxide indicates the presence of the ægerite molecule $NaFe(SiO_3)_2$, and accounts undoubtedly for the dark color of the material. Also the somewhat low percentages of combined alumina and ferric oxide, together with the considerable amounts of lime and magnesia, indicate the presence of the diopside molecule $CaMg(SiO_3)_2$.* The analysis shows that the material is a pyroxene, essentially jadeite, and that the molecules are present in the proportion indicated below:

* A little iron replaces the magnesia.

		Diopside Ca(MgFe)(SiO$_3$)$_2$.	Ægerite NaFe(SiO$_3$)$_2$.	Jadeite NaAl(SiO$_3$)$_2$.	Jadeite Cal. to 100	Jadeite Theory
Sp. grav.,	3.3034					
Silica,	56.69	4.98	6.72	44.99	57.85	59.40
Alumina,	20.46			20.46	26.31	25.25
Ferric oxide,	4.49		4.49			
Ferrous oxide,	.75	.75				
Magnesia.	1.64	1.28		.36		
Lime,	3.28	2.29		.99		
Soda,	11.65		1.74	9.91	15.84	15.35
Potash,	1.15			1.15		
Loss on ignition,	.48					
	100.59	9.30	12.95	77.86	100.00	100.00

No. 13102C. Three analyses indicate that there is no essential difference between the green and the lavender portions. The slight excess of ferric oxide in the green portion indicates the presence of a little more of the ægerite molecule. The somewhat low percentage of alumina and the high percentage of lime and magnesia indicate the presence of the diopside molecule. The calculation has been made upon the analysis of the mixture, and shows that the material is pyroxene, with the jadeite molecule predominating.

	Lavender.	Green.	Mixture.	Diopside CaMg(SiO$_3$)$_2$.	Jadeite NaAl(SiO$_3$)$_2$.	Jadeite cal. to 100%.	Jadeite Theory
Sp. grav.,	......	......	3.2578				
Silica,	57.79	57.49	57.45	7.80	49.65	57.88	59.40
Alumina,	21.40	21.56	21.94		21.94	26.24	25.25
Ferric oxide,	.80	1.05	.91		.91		
Magnesia,	4.72	4.79	3.96	3.00	.96		
Lime,	3.06	2.90	3.10	3.10			
Soda,	12.36	11.98	12.13		12.13	15.88	15.35
Potash,	.....	.....	.....				
Loss on ignition,	.76	.45	.79				
	100.89	100.22	100.28	13.90	85.59	100.00	100.00

The water in this material and the one previous may indicate the presence of a small amount of analcite, Na Al $(SiO_3)_2 + H_2O$. Analcite and diopside would tend to bring the specific gravity below that of normal jadeite, while ægerite, specific gravity 3.5, would tend to increase it.

Jadeite and Analcite.

No. 13215. The low specific gravity of this material is noticeable. The analysis is like that of a jadeite, except for the quantity of water. Professor Iddings, in his examination of thin sections of this material, has noted the presence of an isotropic material with the properties of analcite, Na Al $(SiO_3)_2 + H_2O$, and the presence of this mineral would account both for the low specific gravity of the material and the water. The specific gravity of analcite is 2.28.

		Diopside $CaMg(SiO_3)_2$	Analcite $NaAl(SiO_3)_2+H_2O$	Jadeite $NaAl(SiO_3)_2$	Jadeite cal. to 100%	Jadeite Theory
Sp. grav.,	3.2176					
Silica,	58.41	1.50	15.84	41.07	58.37	59.40
Alumina,	24.64		6.73	17.91	26.05	25.25
Ferric oxide,	.67			.67		
Magnesia,	1.24	.52		.72		
Lime,	1.43	.67		.76		
Soda,	12.76		4.09	8.67	15.58	15.35
Potash,	.58			.58		
Loss on ignition,	1.19		1.19			
	100.92	2.69	27.85	70.38	100.00	100.00

In this connection it is interesting to note the similarity in chemical composition between jadeite, Na Al $(SiO_3)_2$ and analcite, Na Al $(SiO_3)_2 + H_2O$. J. Lemberg * has shown, moreover, that although jadeite is only slightly acted upon by acids and alkaline solutions, fused jadeite can readily be converted into analcite by subjecting it to the action of a hot dilute solution of sodium carbonate under pressure.

Glaucophane and Zoisite (*Klinozoisite ?*)

No. 13005. Only one example of this mixture has been observed in the Collection. Under the microscope there were observed epidote of pale color and low double refraction corresponding to klinozoisite (*Zeitschr. Kryst.*, Vol.

* *Zeitschrift der Deutschen Geologischen Gesellschaft*, xxix. p. 587, 1887.

26, p. 166), a little quartz, and abundant material having the cleavage and optical properties of a mineral belonging to the amphibole group. The presence of nearly six per cent. of soda in the specimen indicates that the amphibole mineral must be related to glaucophane and riebeckite, which are believed to contain respectively the molecules $Na Al (SiO_3)_2$ and $Na Fe (SiO_3)_2$, similar to the soda-alumina and soda-iron silicates jadeite and ægerite. The amounts of alumina, ferric oxide, and alkalies furnish a basis for calculating the chemical composition as follows:

			Glaucophane			Epidote	Quartz
			$NaAl(SiO_3)_2$	$NaFe(SiO_3)_2$	$(MgCa)SiO_3$	$HCa_2Al_3Si_3O_{13}$	SiO_2
Specific gravity,		3.0919					
Silica,	SiO_2,	51.31	11.76	12.00	7.92	15.48	4.17
Alumina,	Al_2O_3,	18.31	5.00			13.31	
Ferric oxide,	Fe_2O_3,	8.08		8.08			
Magnesia,	MgO,	4.05			4.05		
Lime,	CaO,	11.34			1.71	9.63	
Soda,	Na_2O,	5.76	2.66	3.10			
Potash,	K_2O,	.55	.55				
Water,	H_2O,	.76				.76	
		100.18	19.97	23.18	13.68	39.18	4.17

The glaucophane molecules combined constitute 56.83 per cent. of the total material, and are given below after calculation to 100 per cent. There are also given for comparison two analyses of glaucophane from Lyra, one of the Cyclades—I. by Schnedermann, II. by Luedecke (Analyses 1 and 2, p. 399, Dana's Mineralogy).

	13005 Calculation	Glaucophane from Lyra	
		I	II
SiO_2,	55.74	56.49	55 64
Al_2O_3,	8.80	12.23	15.11
Fe_2O_3,	14.22		3.08
FeO,		10.91	6.85
MnO,		0.50	0.56
MgO,	7.13	7.80	7.80
CaO,	3.01	2.40	2.40
Na_2O,	10.13	9.34	9.34
K_2O,	0.97		
	100.00	99.63	100.78

In most respects No. 13005 compares favorably with the glaucophane analyses given for comparison, the discrepancies being in the alumina and oxides of iron. It must be borne in mind, however, that in the calculation all of the iron oxide has been credited to the glaucophane, while undoubtedly part of it belongs to the epidote. It is safe, therefore, to assume that the glaucophane contains somewhat more alumina and less ferric oxide than indicated by the foregoing calculation, but the amount could not be determined without analysis of either the epidote or the glaucophane.

Jadeite and Albite.

Of the minerals analyzed there is only one example of this kind of mixture, No. 13193.

		Nephrite	Jadeite	Albite	Theoretical comparison of a mixture of		
		Ca Mg $(SiO_3)_4$	Na Al $(SiO_3)_2$	Na Al Si_3O_8	Nephrite	Jadeite	Albite
Sp. grav. 2.8345							
Silica,	63.47	2.20	28.80	32.47	2.17	28.87	32.48
Alumina,	20.76		11.53	9.23		12.43	9.20
Ferric oxide,	1.27		1.27				
Magnesia,	1.11	1.11			1.08		
Lime,	1.16	.50	.66		.50		
Soda,	11.98		6.63	5.35		7.46	5.81
Potash,	.34			.34			
Water,	.36						
	100.45	3.81	48.89	47.39	3.75	48.76	47.49

The analysis indicates the presence of a little nephrite.

Diopside.

No. 13086. Only one example of this kind of material is indicated by the analysis. The properties that characterize it are the following: Specific gravity from 3.24 to 3.28, considerably greater than that of nephrite. Hardness about 6. Before the blowpipe the material fuses at about 4, but does not yield a clear glass-like jadeite, and does not impart an intense yellow color to the flame. The powdered mineral is not perceptibly attacked by hydrochloric acid. In order to identify the material with certainty the absence of an appreciable quantity of alumina, and the presence of much calcium and magnesium, should be determined. As indicated by the analysis the amount of soda is very small, and there is some question, therefore, concerning the disposition of the alumina and ferric oxide, for they cannot belong to jadeite of normal composition. By combining the alumina and ferric oxide, however, with silica, soda, and sufficient lime to give a composition corresponding to jadeite, the remaining constituents correspond closely to a diopside, as shown by the calculation.

		Jadeite-like mineral	Diopside Ca Mg $(SiO_3)_2$	Diopside cal. to 100%	Diopside Theory
Sp. grav. 3.2663					
Silica,	54.19	10.80	43.39	54.06	55.57
Alumina,	3.48	3.48			
Ferric oxide,	1.79	1.79			
Magnesia,	14.58		14.58	18.16	18.51
Lime,	24.03	1.74	22.29	27.77	25.92
Soda,	.88	.88			
Water,	.65				
	99.60	18.69	80.26	100.00	100.00

NEPHRITE.

Our knowledge of the chemical composition of the amphiboles is not as satisfactory as that of the pyroxenes. The formula Ca Mg_3 $(SiO_3)_4$ is assigned to a white variety of amphibole known as tremolite, while ferrous iron replaces a part of the magnesia in the green varieties. Small amounts of alumina, ferric oxide, the alkalies soda and potash, and water occur in the amphiboles, but just how they are combined in the chemical molecule is not in all cases well understood. The theoretical percentage composition corresponding to the formula of tremolite, Ca Mg_3 $(SiO_3)_4$, is as follows:

Silica, SiO_2	57.69
Magnesia, MgO,	28.85
Lime, CaO,	13.46
	100.00

On examining the analyses of nephrite it will be observed that the percentages of silica, SiO_2, and lime, CaO, maintain nearly uniform values, near those demanded by the theory of tremolite, but the magnesia, MgO, percentages exhibit not only a considerable variation, but they are lower than the theory. The deficiencies in magnesia are probably in part accounted for by the presence of water, since it has been shown by the analyses of a very pure variety of anthophyllite,* a mineral closely related to tremolite, that water can replace magnesia. It is not probable that the water shown by the analyses comes from serpentine, since the presence of the latter mineral would very perceptibly lower both the specific gravity and the percentage of silica.

The small quantities of alumina and ferric oxide are usually accompanied by an amount of soda sufficient to form the molecules $Na_2Al_2(SiO_3)_4$ and $Na_2Fe_2(SiO_3)_4$. These molecules are present respectively in the minerals glaucophane and riebeckite, which belong to the amphibole group, and they are analogous in composition to jadeite and ægerite of the pyroxene group. Potash may take the place of soda in these molecules.

The analyses of nephrite show a great similarity, and the calculation of a few of them will serve to illustrate the prevailing composition. As a basis of calculation the alumina and ferric oxide have been combined with sufficient silica and alkalies to form the glaucophane and riebeckite molecules. The remaining silica has then been combined with ferrous oxide, magnesia, lime, and water to form a silicate, nephrite, of the general formula $R\ SiO_3$ (R=Fe, Mg, Ca and H_2). For the sake of comparison with the tremolite formula, $Ca\ Mg_3\ (SiO_3)_4$, the nephrite has been recalculated to 100% after increasing the magnesia by an amount equivalent to that of the ferrous oxide and water.

No. 13211.

Sp. grav. 3.0138		Glaucophane $Na_2Al_2(SiO_3)_4$	Riebeckite $Na_2Fe_2(SiO_3)_4$	Nephrite $RSiO_3$	Nephrite cal. to 100%	Theory
Silica,	57.65	3.40	7.44	47.81	56.76	57.69
Alumina,	1.06	1.06				
Ferric oxide,	4.93		4.93			
Ferrous oxide,	.11			.11		
Magnesia,	14.95			14.95	24.19	28.85
Lime,	16.05			16.05	19.05	13.46
Soda,	2.38	.62	1.76			
Potash,	.93		.28			
Water,	2.46			2.42		
	100.52	4.08	14.41	81.34	100.00	100.00

Unaccounted for: Potash 0.65; water 0.04 = 0.69.

* *American Journal of Science and Arts*, Vol. 40, p. 394, 1890.

The presence of a rather large amount of the riebeckite molecule in this nephrite is noticeable.

No. 13030.

Sp. grav. 3.0122

		Glaucophane $Na_2Al_2(SiO_3)_4$	Riebeckite $Na_2Fe_2(SiO_3)_4$	Nephrite $RSiO_3$	Nephrite cal. to 100%	Theory
Silica,	57.78	5.52	2.40	49.86	57.52	57.69
Alumina,	2.35	2.35				
Ferric oxide,	1.60		1.60			
Ferrous oxide,	2.83			2.83		
Magnesia,	14.80			14.80	25.15	28.85
Lime,	15.02			15.02	17.33	13.46
Soda,	1.63	1.01	0.62			
Potash,	1.00	.66				
Water,	2.75			2.45		
	99.76	9.54	4.62	84.96	100.00	100.00

Unaccounted for : Potash 0.34 ; water 0.30 = 0.64.

No. 13233.

Sp. grav. 3.0118

		* Glaucophane and Riebeckite	Nephrite $RSiO_3$	Unaccounted for	Nephrite recalcu.	Theory
Silica,	57.19	7.44	49.75		57.35	57.69
Alumina,	2.24	2.24				
Ferric ox.,	1.60	1.60				
Ferrous ox.,	1.10		1.10			
Magnesia,	21.97		21.97		28.32	28.85
Lime,	13.16	.73	12.43		14.33	13.46
Soda,	.20	.20				
Potash,	1.44	1.44				
Water,	1.82		.90	0.92		
	100.72	13.65	86.15	0.92	100.00	100.00

The foregoing analyses indicate the presence of the well-recognized molecules, glaucophane and riebeckite, and of a silicate of the general formula R SiO_3, where R is Mg, Ca, Fe and H_2. Moreover, if the Fe and H_2 are regarded as taking the place of Mg, the composition approximates to that which is assigned to the crystallized mineral tremolite, Ca Mg_3 $(SiO_3)_4$. The nearly uniform character of the analyses is noticeable. In the few cases where the silica is low (52.98 in No. 13266, specific gravity 2.9506 ; and 52.60 in No. 13216, specific gravity 2.9311) the magnesia and water are high, and it is probable that a little serpentine is present.

* The prevailing alkali is here potash, and it has been necessary to take some calcium to make up for the deficiency of the combined alkalies.

ABSTRACT OF THE REDUCTIONS.

No. 13206B	(China),	Calculated by Clarke.		
		Jadeite,	97.82	
		Unaccounted for,	2.00	
			99.82	
No. 13323	(Tibet),	Calculated by Clarke.		
		Normal jadeite	95.71	98.85
		Pseudo "	3.14	
		Unaccounted for,	1.32	
			100.17	
No. 13243	(China),	Calculated by Clarke.		
		Normal jadeite,	92.42	97.47
		Pseudo "	5.05	
		Unaccounted for,	2.27	
			99.74	
No. 3127	(China),	Calculated by Clarke.		
		Normal jadeite,	91.62	99.51
		Pseudo "	7.89	
		Unaccounted for,	.73	
			100.24	
No. 13336	(Burma),	Calculated by Clarke.		
		Jadeite,	89.92	
		R'''_2 Ca SiO_6,	3.04	
		Nephrite or diopside,	7.07	
		Excess of silica,	.13	
			100.16	
No. 13102C	(Burma),	Calculated by Penfield.		
		Jadeite,	85.59	
		Diopside,	13.90	
			99.49	
		Water not accounted for.		

No. 13255 (China),	Calculated by Clarke.			
	Normal jadeite,	84.29	} 94.36	
	Pseudo "	10.07		
	Unaccounted for,	6.06		
		100.42		
No. 3248 (China),	Calculated by Clarke.			
	Normal jadeite,	81.61	} 98.79	
	Pseudo "	17.18		
	Unaccounted for,	1.47		
		100.26		
No. 13195 (China),	Calculated by Clarke.			
	Normal jadeite,	79.24	} 99.24	
	Pseudo "	20.00		
	Unaccounted for,	1.23		
		100.47		
No. 13242 (Mexico),	Calculated by Penfield.			
	Jadeite,	77.86		
	Ægerite,	12.95		
	Diopside, .	9.30		
	Loss, water,	.48		
		100.59		
No. 13249 (Switzerland),	Calculated by Clarke.			
	Jadeite,	75.61		
	Fe'''_2 Ca SiO_6,	4.82		
	Magnetite ?	1.36	(?)	
	Nephrite,	16.81		
	Unaccounted for,	1.62		
		100.22		
No. 13215 (Burma),	Calculated by Penfield.			
	Jadeite,	70.38		
	Analcite,	27.85		
	Diopside,	2.69		
		100.92		

No. 13267 (Burma), Calculated by Clarke.

Amphibole ($Na_2 Mg_7 Si_8 O_{24}$),	38.79
Jadeite,	55.68
Acmite,	3.99
Excess water,	1.45
	99.91

No. 13193 (Mexico), Calculated by Penfield.

Jadeite,	48.89
Albite,	47.39
Nephrite,	3.81
	100.09

No. 13200 (China), Calculated by Clarke.

Nephrite, approximately,	96.00
Jadeite, "	4.00
	100.00

No. 13334 (Alaska), Calculated by Clarke.

Nephrite,	95.58
Jadeite,	1.36
R'''_2 Ca SiO_6,	1.79
Excess water,	1.49
	100.22

No. 13335 (Alaska), Calculated by Clarke.

Nephrite,	95.57
Jadeite,	1.43
R'''_2 Ca SiO_6,	2.50
Excess water,	1.01
	100.51

13122 (British Columbia), Calculated by Clarke.

Nephrite,	95.05
Jadeite,	.92
Al_2 Ca SiO_6,	3.81
Excess water,	.75
	100.53

No. 13205 (China), Calculated by Clarke.

Nephrite,	94.33
Jadeite ?	4.15
Excess water,	2.05
	100.53

No. 13262E (China), Calculated by Clarke.

Nephrite,	92.83
Jadeite ?	2.15
R'''_2 Ca SiO_6,	3.57
Excess water,	1.72
	100.27

No. 3185 (China), Calculated by Clarke.

Nephrite,	92.72
Serpentine,	1.93
R'''_2 Ca SiO_6,	2.40
Excess water,	3.23
	100.28

No. 3121 (China), Calculated by Clarke.

Nephrite,	92.48
Jadeite ?	5.77
Acmite,	1.62
Excess water,	.56
	100.43

No. 13223 (Switzerland), Calculated by Clarke.

Nephrite,	92.09
R''' Na Si_2O_6,	5.91
Excess water,	2.68
	100.68

No. 13262R (China), Calculated by Clarke.

Nephrite,	91.21
R'''_2 Ca SiO_6,	9.53
Excess Fe_2O_3,	.33
	101.07

No. 13248 (Switzerland), Calculated by Clarke.

Nephrite,	90.64
Acmite ?	3.58
$R'''_2 (SiO_3)_3$,	2.48
Unaccounted for,	4.19
	100.89

No. 3125 (India), Calculated by Clarke.

Nephrite,	89.78
Jadeite ?	2.67
$R'''_2 (SiO_3)_3$,	6.73
Excess water,	1.27
	100.45

No. 13118 (New Zealand), Calculated by Clarke.

Nephrite,	89.52
$Al\ Na\ Si_2O_6$,	2.35
$R'''_2 (SiO_3)_3$,	8.28
Excess water,	.39
	100.54

No. 13214 (China), Calculated by Clarke.

Nephrite,	89.02
Jadeite,	7.36
$R'''_2 (SiO_3)_3$,	3.41
	99.79

No. 3136 (China), Calculated by Clarke.

Nephrite,	88.20
Jadeite,	7.56
$R'''_2\ Ca\ SiO_6$,	2.74
Excess water,	1.30
	99.80

No. 13192H (China), Calculated by Clarke.

Nephrite,	86.89
Jadeite,	2.02
$R'''_2 (SiO_3)_3$,	10.45
Excess water,	1.51
	100.87

No. 3156 (China), Calculated by Clarke.

Nephrite,	86.70
R''' Na Si_2O_6,	11.81
Excess water,	1.51
	100.02

No. 13233 (Switzerland), Calculated by Penfield.

Nephrite,	86.15
Glaucophane and riebeckite,	13.65
Unaccounted for,	.92
	100.72

No. 3148 (China), Calculated by Clarke.

Nephrite,	85.87
Jadeite,	10.70
Acmite ?	2.49
Excess water,	1.43
	100.49

No. 13246 (Siberia), Calculated by Clarke.

Nephrite,	85.86
Al Na Si_2O_6 (Glaucophane?),	3.32
R'''_2 Ca SiO_6,	10.30
Excess Fe_2O_3,	.16
	99.64

No. 13095 (China), Calculated by Clarke.

Nephrite,	85.51
Jadeite ?	9.26
Acmite ?	3.78
Excess water,	1.01
	99.56

No. 13030 (New Zealand), Calculated by Penfield.

Nephrite,	84.96
Riebeckite,	4.62
Glaucophane,	9.54
Unaccounted for,	.64
	99.76

No. 13088 (New Zealand), Calculated by Clarke.

Nephrite,	84.23
$R''' Na Si_2O_6$,	14.69
Excess water,	1.41
	100.33

No. 13006 (New Zealand), Calculated by Clarke.

Nephrite,	83.10
$R'''_2 (SiO_3)_3$,	11.47
$Al R Si_2O_6$ (Glaucophane?),	4.44
Excess water,	1.41
	100.42

No. 3246 (China), Calculated by Clarke.

Nephrite,	81.61
$R''' R' Si_2O_6$,	16.36
Excess water,	2.58
	100.55

No. 13211 (Siberia), Calculated by Penfield.

Nephrite,	81.34
Riebeckite, $Na_2 Fe_2 Si_4O_{12}$	14.41
Glaucophane, $Na_2 Al_2 Si_4O_{12}$	4.08
Unaccounted for,	.69
	100.52

No. 13268 (China), Calculated by Clarke.

Nephrite,	80.90
Jadeite,	12.44
Acmite,	5.43
Excess water,	1.35
	100.12

No. 13008 (China), Calculated by Clarke.

Nephrite,	79.97
Jadeite,	14.66
$Al_2 Ca SiO_6$,	4.23
Excess water,	1.94
	100.80

No. 13212 (Turkistan), Calculated by Clarke.

Nephrite,	78.14
$R''' Na Si_2O_6$,	22.22
Excess water,	.32
	100.68

No. 13007G (China), Calculated by Clarke.

Nephrite,	77.34
$R''' R' Si_2O_6$,	16.57
$R'''_2 Ca SiO_6$,	5.87
Excess water,	1.00
	100.78

No. 13216 (New Caledonia), Calculated by Clarke.

Nephrite,	75.76
Serpentine?	11.32
$R''' (NaK) Si_2O_6$,	9.05
Unaccounted for,	3.16
	99.29

No. 13266 (China), Calculated by Clarke.

Nephrite,	69.87
Serpentine?	21.80
Jadeite?	7.15
Unaccounted for,	.71
	99.53

No. 13210 (Silesia), Calculated by Clarke.

Nephrite,	62.81
$Al Na Si_2O_6$,	23.45
$Fe Na Si_2O_6$,	9.29
Unaccounted for,	4.65
	100.20

No. 13086 (New Zealand), Calculated by Penfield.

Jadeite-like mineral,	18.69
Diopside, $Ca Mg Si_2O_6$,	80.26
Water,	.65
	99.60

No. 13005 (Switzerland), Calculated by Penfield.

$NaAl(SiO_3)_2$	Glaucophane,	19.97
$NaFe(SiO_3)_2$		23.18
$(MgCa)\ SiO_3$		13.68
Epidote, $HCa_2Al_3Si_3O_{13}$		39.18
Quartz,		4.17
		100.18

Professor Clarke remarks in regard to these reductions that the nephrite molecule always reduces to the general formula $R''SiO_3$, when $R'' = Ca, Mg, Fe$, or Mn. In typical nephrite it approximates to $CaSio_3 + 3MgSiO_3$, or $Ca\ Mg_3(SiO_3)_4$; the Fe and Mn replacing a part of the Mg. H_2, K_2, and Na_2 may also replace Mg to some extent, but the Ca is more commonly constant. Variations occur in the reductions which may be due to error in the iron determinations ; and in other cases traces of pyroxene remain, with the ratio more nearly Ca : Mg :: 1 : 1 ; as in diopside, $CaMg(SiO_3)_2$.

When Iddings states that jadeite or its equivalent is present in a nephrite, jadeite and acmite are stated as such. When no definite statement is made, a formula is given which may indicate either jadeite, acmite, glaucophane, or riebeckite molecules ; and formulæ are stated as follows :

$Al\ Na\ Si_2O_6$.
$Fe\ Na\ Si_2O_6$.
$Al\ (NaK)\ Si_2O_6$, or $Al\ R'\ Si_2O_6$.
$Fe\ (NaK)\ Si_2O_6$, or $Fe\ R'\ Si_2O_6$.
$R'''\ Na\ Si_2O_6$.
$R'''\ K\ Si_2O_6$, etc.,

according to the exigencies of the case. All of these are covered by the one general formula $R'''\ R'\ Si_2O_6$, which is sometimes employed.

When alkalies are in excess of alumina and ferric oxide, they are treated as part of the nephrite molecule. When Al_2O_3 and Fe_2O_3 are in excess, two alternatives are presented. First, if the total oxygen of the analysis is greater than in the ratio SiO_3, it is treated as part of the molecule $(Al\ Fe)_2\ Ca\ SiO_6$, or $R'''_2Ca\ SiO_6$; which is mentioned in the paper by Clarke, introducing the chemical section of this work. Secondly, when the silicon-oxygen ratio is normal, that is, 1 : 3, the excess of Al and Fe is regarded as forming the molecule $R'''_2(SiO_3)_3$, which might be considered as a replacement in the nephrite, and equivalent partly to babingtonite among the pyoxenes, and arfvedsonite among the amphiboles. In two or three cases the analyses indicate serpentine as an impurity, which is so stated.

In the jadeites Penfield has shown that Ca, Fe, or Mg, may replace Na or K ; and he computes analyses with small amounts of these elements included. Clarke divided the computation in such cases, giving *normal* jadeite as proportional to the alkalies alone. The remaining portion, Al_2 (CaMgFe) $(SiO_3)_4$, the replacement which Penfield has proved, Clarke calls *pseudo*-jadeite. The sum of the normal and the pseudo-jadeite gives the jadeite of Penfield's calculations.

INCLUSIONS.

Under this head it is proposed to notice briefly the various minerals which have been found in intimate association with jadeite or nephrite. They may be roughly grouped into two classes:

First.—Those which occur in relatively small crystals or patches embedded in jade, and by reason of their sharply defined contrast in color or form are readily visible to the naked eye.

Second.—Those which occur intimately intermingled with the jade, forming an essential part of its mass, and being of the same color and appearance, are recognizable as foreign material only by chemical or microscopic study.

To the first of these may be assigned the following minerals: Chromite, magnetite, garnet, feldspar, pyrite, rutile, limonite, manganese oxide, mica, and several other undetermined impurities.

Chromite or magnetite is by far the most common impurity to be noted in jade. The distinction between them is not generally visible, since both occur in black opaque octahedrons, generally of minute size, and it is necessary in order to their positive distinction to prepare a thin microscopic section. The chromium may then be readily determined, as it is slightly translucent in thin sections and shows a dark brown color in microscopic sections, whereas magnetite is always black and opaque. This class of inclusions is generally too small in percentage to produce any effect except in some cases a change of color of the mass. Again, if a dark crystalline speck is surrounded by a zone of green brighter than the rest of the specimen, it is safe to conclude that the coloring of the green is chromium, derived from the inclusion, which is, therefore, undoubtedly chromite. Both these minerals are very noticeable in translucent jade, as their color is dark and their sharp form is readily noticeable in a translucent mass. When the inclusions are present in a sufficient number in white jade, they frequently give it a grayish tint.

In sufficient number they may even impart a positive black to the mass.

Pyrite, rutile, garnet, feldspar, and mica all occur as inclusions discernible by the naked eye.

Black oxide of manganese is frequently present in both the jade minerals, chiefly as a staining material, and sometimes in such quantity as to impart a positively black color. It also occurs in thin coatings on the walls of cracks or crevices, and again as dendritic markings.

Limonite appears in a number of specimens, perhaps more especially among the artistic pieces, as a staining, generally the result of weathering, and is considered by the Chinese to heighten the effect.

In addition to the inclusions already described, which are perceptible to the naked eye, a large number of minerals exist in minute crystals, and have been determined by microscopic study of jade itself. The following species have been determined by Arzruni, Iddings, and others as occurring in jade :

Andalusite,	Perovskite with Leucoxene.
Cordierite,	Quartz,
Epidote,	Rutile,
Garnet,	Talc,
Limonite,	Titanite,
Muscovite,	Tourmaline,
Olivine,	Zircon.

In addition to these, Arzruni reports graphite as occurring in nephrite.

The second class of inclusions in which the foreign mineral plays a more important part in the make-up of the mass, contains the following species : Analcite, albite, nepheline, plagioclase, feldspar, zoisite (klinozoisite) and diopside. All these are of peculiar interest from the fact that they are found with jadeite and not with nephrite. The only mineral reported as chemically intermixed with nephrite is doubtful serpentine.

The important part that such included minerals play in jade may be seen in four results: 1st. They affect the color of the mass in which they are included, giving it a tint, a mottled appearance, or in some instances a decided color. 2d. They are likely to affect the specific gravity of the mass either by lowering it, as in the case of albite feldspar, or by raising it, as in the case of magnetite and chromite. 3d. They are likely to affect the apparent chemical composition of the mass by their intimate mechanical mixture. 4th. They may likewise, at times, affect the hardness of the mixture.

This class of inclusions may equal or exceed the amount of the jadeite material in the rock, with the changes that may be expected in the lowering of the hardness, toughness, or specific gravity, and in the case of nepheline and analcite, rendering the mass more susceptible to the attack of weathering agencies.

The effect upon the physical and chemical character of jade produced by the presence of the inclusions above mentioned will depend, of course, upon the amount and and character of the inclusions.

ON THE ORIGIN OF JADEITE.

BY L. V. PIRSSON.

INTRODUCTORY.

The very fact, so well known, that the original sources of jadeite have either been unknown or veiled in mystery, in spite of its use and commercial value through such an immense period of time, implies at the very outset that geological observations and knowledge concerning its mode of occurrence and the origin of the material must be still more defective. We know, indeed, that it has been largely gathered in the shape of transported boulders; and the study of the material has led petrographers to classify jade as belonging to the crystalline schists. Anything beyond this, with the exception to be presently noted, which is of any real value in this connection has not come to the writer's knowledge, and it would be of little interest or value to discuss the question from the historical side.

OCCURRENCES IN BURMA AND "TIBET."

The occurrence which has been best studied is that at Tammaw in Upper Burma. As this is described elsewhere in this volume, in the article on the Localities and Geological Occurrence of Jade, the reader must be referred to that section for details. It must here suffice to say that the observations of Noetling and Bauer show that the jadeite is either igneous or metamorphic in character, the results of the careful petrographical examination of Bauer favoring the latter view. The jadeite is associated with serpentine, and glaucophane schist and albitic rocks occur in the vicinity.

The jadeite said to come from Tibet, described by Bauer, has been incorporated also in the same section, and it need only be said here that, while it resembles in general that of Tammaw, it contains considerable nephelite and some albite. Bauer calls attention to the anomaly of the presence of nephelite as a component of a rock belonging to the crystalline schists, since heretofore it has been found only as a component of igneous rocks. The writer hopes to elucidate in the following pages the meaning of this apparent anomaly.*

It may also be mentioned that some specimens of jadeite in the Bishop Collection (Nos. 13215, 3126, 3127, 13242) contain small amounts of albite and analcite.

JADEITE CONSIDERED AS A ROCK.

It is clearly evident, not only from the occurrence at Tammaw described elsewhere, but from its distribution in a number of localities and the size of the masses in which it is found, that jadeite must be considered as a rock, and a definite kind of rock, not some chance formation of a mineral on a considerable scale in a single locality by a peculiar combination of circumstances not liable to obtain elsewhere. It appears to be a well-characterized variety of rock produced by the same laws which govern the formation of other rocks of similar type, and one the number of whose occurrences may be expected to increase as the geological exploration of the world goes on. This position it appears to the writer is so self-evident that it needs no further argument, it is also the one generally assumed.

It may then fairly be asked if jadeite in itself, by its properties, structure, mineral and chemical composition, offers evidences which, interpreted by the aid of our present knowledge of petrology, are sufficient to indicate its origin and petrographic position. The writer believes that this question can be answered in the affirmative, and proposes to show the reasons for so believing.

CHEMICAL COMPOSITION.

The first and perhaps the most important question which can be asked is whether the chemical composition of jadeite

* Cf. *Amer. Jour. Sci.* (4), Vol. I, p. 401, 1896.

as a rock, *en masse*, offers any evidence. If we consider jadeite Na Al $(SiO_3)_2$ as a mineral alone, this requires in theory

SiO_2,	59.4
Al_2O_3,	25.2
Na_2O,	15.4
	100.0

As a matter of fact, however, jadeite, even in the whitest and simplest varieties, almost never has a pure composition, but contains in addition lime, iron, and magnesia, sometimes in considerable amounts, together with small quantities of potash and traces of water, as may be seen from the appended table of analyses, and from the tables given elsewhere in this volume.

Analyses of Jadeite and Phonolite.

	I	II	III	IV	V	VI	3248	13206B	13215	13336
SiO_2,	57.99	58.51	60.52	53.80	58.98	53.95	58.48	57.60	58.41	58.58
Al_2O_3,	20.61	19.66	19.05	23.59	20.54	21.96	23.57	25.75	24.64	23.71
Fe_2O_3,	2.84	3.43	4.22	3.57	1.65	.76	1.68	.....	.67	.51
FeO,	....	.....	.....	1.88	.48	.....	.....	.....	....	.24
MgO,	3.33	.31	.19	.87	.11	7.17	1.33	.13	1.24	1.35
CaO,	4.89	1.53	.59	2.26	.67	2.42	1.62	.58	1.43	1.67
Na_2O,	9.42	10.04	10.63	9.05	9.95	9.37	10.33	13.31	12.76	13.80
K_2O,	1.50	4.71	3.50	4.77	5.31	3.70	3.09	2.20	0.58	trace
H_2O,	....	1.00	.04	1.50	.97	.....	.16	.25	1.19	.16

I—Worked jade from France, Damour, *Bull. Soc. Min.*, 1881, IV., 157.

II—Phonolite, Mte. Miaune, Velay, Emmons, *Inaug. Diss.*, Leipzig, 1874, p. 20.

III—Phonolite-obsidian, Teneriffe, Fritsch and Reiss, 1868, p. 337.

IV—Phonolite, St. Thiago, Cape Verde Is., Doelter, *Vulkane der Cap Verden*, 1882, p. 90.

V—Phonolite, Cripple Creek, Colo., W. F. Hillebrand, *U. S. G. S. Bull.*, 148, p. 161.

VI—Unworked jade, Burma, Damour, *loc. cit.*, 1881.

3248—Analysis by Walden of worked jadeite from China.

13206B—Analysis by Walden of worked jadeite from China.

13215—Analysis by Walden of fragment of boulder from Burma.

13336—Analysis by Foote of fragment of boulder from Burma.

NOTE.—In these analyses only the important elements are given for comparison ; the traces of various metals and bases are omitted as unimportant, and in consequence no summation is shown.

It is clear from what has been quoted from Noetling's description that at Tammaw the jadeite must be either a metamorphic rock, a member of the crystalline schists, or else it must be igneous. And this of course must be true of all jade if we consider it a rock, as its appearance and crystalline character at once exhibit.

If we regard it as a member of the crystalline schists, a metamorphic rock, we must still again if possible endeavor to account for its origin, for these rocks must be also of igneous or aqueous formation originally, unless some of them in places be excepted, as has been done by some geologists, because they are held to be a portion of the earth's original cooling crust. Now we know of no sediments, nor indeed any possible combination of sediments, which could occur that having been metamorphosed would give us jadeite. A possible mixture of salt, sand, and clay well mixed would have approximately the chemical composition, but where conditions were such that salt could deposit, sand certainly could not. It seems not unreasonable to say that the source of the material forming jadeite could not have been of aqueous deposition.

There remains then to consider whether the material may not have been of igneous origin, and when we compare analyses of jadeite with those of igneous rocks, we see at once that it has the composition of the nephelite-syenite group as shown by the comparison of analyses in the table given above. It will be seen that there is a striking agreement between the two groups of rocks, and that the analyses from one group might with ease pass muster in the other. There is one point of general difference however, and that is the small amount of potash shown in the jade analyses. It is not wanting, however, and may exist in considerable quantity as shown in 3248, 13206B, and in No. I. This is not, however, any valid argument against the material being of igneous origin, for while potash and soda are usually found in considerable proportion relative to each other in igneous rocks, this is not necessarily so, and we have actual instances of undoubted igneous rocks, as in dikes and lava flows, showing so great an excess of one alkali as to practically exclude the other. Instances may be seen in the following examples taken from the literature.

	1	2	3	4	5	6	7	8
Na_2O,	1.21	1.39	.90	3.37	7.62	4.21	5.34	17.29
K_2O,	11.91	11.76	7.99	10.06	.10	.17	.18	3.51

The first three of these are leucitic lavas from the Leucite Hills in Wyoming ; the fourth a feldspathic dike from the Highwood Mts. of Montana ; the fifth an aplite dike from Mariposa, Cal.; the sixth diabase, Conn. Valley, Mass.; the seventh porphyritic amphibolite, New Salem, Mass.; and the eighth, urtite from Kola. (The first seven from Bull. 148, U. S. Geol. Surv., the eighth from Ramsay, *Geol. Fore. Stockholm Forh*, 1896, Bd. 18, p. 462.) They have been selected as examples, and numbers of others equally striking might be given in addition, but these are sufficient to show the point involved. The composition of jadeite is precisely that of a phonolite in which the potash is very low or lacking.* The analyses vary from one another in a slight degree, but they all lie within the same limits.

That jadeite has the essential composition of a phonolite is shown most strikingly by the chemical equation :

$$\text{Na Al SiO}_4 + \text{Na Al Si}_3\text{O}_8 = 2\text{Na Al (SiO}_3)_2$$

$$\frac{\text{Nephelite} + \text{Albite}}{\text{Phonolite}} = \text{Jadeite.}$$

That is to say that a soda feldspar and nephelite, the chief constituents of a phonolite, if united would form jadeite. Clarke,† in discussing the structural formulæ of minerals of the pyroxene group like jadeite calls attention to the

* Rosenbusch briefly remarks that jadeite has the composition of a nephelite-syenite magma. *Elemente der Gesteinslehre*, p. 508.

† *Constitution of the silicates*, Bull. U. S. Geol. Surv. No. 125, p. 87.

fact that on alteration spodumene splits up into feldspar and eucryptite, the latter a lithia nephelite, while leucite, which has a similar empirical formula, divides into orthoclase and nephelite, soda replacing part of the alkali in both cases. From this Clarke argues that the real structural formula of spodumene is not that of a simple metasilicate, $R\ SiO_3[Li\ Al\ (SiO_3)_2]$, but $Al_6\ (Si_3O_8)_3(SiO_4)_3Li_6$, which expresses the relations mentioned above. Following out this line of reasoning then, jadeite, also a member of the pyroxene group and closely related to spodumene, would not have the simple empirical formula $Na\ Al\ (SiO_3)_2$, but the one $Al_6(Si_3O_8)_3(SiO_4)_3Na_6$, and theoretically it is merely an addition product of the albite and nephelite. Such addition products might readily be formed if chemical action was taking place under great pressure such as is developed under dynamo-metamorphic processes, since in that case there is a tendency to form denser molecules of higher specific gravity; thus one molecule of albite, sp. gr. 2.62, and one molecule of nephelite, 2.60, could unite to form one molecule of jadeite, 3.33.

Associated minerals and structure.

In this connection the jadeite from Tibet described by Bauer is most significant. Here it is accompanied by nephelite and feldspar. Now nephelite is known, so far, to occur only as a product of the cooling of a molten magma in igneous rocks, and it is indeed difficult to imagine how the material of which it is composed could originate in any other way. Certainly not as a sediment. The occurrence of this mineral in the jadeite from Tibet points most strongly towards the igneous origin of the material in which it occurs, and the presence of the feldspar would lend additional value to this idea.

Similar remarks and conclusions apply to those specimens of jadeite in the Bishop Collection, in which, as has been mentioned, analcite occurs. This mineral, a hydrous metasilicate of soda and alumina, occurs commonly as a secondary product resulting from the alteration of minerals rich in soda in the igneous rocks, but it has also been shown recently to be a primary constituent of certain dike-forming igneous rocks. The mode of its occurrence as described by Iddings would indicate that it is here probably either a primary constituent, or that it is the result of the decomposition of nephelite or albite, indicating an igneous origin for the rock in either case. There is also a possibility that it is derived from the jadeite itself, though the description would seem to preclude this.

On the other hand, certain facts in this connection must also be considered. Jadeite, the mineral, from its chemical composition, is a pyroxene which *a priori* might be considered extremely likely to occur in alkaline igneous rocks rich in soda. As a matter of fact, not a single instance of this, so far as is known to the writer has been recorded. Moreover, the broken cataclastic structure of the mineral, and in fact the whole structure of the rock, so carefully described by Bauer, points most clearly to a type originating from metamorphic processes. The associated rocks found with the jadeite in the region in Upper Burma, are an albite hornblende schist and a glaucophane schist, both of them rocks rich in soda and metamorphic in type. Both facts are significant.

Summary and Conclusions.

Briefly summarized we have then the following facts to deal with. The evidence of the only place where jadeite has been well studied in place by a competent geologist does not afford a definite conclusion as to the origin of the rock; it may be igneous, or it may be metamorphic, the microscope evidence tending to confirm the second conclusion. The composition of jadeite considered as a rock is that of an igneous one and a member of the nephelite-syenite group, characterized by the absence of, or small amount of potash it contains. In one occurrence nephelite is found in the jadeite and in others analcite. The chemical composition of jadeite precludes the material from having an origin by aqueous deposition, it must be igneous. On the other hand, jadeite has not been found as a component of evidently unaltered igneous rocks, though the chemical composition of some of them might favor its formation; the structure of jadeite is that of the crystalline schists, and the rocks associated with it are members of that family. All these facts point to only one possible conclusion. Jadeite is a metamorphosed igneous rock, a member of the phonolite family. The whiter varieties are probably metamorphosed dikes of the aplitic, leucocratic* type, belonging in this family and the darker green types those containing more iron-bearing dark silicates like the tinguaites.

And it may be suggested here that the non-appearance of rocks of the phonolite families as such among the crystalline schists may be brought into relation with the occurrence of jadeites, albite, and glaucophane schists and other types rich in alkalies, whose homes are in the metamorphic complexes.

* Brögger, *Das Ganggefolge des Laurdalits*, 1898, p. 264.

THE RELATION OF JADEITE AND NEPHRITE.

BY J. P. IDDINGS.

The origin of jadeite has already been discussed in the preceding section, by Professor L. V. Pirsson, who shows that the available evidence is in favor of the view that jadeite is not an unaltered igneous rock, but that it is probably the result of the metamorphism of an original igneous rock of the nephelite-syenite-phonolite family. As the evidence is presented very fully by him, it is unnecessary here to do more than refer to his article, with the conclusions of which I agree in the main.

I need only add that the origin or formation of jadeite rocks will remain in doubt until they have been found in place in such a manner that their outward relations to the associated rocks may be discovered. For though they may be intimately associated with crystalline schists, and may exhibit schistosity in part, they may, however, have been originally igneous intrusions with the mineralogical composition of jadeite rocks, the structure of which has been subsequently somewhat modified by dynamic processes.

Whatever may have been the origin of jadeite-rock, it has undergone since its formation various degrees of metamorphism, which has produced either slight modifications of the original texture of the rock or has altered it more or less completely both in texture and in chemical composition. By metamorphism is understood any change that may take place in a rock by which it may be changed into a coherent solid mass differing in some respect from the original rock. In many cases the resulting rock is harder and more crystalline than that from which it was formed, but this is not universally the case, and no simple definition of metamorphism can be framed unless we adhere to the etymology of the word and state that it is a change in the form of the rock.

The change may be limited to one of its characters or may affect several or all of them. It may operate in one direction or in a reverse one. Thus metamorphism may modify the form of the minerals without producing any chemical differences in them, as when a rock composed of a single kind of mineral has the crystals of the mineral reduced in size by crushing. They may by other metamorphic processes be enlarged. The first process would tend to make the rock less crystalline, the second to make it more crystalline.

While it is possible for single or simple processes of metamorphism to affect a rock without the accompaniment of other processes, and while it may be desirable in the discussion of such actions to consider them separately, it seldom happens that in actual fact any one force or agency of alteration has acted independently of others. More often several have co-operated to produce the changes that have taken place.

In the case of the rocks grouped under the general term jade, which with few exceptions consist of jadeite or nephrite, the question of metamorphism has a special bearing on the origin of one of these component minerals, namely nephrite, and must also be called into account to explain the texture exhibited by the jadeite rocks.

It is well known that the simple effect of dynamical forces tending to compress or distort a mass of crystals is to set up molecular stresses, which result in molecular strains within the individual crystals or which produce rupture and fragmentation. The latter shows itself under the microscope by the mingling of comparatively large crystals with small ones in such a manner as to indicate that the small particles are fragments of larger crystals. The small grains occur in streaks along cracks, or act as a cement or matrix for the larger grains. This is sometimes called cataclastic structure, and is to be seen in thin sections: 3248, 13192D, 13243, 13255. Crushing may be accompanied by other alteration, as in the cases just mentioned. The minute particles are still jadeite and the whole mass is a coherent rock held together by the adhesion of the component crystals. Similar metamorphism has been produced in the laboratory by Professor Adams of Montreal, by means of simple pressure.

The effects of molecular strains which may not have led to the production of visible fractures are shown by the optical behavior of the strained crystals when examined between crossed nicols. The results may be molecular displacement, producing a mottling of the interference color exhibited by a thin section of the crystal so affected. This may be more or less pronounced, varying from the faintest suggestion of mottling to one in which the mottling resembles mosaic work, with a distinct demarkation between each piece, where an actual fracturing of the crystals may have taken place.

In other cases the molecular displacement may cause the molecules to shift their position along certain planes in the crystal, producing layers or laminæ in twinned position with respect to the original crystal. In pyroxene one such plane is parallel to the basal pinacoid, and crystals of pyroxene subjected to this kind of molecular strain exhibit a more or less distinct banding of the interference color shown by thin sections when observed between crossed nicols. Examples of both of these kinds of molecularly strained jadeite may be seen in thin section, 13192D. The material is still jadeite, but the original adjustment of the crystal molecules has been altered. Such changes as those already illustrated by the jadeite sections may be called simple dynamical metamorphism.

It has been found that when crystals are in a state of molecular strain they are more susceptible to chemical and crystalline alteration, if agencies capable of promoting such changes are at hand. The same is true when the crystal is in fine particles which expose greater surface to attacking agencies, such as gases and liquids, than larger fragments do. It follows from this that rocks subjected to dynamical forces sufficient to produce metamorphism are the more easily altered by chemical processes, the commonest of which is the interaction of elements in adjacent crystals of dissimilar minerals, or of those in adjacent crystals and liquids which may penetrate the mass. These liquids may act as agents to promote the mobility of the molecules of adjoining crystals, by solution, or may be the vehicle by which elements may be transferred from one rock to another.

It frequently happens that rocks exhibiting dynamical metamorphism in the form of crushing and shearing or dragging also show chemical metaphorism, the chemical composition of the original rock being changed to a greater or less extent and a new crystallization taking place, that is, new minerals forming at the expense of those originally present.

Of the transformations of this kind commonly met with in rocks the change of pyroxene into amphibole is one of the most frequent. The close chemical and crystallographic relationship between these two groups of minerals in part may account for the frequency of this transformation. The probably greater complexity of the pyroxene molecule, to which Professor Clarke has called attention in another section of this work, may account for the fact that the alteration is usually from pyroxene to amphibole. In every such change there is necessary a chemical displacement, for the elements do not occur in the same proportions in the two groups of minerals. The extent of this chemical metamorphism varies with attendant conditions, and may be considerable. In the case of some minerals the displacement has gone to the extent of replacing all the elements originally present by others totally unlike them. This is illustrated by paramorphs of the greatest variety.

The microscopical and chemical investigation of the specimens in this Collection demonstrate clearly that jadeite is commonly changed into aggregations of minute amphiboles—nephrite—subsequent to, or accompanying, dynamic metamorphism, and that the chemical change involved the displacement of aluminium and sodium by magnesium, calcium, and iron. Chemical metamorphism as radical as this may be found in the transformation of albite and orthoclase into talc or chlorite.

The evidences of dynamical and chemical metamorphism in the jades of this Collection have been described in detail in another place. They may be summarized briefly as follows: In some specimens of jadeite, a cataclastic structure has been developed, in others this structure together with mottlings of the interference colors and banding due to secondary lamellar twinning; in some jadeite specimens there are bladed crystals of amphibole; in specimens of nephrite there are fragments of jadeite; in some nephrites the amphibole crystals are arranged in patches corresponding to grains of jadeite in the jadeite specimens; this character gradually disappears in nephrite with more and more pronounced fibrous or laminated structure.

From these phenomena it may be concluded that jadeite is sometimes metamorphosed into nephrite; conversely that nephrite is sometimes metamorphosed jadeite. But it does not necessarily follow that all nephrite is metamorphosed jadeite, or that the only product of the metamorphism of jadeite is nephrite. It may be added that so far as the Collection of jades studied is concerned no other changes have been observed. From which it may be concluded that this relationship between jadeite and nephrite is the normal one.

LOCALITIES AND GEOLOGICAL OCCURRENCE OF JADE.

BY HENRY S. WASHINGTON.

Introductory. Discussion of the localities and occurrence of jade (including jadeite and nephrite) is of interest from two points of view. From the geological and mineralogical it is of great importance as furnishing us with facts which may elucidate the problem of the origin of the rock; from the archæological it is of equal importance as bearing on such questions as ancient lines of trade and intercommunication, and the spread of customs and migration of races.

We are met at the outset of such an investigation by the difficulty of lack of sufficient data. Although jade objects are widespread (within certain limits), and their number is very considerable, and though the use of this material goes back to the Stone Age, yet less than a dozen localities are known where the material occurs *in situ*, and a few more where it is found as rough blocks which have been transported from their original situations by river or glacial action. This state of affairs is somewhat remarkable in view of the peculiar qualities of jade—its toughness and composition, which offer great resistance to destruction by meteoric and other agencies, and its often striking coloration which, one might expect, would lead to its easy discovery.

For the purposes of the present paper it will be well to divide the occurrences into four groups, fundamentally distinct in character, which, in the order of their usefulness and importance, are as follows:

1. Occurrences of jade *in situ.*
2. Occurrences of jade as transported blocks.

3. Occurrences of jade as worked objects, generally of unknown exact ultimate provenance.
4. Localities mentioned by various authorities, but of very uncertain character.

In such a division we start with geological data which are fairly safe and well established, and where the conditions of occurrence are more or less well known, through occurrences where the original conditions are to a large extent inferential, and finally end with groups where the origin is hypothetical and highly uncertain.

For the sake of convenience, in the following description, the first two groups will be treated together to a great extent, and also here the occurrences of jadeite and nephrite will be mentioned indiscriminately, though in the subsequent discussion the two will be sharply discriminated.

BURMA.

It seems appropriate to begin with this locality, since it is one of the greatest sources of the material, and is also one of those which have been the best studied. The quarries are found in Upper Burma, in the Kachin Country, near the junction of the Chindwin and Uru rivers, in about Lat. 25° N. and Lon. 95° E.

The quarries were discovered accidentally by a Yunnan trader in the thirteenth century, and several unsuccessful expeditions were sent out from Yunnan in that and the succeeding centuries. The attempts were abandoned till 1784, when a trade was opened between China and Burma, and a regular supply of the stone was carried into Yunnan. Since 1806 Mogaung has been the headquarters of the jade trade in Burma.

Apparently the first * notice of this locality by a European is that of Capt. Hannay,† who obtained in Mogaung several pieces of a green mineral called by the Burmese "Kyouk-tsein" and by the Chinese "Yueesh." ‡ This was considered by Hannay to be "Nephrite."

* Cf. Noetling, op. cit. infra., p. 3.

† Hannay. *Jour. As. Soc. Bengal.* VI. pp. 265 ff., 1837.

‡ This is no doubt a transcriber's error for Chinese *yü-shē*, or *yü-shih*, "jade-stone." The Burmese name for the mineral is *kyouk-sein*.—*Note by the Editor.*

The next European writer to mention the locality, and, according to Noetling, the first to visit it, was Dr. Griffith,* who considered the rock to be serpentine.

Capt. Yule † speaks of the locality, but (according to Noetling) apparently bases his remarks on the observations of the two preceding writers.

The quarries are next described by Dr. J. Anderson,‡ but his account is short, and it does not appear that he himself visited the locality.

In 1888 Mr. W. Warry,§ political officer at Bhamo, made an extensive report on the jade mines of Mogaung. It deals chiefly with the history of the quarries, the methods of mining, and the question of revenue, but the following may be quoted.

"The jade-producing country is partly enclosed by the Chindwin and Uru rivers, and lies between the twenty-fifth and twenty-sixth parallels of latitude. Jade is also found at Mawhun in the Myadaung district, and the most celebrated of all jade deposits is reported to be a large cliff overhanging the Chindwin, or a branch of that river, and distant eight or nine days' journey from the confluence of the Uru and Chindwin. Of this cliff, called by the Chinese traders Nantelung,‖ nothing is really known, as no traders have gone there for at least twenty years. Within the jade tract described above, however, small quantities have been found at many places, and abandoned quarries are numerous. The last old quarry is Sanka, situated seventy miles north-west of Mogaung. The largest quarries now being worked are Tomo, Pangmo, Iku, Maikenmo, and Mienmo; they are distant about eight miles from Sanka. These mines are situated in the country of the

* Griffith. *Journal of Travels in Assam, Burma, Butan,* etc. Calcutta, 1847, p. 132.

† Yule. *Narrative of the Mission to the Court of Ava.* London, 1858, p. 146.

‡ *Report on the Expedition to Western Yunnan viâ Bhamo.* Calcutta, 1871, p. 66.

§ *Report on the Administration of Burma* for 1887–88. Rangoon, 1888, p. 59. Abstract in Watt, *Dict. of the Econ. Prod. of India,* 1890, IV., pp. 536 ff.

‖ Properly *Nan-tê-ling,* meaning "mountain-ridge difficult of access."—*Note by the Editor.*

Merip Kachins. The largest mine is about fifty yards long, forty broad, and twenty feet deep. The season for jade operations begins in November and lasts until May. The most productive quarries are generally flooded, and the labor of quarrying is much increased thereby. In February and March, when the floor of the pit can be kept dry for a few hours by baling, immense fires are lighted at the base of the stone. A careful watch is then kept in a tremendous heat to detect the first signs of splitting. When these occur the Kachins attack the stone with pick-axes and hammers, or detach portions by hauling or by levers inserted in the cracks. The heat is almost insupportable, the labor severe, and the mortality among the workers is high."

The last and by far the best work which has been done on the locality is that by Dr. Fritz Noetling * and Dr. Max Bauer.† The former visited the locality and describes it geologically. The latter examined petrographically the material brought back by Noetling.

From Noetling's description the following is quoted: "As far as our present knowledge goes the occurrence of jadeite in Upper Burma is confined to a small spot on the upper course of the Uru river. It cannot be told at present whether it occurs elsewhere, though in my opinion this is not improbable. Jadeite pebbles are said to have been found in the alluvium of the Irrawadi above Myitkyina. . . . The following remarks therefore are confined to the occurrence on the Uru. As the centre of the jade-producing district one can take the village of Tammaw, which lies in about 25° 44' N. Lat. and 96° 14' E. Long. It must be remarked that Tammaw is not a permanent settlement, but is abandoned by the workmen during the rainy season. A permanent place of residence is the Kachin village of Sanka, which lies about six miles to the east. Inside this district the jadeite is obtained in two ways, from the allu-

* Noetling. *Rec. Geol. Surv. India*, XXVI., 1893; also *Neu. Jahrb. Min.*, 1896, I. pp. 1-17. Map on Taf. I.

† Bauer. *Rec. Geol. Surv. India*, XXVIII. p. 91, 1895; *Neu. Jahrb.* 1896, I. pp. 18-51.

vium of the Uru river and from quarries near Tammaw."

The author then describes the general geology of the country, and shows that crystalline schists, limestones of probably Carboniferous age, Miocene sedimentaries, alluvium, and eruptive rocks occur. Basalts occur along the Irrawadi to the east and also near Sanka. Serpentine occurs at two places, at one of which, Tammaw, in connection with jadeite. This is described as follows :

"The second serpentine occurrence, which is the one which interests us most here, is situated west of the village of Sanka, on the top of a plateau, which, as far as known, consists entirely of Tertiary sandstones. The serpentine occurs here in the form of a low knoll, which is, however, visible at present only at the east side of the quarry, and which apparently passes under the Tertiary strata toward the east side.

"Below the serpentine, but separted from it by a crack which is about half a metre wide and which is filled with soft, friable rock, the jadeite occurs, which offers a sharp contrast to the dark serpentine by its dazzling white color.

"The quarry operations have opened a pit about 100 metres long and extending from east to west, but the walls of this have unfortunately fallen down except at the west side. I could not therefore determine exactly what rock was in place on the other sides, since outside the excavations an impenetrable thicket made all investigation impossible. But according to the inquiries which I made, the workmen came again upon the dark rock after penetrating the jadeite, especially on the west side. One thing was very plainly evident ; the quarrying moved generally towards the east, while the floor of the quarry sank gradually in the same direction. I consider that this goes to show that the jadeite passes under the serpentine, at least in this direction. The distinct crevice which, also with an eastward dip, separates the serpentine and jadeite, and by which much water reaches the surface, appears to point to a tectonic disturbance, which implies that the relation between the serpentine and the jadeite is not as intimate as it appears to be at first sight.

"From these observations the following definite conclusions may be drawn:

"1. The jadeite crops out below the serpentine, but at least at one place is separated from it by a crevice.

"2. The serpentine and the accompanying jadeite are surrounded on all sides by Tertiary sandstone although no contacts between the two could be observed.

"This occurrence admits of two explanations. The jadeite and serpentine may have formed at the time of the deposition of the Tertiary strata, a knoll about which the Miocene sandstone was deposited. . . . Or the serpentine may be of eruptive origin, in which case it would be of post-Tertiary date. In this case the jadeite may be either a mass brought up from below by the serpentine, or it may be due to a later eruption of jadeite."

Between these alternatives Noetling is unable to decide, but he is inclined to regard the serpentine at any rate as eruptive, on the ground of other occurrences in Burma.

Bauer's examination, together with the chemical analyses of Busz, establish the fact that the jade is a true jadeite. Bauer also describes the serpentine from this locality, which shows a somewhat cataclastic structure, and contains considerable (43 per cent.) unaltered olivine. An albite-hornblende rock and a glaucophane-schist, both from boulders at the locality, are also described. His conclusions on the geological age and mode of occurrence of the jadeite and serpentine are of great interest, and are quoted here in full.

"From the above description of the rocks occurring in the jadeite mines at Tammaw, viz., the jadeite, the olivine-serpentine, the albite-hornblende rock, and the amphibole glaucophane-schist, we are enabled to form a clear conception of their nature. Noetling believes that the jadeite and the serpentine penetrate the surrounding Tertiary sandstone, while with regard to the relations between the occurrence of the two other rocks and the jadeite, nothing is known. Noetling's view necessitates the assumption of an eruption of jadeite and another of olivine rock, following one another; but the petrological composition of these rocks is not favorable to such a view, which would include them among the Tertiary eruptive rocks. Judging by the petrological characters we must consider them as representing a system of crystalline schists.

"Now there is no doubt that in former geological times olivine rocks were produced by volcanic eruption. Nowhere, however, have rocks of this nature been found in beds of such modern date, being according to Noetling not older than of Miocene age. Wherever Tertiary masses of olivine are known to occur, as for example the enclosures in basalt, they are perfectly fresh, and show no signs of serpentinization. I wish particularly to emphasize this fact, since the basalt, which I shall presently describe, and which occurs in close proximity to the jadeite mines, has no geological connection with the jadeite, but is unquestionably an eruptive rock passing through Tertiary strata. In this basalt the serpentinization of the olivine has just begun, but has not progressed beyond the first stages, while such a complete alteration as that exhibited in the above specimens is characteristic of all ancient olivine rocks—such as palæopikrite—and, as I have already observed, of the crystalline schists.

"To consider the jadeite as an eruptive rock would be entirely unjustifiable; for neither in the older, nor yet in the more recent, eruptive rocks has any rock of the nature of jadeite been found. In Turkistan, however, it has been proved to be embedded with nephrite in the crystalline schists (gneiss and mica-schist), and belongs to that series.

"The other two rocks also offer material proof in favor of this view, for it is highly probable that the glaucophane-schist is one of the crystalline schists. Hitherto, glaucophane has been found only in gneissic rocks and mica-schists, no instance having been recorded of its occurrence in eruptive rocks, much less of its entirely composing such rocks. The same holds good for the albite of the albite-hornblende rock. This mineral frequently occurs as a component part of the crystalline schists, but hardly of eruptive rocks. The peculiar aggregation of the albite grains is in perfect harmony with this view, for such a structure would be by no means remarkable in a crystalline schist. I am therefore of opinion that the jadeite and the other rocks must be looked upon as part of the series of crystalline schists, overlaid by Tertiary beds and probably denuded by erosion. It is most probable that they were raised to their present level together with the surrounding Tertiary rocks, when these latter were subjected to folding. I have repeatedly laid stress on the fact that these rocks must have been subjected to great pressure, which can only be accounted for by folding. I do not assert for a moment that the above arguments are absolutely convincing, but they certainly support the view which best accords with the petrological evidence, while the stratigraphical conditions observed by Noetling in the mines at Tammaw fully bear out this view. Further observations, however, with regard to the geological conditions of that country, will certainly decide the question. On the geological map of Burma, west of the Irrawaddi, even west of Mogaung, towards Tammaw, submetamorphic rocks are indicated; while crystalline limestones, probably of Silurian age, extend to within about two miles of the eastern side of the jadeite mines."

It will be seen from the above that, while Noetling is unable to decide from field evidence the question of the origin of the jadeite, Bauer is decidedly of the opinion "that the jadeite and the other rocks must be looked upon as part of the series of crystalline schists." This account of Bauer has already been referred to by Pirsson, who, to a great extent, bases upon these observations his conclusions as to the origin of jadeite, as set forth in an earlier section of this work.

INDIA.

Although Fischer * is rather sceptical about the occurrence of jade in India, yet certain observations of the Geological Survey of India leave little doubt that it does occur

* H. Fischer. *Jadeit und Nephrit.* 1880, p. 323.

in several places in Central India, though apparently only to a small extent. It is not stated whether any mining is done at these localities or not.

The best-described occurrence is in the small State of Rewa, where it is associated with corundum.* A section from south to north across a small hill between Pipra and Kadopani is as follows:

a. White quartz-schist.

b. Hornblende-rock passing into jade, a few yards thick.

c. White tremolitic quartz-schist.

d. White and green jade, including some purple corundum and containing euphyllite and schorl.

e. Bed of corundum several yards thick.

f. Porphyritic gneiss with hornblende-rock.

It is also stated elsewhere † that in south Mirzapur (which is east of Rewa) "the hornblende-rock west of Dumrahur and Urijhut passes into a finely granular to nearly compact tremolite forming coarse jade, and that this last is also found between Kotomowa and Bhamni and at the top of Kurea Ghât. An olive-green jade also occurs north-west of Kisari."

It is uncertain, in the absence of mineralogical and chemical details, whether the material spoken of as jade is really so or not, and, if so, whether it is jadeite or nephrite. Since the geologists of the Indian Survey were undoubtedly well acquainted with jade, it can scarcely be doubted that what they called jade was really that material. Whether it was jadeite or nephrite is another matter, but the transition from a hornblende-rock to the jade points with some probability to the latter, at least in some cases. It is to be noted that the section at Pipra points unmistakably to a metamorphic complex, and that all the localities mentioned lie in the area of the Bengal gneiss.

The examination of the specimens from India in the Bishop Collection is of great interest in this connection. These—or at least the greater part of them—are easily

* Cf. *Manual of the Geology of India.* Economic Geology. Part I, Corundum, 1898, p. 50.

† *Dictionary of the Economic Products of India* IV. p. 385, 1890.

distinguished by the trained eye (some even by the casual observer) from the jades of Burma, the K'un Lun, and other localities, by their peculiar texture and color. The marked character and general constancy of this individuality, taken together with the fact that the microscopical, chemical, and specific gravity examinations show that these Indian jades are all nephrite,* would indicate that a large part of the material comes from one locality, and that it is native, *i. e.*, of Indian origin. It is difficult, and has been so far impossible, to ascertain the exact location, or even the existence, of such quarries or other sources, but from the occurrences just mentioned, it is to be presumed that they exist in Central India. It will be recalled that the indications here were that the jade was nephrite.

TURKISTAN.

The localities of jade in this region are among the most important in the world, and apparently the longest known, to Europeans at least. They were first noticed by Marco Polo (1271–1313), and by a number of other writers. They are also fairly well known geologically, having been investigated by several modern travellers. The localities are all in the K'un Lun Mountains south of Khotan, in southeastern Turkistan. The jades of this region are true nephrites, both white and green, and jadeite does not seem to occur abundantly.†

The first reliable investigation was that of the brothers Schlagintweit in 1856 and 1857. H. von Schlagintweit ‡ describes the localities as follows, his remarks, on account of their importance, being transcribed *verbatim* (with some small omissions).

* In the Collection there is but one exception to this general statement, No. 13308, a beautifully jewelled butterfly with wings of brilliant emerald-green jadeite. The workmanship is decidedly Indian in style. No microscopical or chemical examination of it has been made.

† Schoetensack (*Inaug. Diss. Univ. Freiburg.* Berlin, 1885) describes some specimens brought by von Schlagintweit which are partly of nephrite and partly of jadeite.

‡ Von Schlagintweit. *Sitz. ber. d. Math. phys.* Classe. Akad. Wiss. München. III. pp. 236–242. 1873.

"We found nephrite *in situ* in Khotan on both slopes of the K'un Lun range. In 1856 and 1857 we found at the northern boundary of the nephrite area large groups of quarries near Gulbashen, a station on the right bank of the Karakash river, in Long. 78° 15′ E. of Greenwich and Lat. 36° 13′ N.; at an elevation of 12252 feet. These quarries appear to be abandoned: they were deserted in both years.

"One group of quarries, which we were informed was called Konakan, is close to Gulbashen, the other, called Karala, about 6½ miles down the valley. In both, the outcrop of nephrite is only a little higher than the floor of the valley, which here separates the northern slope of the Karakorum chain from the southern slope of the K'un Lun chain.

"The road from the river to the Konakan quarries leads along a talus slope, which contains many pieces of nephrite, derived partly from weathering and partly from blocks fallen from the workings. The masses of nephrite in the large quarries are evidently *in situ*, and indeed a metamorphic phase * of the crystalline rocks generally parallel in dip and strike with the foliation (? *Zerkluftung*) of the rocks which bound it; though in the nephrite mass itself no such foliation (?) is found. The direction of strike of the foliation (?) planes is about the same as that of the slope of the mountain down toward the river, but their dip is steeper than that of the mountain slope, so that the whole succession and mutual relations of the rocks are visible.

"The prevailing rock in the Konakan quarries is gneiss, granite also occurring, but in smaller amount. It occurs both above and below the nephrite, but near the nephrite itself greenstone (or "diorite") occurs on both sides, which penetrates the gneiss for short distances.

"The diorite is a mixture of hornblende and feldspar, in which orthoclase occurs sporadically, while albite is predominant. The rock is very compact. The diorite does

* The meaning here is not quite clear, but the metamorphic character of the occurrence is evident. H. S. W.

not penetrate the nephrite as it does the gneiss, but is on the contrary separated from it by a layer of altered substance of varying thickness.

"The Karala quarries proved to be very similar to the above in their rock structure, though the nephrite occurs in even greater quantities. At Karala the rocks of the mountain slope are micaceous and dioritic. They are not as pure as the gneiss and diorite of Konakan, but are likewise very compact. The layers of soft, friable substance in connection with the nephrite are thicker. This is partly yellow and partly red, and is evidently a product of decomposition by percolating water, mixed with talc. It is certainly not a tectonic fissure. The strata of nephrite are also here much greater, from 20 to 40 feet thick. The thickness could be measured directly in places which had been quarried and which showed the rock in profile. It is possible that this thickness of pure neprite is continued still deeper in the mountain, yet the mass of nephrite seems in general to be underlain at some depth by the very variable crystalline rocks. It does not form a dike or stock, but is clearly interstratified, the stratum running along the slope, with the strike parallel to that of the foliation. In the nephrite masses only joint planes occur which differ in origin and position from the fissures of the surrounding rocks.

"At a greater altitude, nearer the crest of the K'un Lun, along the south slope, no additional nephrite was met with, either along our line of march over the Elchi Pass, or over the Kilian Pass west of this. Along the latter diorite is the prevailing rock as far as the pass. Granular varieties of gneiss frequently occur, as well as gray schists in thin strips. Foliation is always evident. Our route over the Elchi Pass showed that this was quite analogous to the Kilian Pass, geologically. On the north slope of the K'un Lun, as far as the border of the Plain of Turkistan, no more nephrite was seen along the route. This does not occur at all west of the province of Khotan.

"On the road from Elchi Pass to Elchi, the chief city of Khotan, however, there are two nephrite quarries. We ourselves could not visit these quarries on account of political difficulties, but Mohammad Amin knew of them and had told of them in an official report which he made in 1862 at Lahore. The upper of the quarries is at Amsha, a small village about twenty-five English miles from Elchi. This quarry does not appear to be any longer in use. Those layers at least which are exposed in the present condition of the quarry show relatively little pure nephrite. The quarries near the village of Kamat are far more promising. The quality of the nephrite found there *in situ* is so excellent that it finds a ready sale. The situation near the edge of the mountain, and its distance of only fifteen miles from Elchi, at a height greater by 1500 feet, favor the distribution of the quarried material.

"Nephrite is found as river-boulders as far as the plains of eastern Turkistan. The rivers in which such boulders are found are: the Karakash, the Khotan, the Yurungkash, and the Keria.* I know nothing of the occurrence of nephrite pebbles in the Yarkand river, which is west of the Karakash. This seems to confirm the absence of nephrite in the province of Yarkand."

Von Schlagintweit also refers briefly to short accounts by a few travellers who have visited the localities, but which add little of value here. Dr. H. Cayley, who travelled through the country in 1868, and who is mentioned by von Schlagintweit, published later an account of the jade mines which closely corresponds to that of von Schlagintweit, and need not be quoted here. †

Somewhat later the occurrence of jade at these localities was described by Dr. F. Stoliczka, geologist of the Indian Geological Survey. From his paper ‡ we abstract the following:

"The portion of the K'un Lun range which extends from Shahidulla eastwards towards Koten, appears to consist entirely of gneiss, syenitic gneiss, and metamorphic rocks, the latter being quartzose, micaceous, and horn-

* The author shows that all these drain from the K'un Lun Mountains.

† Cayley. *Macmillan's Magazine*, XXIV. p. 472, 1871.

‡ Stoliczka. *Quart. Jour. Geol. Soc.*, XXX. pp. 568--570, 1874.

blendic schists. On the southern declivity of this range, which runs along the right bank of the Karakash river, are situated the old jade-mines, or rather quarries, formerly worked by the Chinese; they are about seven miles distant from the Khirgiz encampment of Belakchi, which is itself about twelve miles S. E. from Shahidulla.

"We found the principal jade locality to be about a mile and a half from the river, and at a height of about 500 feet above its level. Just in this portion of the range, a few short spurs spring from the higher hills, all of which, however, as is usual, are thickly covered with dêbris and sand, the result of the disintegration of the original rock.

"Viewing the mines from a little distance, the place seemed to resemble a number of pigeon-holes worked in the side of the mountain, except that they were rather irregularly distributed; on closer inspection we saw a number of pits and holes dug out in the slopes, extending over a height of nearly a couple of hundred feet and over a length of about a quarter of a mile.

"The rock of which the low spurs at the base of the range are composed is partly a thin-bedded, rather quartzose, syenitic gneiss, mica, and hornblende schist. The feldspar gradually, but entirely, disappears in the schistose beds, which, on weathered plains, often ave the appearance of a laminated sandstone; they include the principal jade-yielding rocks, being traversed by veins of a pure white, apparently zeolitic mineral, varying in thickness from a few to about forty feet, and perhaps even more. The strike of the veins is from N. by W. to S. by E. or sometimes due E. and W.; and their dip is either very much towards the north, or they run vertically. I have at present no sufficient means of ascertaining the true nature of this vein rock, as it may rather be called, being an aggregate of single crystals.

"This zeolitic rock is again traversed by veins of nephrite, commonly called 'jade' which, however, also occurs in 'nests.' There appear to be two varieties of it, if the one of which I shall presently speak really deserves the name of 'jade.' It is a white· tough mineral, having an indistinct cleavage in two different directions, while in the other directions the fracture is finely granular or splintery as in true nephrite.

"Portions of this mineral (which is apparently the same as that which is usually called white 'jade') have sometimes a fibrous structure. This white jade rarely occupies the whole thickness of the vein: it usually occurs only along the sides in immediate contact with the zeolitic vein-rock, with which it sometimes appears to be very closely connected. The middle part of some of the veins, and most of the others, entirely consists of the common green jade, which is characterized by an entire absence of cleavage.

"The hardness is always below 7, generally only equal to that of common feldspar, or very little higher, though the polished surface of the stone appears to attain a greater hardness after long exposure to the air. The color is very variable, from pale to somewhat darker green, approaching that of pure serpentine. The pale green variety is by far the most common, and is in general use for cups, mouthpieces for pipes, rings, and other articles used as charms or ornaments. I saw veins of the pale green jade amounting in thickness to fully ten feet; but it is by no means easy to obtain large pieces of it, the mineral being generally fractured in all directions.

"Green jade of a brighter color and higher translucency is comparatively rare, and on that account alone, no doubt, much more valuable. It is usually found in thin veins of one or a few inches; and even then it is full of flaws. Since the expulsion of the Chinese from Yarkand in 1869, the jade quarries in the Karakash valley have become entirely deserted: they must have yielded a considerable portion of the jade of commerce; and though, no doubt, the workmen made a good selection on the spot, taking away only the best-colored and the largest pieces, even now a great number of fair fragments measuring from twelve to fifteen inches in diameter form part of the rubbish thrown away as useless.

"The Belakchi locality, however, is not the only one which yielded jade to the Chinese ; for there is no reason to doubt the existence of jade along the whole of the K'un Lun range, as far as the mica and hornblende schists extend. The great difficulty in tracing out the veins and following them when once discovered, is due to the large amount of superficial débris and shifting sand which conceal the rock. However, fragments of jade may be seen among the boulders of almost every stream which comes down from the range.

"We also observed large fragments of jade near the top of the Sanju Pass, which, on its southern side at least, mostly consists of thin-bedded gneiss and hornblende-schist. Another rich locality for jade appears to exist somewhere south of Koten, from which the largest and best-colored pieces are said to come : most of them are stated to be obtained as boulders in a river bed, though this seems rather doubtful. Very likely the Chinese worked several quarries south of Koten, similar to those on the Karakash valley ; and most of the jade from this last locality was no doubt brought into Koten, this being the nearest manufacturing town."

A locality of jade boulders near Ilchi (the chief town of Khotan) has been visited recently by Svèn Hedin, who speaks of it thus : * "I made an excursion to the village of Kaltakumat (Short Sand), situated two and a half *potais* (six and one-quarter miles) northeast of Ilchi. To reach it I had to ford the river Yurunkash. On the other side of Tam-aghil (the Stone Village) the desert began, with occasional sand-dunes and ravines left behind by the stream. After that the ground became excessively stony, and I soon perceived that we were riding along an old river-bed.

"This disused river-bed is one of the places that yield the largest supplies of jade. Everywhere the ground was cut by trenches six or seven feet deep, a few feet wide and at most thirty feet long, although varying somewhat as regards size according to the amount of work done in them. The material which is thrown up out of the

*Hedin. *Through Asia*, New York, 1899. II. p. 738.

trenches consists of round, polished stones, sand, and clay. It is among these stones that the jade is found."

Some of these pebbles obtained by Svèn Hedin are at present in the Bishop Collection (Nos. 13432, 13433, and 13434), as well as several hundred from the Yurung-kash and Karakash rivers in Khotan, obtained from Peking (Nos. 13518, 13519, and 13520).

It must be added that Professor Hintze * says that nephrite occurs *in situ* on the Raskan Daria, a tributary of the Yarkand Daria (three or four degrees west of the city of Khotan), and that the Yarkand also contains boulders of nephrite, which resemble the material of the great monolith on the tomb of Timur at Samarkand. His authority for these statements is not given.

SIBERIA.

The fact that jade occurs in Siberia has long been known, though some of that brought from Kolywan, the earliest-mentioned locality, has been shown to be really prehnite. A number of writers † have described nephrites from the province of Irkutsk near Lake Baikal, in eastern Siberia, and from rivers flowing north from the Sayan Mountains, in south-central Siberia. All these refer, however, to jade occurring as boulders or transported blocks. It is only within the last few years that jade (nephrite) has been found in Siberia undeniably *in situ*. This has been done by Professor L. von Jaczewski, whose account (slightly abridged), written specially for this work, is here given.

JACZEWSKI'S EXPLORATIONS.

Renovanz (1744–98) reported the occurrence of nephrite in the Altai, but later investigations have not confirmed his statements.

The first reports about nephrite in the Belaja river

* *Schlesische Zeitung*. Breslau. June 21, 1899.

† Von Fellenberg. *Neues Jahrb.* 1871, p. 173.
Geinitz. *Neues Jahrb.* 1873, p. 916.
Jannetaz and Michel. *Bull. Soc. Min. de France.* IV. p. 178, 1881.
Beck and Muschketow. *Verh. russ. min. Ges.* (2). XVIII. pp. 9–33, 188.
Arzruni. *Zeit. für Kryst.* 1885, p. 510.

system date from the beginning of the nineteenth century, but systematic investigations were not made until 1850, when Permikin was sent out by the Imperial court ministry to find nephrite for the stone-cutting establishment at Peterhof.

Permikin found a great number of nephrite blocks on the lower part of the Onot river and along the borders of the Dajalock. Among the papers and maps left by him were found notes regarding an occurrence *in situ* of the mineral on the brook Zagan-Chori.

Tschersky, the well-known Siberian explorer, made an unsuccessful search under very unfavorable circumstances, in the upper course of the Onot, and of the Zagan-Chori brook; and Bogdanowitsch, in 1894, was prevented by heavy rains from reaching the Dajalock river, where he had hoped to find nephrite *in situ*.

In 1895 I made a short trip to the river Onot, penetrated to the mouth of the Usin, and reached above the latter a narrow pass—a real cañon—which I could not enter. I then turned back. The result of this expedition revealed the important fact that nephrite *in situ* must be sought for at points much further up the river than those at which Permikin found his blocks.

In 1896 His Majesty's cabinet invited me to search for nephrite *in situ* for the purpose of procuring a monolith for a sarcophagus to be placed on the grave of the Emperor Alexander III. My work lasted two years, 1896 and 1897. Incessant rains rendered the first year almost barren of results.

The region explored forms a part of the Sajan mountain system. This part lies between the upper course of the Kitoi on the south, the Urick river on the west, the lower course of the Belaja river on the north, and the Onot river on the east.*

* The accompanying map was drawn according to observations made without instruments in the course of my researches. A more detailed map does not exist. The Belaja river is a right-bank tributary of the Angara. The rivers Onot and Urick enter the Belaja on its right bank. The names here given are those in common use among the Russians and Burjats living at the base of the northern slope of the Sajan tableland. The Sojots, who have their cabins in the mountains, call the Onot "Osspa," and the upper course of the Urick "Chorock." The Kitoi also joins the Angara above the Belaja.

To reach this region the traveller uses the great Siberian railroad to the Tscheremshowo station, whence a Siberian tarantass takes him southward for a distance of 50 wersts to a village called Golumeteiskoje, where he must organize a mounted caravan to penetrate the uninhabited, utterly wild, and mountainous Taiga. The caravan must needs be large, as a month is required to visit all the nephrite finding-places, and provisions have to be taken along for all that period. So far as the mounts are concerned, the Russian and Burjat horses can be used only for the trip along the lower course of the Onot and Urick. Along the upper courses, where serious obstacles are to be overcome, they must be exchanged for Sojot horses, which are used to travelling on uncommonly steep mountains and ledges, while able to live on the scantiest grass diet.

A very good road leads from the village of Golumetei to the last Russian blockhouse on the Onot, a distance of about 40 wersts, according to general calculations. At this point begins the Taiga, and the mountain region, with their scenic beauties and obstacles.

For a further distance of about 50 wersts—*i. e.*, to the mouth of the Ugungol—there is a narrow footpath, occasionally used by hunters, but from that point onward the traveller must make his own road. The river runs in cascades and waterfalls, and rocks reaching up to 100 metres in height block the advance on either way. Consequently it is necessary to wade from one bank to the other. These crossings are often very difficult, and fords are few; therefore one must either build a raft, or, as I did after my experience in 1896, use canvas boats. These serve to ferry the travellers and their packs across; the horses must swim.

In a few cases the members of the expedition were exposed to serious danger in these boats, while some of the horses were carried away and drowned. Three or four crossings had to be made in the course of a day's journey, with the result that the distance covered sometimes amounted to only 2 to 5 kilometres, and never to more than 25.

Where the Onot passes through the cañon, it was necessary to carry the packs up high mountains, and to pull the horses up with ropes. It should be added that the Burjats and Sojots, like the Russians, understand how to overcome seemingly insuperable difficulties. The Sojots will climb up an almost perpendicular mountain like chamois.

With few exceptions, the whole journey had to be made through territory of this character.

The following marches were made in search of nephrite deposits:

The Onot and Urick rivers and Dajalock and Zagan-Chori rivers were followed from beginning to end, while, in addition, excursions were made to right and left into the country lying between them.

Orographic Characteristics.

I apply the name 'Sajan mountain region' to the tableland which begins on the right bank of the Jenissei, embraces the whole southern part of Siberia, and ends in the east with the meridian of Selengo. Towards the south this tableland merges into Mongolia. At the north it ends abruptly with a considerable scarp, running from southeast to northwest, and just south of the great Siberian railway. This immense tableland owes its present aspect to tectonic and erosive processes. The former have brought about the general outline; the latter have chiselled the details of the design. In Siberia the highest points of this tableland are grouped along the mountainous chain on its border, some of them reaching an altitude of 3000 metres. Towards the north, the elevations diminish gradually.

The deeply cut river valleys have divided the Sajan tableland into a few rather well-defined mountain ranges, the Tankins and Kitoi Alps, and a whole chain of mountains which follow more or less a north and south direction.

To give the reader some idea of the elevation of this region, I add here the following figures:

On the northern border of the scarp, the foot of the terrace is situated at an altitude of about 650 metres; the terrace itself reaches at its crest a height of 800 metres.

In the Kitoi Alps the transition from the sources of the Onot (Osspa) to the Zagan-Chori, is situated at an altitude of 2608 metres; the neighboring basalt peaks overtop the ridge by at least 3000 metres. The Chalbin mountain ridge lies at an altitude of 2315 metres.

One can form some idea of the nature of the Onot and Urick rivers from the figures of their fall. Thus, the Urick has a fall of more than 400 metres in a distance of 100 kilometres along its lower course, between the Gadshirskoje blockhouse and the mouth of the Chouschon.

Geological Characteristics.

The Sajan tableland is bordered on its northern side along the scarp-line by old palæozoic deposits, which are generally classed with the Cambrian. These deposits are occasionally covered by overthrust older crystalline schists.

Below the surface, the tableland consists of metamorphic schists, and different varieties of gneiss and granite. These are cut by thick dikes of diabase and gabbro, which furnished the material for the serpentine now so generally present.

The basalts reach a high degree of development. They cover the greater part of the region with a thick sheet, reaching a thickness of 300 metres in some spots. They have flowed into the valleys, which have a general direction from north to south. These basalts have determined the table form of many of the peaks, particularly in the northern part of the Kitoi valley.

So far as the nephrite deposits are concerned, the chief interest centres in a group of metamorphic schists, which, petrographically considered, show considerable diversity. Here we have argillaceous schists (? Tonschiefer) changing into phyllitic schists. talc, chlorite, mica, and actinolite-schists. A whole series of schists here are a product of mechanical change from diabases. The strata of all these schists are much disturbed, and many are much folded. It is not only the schists, however, that bear strong traces of mechanical deformation, but also all the other rock varieties, the basalts forming the only exception.

The Nephrite Deposits.

The first primary deposit of nephrite was found at an altitude of about 2000 metres on the Chara-Shelga, a tributary on the right bank of the upper course of the Urick (or Chorock). This brook, which is but 15 kilometres long, flows from SSW. to NNE., almost at right angles to the direction of the strike of the strongly crushed and much folded schists. In its lower course argillaceous schists are in immediate contact with limestone, through which the Chorock forces its way in a gorge several hundred metres deep, and so narrow that the "Kabargi" (chamois) can jump it with ease.

Farther up the course of the Chara-Shelga only dike-like, actinolitic schists occur, which have to a great extent been changed into serpentine, and contain large aggregations of nephrite. Still farther up, these are supplanted by granite, which, in turn, is succeeded by argillaceous and actinolitic schists. The latter of these have been changed into nephrite. The remaining products of the hydrodynamic change are serpentine and magnetite schists, which remind one of listwanite. The depth of these nephrite deposits can be estimated at the places where the mineral crops out. It reaches here a depth of six metres and more. The nephrite here has a beautiful color, almost emerald-green. A characteristic admixture is graphite.

A second primary deposit of nephrite is found on the Onot, near the mouth of a brook called Tehe-Cher. I did not search here for the primary deposits, as the Cabinet considered this unnecessary. The many sharp-edged nephrite blocks found here, which reached a diameter of six metres, demonstrate that the discovery of the vein itself would offer no difficulties.

In the same way only superficial search was made on the Zagan-Chori, but here, too, nephrite blocks were found, Following the information vouchsafed by the Sojots, I found the spot, near a larch-tree, where, fifty years before, Permikin had made a mark. Nephrite did not break through at this spot, however, but on this stream, too, the search for the deposits would offer no difficulties.

As for the Dajalock, no nephrite was found in the valley through which it runs. This should not be taken, however, as evidence that the mineral does not occur there. When I visited the Dajalock, my researches were seriously hampered by torrents of rain, so that my failure should not be regarded as final.

The question of the occurrence of primary deposits of nephrite in Central Siberia may thus be considered as settled. The results obtained are more than sufficient for the purpose for which the investigations were made.

The mineral, which fully deserves the name of "rock," occurs in such vast quantities and masses, that not only sarcophagi, large vases, and similar objects can be cut from it, but also whole columns and monuments.

It is evident from this description of Jaczewski's that the Siberian nephrite, as observed *in situ*, occurs in connection with a metamorphic complex, analogously to its occurrence elsewhere (as, *e. g.*, in the K'un Lun), being found in close association with gneisses and schists of various kinds.*

Although the work of Beck and Muschketow is confined entirely to the examination of pieces not *in situ*, yet, for the sake of completeness, it will be well to give a list of the localities mentioned by them.† These are: Belaja river in Transbaikal, Kitoy river in the Nertchinsk mining district, Bustraja river in Irkutsk Province, and several other localities, the so-called jades of which turned out to be serpentine, garnet, or other material.

CHINA.

The occurrence of jade in China itself is as yet somewhat uncertain, though there is evidence which points to its

*Saytzeff (Ref. in *Neu. Jahrb.*, 1897, I, p. 286) describes petrographically some of the rocks of the Sayansk mountains, among which are mentioned syenites, gabbros, and gneisses.

†Beck and Muschketow. *Verh. K. Min. Ges.* St. Petersburg, XVIII. pp. 1-76. 1882.

presence. The large number of jade objects from this country are in the vast majority of cases undoubtedly made of nephrite from Turkistan or of jadeite from Burma. Possibly the Siberian nephrite has been used, but, if so, only to a small extent, as is also true of the New Zealand nephrite. Pumpelly * mentions several localities: six in Shensi, four in Yunnan, and one in Kweichow. While these and other reports are not wholly trustworthy, yet evidence that jade is found in China proper, at least as pebbles, is furnished by specimens in the Bishop Collection.

These consist of four pebbles stated to have come from the Liu Yang river, which rises in the western part of Kiangsi, and flows westward to the Siang river at Chang Sha Fu in Central China. There seems to be no reason to doubt the correctness of the provenance of these specimens, which are therefore of importance as establishing the fact of the occurrence of jade in China.

EUROPE.

Jordansmühl.

Although boulders and worked objects in jade had been known in Europe for many years, it was not till 1884 that jade (nephrite) was discovered *in situ* in this quarter of the globe. The very great importance of this discovery, as bearing on many archæological problems, is evident, and is dealt with in another part of this volume. †

The discovery was made near Jordansmühl, S. W. of Breslau, in Silesia, by H. Traube, who announced it in a short note.‡ In a later paper § he describes the occurrence at some length, from which we abstract the following:

"The nephrite occurs in connection with granulite or serpentine, which, together with "gabbro," forms a low range of hills stretching in a northwesterly direction from

* Smithsonian Contributions. No. 202, p. 117, 1866.

† Cf. on this point Hintze. *Schlesische Zeitung*. Breslau. June 21, 1899.

‡ Traube. Leopoldina. XX. 1884, No. 7-8.

§ Traube. *Neu. Jahrb.*, Beil. Band., III, pp. 412-427. 1885.

Jordansmühl to Naselwitz, the so-called Steinberge (Stone Mountains). The gabbro* occurs only in the northwestern spurs. Near Jordansmühl itself the serpentine is exposed to a considerable depth in a large quarry, which has been worked for a long time, and in which also granulite crops out. In this locality the latter penetrates the serpentine as a wedge-shaped ridge, which increases in size towards the bottom, so that the serpentine overlies it, as it does elsewhere in the Zobten region, as, *e. g.*, at Mlietsch.

"The nephrite occurs at the contact of the granulite and serpentine, and accompanies both of them for long distances, in layers which are often over a foot in thickness. The nephrite also occurs in the serpentine itself as small inclusions and knobs, which, however, are always near the granulite contact. It is to be remarked that the nephrite enclosed in the serpentine is always light, while the others show darker colors.

"As the nephrite is approached, the granulite, which is composed essentially of quartz, orthoclase, and plagioclase, and a little mica, changes in composition in a remarkable way. The feldspar is altered almost completely to compact epidote and zoisite, the quartz and mica disappear; and a green, finely fibrous hornblende appears as a new component. Under the microscope the last appears perfectly colorless, much frayed, and shows between crossed nicols a structure analogous to that of nephrite. . . . As the junction is approached the hornblende predominates more and more, until the last zone of the rock is such an intimate mixture of hornblende and epidote that the two cannot be distinguished by the naked eye. The microscope also shows that pyroxene enters also as a new component.

"Both hornblende and pyroxene in this rock are still very fresh, with spindle-shaped outlines, but can only with difficulty be discriminated, since cleavage is seldom

*These gabbros of Traube are the Zobtenite of J. Roth—*i. e.*, rocks with the mineralogical and chemical characters of true eruptive gabbros, but metamorphic in origin. They are probably metamorphosed eruptive gabbros.

to be seen. A transition of the pyroxene to nephrite through the setting up of a fibrous structure (uralitization) is unmistakable in many places.

"The more the zoisite disappears the finer-grained becomes the rock, until finally it is seen to be composed of small, flattened, nearly round grains, which do not admit of sure determination as either amphibole or pyroxene. In general, however, they would seem to be the latter, at least judging from the change into nephrites, which is constantly observed, and which can only take place with pyroxene. This nephrite is composed of short, thick, interwoven bundles of fibres."

An analysis gave:

SiO_2	57.26
MgO	19.96
CaO	13.19
FeO	4.22
MnO	0.74
Al_2O_3	1.40
H_2O	2.53
	99.30

It will be seen from this that this pyroxene-amphibole rock does not differ materially from nephrite in chemical composition.

"Green nephrite proper usually comes next to the above-described rock. Sometimes the pyroxene-amphibole rock alternates with layers of compact zoisite, but again this appears to be lacking entirely, especially when the nephrite (which borders the granulite) is coarse-fibred."

The microscopic characters of thin sections of the nephrite are given by the author in great detail, many of them being shown to resemble the nephrites of New Caledonia, though there is considerable variety.

"Arzruni * has reached the conclusion, based on the results of his examination of nearly all the different nephrites known thus far, that the nephrites are partly of primary origin, and partly due to the uralitization of pyroxene. The former are called primary nephrites, the

* Arzruni. *Zeit. für Ethn.*, 1884, p. 300.

latter pyroxene-nephrites. The dark-green nephrite of Jordansmühl described above appears to be derived from pyroxene. A secondary origin would consequently have to be ascribed to the greater part of the hornblende.

"The far rarer light-colored nephrites occurring in serpentine differ in many respects from those just described. The Jordansmühl serpentine is derived exclusively from diallage. No traces of original olivine, which can be seen in other localities of the Zobten district, could be found here. The alteration of the diallage is generally far advanced, but remains of microscopic bastites are frequently to be observed. The rock which surrounds the nephrite appears to be much fresher."

The characters of these nephrites are described in detail and the conclusion reached, that "The nephrites which occur in serpentine differ from those which occur in connection with granulite not only in their structure, which is usually perfectly schistose, but also in their composition, since here primary amphibole plays a prominent rôle. Consequently this nephrite may be considered on the whole as primary nephrite proper, even though pyroxene may have contributed in part to its formation."

The author goes on to remark that the Jordansmühl nephrites show peculiarities of structure and appearance which differentiate them from all other known nephrites, though on a former page he had noted their general similarity to those of New Caledonia.

"The original relations of the nephrite of Jordansmühl to the diallage rock, the mother rock of the serpentine, and the granulite, may perhaps be represented by the assumption of the former existence of a zone of pyroxene rock rich in finely fibrous amphibole between the diallage rock and the granulite, both of which at this point contained finely fibrous hornblendes. Furthermore an analogous rock would have formed the inclusions and bands in the diallage rock, though here finely fibrous, nephritic amphibole surpassed the pyroxene in quantity."

In his final paragraph the author points out the great similarity obtaining in the conditions and character of the occurrences both at Jordansmühl and at the K'un Lun quarries.

In April, 1899, Mr. George F. Kunz visited this jade locality along with Professor Hintze of Breslau, Lieutenant Oscar von Kriegsheim, on whose estate it is, and several others, and secured many good-sized specimens of nephrite, including one large block weighing 2140 kilogrammes, now in the Bishop Collection and numbered 13521.

He describes the finding-place as "a quarry forming a gap 400 feet long and 200 feet deep in what was originally a low hill probably 600 feet in length and 300 in width, with a central height of 70 to 80 feet above the floor of the quarry, which at its entrance is on a level with the surrounding plain. At one end stood large columnar masses of a white and flesh-colored quartzite, rising to a height of twenty-five feet from the floor of the quarry, and varying from three to twenty feet in width, with a slight dip to the north. They had been left by the quarrymen when they removed the softer surrounding serpentine. About fifty feet to the southwest of these quartzite masses the floor of the quarry seemed to be some eight to ten feet higher than elsewhere. A blow of the hammer showed that this was a bed of nephrite that had been passed over by the workmen owing to the difficulty of quarrying it. Near the central point of the quarry a mass of serpentine and talcose schists and apparently altered nephrite was found in a vein of serpentine which had a dip of 55° to the north, the vein rounding at the edges and presenting a bow-like appearance.

"The serpentine is overlain by a deposit of loëss varying in depth from one foot to six feet, and in this was found a large piece of rich red syenite." Mr. Kunz further adds that "it is interesting to note that the nephrite was found in a part of the quarry not far distant from the beautiful white garnets of such rare occurrence, and immediately adjacent to the masses of quartzite which may be a fused sandstone in character resembling the red and chocolate-colored rock found at Sioux Falls, Dakota, and generally known as Norwegian porphyry."

Among the rocks and minerals collected in the quarry were serpentine; quartz-zoisite rock, granulite; quartz-zoisite rock, wiesstein; loëss; altered magnesia-silicate rock; altered actinolite-schist or slate; hyalite or hornblende—zoisite rock; hornblende rock with white and green spots resembling nephrite; actinolite with serpentine; and kaolin.

Reichenstein.

In 1887 Traube announced the discovery by himself of another locality of nephrite *in situ*, at Reichenstein in Silesia. In his paper * he gives the following details:

"The arsenical ores of this locality are found, not only in serpentine and serpentine-bearing limestone, but also in strata which consist essentially of diopside, but which carry also tremolite and chlorite. The grayish-green to greenish-white diopside is often very coarse and broad-fibred, the irregular crystals of which are not infrequently 10 centimetres long, showing good prismatic cleavage and parting parallel to the base. It also forms fine-grained to compact masses, whose mineralogical composition can scarcely be made out with the naked eye. In its prismatic development the diopside frequently shows alteration to coarse-fibred, light green tremolite. The frequency of this transformarion of the diopside into fibrous hornblende had already led me to believe that nephrite must occur here. But of all the specimens which were examined for this porpose, of which the Mineralogical Museum at Breslau possesses a large number, a few indeed appeared nephritic, in consequence of a finely fibrous structure, but none of them showed that finely felted structure under the microscope which is so characteristic of nephrite, and to which it owes its toughness.

"During a visit to Reichenstein last year I took out of the material hauled up at the Fürstenstolle (Prince's Mine) a large specimen which showed clearly the characters of nephrite in all respects. This was confirmed by Arzruni of Aachen, to whom I sent a piece for examination.

* H. Traube. *Neues Jahrb.* 1887. II., pp. 275–278.

"This Reichenstein nephrite, which forms a layer about seven centimetres thick in the diopside rock, shows a bright grayish-green color, resembling that of the southern Siberian localities, in places with a reddish tinge, a very imperfect foliation, and the characteristic splintery, dusty-looking fracture, on freshly broken surfaces. In general the nephrite is perfectly compact and fibrous only in a few places, while at the borders, where it was originally in contact with the surrounding rock, it shows the beginnings of serpentinization. It contains only very little arsenical pyrites, and in places is quite free from this."

This identification as nephrite was fully confirmed by the microscopic and chemical examination. The author ends his note with the significant remark: "Although the Reichenstein nephrite has never been worked, yet the new find, which has been made at a much-visited locality, and one which has been often investigated mineralogically and geologically, shows how easily it may be overlooked, and also indicates the probability that it occurs *in situ* at a greater or less distance from the localities where it is met with in a worked state." This nephrite is represented in the Collection by Nos. 13480, a piece of a pale green color, and 13481, of a darker green, and thickly sprinkled with crystals of arsenopyrite.

Apart from these two localities nephrite has never been found *in situ* in Europe, though it is very probable that it will eventually be discovered among the metamorphic regions. Of boulders of nephrite the following may be mentioned:

The discovery of a block of nephrite in the sands of Potsdam was reported by Prince Gallitzin as far back as 1794. This was investigated by Fischer * and by Arzruni † and shown to be green nephrite. A second find was that described by Breithaupt ‡ in 1815, of a smooth polished block of stone, which was found in the peat-bog of Schwemsal, near Duben in Prussian Saxony. This was

* Fischer, *op. cit.*, pp. 2, 156, 157.

† Arzruni. *Zeit. für Kryst.* 1885, p. 540.

‡ Breithaupt. *Handbuch von C. A. S. Hoffmann.* II., 254, 1815.

shown by Breithaupt to be nephrite, and was subsequently investigated by von Fellenberg,* Fischer,† and Arzruni.‡ A piece of it is No. 13482 of the Collection. A third early find is that of the Leipzig specimen, found in a peat hole near Leipzig, and first mentioned and analysed by Rammelsberg,§ in 1844. This was also briefly described by Fischer ‖ and Arzruni.¶

It was suggested by Fischer ** and others that these specimens had been brought by early man from Siberia or Turkistan and accidentally lost. The necessity for this hypothesis has been done away with by the discoveries of Traube already noticed, and they were vigorously opposed by Credner †† on geological grounds. He points out that:

1. The three localities lie in the region of the North German Diluvium.
2. The three specimens were all taken from glacial deposits.
3. The three localities lie in a zone which corresponds exactly with the direction of transportation of glacial material from Sweden through the North German Plain towards the elevated part of Saxony.

He argues that: "On the basis of all investigations in North German glacial deposits, it would be accepted without question for any other stone so found, that it was erratic and had originated in Sweden and had been transported to Germany by the ice. This is disputed in the case of nephrite on the grounds that: 1. no occurrence of nephrite is known in Sweden, 2. on account of the great petrographical resemblance between the German blocks and the nephrite of Siberia. These facts cannot be denied, but they lack force. The geological knowledge of

* Von Fellenberg. *Verh. d. Schweiz. Ges. in Solothurn*, Aug., 1869.
† Fischer, *op. cit.*, p. 253.
‡ Arzruni. *Zeit. für. Kryst.*, 1885, p. 540.
§ Rammelsberg. *Pogg. Ann.*, LXII., p. 148, 1844.
‖ Fischer, *op. cit.*, p. 217.
¶ *Zeit. für Kryst.*, 1885, p. 540.
** Fischer. *Neu. Jahrb.*, 1881, I., pp. 196 ff.
†† Credner. *Neu. Jahrb.*, 1884, II., 235, ref.

Sweden is so incomplete that it is impossible to determine the exact place of origin of many of the boulders found in the North German diluvium, and yet no geologist hesitates to attribute them to Sweden. The petrographic argument is likewise of little value." Credner also points out that Sweden offers the same geological conditions which are associated with the occurrence of nephrite elsewhere, namely the presence of gneiss and hornblende schists.

Additional specimens of nephrite occurring as boulders have been found in Styria, Austria. With the doubtful exception of one from the valley of the Sann, these all come from the valley of the Mur river, on which the town of Graz is situated.

The first of these is said to have been found in 1880 at the Sann bridge, one hour's journey from the village of St. Peter.* It is a light leek-green, and resembles the *Kawa-kawa* of New Zealand. Five other boulders or pebbles have been found at Graz, either in the bed of the Mur, or in rubble derived from this, within the town limits.† These resemble very closely that from the Sann river, so much so that there is scarcely a doubt that this also comes from the valley of the Mur, as Berwerth suggests. Berwerth also remarks: "since it has been demonstrated that nephrite boulders of a particular type occur in the Mur river region, we may confidently expect the discovery there of nephrite *in situ*. The mineral will be found probably in very thin layers or flat pieces in the mountains of metamorphic schists."

Down to the present time no true jadeite has been discovered *in situ* in Europe. Penfield ‡ has described a massive jadeite-like mineral from St. Marcel in Piedmont, which apparently occurs *in situ*. It is described as "an interwoven aggregate of prismatic crystals, resembling in structure a rather coarse jadeite. The material is very

* Meyer. *Abhand. Naturw. Ges. Isis in Dresden.* P. 77, 1883.

† Meyer. *Mitth. Anthrop. Ges.* Wien. XIII. p. 216, 1883.
Berwerth. *Ann. Hofmus.* Wien. III. p. 79, 1888.
Berwerth. *Ann. Hofmus.* Wien. XIII. p. 115, 1899.
Meyer. *Das Globus.* LXXV. May 6, 1899.

‡ Penfield. *Amer. Jour. Sci.* (4), Vol. XLVI. p. 291, 1893.

tough, and the color a sort of ash gray." The specific gravity varied from 3.257 to 3.382, and the analysis resembled those of other jadeites. Boulders of this had been previously found at the locality, and were analysed by Damour, * who also analysed a jadeite † forming a small vein in quartzite at St. Marcel. It is of interest to note that glaucophane schists are found in this region, recalling the similar occurrence at Tammaw in Burma. Another specimen is described by Damour ‡ as having come from Monte Viso, in Piedmont. There has been much discussion about this piece, but there seems to be no reason for doubting that it is a true jadeite and comes from this region. Meyer § reports the finding of two boulders of jadeite on the shores of Lake Neuenburg, Canton of Freiburg, Switzerland. They are green and resemble the material of some of the Swiss stone implements. A pebble found by Damour ‖ at Ouchy, near Lausanne, on the shore of Lake Geneva, is also undoubtedly true jadeite.

NORTH AMERICA.

Mr. G. P. Merrill, of the U. S. National Museum, has written a paper on the occurrence of jade in America for Mr. Bishop, which has been used in the following pages.

Alaska.

"Various aboriginal objects, principally hammers, cutting implements, and small ornaments, made of nephrite and jadeite from the western coast of America, have been known to archæologists for many years, but it is only recently that the exact source from which any of the material was derived has been discovered.

"The late Professor S. F. Baird, who took a great interest in the source of these materials, urged Lieutenant G. M. Stoney, who in 1884 was preparing to explore the

* Damour. *Bull. Soc. Min. France.* Vol. IV. p. 161, 1881.

† Damour. *Comptes Rendues.* Vol. XCII. p. 1313, 1881.

‡ Damour. *Comptes Rendues.* Vol. XCII. p. 1312, 1881.

§ Meyer. *Antiqua. Zürich.* 1884. Cf. *Neu. Jahrb.* 1885, II. 6.

‖ Damour. *Bull. Soc. Min. France.* Vol. IV. p. 161, 1881.

Kowak river of Alaska, to make a special effort to ascertain whence this material comes, and to obtain specimens."

Lieutenant Stoney discovered the locality, the so-called Jade Mountain, about 150 miles above the mouth of the Kowak river, in Lat. 67° 05′ N., and Long. 158° 15′ W. The mountain is described by Stoney as being bright green in color and from 1000 to 1500 feet high.

The material brought back by Stoney in 1884 was shown by Merrill * to be serpentine, but on his second visit he secured true nephrite. Stoney, unfortunately, does not describe the geology of the occurrence, but merely speaks of the occurrence of shale and serpentine along with the jade, and that the latter crops out on the surface.

This locality is probably identical with that spoken of by E. W. Nelson,† as the source of the material of the jade implements in use by the Innuits of Kotzebue Sound, and which they all declared came from a steep hill ascending from one of the rivers. Nelson also mentions jade celts in use among the Indians of the Yukon about Nulato, the rough material of which they claim is found upon the side of a mountain about twenty-five miles from Nulato. He also states, on the authority of the natives, that jade occurs in the mountains on the western part of the Kaviak Peninsula near Bering Strait. There are also indications that it is found near Bristol Bay. Nelson speaks of a few jade fragments being seen by him on the Siberian shore of Bering Strait, but was informed that they came from the American side.

Specimens of the jade brought back by Stoney, as well as numerous implements from Alaska, have been examined by Clarke and Merrill ‡ and shown to be true nephrite, which closely resembles that of Siberia, New Zealand, and some of the lake dwellings in Switzerland.

In this connection it must be mentioned that the Bishop Collection contains a large pebble of nephrite (No. 13391)

* Merrill. *Science*, March 13, 1885.

† E. W. Nelson. Letter to Professor Baird. *Proc. U. S. Nat. Museum*, Vol. VI, p. 426, 1883.

‡ Clarke and Merrill. *Proc. U. S. Nat. Museum*, 1888, p. 115.

from Sulphur Creek, a tributary of Indian river, about forty miles from Dawson.

British Columbia.

In 1887 Dr. G. M. Dawson * announced the finding at Lytton and Yale on the lower part of the Frazer river in British Columbia, of two partially worked nephrite boulders of such a nature as to show that they had been derived from the immediate banks of the river, where they had been doubtless deposited by the river itself. This material was studied by Professor B. J. Harrington † and shown to be a true nephrite, and partially indentical with that of Alaska. A number of jade celts from graves near Lytton have lately been examined by Professor J. F. Kemp ‡ and shown to be nephrite. Outcrops of this are said to occur "in a creek tributary to the Frazer river some miles above Lytton."

Boulders of nephrite have also been found by Dr. Dawson § and Mr. Ogilvie on the Upper Lewes river, near the Alaskan boundary. Dr. Dawson says: "Though not actually observed in place, the material is evidently derived from the altered (metamorphosed) volcanic rocks, probably of paleozoic age which are abundant in the district." It is also reported that nephrite has been found in Miles Cañon and at the Kwikpak mouth of the Yukon.‖

NEW ZEALAND.

The first notice of the occurrence of jade in New Zealand is in 1774, ¶ when Hawksworth speaks of the natives using for axes and planes a "green, talc-like stone, which is not only hard but also tough."

The next author to mention it is J. R. Foster,** who says

* *Canadian Record of Science.* Vol. II. p. 364, 1886–7.

† Harrington. *Trans. Roy. Soc. Canada.* 1890, Sec. III, p. 61.

‡ Kemp. *Mem. Acad. Mus. Nat. Hist.* Vol. II. Anthrop. I, pp. 132–3, 1899.

§ Dawson. *Science.* Vol. XI, p. 186, 1888.

‖ Dana. *System of Mineralogy.* P. 397. 1899.

¶ *Cf.* Fischer, *op. cit.*, p. 134.

** *Cf.* Fischer, *op. cit.*, p. 135.

that according to the unanimous testimony of the natives, it occurs "beyond the inner part of Charlotte Sound, towards the south-west." He also states that he found the rock at the small island of Motuaro, in "dykes," some two inches thick, partly vertical and partly oblique, in a mountain of gray talcose rock.

The occurrence of nephrite, which the natives call pounamu, in New Zealand, is described rather meagrely by von Hochstetter,* from whose paper the following extracts are taken:

"All New Zealand nephrite comes from the west coast of South Island, where it is found partly *in situ*, but mostly in the form of boulders and rolled masses, in river beds, and on the sea-shore. No nephrite is found on the east side of the South Island, or on the North Island. The South is called Te Wahi Pounamu, *i. e.*, Jadeland, or the region of jade.

"But little is known thus far regarding the occurrence of the mineral *in situ*. The imformation given by the natives and others indicates that there are three principal places where pounamu is found.

"The first is situated on the Arahaura or Brunner River, about fifteen miles from its mouth. The natives say that the nephrite projects from the river bed, several feet thick, in the form of an overturned canoe, standing upright. They therefore call the locality *Te Whaka* (the Canoe). The rock is said to be so hard and compact that they cannot break it, but most content themselves with pieces which they find in the river and on the sea-shore. The natives describe the country-rock as a green schist, probably talcose or chlorite schist or serpentine.

"A second locality lies south of Mt. Cook in the neighborhood of Jackson's Bay, or on Milford Sound.

"Dr. Hector, the geologist of the Province of Otago, who investigated Milford Sound during an expedition to the west coast, says in his report,† regarding the occur-

* Von Hochstetter. *Sitzber. Akad. Wiss.* Wien. XLIX. pp. 466-480, 1864.

† *Geological Expedition to the West Coast of Otago.* Provincial Government Gazette. 1863, p. 460.

rence at Milford Sound: "We anchored for a short time in Anita Bay (by Milford Sound), for the purpose of examining the shore whence the Maoris obtain jade or greenstone for their ornaments and weapons. This rock is found among the beach pebbles in rolled pieces, together with pieces of hornblende-gneiss and felsite. Although I found many boulders of jade, I could not discover the original place whence they were derived. But a thick dyke of felsite crops out back of the shore, in contact with green horneblende-rock and serpentine, and since the felsite near the corner of the dyke contains green grains with the characters of this mineral, it is probable that the jade has been formed in nodules and irregular masses along the contact." *

"A third locality is said to be Lake Pounamu, in Otago Province, which is identical with that given on the maps as Lake Wakatip.

"Some pebbles and boulders of nephrite are found along the whole west coast from Cape Foulwind on the north as far as beyond Milford Sound to the south. I myself found a small knobby, unrolled piece, three inches in diameter, among the pebbles on the shore of Current Basin, north of Nelson, where a thick bed of serpentine (the surpentine of Dun Mountain) occurs, accompanied by various schists; *i. e.*, in the same geological conditions as those described by Dr. Hector at Milford Sound, where also serpentine occurs in the vicinity."

Von Haast † says: "Nephrite is also found in the gneiss-granite formation on the west coast in Greenstone Creek, the Arahaura, and some other localities. I have never observed it *in situ*, but the Canterbury museum possesses a specimen of nephrite to which a small portion of the bed-rock, chlorite schist, is still attached."

Of the Milford Sound locality Ulrich ‡ says: "It is a nar-

* Chapman (*Trans. N. Z. Inst.* XXIV. p. 525, 1891) says of Hector's search: "He failed to find the dyke, which was my experience tihrteen years later, but I am now informed that it is higher up the shore."

† Von Haast. *Geol. of the Provinces of Canterbury and Westland.* Christchurch, 1879, p. 255.

‡ *Cf.* Fischer. *Mitth. Anthr. Ges.* Wien. VIII. p. 166, 1879.

row boulder bank at the foot of a mountain, overgrown with crowded shrubs, and which is accessible only to the Maoris. The massive rock seems to be a syenite, and nephrite probably occurs in small veins or pockets high up on the slope."

New Caledonia.

Axes from New Caledonia have been known for a long time. They are green in color, and are apparently of nephrite. This occurs *in situ* at the west coast of the Island of Uen, off the southeastern point of New Caledonia, and probably elsewhere.* The occurrence has been described by Garnier.†

"The euphotides (gabbros) of the Koutoure Bay region differ in appearance. They pass in to diorites with large feldspar and hornblende crystals. Towards Nogouneto one finds rocks of a beautiful green, translucent at the edges, with a somewhat greasy luster, a splintery fracture, but still retaining, notwithstanding this changed appearance, the greenish, foliated aspect of the euphotide in some parts of its beds. It is easily seen that the beds of these different rocks are unconformable.

"These new beds are only slightly homogeneous in composition. Certain parts, compact and green, are of about the hardness of glass; others, on the contrary, are very soft. Their structure is schistose, with very thin undulating white or green scales, like serpentine. This rock occurs here in conjunction with serpentine schists, veins of impure quartz, and compact feldspar. This fine white stone, with green veins, easily fusible before the blow-pipe, has many of the characters of hatchet jade."

The varieties distinguished by the natives are very numerous, and are only true nephrite in part, some being undoubtedly serpentine. They have been described at some length by von Hochstetter‡ and Reverend J. W. Stack.§

* *Cf.* Meyer. *Jadeit und Nephrit Objecte.* Part III. pp. 53 ff.

† Quoted in Meyer, *op. cit.*, p. 56.

‡ Von Hochstetter, *op. cit.*, pp. 469–475.

§ *Cf.* Chapman. *Trans. N. Z. Institute.* Vol. XXIV. p. 513, 1891.

WORKED OBJECTS AND UNCERTAIN LOCALITIES.

It would be out of place here to give a list of all the localities where worked objects of jade have been found. The catalogue of the Bishop Collection is sufficient evidence of their number and variety, and gives a practically complete list. An attempt will be made to indicate only those cases which may have a bearing on the main subject of this paper, *viz.*, the geological occurrence of jade.

Apart from China a large number of jade objects have been found in Asia. The most noteworthy is the huge monolith of dark green nephrite which is placed on the tomb of Timur in the Gur-Emir mosque at Samarkand. The provenance of the material is as yet unknown. Schoetensack* describes a dark green nephrite disc from Manas, on the north slope of the T'ian Shan range, and remarks on its resemblance to the nephrite of the Samarkand block. A good-sized boulder, pierced with a hole and with traces of lacquer and gilding, is in the Bishop Collection (No. 13500). It is said to come from Manas or Barkul, and was received from Dr. S. W. Bushell of Peking.

Tibet is said also to be a locality for jade, though there is some doubt on this point. It is very probable that by "Tibet" is meant Little Tibet or Baltistan, which lies northwest of Cashmere and southwest of, and not far from, Khotan, near the Karakorum mountains. The large size of the blocks said to have been brought from Tibet by certain well-known travellers would seem to exclude Tibet proper.

Schoetensack examined a specimen said to have come from Tibet, and showed that it closely resembled typical Burmese material. Fischer,† Cohen,‡ and Bauer § also describe jadeites from this region, and there are several specimens in the Bishop Collection.

* Schoetensack. *Inaug. Diss, Freiburg.* Berlin, 1885, p. 2.
† Fischer, *op. cit.*, p. 235.
‡ Cohen. *Neues Jahrb. für Min.*, 1884, i. p. 71.
§ Bauer. *Neues Jahrb. für Min.*, 1896, i. p. 85.

According to Bauer the "Tibetan" jadeite closely resembles that of Tammaw in Burma, showing also the same cataclastic structure. Its most striking feature is the presence of nephelite, a small amount of albite being also visible. The bearing of this on the question of the origin of jadeite has already been discussed in this work by Professor Pirsson.

At Schliemann's excavations at the site of Troy in Asia Minor, a number of hatchets, both of nephrite and jadeite, were found. A hatchet and a cylinder from Mesopotamia have also been reported, as well as a jadeite hatchet from Sardis, in Asia Minor. A small number of worked jade objects have also come from Japan, but probably in the course of commerce from China, as we have the explicit statement of Mr. Wada, formerly professor of Mineralogy at the University of Tokio, and ex-Director-General of the Geological Survey of Japan, that jade is not found geologically in that country.

In Europe very many objects have been found both of nephrite and jadeite. Implements of nephrite have been found in abundance in the ancient lake-villages of Switzerland, as for instance at Lakes Constance, Zürich, Neufchâtel, and Pfäffikon. These are usually of a dark leek-green color and foliated structure. Very few nephrite implements have been found north of Switzerland. A few have been found in Belgium, and a few in Germany. Three have been reported from France, some from Italy (chiefly Calabria), and one or two from Greece. It is seen, therefore, that the nephrite objects of Europe are almost exclusively confined to the Swiss localities.

Objects of jadeite are much more widely distributed, and may be broadly divided into the large flat celts of northwestern Germany, France (especially Morbihan), and Belgium, and the small polished celts of western Switzerland, Italy, and the Rhine Valley of southern Germany. In the lake-villages, on the contrary, jadeite implements are rare. Besides the countries mentioned above, jadeite implements have been found in Denmark, Spain, and Portugal.

In America, as has been already said, the only localities for nephrite are Alaska and British Columbia. It may be added that Meyer * mentions the finding of a piece of rough jadeite in Louisiana, though, from the known geological features of this State, it must have been brought from a distance.

It is not known to me whether any nephrite or jadeite objects have been found in the western parts of the United States, though, it may be mentioned here, that some of the conditions in California would seem to be favorable for the discovery of jadeite there.

In Mexico, soon after its discovery, the Spaniards became acquainted with a hard green stone, highly valued by the natives, and called by them "chalchihuitl." Although a number of different substances were probably embraced under this head, yet a large number of objects of jade which have been found in Mexico proves that the ancient inhabitants were acquainted with this material. These have been examined by a number of authorities † and are in general of jadeite, though a few seem to be of nephrite. Most of them come from the State of Oaxaca.

Central America also furnishes objects of jadeite which closely resembles that of Mexico. Specimens investigated by Clarke and Merrill ‡ come from Costa Rica, Nicaragua, and Guatemala. Those from Costa Rica are not only the most numerous, but also the finest.

Pebbles of a green, opaque, jade-like stone, capable of a very fine polish, are said to be found on the beach at Port Royal, Jamaica.§ These are said to be the same stone out of which the Indians made their hatchets.

Several celts and an idol are reported by Fischer and Meyer as coming from various islands of the West Indies, but their real provenance seems to be uncertain.

From South America celts and other objects have been

* Meyer. *Das Ausland.* June 4, 1883.

† Damour. *Comptes Rendues.* XCII. p. 1312, 1881.
Meyer. *Nephrit und Jadeit Objecte.*
Clarke and Merrill. *Proc. U. S. Nat. Mus.*, 1888, p. 121.
Arzruni. *Zeit. für Kryst.* 1885, p. 540.

‡ Clarke and Merrill., *op. cit.*, p. 124.

§ *Nat. History of Jamaica*, by Sir Hans Sloane, 1820.

described by Fischer and Meyer. They come from a few localities in Colombia, Venezuela, and Brazil, and are all of nephrite. A green stone, called Amazon-stone, is mentioned by several writers, as far back as Buffon and Humboldt, as coming from Guiana and Brazil, but its nature is uncertain. An olive-green jade is also stated to have been found on the sea-coast of Peru by La Condamine.* A stone axe brought by Humboldt from Peru was thought by Fischer † to be probably jadeite.

From New Guinea (Papua) a number of axes of jadeite and chloromelanite have been described. Whether the raw material is derived from that island or not is not known. It is of interest to note, however, that chlorite schists have been noticed at Humboldt Bay,‡ so that it seems possible that they are of native origin.

Implements and ornaments of jade have been reported from Java, Otaheiti, the Marquesas, New Hebrides, and elsewhere in the Pacific, but of their occurrence and real provenance practically nothing is known. The same is true of the few objects reported from various parts of Africa.

GENERAL DISCUSSION.

Distribution of Jade.

From the facts regarding the occurrence of jade set forth in the preceding pages, we may draw the following conclusions as to its distribution :

In the first place it is evident that neither nephrite, nor jadeite, is of common occurrence. This is especially true of jadeite. So far as known at present nephrite occurs *in situ* only in the K'un Lun Mountains, Central Siberia, Silesia, Alaska, New Zealand, and New Caledonia, and probably India ; while localities, indicated by boulders and worked objects found, probably remain to be discovered in Sweden and elsewhere in Europe, as well as in China, the T'ian Shan Mountains, the other points in Asia. Jadeite

* Buffon. *Hist. Nat. des Min.* IV. p. 17, 1798.

† Fischer., *op. cit.*, p. 196.

‡ Meyer. *Jadeit und Nephrit Objecte*, p. 51 ff.

has so far been found *in situ* in Burma only, though possibly also in India, and Little Tibet, and jadeite-like rocks occur in Piedmont, while worked objects point to localities in Mexico and Central America, New Guinea, and Europe. It is decidedly unfortunate that all of these known localities, with the exception of Silesia, are in regions difficult of access, and in which the geological conditions are comparatively little known.

A second conclusion is that nephrite and jadeite are, as a rule, found to occur independently of each other in separate localities. It is true that there are exceptions. Some of the sections examined by Iddings and already described in this volume, as well as the chemical analyses, show the the presence of both minerals in the same specimen. Schoetensack* describes specimens brought back from Turkistan by von Schlagintweit which consist partly of jadeite and partly of nephrite; Bauer† speaks of "jadeite embedded with nephrite in the crystalline schists of Turkistan"; and other instances might be given.

These facts are of great interest as forming the basis of Iddings' theory that nephrite is sometimes derived from jadeite by secondary metamorphic processes of uralitization and chemical replacement. But the general statement remains true that at certain localities nephrite predominates to the total, or almost total, exclusion of jadeite, while elsewhere exactly the reverse holds good, jadeite being found alone or with only very subordinate amounts of nephrite.

The third conclusion to be drawn is, that, as compared with nephrite, jadeite is of very rare occurrence, that is, *in situ*. This is not only of great interest from an artistic and archæological standpoint, but is closely connected, as we shall see, with the question of the origin of the two minerals.

Geological Conditions of Occurrence.

Though the occurrences of jade are few and not yet, in most cases, satisfactorily investigated, yet we are not left

* Schoetensack, *op. cit.*, p. 8.

† Bauer, *op. cit.*, p. 104. He refers possibly to Schoetensack's observations.

in much doubt as to the general character of the geological conditions. The testimony of the observations, both in the field and with the microscope, is unanimously in favor of the view that both nephrite and jadeite belong to the series of crystalline schists. That is, they owe their present characters to changes induced in the original rock bodies through pressure, heat, etc., consequent on crustal movements, these changes being known collectively as metamorphic. This is a fact universally recognized by petrographers, as is shown by the position assigned them in all the petrographic works dealing with the subject.

For the petrographic details which lead us to this conclusion the reader must be referred to the papers of Iddings and Pirsson in this volume, to those of Arzruni, Bauer, Traube, Clarke and Merrill, and others cited in the preceding pages, and to standard works on rocks, such as those of Zirkel and Rosenbusch.

The geological evidence is set forth in the preceding pages, but it may be of use to summarize and make a few remarks on the various occurrences.

As regards the Tammaw (Burma) occurrence Noetling is in some doubt as to its character. Bauer's evidence, however, is sufficient to remove these doubts, which are largely due to the difficulties of observation in that region, and to assure us that the rock belongs to a metamorphic complex, and occurs in connection with serpentine of a metamorphic character. Attention must again be called to the presence here of glaucophane-schist and a hornblende-albite rock, the importance of which will be brought out subsequently.

The evidence as to the jade occurrences at Rewa in India is also conclusive. While there is doubt as to whether the jade here is a nephrite or jadeite, yet the association at the hill-section at Pipra is undeniably of a metamorphic character, and these localities are all in a region of gneiss. The important feature of the occurrence of corundum with the jade must be recalled.

The observers to whom we are indebted for our knowledge of the Turkistan localities—von Schlagintweit

Cayley, and Stoliczka—differ, it is true, in certain small details. These discrepancies may be explained by the hurried nature of their observations and by the absence of petrographic and mineralogical study of the materials.* In the main, however, and in the essential features, they are all very closely in accord; and their observations prove conclusively that the jade is part of an extensive metamorphic complex, associated with gneiss and mica and amphibole schists.†

The observations of Jaczewski in the Sayan Mountains in Siberia show conclusively that the nephrite occurs in a region of argillaceous and actinolite schists, and in association with serpentine, magnetite, and graphite. In fact, this author states definitely that the actinolite schists have been changed into nephrite. It would be of very great interest to have a more detailed account of this occurrence.

The observations and descriptions of Traube establish clearly and in great detail the passage of gneiss and other rocks into nephrite, in an area which is metamorphic. It may also be mentioned that the probable derivation of the German boulders from the metamorphic rocks of Scandinavia is urged with great force by Credner.

The New Zealand, New Caledonian, Alaskan, and British Columbian occurrences are, unfortunately, of little use, owing to the paucity of details, but the few which are given serve to strengthen the view that the nephrite here is of metamorphic origin.

The Bishop Collection furnishes very good examples which illustrate the metamorphic character of these rocks. In the majority of the worked pieces this is not evident to the naked eye, being visible only in thin section under the microscope, but the large cylindrical brush-holder No. 3052 shows traces of a schistose structure. Certain of the "tomb pieces" (*e. g.*, 13158 and 13168) show clearly a

**Cf.* Beck and Muschketow. *Op. cit.*, p. 70.

† The observations and more recent petrographic knowledge of Stoliczka, seem to show that the "greenstones" of von Schlagintweit are really amphibole schists, and not igneous diorite.

streaked mixture of colors, closely approaching that produced by shearing forces.

A very distinct and well-marked schistosity is, however, shown by many of the archæological pieces (*e. g.*, 13221, 13227, 13229, 13230, 13243, 13251 and 13429), where the schistose structure has evidently been taken advantage of in fashioning the article. This structure is especially well brought out by weathering (Nos. 13227, 13229, 13251).

The same structure is very clearly seen in many of the rough pieces (*e. g.*, 13189, 13210, 13212, 13334, 13335), the last two especially (both from Alaska) exhibiting it very beautifully, both on the rough surfaces and on the polished faces, on the latter being seen the fine, wavy lines produced by cutting across the corrugations.

Discussion of the Origin of Jade.

This subject has been already dealt with in this volume, by Pirsson and Iddings, but the facts brought out by the review of the geological occurrences lead me to make a few remarks on this topic. The metamorphic character of both species may be accepted without question. This is an important point gained, but only throws the question of their origin back one step. Before undergoing metamorphism what were they? Were they sedimentary or igneous rocks?

As far as jadeite is concerned, the clear and logical paper of Pirsson, together with the remarks of Iddings on this subject (both having been written independently of each other), can leave no doubt that jadeite is a metamorphosed soda-rich, igneous rock, originally a nepheline-syenite, a phonolite, or a tinguaite. This view has been so forcibly brought out by the two writers just mentioned that I need add nothing to their remarks on this point.

With nephrite, however, the case is quite different. In chemical composition it does not, like jadeite, resemble very closely any of the igneous rocks, being distinguished chiefly through its very low alumina; though there is much analogy in this respect with the websterite* of

* G. H. Williams. *Amer. Geol.* VI. pp. 42 and 44, 1890.

Maryland and North Carolina, which is an igneous diopside-bronzite rock with granitic structure. It also resembles, in general features, the pyroxenites, etc., though in these, as a rule, the content in alumina is much higher.

Arzruni, it will be recalled, divided the nephrites into primary nephrites and those derived from pyroxene by uralitization; by pyroxene meaning not jadeite, but diopside. Iddings shows that in many cases nephrite is undoubtedly derived from jadeite. He does not, however, deny that it may not be so derived, but may in some cases be the product of metamorphism of an original diopside or amphibole rock, itself igneous or metamorphic. In such a case it preserves essentially the *chemical* character of the rock which produced it.

Traube's descriptions leave little or no doubt that at the Silesian localities the nephrite is not derived from jadeite by metasomatism (the chemical interchange of matter), but that it is here derived from either an orignal pyroxene (diopside) rock, or partly, as far as can be judged, through the further metamorphism of an amphibolic rock. At the Indian localities and in Siberia the evidence goes to show that here also the nephrite is not derived from jadeite; since at both localities specific mention is made of hornblende rock passing into jade.

It is true that the chemical analyses of material from these localities, as well as from New Zealand and New Caledonia, show small amounts of soda, which, according to Clarke's reductions of the analyses, is present in molecules of glaucophane and riebeckite, the amounts of these being always very little. It is to be remembered, however, that soda is almost constantly present in igneous rocks, though sometimes to a very small extent, even in the pyroxenites and other basic rocks, so that its presence here is no valid argument for an origin from jadeite. In all these cases there seems to be little reason to invoke such a decided and complete interchange of substance as that involved in the change of jadeite into nephrite.

At the K'un Lun localities, however, the case is different. Here the observations of Schoetensack and Iddings, as well as the chemical analyses, show that jadeite is present along with the nephrite; and the microscope showed Iddings that there really had been such a passage of one into the other. In fact, the best examples found by Iddings of a change of jadeite into nephrite are specimens from Turkistan and China, the material of the worked objects of which latter country being undoubtedly derived, at least in the greater number of instances, from Turkistan and Burma. In Burma, also, there is evidence that the jadeite has to a certain extent been changed into nephrite.

In this connection it is of interest to note that all the three observers of the K'un Lun quarries, von Schlagintweit, Cayley, and Stoliczka, speak variously of an "altered" or a "soft, friable substance—evidently a product of decomposition by percolating water," "a white, powdery clay," or "veins of a pure white, apparently zeolitic mineral," appearing either between the nephrite and the schist or in close connection with it. A similar substance is also mentioned by Noetling as occurring at Tammaw along with the jadeite.

Now, in the replacement of alumina and soda by magnesia and lime, which is necessitated by the change of jadeite to nephrite, the two last would have been provided in abundance by the amphibolic schists and the serpentine. The alumina and soda would not entirely disappear, but traces of them should be met with somewhere. These white or light-colored bands, then, may reasonably be supposed to be derived from the replaced alumina and soda of the original jadeite. They may be zeolitic, as suggested by Stoliczka, in which case they might be largely natrolite, a hydrous silicate of soda and alumina; or they may be, and more probably are, chiefly one of the kaolins, hydrous silicates of alumina alone, the soda having been removed by solution. This is, of course, largely hypothetical, since we have no detailed chemical or mineralogical description of these bands, but the suggestion seems to be a reasonable one. It is to be remarked, in this connection, that there is no mention of the presence of such material at either of the three localities where the nephrite is evidently not derived from jadeite.

Having thus gained a general and probably fairly correct notion of the origin of jadeite and nephrite, one of the reasons for the rarity of their occurrence becomes evident. Leaving apart the metamorphic processes involved, of the exact nature of which for the production of the characteristic qualities of jade we are not yet in a position to speak, we can examine the matter from the point of view of the rocks from which jade is derived.

In regard to jadeite, the nepheline-syenites and phonolites from which it is derived are among the more rarely occurring of all the igneous rocks; so that its rarity naturally follows. Following the same line of argument, the occurrence of jadeite-derived nephrite would naturally be also rare, possibly even more so than jadeite. Igneous rocks from which nephrite could be derived without radical change of substance, such as the websterites, cortlandites, and other pyroxenites, hornblendites, or peridotites, are also rare, though occurring more frequently than the nepheline-syenite family. The amphibolites and other such schists are also of extremely common occurrence. We would consequently expect to find nephrites more often than jadeites, and the fact that they are so found is, in a way, evidence that in the majority of cases nephrite is not derived from jadeite.

Probable Localities elsewhere.

While we are dealing with the localities of jade, it will probably be of value to those interested in jade to indicate where nephrite and jadeite may reasonably be expected to occur *in situ*, and to point out the rocks which are likely to occur in connection with them, and whose presence may indicate their possible discovery.

It may be stated with confidence that both are only to be looked for *in situ* in regions of crystalline schists, and more especially, perhaps, in regions of amphibole schists; though they are known to occur also in connection with gneiss and mica and chlorite schists.

Nephrite is undoubtedly far more abundant than jadeite, a point which has been already touched on, and it would naturally be looked for in regions where so-called basic rocks occur, *i. e.*, rocks high in iron, lime, and magnesia. On the hypothesis that it is ultimately derived from igneous rocks, we would expect to find it in metamorphic regions where gabbros occur, as in Silesia, or regions where olivine rocks or serpentine are found, as in New Zealand, or along with pyroxenites or hornblendites.

It would take up too much space to give a list of the localities of such rocks, and, furthermore, it seems probable that it will be found in quantity only in regions at present but little known. It must be confessed, however, that its discovery at Jordansmühl and Reichenstein shows that it may be found eventually at localities with which we are supposed to be well acquainted, as, for example, possibly the Adirondack region of New York State, and North Carolina.

Jadeite, being derived from rocks of the nepheline-syenite family, will, as has already been pointed out, be much rarer than nephrite. If nepheline-syenites or ancient phonolites occur in metamorphic areas, and if their advent is prior to the general metamorphism, the occurrence of jadeite would be not unexpected.

There are, however, two additional facts of some interest to be noted here. In the first place, we have already seen that glaucophane-schists occur in connection with jadeite in Burma and Piedmont. Although this group of schists has been but little investigated, it seems probable that they are the result of the metamorphism of basic, igneous rocks, of the general composition of gabbro, which are sometimes found in association with the family of the nepheline-syenites. These schists are of a peculiar blue color, often running into epidotic and garnetiferous rocks, so as to be usually easily recognizable, and their presence in any region would lead us to hope for the occurrence of jadeite *in situ*.

These peculiar schists are of very rare occurrence, and their chief localities may be mentioned. These are Syra, and other islands of the Ægean Sea, together with various localities along the east coast of Greece ; Isle de Groix in Brittany (Morbihan),* Piedmont, Croatia, Corsica, and Andalusia ; Island of Shikokū, Japan ; and in California.

The second point to be mentioned is a possible connection between the occurrence of corundum and jade. Corundum occurs as a primary constituent of various igneous rocks, in crystalline schists, and in limestones. The igneous rocks in which it occurs differ considerably. In some cases they are very basic, as the peridotites of North Carolina and the cortlandites, etc., of Peekskill, N. Y. But the rocks which are of especial interest to us here are the nepheline-syenites and other alkaline plutonic rocks. Such corundum-bearing rocks occur in the Urals,† in Ontario,‡ in India,§ and elsewhere, though they are very rare.

A discussion of all these localities would lead us too far, and we need only note here that the soda-rich rocks are generally high in alumina and more or less apt to carry corundum, though its occurrence in them is as yet, and probably will always be, a great rarity. It follows, however, that corundum may be (but by no means necessarily is) an indication of the presence of soda-rich rocks, and, hence, in metamorphic regions, of possible jadeite.

As an instance of such an association, we may note that south of the jade mines of Tammaw in Burma corundum occurs as gem material in various localities, being found in a limestone which Judd has shown to be probably derived from an original igneous rock.‖ These rocks were basic, and are correlated by Holland with the corundum-bearing anorthite rock of the Salem district in Madras, and possibly with those of Ceylon. They seem

* The finding of worked jadeite and chloromelanite objects at Morbihan and Dordogne is very suggestive in this connection.

† Morozewicz. Tschermak's *Min. Pet. Mitth.* XVIII. p. 215, 1899.

‡ Coleman. *Jour. of Geol.* VII. p. 437. 1899.

§ *Manual of the Geology of India.* Econom. Geol. Part I. T. H. Holland. Corundum. Pp. 11 and 37. 1898.

‖ Judd and Brown. *Proc. Roy. Soc.*, No. 345, 1895. Cf. *Amer. Jour. Sci.* (4). Vol. I. 64, 1896.

to correspond closely to the corundum-anorthite "kyshtymites" of the Urals, recently described by Morozewicz in the paper already cited. These are high in lime, and are basic phases of rocks very rich in soda and alumina. Possibly, as suggested by Holland, the Rewa occurrences are of a similar character, in which case the jade would be a jadeite; though, as already noted, the probabilities seem to be in favor of its being nephrite, especially since corundum is known to occur in basic, soda-free rocks.

It must be repeated that all the above is highly speculative, and is inserted chiefly as being of suggestive interest; but, from the facts given, the conclusion may be drawn that the occurrence of nepheline-syenites, glaucophane-schists, or corundum, in metamorphic regions, would suggest to the traveller the possible presence of jadeite. The hypothetical character of these remarks, however, emphasizes the extremely scanty and unsatisfactory character of our knowledge regarding the occurrence and origin both of jadeite and nephrite, and shows the necessity of much more detailed and careful observations before we attempt to generalize with confidence.

MINERALS SOMETIMES MISTAKEN FOR JADE.

While it is the province of this volume to treat simply of the mineral *Jade* (nephrite and jadeite), it has been thought well to make mention of such minerals as are frequently mistaken for jade, and at the same time to furnish a few ready and simple means of detecting them without injury to the article examined.

The materials that have been mistaken for nephrite and jadeite are of three kinds :

1st. Natural minerals that resemble nephrite or jadeite in color, toughness, or lustre ;

2d. Minerals that have been stained or colored to imitate jades, sometimes with considerable success.

3d. Artificial imitations of jade, such as the glass mixtures.

The natural minerals that resemble jade, either nephrite or jadeite, and have been confused with them, may be grouped in three classes :

(A) Those composed of silica alone, *i. e.*, forms of quartz, chalcedony, or jasper. In these the color may be due either to the presence of small amounts of oxide of iron or of chromium, or to the mechanical inclusion of considerable amounts of other green minerals, such as prochlorite, delessite, etc. These are all readily distinguishable from true jades.

(B) Compounds of silica, *i. e.*, the silicates. This is a very numerous and complicated body of minerals, to which both jadeite and nephrite themselves belong ; many of them are closely related to each other and to the true jades, and are similar, not only in aspect, but in structure and composition. Hence, there are several members of the silicate group that are not easily distinguishable from jade, and their discrimination requires great care and experience. Others, while of similar aspect, can be readily determined.

(C) Minerals which do not contain silica—phosphates and carbonates. These are few—turquoise, malachite, and mossotite—all easy of recognition as not jades, though resembling some of them in color.

Among all the minerals here described as having been confounded with true jade, or liable to be confounded with it, only a few are incapable of ready distinction by the collector, by means of tests that are simple and easy. The hardness and specific gravity will decide in most cases, without recourse to any more elaborate methods.

As has been shown in the preceding pages, the true jades range in hardness from 6 to 7, and in density from 2.9 to 3.4. Jadeite is the harder and the heavier species, its hardness being 6.5 to 7, and its density from 3.20 to 3.41, as extremes; nephrite having a hardness of 6 to 6.5, and a density between 2.90 and 3.18. Any minerals, therefore, that fall outside of these limits, in either respect, are not jades.

All the forms of quartz have a hardness of about 7, but their specific gravity is from 2.59 to 2.66; some of the jaspers are at times a little higher; but much below nephrite, while the hardness compares only with the hardest jadeite. To the touch, also, there is a resistance of surface that is quite different from the smooth, unctuous feeling of the jades. Beryl, or emerald, with a specific gravity of 2.66 to 2.80, is far harder than any jadeite—7.5 to 8—easily scratching the hardest jade specimens. Amazon-stone, though in hardness about the same as nephrite, 6 to 6.5, has a density of but 2.54 to 2.57. Labradorite is a little heavier, 2.70 to 2.72, but much less hard, 5 to 6. Any of the feldspar group that might possibly be encountered will fall between these limits; and their strongly marked cleavage-tendency, often visible, and their total absence of fibrous or matted structure, are characteristic features of distinction.

Among minerals confounded with jade, perhaps the first place, both historically and in closeness of resemblance, belongs to that known as *Saussurite*. It has been called *jade tenace* and *jade de Saussure*, and is a compact, tough, and heavy mineral, with splintery fracture, in hardness (6.5 to 7) and density (3 to 3.4) almost identical with jadeite; ranging from very translucent to nearly opaque, and in color from white to gray, grayish-green, and bluish-green. It was first noticed by H. B. de Saussure, in 1780 (*Voy. Alpes*, I, 112), and by him called jade; the name Saussurite was given to it in 1806, by his son Theodore (*Jour. Mines*, XIX, 205). It is a Swiss mineral, occurring largely in boulders distributed in the glacial period over the Geneva region and the Rhone valley. Guyot traced these to their source, 150 miles distant, in the chain of the Saasgrat. The late Professor T. S. Hunt, in 1858, recognized it as a soda-bearing variety of the mineral zoisite, and it is generally so regarded. But it is an alteration product, and, like all such materials, is not constant or homogeneous in either structure or composition. Zoisite is generally present in it, but sometimes replaced by epidote, while more or less feldspar and other accessory minerals are intermingled. It has been derived from feldspar by a chemical process known as "saussuritization." The texture is often so exceedingly fine-grained as almost to defy microscopic determination of its components.

Next in point of resemblance to jade is the mineral known as *Fibrolite*, called in the United States sillimanite. It was a favorite material with prehistoric man in Central Europe, and has been mistaken for jadeite, which it closely approaches in aspect and structure. The density, 3.23 to 3.24, and the hardness, 6.5 to 7, as with saussurite, are about the same; when in a fibrous form it is densely compact and very tenacious, almost as much so as nephrite. It is a pure silicate of alumina (silica 36.8, alumina 63.2), often occurring in radiating or blade-like crystals, and passing into fibrous and massive. In this latter form it was largely wrought in prehistoric times into implements, multitudes of which have been found in France and Spain, and described by Damour, Clarke, Quiroga, and others. To distinguish it from jade, otherwise than by analysis, it may be observed to have a visibly fibrous structure, less confused than nephrite, and less crystallization than jadeite, a lustre vitreous and not horn-like, as with nephrite, and a whiter aspect, inclining to pinkish or flesh color.

In Alaska, the natives of the coast have used quite extensively, for a variety of purposes,—hammers, small celts, knives, scrapers, etc.—the mineral *Pectolite*, in a massive form in which it much resembles jade. This is a silicate of lime and soda, closely related to jadeite (which contains no lime, however), and, like it, belonging to the pyroxene group. It is a mineral of the igneous rocks, and usually occurs in tufts and radiated masses of beautiful white, needle-like crystals; but is sometimes compact and massive. The specific gravity is from 2.6 to 2.87 (as in the Point Barrow specimens), close to that of nephrite; but the hardness is much less, being only 5, so that it is easily distinguished by being scratched with a knife or with a nephrite point. Before the blow-pipe, also, it fuses readily to a porcelain-like globule, and the flame is colored intensely yellow, indicating the presence of sodium. Though usually a very white mineral, that from Alaska has also many shades of green and yellow-green, and even when white always presents a distinct grayish-green tint. It is remarkably tough, and well suited for hammers.

Another mineral of the pyroxene group that is occasionally taken for jade, is *Wollastonite*—a simple silicate of lime with a very small percentage of magnesia and iron oxides, differing from pectolite just described in the absence of soda, and from jadeite in the absence of both alumina and soda. It is usually crystallized or has a marked crystalline structure, passing into cleavable massive and fibrous. In the last-named condition it might, like pectolite, easily be taken for jadeite; though it is not known to have been used for implements, as pectolite has. It has very nearly the toughness of nephrite, and about the same density—2.8 to 2.9; but its hardness is much lower—4.5 to 5, so that it may very easily be distinguished by this test alone.

There are two or three green to white minerals, belonging to the group known as feldspar, that sometimes resemble forms of jade. Among these may be noted amazon-stone, already mentioned, euphotide, and saccharite. The feldspars are compounds of silica with alumina and one or more of the alkaline oxides—potash, soda, and lime. *Amazon-stone* is a bright verdigris-green, or bluish-green variety of the species called microcline, a triclinic feldspar, containing 16 or 17 per cent. of potash. It is not a common mineral, though found occasionally in various countries. The name of amazon-stone is recent, and was given to it when brought from the region of the Amazon, in Brazil, in the form of numerous archæological ornaments.

Amazon-stone, however, is easily distinguished from any of the jades by its much lower density, which varies from 2.54 to 2.57. Hence it is easily determined either by weighing or by the Sonstadt solution. The hardness is 6.5, that of nephrite; but it differs in its lustre, which is vitreous rather than unctuous, and in possessing a very marked and perfect cleavage, which can generally be detected by the eye without breaking the specimen, and an aspect, when closely examined, of fine parallel lines traversing the mineral.

Among the forms of *Jade ascien*, which in former times served the natives of New Caledonia for the manufacture of their beautiful green adzes and beads, and was prized as an article of trade or of plunder among the inhabitants of neighboring islands, is apparently a green lamellar feldspar of the variety termed euphotide, somewhat altered, however, from its original condition. It is described as a beautiful green, translucent rock, of greasy lustre and splintery fracture, retaining in part the laminated aspect of a true euphotide which occurs not far away.

One more feldspar may be noted here, as having been occasionally taken for nephrite when in rolled pebbles or fragments. This is *Labradorite*, another triclinic soda-lime feldspar, of dark gray or greenish color, with frequently a very beautiful play of iridescent hues, especially blue and green. This feature has given it the name of opalescent feldspar, and renders it a material of great beauty in the ornamental arts. The lustre is pearly, passing into vitreous or sub-resinous. It is rather a rare mineral, and may be distinguished from the jades by several features, *e. g.*, its lower hardness (5 to 6); its lower specific gravity (2.70 to 2.72); and its evident cleavage structure, as well as, generally, by its play of colors.

Two very important silicate groups, closely related in chemical and physical characters, and embracing numerous varieties under each, are pyroxene and hornblende (or amphibole). Jadeite is related to the former, though distinct, and nephrite has been classed with the latter. There are some varieties of pyroxene, however, that closely approach the jades in aspect, and have been described as such, and some that seem almost intermediate varieties. Such are the "jades" of St. Marcel, Val d'Aosta, and Fay, and certain forms of diopside.

A grass-green pyroxene, granular to foliated, called *Omphacite*, intermingled with garnet, forms a peculiar and beautiful rock known as eclogite, often interlaminated with a bright green amphibole called smaragdite. This omphacite has a specific gravity of 3.2 to 3.3, about that of jadeite, a hardness rather lower, 5.5 to 6, and the cleavage of pyroxene. To it have been referred two noted instances of supposed jades—those of Val d'Aosta and St. Marcel.

A pebble found by Dr. Pitorre in the Val d'Aosta, on the road to Little St. Bernard, had a hardness, density, and fusibility similar to jadeite, a beautiful grass-green color, and a fibro-crystalline structure. It much resembled some Chinese specimens, and was believed at first to be identical with them.

A similar stone was found at St. Marcel, in Piedmont, by Herr Bertrand de Lon, forming a small vein in white quartzite. Fischer regarded both of these as omphacite, to which they approach somewhat on analysis. Meyer (*Jadeit und Nephrit Objecte*, II, 13) considers them to be intermediate substances between jadeite and nephrite.

The Fay specimen was a green crystalline mineral from the village of Fay, in the department of Loire Inférieure, France, not far from Nantes. It contained red garnets, and formed a vein in gneiss; the hardness, density, and fusibility were nearly the same as in jadeite. From its mode of occurrence, Fischer referred this substance also to omphacite, but an analysis by Damour showed it to be quite different, and nearer to some of the true jadeites, especially of the chloromelanite type.

Diopside is a true pyroxene, in color varying from white through yellowish and grayish to pale green, and sometimes dark green. It is usually found in prismatic crystals, which, when transparent and of fine color, have sometimes been cut as green gems; but it also occurs in granular, columnar, and lamellar masses, and has then in some instances been taken for jade. The density is 3.2 to 3.38, and the hardness 6 to 6.5. The principal character by which it may be distinguished from jadeite is its facile cleavage, and also its usually greater translucency. On analysis it yields silica 55.6 per cent., alumina 25.9, and magnesia 18.5; while jadeite has less alumina, almost no magnesia, and considerable soda.

Nephrite, as above stated, is a variety classed with the amphibole or hornblende group; another variety is known as *Actinolite*, very closely akin to nephrite, and in some of its forms it has been taken for it. Actinolite is usually in slender crystals, radiating or matted together, and passing into fibrous and asbestos-like forms; the color is light to dark green. Some specimens of a massive, pale green mineral, from the Rylshytte mine, near Garpenberg, Dalecarlia, Sweden, were sent for analysis to Meyer, Frenzel, and Cohen, under the supposition that they might be nephrite. Chemical and microscopical examination showed them to be dense actinolite, rather too soft and coarsely granular for nephrite, and without its typical fibrous tufted structure.

At the head of all green minerals, for beauty and value, stands the *Emerald*, a variety of beryl. It has been prized as a gem from the remotest antiquity, and maintains its rank unrivalled and unimpaired. So far as any resemblance to the jades is concerned, it is only the rougher and more opaque forms of emerald that could be so confused, but with those it is quite possible, and hence its mention here.

Beryl is a silicate of alumina and the rare earth glucina, containing silica 67 per cent., alumina 19, and glucina 14. It varies from very pale green to light blue and to golden-yellow, and all intervening tints, and if a small amount of oxide of chromium is present, the green becomes deep and brilliant, producing the emerald. The hardness is 7 to 8, and the specific gravity 2.7 ; the lustre is vitreous, and sometimes resinous. The mineral crystallizes in six-sided prisms, only rarely becoming columnar or massive. It is generally translucent, varying from transparent to opaque ; and brittle with conchoidal or irregular fracture.

In massive pieces, when opaque or sub-translucent, either beryl or emerald may resemble nephrite ; and there has very likely been confusion between them in the case of some archæological objects. But beryl, or emerald, can very easily be distinguished from any jade, (1) by its greater hardness, readily scratching both nephrite and jadeite ; (2) by its less density, 2.6 to 2.8 ; and (3) by the absence of cleavage and also of anything approaching the fibrous texture of nephrite.

One of the minerals that most frequently resemble certain of the jades is the silicate of magnesia, known as *Serpentine*, and especially a white or pale greenish variety called bowenite. Serpentine is abundant in many countries, and has an endless variety of shades of green, from pale to yellow-green and waxy brown, olive, bluish-green, to almost jet-black, often intermingled in spots and clouds of different tints. It was rarely used for celts, as it is not very hard, and somewhat fragile. But many art objects have been made of serpentine, which to the unpractised eye easily pass for nephrite. Its inferior hardness, however, never more than 6, and usually between 4 and 5; its low specific gravity, never above 2.65; its greasy rather than unctuous lustre and feel; and the readiness with which it loses its lustre before the blowpipe, and generally turns whitish-gray, readily distinguish this mineral in its many varieties from both nephrite and jadeite.

Most of the serpentines are opaque, but the variety known as precious or noble serpentine is translucent, and makes a beautiful ornamental stone, but very soft,—2.5 to 3,—scarcely as hard as ordinary marble. Antigorite is a lamellar variety from the Antigorio Valley, in Piedmont, sometimes of a rich leek- or emerald-green, by transmitted light, but also not harder than 2.5. Williamsite is a beautiful variety from the chrome-mine at Texas, Lancaster County, Pennsylvania. It is harder—4.5—and of exceedingly rich colors, emerald-green and blue-green, sometimes mingled with white, strongly resembling some of the handsomest of Chinese jades. It probably owes its peculiar beauty of color to oxide of nickel, and sometimes contains small disseminated crystals of chromic iron.

The variety *Bowenite*, however, is the form of serpentine that has really been confounded with nephrite. It is a compact variety, white and grayish-white to pale green. It was found at Smithfield, Rhode Island, by Geo. T. Bowen, and described by him as nephrite, in 1822 (*Am. Jour. Sci.*, V, p. 346). Dana, however (*Syst. Min.*, p. 265, 1850) recognized its character, and gave it the name of bowenite. It has the unusual hardness, for a serpentine, of 5.5 to 6, a density of 2.6 to 2.8, and a greater toughness than probably any variety of this mineral elsewhere known. It is massive, very fine granular in texture, and closely resembles jadeite.

The "*Tangiwai*" variety of New Zealand greenstone, usually classed as jade, is apparently the same as bowenite—a hard, compact serpentine. It has the same hardness, and very nearly the same density, but is bright green and translucent. This mineral has been frequently confounded with jade.

A jade-like stone called *Sang-i-yashm* by the Persians is only another form of this same bowenite. It varies from dark grayish-green to pale sea-green, mottled with white, and is worked into small articles of ornament at Bhera in the Punjaub. It has, however, the inferior hardness (5) and density (2.59) which belong to the serpentines, and readily distinguish it from any of the true jades.

Among the numerous varieties of non-crystalline or cryptocrystalline quartz, which vary from translucent to opaque, and present many tints and shades of color, there are several green varieties that have been, and may be, readily confounded with jade. Four of these may be briefly referred to here, and their distinctive characters indicated. These are prase, chrysoprase, plasma, and green jasper.

Prase is a dull-green, semi-crystalline quartz, sometimes approaching leek-green. It has never been much valued for an ornamental stone, as its colors are not rich or clear, but its aspect is not at all unlike certain of the jades.

Plasma is a closely related variety, often spoken of as leek-green, sometimes even emerald-green, translucent or sub-translucent. From its frequent bright green tint, almost the peculiar yellowish or golden-green of some of the finest nephrites, especially as seen by transmitted light, plasma is easily mistaken for them, but is readily distinguished.

Chrysoprase is another variety of chalcedony (or carnelian), a translucent cryptocrystalline quartz,—colored a rich, delicate apple-green by a small quantity of oxide of nickel, from one per cent. to four-tenths of one per cent. of which is present. It is a beautiful stone, but of rare occurrence.

Green Jasper is another mineral of the same general group, but the opaque and amorphous variety of quartz, lacking the translucency of the previous kinds. The coloring matter is generally oxide of iron, the protoxide giving the green tints, and the sesquioxide the yellows and reds that appear in many jaspers. Sometimes the two are mingled in bands or spots, as in the dark-green variety flecked with bright red specks or drops, known as bloodstone or heliotrope—though of this, see further on. Green jasper has often been confounded with jade; so that many of the earlier references to jasper may have been really to jade, and *vice versa.*

Besides these varieties, there are several that resemble them, but owe their green tints not to the presence of coloring oxides, but to the mechanical inclusion of other minerals. Much green jasper, particularly the bloodstone variety above mentioned (properly called *Heliotrope*), owes its color to the presence of a large amount of dark, green delessite (a chlorite-like mineral—a hydrous silicate of alumina, magnesia, and iron) included in the chalcedonic base. In the same way, some prase is a chalcedony colored by minute inclusions of prochlorite (a silicate similar to delessite). Such is probably the supposed jade from Corsica, which was mentioned as a locality for it by Lenz, in 1800, and von Leonhard, in 1808. On investigation of a specimen in the University Collection at Strasbourg, labelled "Nephrit aus Corsica," Fischer found a prase-like mineral, which, however, gave an uncertain result upon analysis, not corresponding to nephrite, and very far from prase. It showed considerable alumina, magnesia, and iron oxide as present, and is probably a quartz with inclusions of some chloritic mineral. Occasionally, quartz is so filled with prochlorite as to resemble some of the dark varieties of chloromelanite; and if either quartz or chalcedony contains such minerals in large proportion, as the specific gravity of prochlorite varies from 2.8 to 2.96, the specific gravity of the mixture might easily be raised to very nearly that of nephrite.

Other varieties of this kind are the so-called Chinese *Moss-agate*, a very beautiful stone, really, in most cases, from India, near Ahmedabad. Here a translucent white or bluish chalcedony, is filled with green, moss-like, or sea-weed-like markings, which were formerly supposed to be of vegetable origin, but are merely fine crystallizations of metallic oxides, chiefly iron, forming patterns like those of frost-work on a window-pane in winter. At times, these become so dense as to fill up the stone, which then presents a homogeneous, dark, green color, like a rich jade.

Many specimens of so-called "imperial jade" (the *fei-ts'ui* of the Chinese) have proved on examination to be the beautiful green *Aventurine.*

All these more or less jade-like varieties of quartz may be distinguished by characters easily determined. As compared with either nephrite or jadeite, they have a somewhat greater hardness (7), and a less density (2.6–2.65), and so may be separated from them either by direct weighing or by the Sonstadt solution. The quartz minerals all have a greater resistance to the touch, and there is nothing like the horn-like structure and fracture of nephrite or the crystalline texture of jadeite. The structure of the jaspers is wholly amorphous, and that of the other varieties described is cryptocrystalline. In microscopic examination it is found to possess the optical properties of quartz, which belongs to the hexagonal system.

An exception may be noted in regard to the density, in the cases above referred to, where a large amount of included foreign matter of greater density may raise the specific gravity above that of quartz to nearly that of nephrite ; but the other characters remain as means of discrimination for all forms of quartz.

The remaining minerals, except the really difficult ones to be specially noted beyond, are very much softer than any real jades, and can be at once separated. *Agalmatolite* in all its forms, natural or carved and stained for imitation, oncosin, chonicrite, etc., fall under this general statement; their hardness rarely exceeding 3,—often less,—so as to yield to the first touch of a knife. The same may be said of the serpentines, though some of them occasionally have a higher hardness (Williamsite, 4.5), and all are also less dense, averaging from 2.5 to 2.6 in specific gravity. Bowenite alone among serpentines is both hard and heavy enough to have been seriously confounded with nephrite.

The really difficult minerals will now be briefly dealt with; of these there are only a few, as follows:

A delicate, pale-green, translucent mineral named *Prehnite*, after an early discoverer, Col. Prehn, has in some instances been mistaken for jade. It is a silicate of alumina and lime, with a hardness of 6 to 6.5, and a density of 2.80 to 2.95, closely approaching nephrite in both these features. It is light green, or oily green of various shades, but differs from nephrite in its vitreous lustre, and very markedly in its lack of toughness; being so brittle as to break quite readily. It is one of the minerals found in the cavities of trap and similar rocks, and never occurs in large masses, though small pieces of it are sometimes cut and polished for ornamental work. But it is not known to have been used by prehistoric man at all, and is not likely to be met with by collectors, save in the form of pebbles or fragments; though possibly some small Chinese objects may prove to be prehnite.

Epidote is another complicated silicate, somewhat similar in composition to the last, but with more iron and alumina, and little or no magnesia. It has various shades of yellowish- and olive-green, to almost black, and is frequent in prismatic crystals, monoclinic, but very much modified, in metamorphic and sometimes in igneous rocks; also granular and forming at times rock-masses. Its hardness, 6 to 7, and density, 3.25 to 3.5, are close to jadeite, but it has a strong cleavage and a vitreous lustre. Epidote is sometimes one of the minute components of Saussurite, elsewhere described; but it is not a mineral likely to be confounded with jade, save in the following relation: It often occurs intermingled with quartz or with orthoclase feldspar, or with both, at the juncture of a vein in a course granular or pegmatite rock. The fine intermixture of the green epidote with the white or flesh-color of the quartz and feldspar produces a mottled yellowish-green that resembles some varieties of nephrite. As the hardness and density are near those of jadeite, it might be taken for that mineral when the epidote was predominant, and for nephrite if the density of the mixture was brought below 3 by a large proportion of the other minerals. Before the blow-pipe, however, epidote fuses at 3.5 to a dark or black mass that is frequently magnetic—owing to the large content of iron in the mineral. The separate crystals are quite brittle, but as a rock-mass, or in a rock-mixture, it is tough.

Vesuvianite, or idocrase, is a mineral that in massive form has been taken for jade in a well-known instance. It is a complex silicate, of alumina, lime, magnesia, and iron, and is named from its frequent occurrence in the lavas of Vesuvius; but it also occurs in many metamorphic rocks, serpentines, limestone, etc.—usually in square prismatic crystals, but sometimes massive. Its color is brownish-green, olive, yellow-green to brown, or even yellow; hardness, 6.5; specific gravity, 3.35 to 3.45; lustre vitreous, inclining to resinous; fracture sub-conchoidal to uneven; texture brittle. This last feature, and its marked translucency and vitreous lustre are the best external distinctions of idocrase from jadeite, for which it was taken by Fellenberg (*Jahrb. für Miner.*, I, 103, 1889); but it was identified by Damour and others.

In 1887 Berwerth described a jadeite from Borgo Novo, Graubundten (*Ann. Hof. Nat. Mus.*, Wien, 1887, II, hft. 3), and Virchow referred to it from this locality, in the *Zeitschrift für Ethnologie* (561, 1887). It seems, however, that this was a mistake, owing to specimens having been sent for examination from a Professor Stampe, of Borgo Novo, and that the real locality, as announced by von Fellenberg, was in rolled masses in the bed of the Orlegna, near the village of Casaccia, in the Upper Engadine. He and Professor Stampe discovered it in place on the south side of the Piz Longhin, in the Bergellthal, near the foot of a precipitous mountain wall. They found it as a white vein, forming lens-shaped masses in a hard yellowish-gray rock. Subsequent examination of this Piz Longhin material by Meyer and Frenzel (*Neues Jahrb. für Miner.*, 1889) proved that it was not jadeite, but a compact form of vesuvianite.

Agalmatolite, pagodite, or Chinese figure-stone, is one of the minerals most frequently sold to the inexperienced or unwary traveller in China under the name of jade. It is at once distinguishable, however, by its softness. Its structure is very compact, fine, and homogeneous, taking the most delicate tool-marks, and making it an ideal material for carving. Its natural color is whitish, grayish, or yellowish ; but it readily absorbs coloring-matters, and is frequently stained green or greenish to imitate nephrite, sometimes clouded or spotted with brown. Agalmatolite is an altered mineral, derived from two or three species of aluminous and magnesian silicates ; much of it is essentially pinite, though containing a little more silica ; some of it is pyrophyllite, and some is practically steatite (compact talc). In all its forms, however, the hardness is only from 2 to 3 ; so that a mere touch with the knife, or even rubbing with the hand, is enough to identify it and remove all question of jade. The feel is soft and unctuous, and the specific gravity varies between 2.7 and 2.9.

A beautiful variety of what seems to be the same stone is found near Washington, Georgia ; this is often translucent, and of a very attractive bluish-green to emerald-green color. It was carved by the Indians into banner-stones and similar ornaments ; these are sometimes found in ancient graves in Georgia and the Carolinas, and have repeatedly been taken for nephrite.

Turquoise, the Turkey-stone of the sixteenth and eighteenth centuries, was so called from having reached Europe from the East through Turkey. It has been chiefly obtained from mines in Persia, at Nishapur, in Khorassan, though found at a few other points, and it has been used as a gem from very early times.

The proper color of turquoise is sky-blue, inclining slightly to green. But much of it is of greenish-blue and green tints, and the inferior qualities are pale and muddy yellowish-greens. The blue tint so much prized is often readily altered to green, both naturally by exposure to the weather, or even to the air, and artificially by heat; or when worn, by contact with fatty acids, perspiration, soaps, or perfumes; so that turquoises must be kept for some time before mounting for jewelry, to see if this color is permanent, and must be worn with care, especially as to contact with soaps and perfumes, the oils from which are very apt to alter the color.

The ancient Mexicans had a green stone which they prized immensely, and carved into a variety of ornaments and talismans. This they called *chalchihuitl*, and it has figured largely in American archæology. Professor W. P. Blake, on the discovery of the ancient turquoise mines in New Mexico, argued strongly that this was the celebrated and mysterious chalchihuitl (*Amer. Jour. Sci.*, XXV, 227, 1858; and XXV, 197, 1883). Others regard it as rough emerald, and others perhaps jade. The name was no doubt a general term covering several kinds of handsome green minerals, rather than any one in particular.

The green varieties of turquoise much resemble jade, but may be distinguished quite readily in several ways: (1) by the lack of toughness; (2) by inferior hardness, being only 6; (3) by the lower specific gravity, 2.6 to 2.8, easily determined either by weighing or by the Sonstadt solution; (4) by the texture, which is compact and smooth, with no trace of anything either fibrous or crystalline—a scraped surface having the perfect smoothness of soap or ivory when cut with a knife; (5) by the complete absence of cleavage, and almost uniform opacity. Turquoise is a hydrous phosphate of alumina, the color being due to a small amount of copper compound, probably a phosphate.

The celebrated and beautiful stone called *Malachite* is a hydrous carbonate of copper, rarely crystallized, but often fibrous and massive, with a mammillary or "botryoidal" surface. The color is brilliant emerald-green, lighter and darker, frequently finely banded and clouded in different shades, and usually quite opaque. It is found all over the world, but rarely in large masses. All races and periods have known and used it; and some malachite articles have been mistaken for jade. There need never be any question, however, as its hardness is much less (3.5 to 4), easily scratched with a penknife, and its density much greater (3.9 to 4) than either nephrite or jadeite. A drop of nitric or hydrochloric acid at once causes effervescence, liberating the carbonic-acid gas. Its brilliant color, moreover, its opacity, and the very general appearance of fine agate-like bands and lines, concentric or wavy, parallel all through it, in lighter and darker green, are unlike any aspects of jade.

One more mineral may be mentioned as being possibly confounded with jade, but very easily recognized by tests similar to the last. This is *Mossotite*, a rare variety of aragonite, a carbonate of lime, colored a delicate light greenish-blue by a trace of copper. The color is very characteristic of jadeite; but the hardness is only 3.5 to 4, as in malachite, and the acid test acts in precisely the same way, causing effervescence, and showing it to be a carbonate. A lens reveals at once the fibro-columnar structure of aragonite.

Chonicrite, a massive, crystalline-granular to compact mineral, forming seams in serpentine rock on the Island of Elba. It has a specific gravity of 2.91; a hardness of 2.5 to 3, a white color, and a faintly glimmering or silky lustre. To this has been referred, as closely allied, a supposed nephrite found near Easton, Penn., in 1824. Fischer, in 1865, showed it to be near chonicrite, and gave it the name of pseudo-nephrite (*Nephrit und Jadeit*, p. 244).

Possibly in no country more than in China have so many substances been mistaken for jade, due probably to the fact that exact mineralogical knowledge does not exist there. In no country in the world is jade more sought for and used; and at the same time, nowhere have more clever deceptions been practised in the polishing of the surface than in China.

One who is not well versed in the study of jade may be surprised at the absence from the Bishop Collection of what has been so much spoken of from time to time by collectors as *Pink Jade*. In reality, the only specimens of jade that have any approach to pink are the Burmese pieces, in which the color is not really pink, but a pinkish-lavender. That this form of jade is not represented may be readily explained by the fact that true pink jade is probably unknown; although many specimens have been sold from time to time at fabulous prices by dealers on both sides of the Atlantic. A careful examination of these so-called pink jades was made, with the following results:

1st. The specific gravity of all the pieces examined varied from 2.6 to 2.63. 2d. The hardness of all the pieces was 7. 3d. In several small transparent spots in the object it was possible to place the translucent parts under the stauroscope, and to prove that the material crystallized in the hexagonal system. It required but a single specimen to prove that the material itself was pure silica, and when the hand was rubbed over the objects the surface offered that resistance peculiar to quartz, and not the soft, unctuous feel of the nephrite, or the peculiar, almost slippery feel of the jadeite. The pink color of all these objects was very striking, not a natural color, in fact, but a strong aniline in character. With a pocket lens it could be readily seen that the entire objects were fissured and flawed partly through, naturally and closely, but that probably they had also been crackled, and that in these minute cracks alone could the coloring matter be found. A bit of cotton, saturated with alcohol and carefully rubbed over a part of the object, in all instances brought forth a bit of aniline stain, leaving no question as to the fact that the objects had been made out of a crackled, almost milky quartz, by being heated and plunged into cold water or a cold aniline solution; or that the material had been crackled and the objects then boiled for some time in an aniline solution. The boiling would expel all the air from the cracks and close them, and upon cooling in the solution the cracks would again open and absorb the coloring material. They were then washed, and to the practised eye appeared more brilliant, more beautiful, and more charming than any piece of natural jade ever produced. This imitation is somewhat like the blue-green and red gems that have been made for the past century and generally sold under the name of Mont Blanc rubies, sapphires, and emeralds, and by the French called in the latter part of the 18th century "rubasse." In the latter case, however, pure rock-crystal was used, and it was only flawed enough to absorb the color, giving the appearance when stained of a transparent blue-green or red gem.

One of the simplest, most common, and most ingenious of all artificial jades is that made of a heavy "paste" glass—a lead glass containing a quantity of oxide of lead in place of the soda in ordinary glass. This material is colored with wonderful skill and fidelity to nature, to imitate all varieties of jade. A frequent kind is made pure white and nearly opaque, with rich splashes of green, to simulate the *fei-ts'ui*, the so-called "imperial jade" of China. This form may be found in bracelets, earrings, and other trinkets, wherever a Chinese shop exists. Again, it is made altogether green—the particular bluish-green of the Burmese jadeite—and sold in the same forms as the last. Another kind is entirely white, or faintly tinged with lavender to imitate the white and lavender jades. Some glass has been made almost of a black-green. One well-known imitation is given the rather pleasing French name of *pâte de riz*, as though a rice-paste ingeniously united and hardened; whereas it is merely a white glass with a faint tint of bluish-green or bluish-gray.

But the coloring is by no means all. The expert

Chinese glass-makers well understand the art of deadening the lustre of the surface—first producing a high polish, and then with a fine, hard powder reducing it slightly so as to impart to the glass almost precisely the lustre of jade. These imitations, moreover, are not confined to small objects, but many very fine and large pieces have been made, which represent, of course, only a trifle of the experience, and a fraction of the time of the carver, as compared with such objects in real jade.

GEORGE FREDERICK KUNZ.

ON JADE IN CHINA.

Its places of production, varieties, literature, and manufacture.

By Stephen W. Bushell, B. Sc., M. D.,

Physician to H. B. M. Legation, Peking, China.

An introduction to *Yü Shuo*, by T'ang Jung-tso.

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Reverence of the Chinese for Jade. The character *Yü*. Jade Rivers. Mountains, towns, and quarries of Khotan. Jade of Chinese Turkistan according to Ying Ho. Jade of the Mirtái Mountains and from Yurungkash river. Present supply to Peking. Ch'ien-lung Jade. Burmese. Ancient and Prehistoric. Insignia of rank. Symbols in worship. Talismans and Amulets.

Detailed reference to *Po ku t'ou* (Illustrations of Ancient Bronze, thirty books); *K'ao ku t'ou* (Illustrated Researches of Antiquities, ten books); and *Ku yü t'ou* (Illustrations of Ancient Jade, two books), as one work edited by Huang Shêng in 1753 A. D.; and to *Ku yü to'u pu* (Illustrated Description of Ancient Jade, one hundred books), edition of 1779 A. D.

With Maps of the Jade-producing district of Chinese Turkistan, Figures of inscriptions, and thirteen colored Illustrations of the Manufacture of Jade, painted in Peking by the artist Li Chêng-yuan.

ON JADE IN CHINA.

I have been asked to write a few words on Chinese Jade, by way of introduction to the learned *Discourse on Jade*, by my friend T'ang Jung-tso,* which is remarkable not only for its research into the vast store of native literature,

*In Chinese names the surname comes first, the next two syllables connected by a hyphen being the personal name. Chinese is a strictly monosyllabic language, and in the transcription of foreign names, in the same way as in that of the native Manchu, each syllable must be rendered by one or more Chinese characters, e. g., *Bi-sho-po* for Bishop. I have followed Sir Thomas Wade's system of orthography, which is now so generally adopted, as by my friend Mr. Hippisley, in the Catalogue of his Collection of Chinese Porcelain published by the Smithsonian Institution, Washington, 1890. Mr. Giles in his large Chinese dictionary uses the same system of transliteration.

With regard to pronunciation, the consonants are generally pronounced as in English, with the exception of *j*, which is nearly the French *j* in *jaune*, the English *s* in *fusion* or *z* in *brazier*. The initials *ch*, *k*, *p*, *t*, *ts*, *tz* occur also aspirated, and the aspirate which intervenes between them and the vowel following is indicated by an apostrophe in preference to an *h*, lest the English reader should pronounce *ph* as in *triumph*, *th* as in *month*, and so on. To pronounce *ch'a*, drop the italicised letters in *mu*ch-ha*rm*, for *t'a* drop the italics in *hi*t-ha*rd*. The initial *hs*, with a slight aspirate preceding and modifying the sibilant, is a peculiar sound which can only be acquired by practice.

The vowels and diphthongal sounds are pronounced as in Italian, in accordance with the following table :

Vowel Symbols	Webster's System	English Value
a	ä	a as in *father*
e	ĕ	e as in *yet*
ê	ẽ	e as in *fern*
i	ï = ē	i as in *marine*
ih	ĭ	i as in *pin*
o	ô	o as in *lord*
u	ṳ	u as in *prune*
ü		ü as in German *München*
ŭ	ĭ or ŭ	between *i* in *bit* and *u* in *shut*.

For the last vowel sound, *ŭ*, which is found only with the initials *ss*, *tz*, *tz'*, we have no equivalent in English. In the diphthongal sounds each of the vowels is separately pronounced in the Italian fashion ; thus, *ai*, nearly our *aye*, is better represented by the Italian *ai* in *hái*, *amái* ; *ia* by the Italian *ia* in *piazza* ; *ie* is pronounced as in the Italian *siesta*, *niente*, etc. Each Chinese monosyllable has its own special tone or musical intonation, but for this the inquirer must be referred to special works on the subject.

but also for the knowlege it shows of ancient and modern work in Jade. It has been written to illustrate the important and *recherché* collection of Mr. Heber R. Bishop, who requested "a condensed article on jade by a native Chinese scholar, treating upon its uses in China from the earliest period down to the present day; stating what appreciation it obtained when first brought into use, and for what purposes it was used; a general statement of the estimation in which it was held, and of the general sentiment associated with it on the part of the Chinese, especially regarding it in its crude condition, as well as when worked into forms for implements or artistic purposes. If they have any particular religious associations with it, that should also be stated; and then also to what extent it was used and appreciated by the Imperial Government; and to what extent it is now mined, and for what purposes."

The author has, in accordance with these instructions, which were communicated to him by me, divided his article into nine sections, entitled:

I. Sources of Jade.
II. Crude Jade.
III. Value of Jade
IV. Objects made of Jade.
V. Jade used by the Son of Heaven.
VI. Jade used by the State.
VII. Colors of Jade.
VIII. Ancient Jade.
IX. Fei-ts'ui.

It concludes with an Appendix, containing the titles of 71 books quoted in the article, which range through at least three thousand years, and belong to every class of literature, from the official annals to the relations of Taoist legend. I have given the names of most of the writers of these books, and their approximate dates. The *Discourse* itself I have translated as literally as possible, so as to try to convey the spirit of the original. There is hardly space for comment or for minute criticism of details, even were it advisable.

The Chinese seem to have had the highest appreciation of jade from prehistoric times, before the migration of the black-haired race to China, and while they were still residents of Central Asia, the native country of the best jade. This is shown by the frequent reference to it in the classical books and in the early annals. Kuan Tzŭ, the famous Minister of Duke Huan* of Ch'i, who lived in the seventh

*Duke Huan (B. C. 693–642) was the fifteenth hereditary prince of Ch'i, a state situated in the north of what is now the province of Shantung, a fief bestowed by *Wu Wang*, the founder of the *Chou* dynasty, upon Shang-fu, one of his chief advisers both in peace and in war. For thirty-nine years Duke Huan was the acknowledged head of the confederacy of states which ruled the internal affairs of China under the nominal sovereignty of the house of *Chou*, owing his success in great measure to the advice and statesmanship of his famous counsellor, Kuan Chung, who died in B. C. 645, and who is enrolled in the list of sages under the title Kuan Tzŭ, and is the author of the philosophical book on government and legislation which bears his name. The feudal princes at this period were ranked as *kung*, *hou*, *po*, *tzŭ*, and *nan*, fairly rendered, duke, marquis, earl, viscount, and baron. These hereditary titles are still used in China, although the feudal system, as in Europe, is long extinct.

The *Chou* was the third of the three ancient dynasties with which authentic Chinese history begins, after a prolonged fabulous and legendary period ending with the reigns of *Yao* and *Shun*, which head the first chapters of the *Shu Ching*, the classical Book of Annals. The successor of the emperor *Shun*, *Yü* the Great, was the founder of the *Hsia* dynasty, under which the rule was handed down in hereditary succession till his house was overthrown by *T'ang* the Successful, the founder of the Second dynasty, the *Shang* or *Yin*. The reigning Manchu dynasty is the twenty-fifth in the line according to the following table :

ABSTRACT OF THE CHINESE DYNASTIES.

Dynasty	Remarks	Began	Duration, years
1. Hsia	17 sovereigns	B. C. 2205	439
2. Shang	28 sovereigns. The 16th, P'an Kêng, changed the dynastic title to Yin, B.C. 1401	1766	644
3. Chou	34 sovereigns. The 13th, P'ing Wang, moved the capital to Lo, B. C. 770, founding the Eastern Chou. Confucius flourished B. C. 551–479	1122	867
4. Ch'in	Founded by Ch'in Shih-huang, builder of the Great Wall, whose son reigned only 3 years	255	49

century B. C., writes in his book on political economy: "Jade comes from Ou-ti, gold comes from Ju Han, pearls are produced in Ch'ê-yeh. The former kings, because these things came from afar, and were obtained with difficulty, made use of them according to the respective value of each, pearls and jade being estimated highest, gold placed in the middle class, copper knives and spade-shaped coins belonging to the lowest class."

The character *yü*, meaning jade, is a very ancient one. It consisted originally of three horizontal lines, connected by a vertical line, representing three stones strung together, the dot on the right being a modern addition, to

5. Han	Styled Western Han from the site of its capital at Ch'ang-an, now Hsi-an-fu. 14 emperors		206	231
6. Later Han	Also styled Eastern Han from its capital at Lo-yang, in the province of Honan. 12 emperors		A. D. 25	196
7. Minor Han	2 emperors. Divided the empire with the Wei and Wu Epoch of Three Kingdoms. San Kuo		221	44
8. Chin	4 emperors		265	52
9. Eastern Chin	11 emperors. The founder, Yuan Ti, removed the capital to Chien-K'ang, now Nanking		317	103
10. Sung	8 emperors	Epoch of Divison between North and South, Nan Pei Ch'ao, the Tartar dynasties of Wei (386-549), Ch'i (550-577), and Chou (557-581) ruling the North.	420	59
11. Ch'i	5 emperors		479	23
12. Liang	4 emperors		502	55
13. Ch'ên	5 emperors		557	32
14. Sui	3 emperors		589	29
15. T'ang	20 emperors		618	289
16. Posterior Liang	2 emperors	Epoch of the Five Dynasties—Wu Tai—during which 13 rulers reigned only 53 years.	907	16
17. Posterior T'ang	4 emperors		923	13
18. Posterior Chin	2 emperors		936	11
19. Posterior Han	2 emperors		947	4
20. Posterior Chou	3 emperors		951	9
21. Sung	9 emperors		960	167
22. Southern Sung	9 emperors. Shared the empire with the Chin Tartars (1115-1234)		1127	153

distinguish it from the similar character, *wang*, "king." Two characters, placed side by side, and read *chüeh*, meant two pieces, and the character *chü* signified, specially, ten pieces of jade.

23. Yuan	9 emperors. Founded by Kublai Khan, grandson of Gengis Khan	1280	88
24. Ming	16 emperors	1368	276
25. Ch'ing	The present Manchu Tartar line, of which the 9th emperor, Kuang Hsü, is now reigning	1644	

The MING Dynasty

Dynastic Title, or *Miao Hao*	Title of Reign, or *Nien Hao*	Year of Accession
T'ai Tsu	Hung Wu	1368
Hui Ti	Chien Wên	1399
Ch'êng Tsu	Yung Lo	1403
Jên Tsung	Hung Hsi	1425
Hsüan Tsung	Hsüan Tê	1426
Ying Tsung.	Chêng T'ung	1436
Tai Tsung Ching Ti	Ching T'ai	1450
Ying Tsung (restored)	T'ien Shun	1457
Hsien Tung	Ch'êng Hua	1465
Hsiao Tsung	Hung Chih	1488
Wu Tsung	Chêng Tê	1506
Shih Tsung	Chia Ching	1522
Mu Tsung	Lung Ch'ing	1567
Shên Tsung	Wan Li	1573
Kuang Tsung	T'ai Ch'ang	1620
Hsi Tsung	T'ien Ch'i	1621
Chuang Lieh Ti	Ch'ung Chên	1628

The Reigning (CH'ING) Dynasty.

Dynastic Title, or *Miao Hao*	Title of Reign, or *Nien Hao*	Year of Accession
Shih Tsu Chang Huang Ti	Shun Chih	1644
Shêng Tsu Jên Huang Ti	K'ang Hsi	1662
Shih Tsung Hsien Huang Ti	Yung Chêng	1723
Kao Tsung Shun Huang Ti	Ch'ien Lung	1736
Jên Tsung Jui Huang Ti	Chia Ch'ing	1796
Hsüan Tsung Ch'êng Huang Ti	Tao Kuang	1821
Wên Tsung Hsien Huang Ti	Hsien Fêng	1851
Mu Tsung Yi Huang Ti	T'ung Chih	1862
(The Reigning Sovereign)	Kuang Hsü	1875

Marco Polo was the first European to visit the district of Khotan, celebrated for its jade. He passed through it on his way to China, in the thirteenth century, and refers to the quantities of jade, which he calls jasper, and chalcedony, found in the rivers of the country.* A more detailed account of the "fishing" for jade is found in the diary of Chang Kuang-yi, an envoy from the Emperor of China to Khotan in the tenth century, as described by our author. He alludes to three rivers, called White Jade River, Green Jade River, and black Jade River, from the different colors of the pebbles of jade found in their beds. An Arab historian of Timur † (Tamarlane) tells of the two rivers of Khotan, whose stones are of jasper (*yeshm*), called Orangkásh and Karakásh, signifying in the Eastern Turki tongue White jade and Black jade, and adds that these two rivers have their source in the mountain of Kárangotág. These names may all be found in modern Chinese maps of Eastern Turkistan, and they are placed at about the same distances from Khotan as by Chang Kuang-yi over nine centuries ago. The walled city of Karakásh, 70 *li* ‡ northwest of Khotan, and the village of Yúrúngkásh, 10 *li* east of Khotan, both take their names from the rivers on which they stand. Johnson, describing his visit to Khotan in 1865, talks of jade as "obtained from the Kárangoták mountains at a height of 8735 feet."

These mountains are really part of the great K'unlun Range, and the same as the K'un Mountains referred to in the Itinerary of Chang Kuang-yi as the source of the Jade Rivers. This range, which starts in the east from the borders of China Proper, on the south of the lake Kokonor, forms the boundary line between Chinese Turkistan and Tibet. I have compiled the accompanying maps of the jade-producing districts of Chinese Turkistan from Chinese sources, to illustrate this paper. They are based upon the

* *The Book of Ser Marco Polo*, newly translated and edited with notes by Colonel Henry Yule, C. B., R. E. In two volumes, London, 1871. A second edition, revised, with new matter and more illustrations, was published in 1875. Both editions are now out of print and scarce.

† *Histoire de Timur*, traduite par Petis de la Croix. Tome III, p. 219.

‡ A *li* may be roughly estimated at one-third of an English mile.

maps produced after the surveys made by British and Russian officers, which were published at Dehra Doon, at the Office of the Great Trigonometrical Survey of India in 1875, compared with more recent maps published in the Journals and Proceedings of the Royal Geographical Society of London, to illustrate the journeys of Lieutenant Younghusband and other travellers. The K'unlun Range may be seen traversing the map from Southeast to Northwest, it being known by various names in different parts of its course. The part to the south of Khotan is called Nan Shan, or Southern Mountains, which is continuous on the west with the Margulugh Mountains, and these pass into the Mirtái Mountains, which last extend northward as far as the town of Khusharáb (meaning "Twin Peak Stream"), where the Yárkand or Zarafshán ("Gold-scattering") River emerges through a precipitous defile. These Mirtái Mountains are described in the paper of T'ang Jung-tso as situated 230 *li* southwest of the town of Yárkand under the name of Mirtái Tapan, Tapan standing here for Dabán, which in Manchu signifies mountains. They are usually called in older Chinese books the Bilor Mountains, and it is by this name, or the Turki form, Belurtág, that they are generally described in European works. It seems likely that this name of Mirtái, also written Milotai, is merely a corruption, or rather a dialectal variation of Bilotág, the final syllable being softened and the *b* replaced by *m*. This latter change is a common one in the dialect of the Kirghis mountaineers, who always, for example, pronounce Táshbalik ("Stone-town"), Táshmalik. These Mirtái Mountains, which are described as covered with perpetual snow, extend nearly ten miles from base to summit, and are composed of three series of strata, of which the middle series contains the jade, the lowest and highest being formed of common rock. They are called Yü Shan, or "Jade Mountains," in modern Chinese geographical books, just as the Zarafshán, the "Gold-scatterer," is known to the Chinese by the alternative name of Yü Ho, or "Jade River." In ancient times, as shown above, the chief supply of jade was obtained from places within the boundaries of the district of Khotan, in modern times the largest quantity comes from Yárkand. All the principal mountain quarries and jade-producing rivers are comprised within these two provinces.

There are many Chinese books on Turkistan (*Hsi Yü*). Among the most important are the voluminous geographical description, with maps, entitled *Hsi yü t'ou chih*, published by imperial commission in the reign of the Emperor *Ch'ien Lung*, and the *Hsin chiang chih lüeh*, another detailed description of the New Dominion (*Hsin Chiang*), issued also with the imperial imprimatur in A. D. 1821, the first year of the reign of the Emperor *Tao Kuang*. I have taken the Chinese names of the places principally from these two works, the original Turki names being so variously transliterated in Chinese by different authors.

A fuller account of the jade quarries is to be found in the *Hsi Yü Shui tao chi*, "Description of the Rivers of Chinese Turkistan," in five books, by Ying-ho, a learned Manchu officer, published in the year 1823. This gives an itinerary from Yárkand to the mines in the Mirtái Mountains, 410 *li* distant:

From Yárkand to Posgám, South, 70 *li*
Posgám to Khan Langar, Southwest, 50 *li*
Khan Langar to Yengi Chuang, Southwest, 150 *li*
Yengi Chuang to Tsipan Mountains, Southwest, 30 *li*
Tsipan Mountains to Atzu Khansar, Southwest, 50 *li*
Atzu Khansar to Mirtái Mountains, Southwest, 60 *li*

It also gives, under the description of the Yárkand River, an account of the stations along the course of the river-bed at which the camps are pitched when the Mohammedan natives are levied for the "jade-fishing." This starts from Khusharáb, a town the name of which is derived from words meaning "twin peaks" and "water," where the river emerges from the precipitous K'unlun Range, some 260 *li* distant in a southwesterly direction from the chief town of Yárkand. This is the "sixth jade camp," situated on the south bank of the river. 40 *li* from this is the town of Katsung, the "fifth jade camp," 60 *li* further the town of Alimas, the "fourth jade camp," both situated on the north bank. 50 *li* in a northeasterly direction from Alimas we come to the village of Targachi, the "third jade camp," 30 *li* northeast of this to Ulughming, the "second jade camp," and 30 *li* northeast of this to Ulughtop, the "first jade camp," all these three being pitched upon the south bank of the river. This "first jade camp" is distant 50 *li* in a southwesterly direction from Yárkand. When the expedition is on foot the camps are pitched for some three days at each of these stations, so that the river bed may be thoroughly searched, and the men are finally sent out into the mountains at Katsung, to complete the tally of the quantity required for the annual imperial tribute. No piece of less weight than two ounces is accepted.

The jade produced here is said to be of the best quality, of brilliant color and strong substance, and to emit the clearest sound when struck with the hammer, vibrating for a long time, till the sound stops abruptly in the way characteristic of jade. In the twenty-ninth year of *Ch'ien-lung* (1764), as Ying-ho relates, the Governor of Yárkand forwarded to the Emperor thirty-nine large slabs, weighing altogether 3975 catties (the catty being equivalent to 1 1/3 lbs.)* to make the peculiar musical stones called *ch'ing*, besides a large supply of smaller slabs; and, the year after, sent a further large quantity for imperial use. The slabs were all quarried in the Mirtái Mountains, and sawn there by natives of Sungaria.

* 24 *chu*, or pearls,	make 1 *liang*, or tael,	= 1 1/3 oz.	avoirdupois
16 *liang*	make 1 *chin*, or catty,	= 1 1/3 lb.	"
100 *chin*	make 1 *tan*, or picul,	= 133 1/3 lbs.	"

The ordinary measures of length are:

10 *fên*, or lines,	make 1 *ts'un*, or inch		
10 *ts'un*	make 1 *ch'ih*, or foot =	12.1 inches,	English
5 *ch'ih*	make 1 *pu*, or pace =	5.064 feet	"
2 *pu*	make 1 *chang* =	10.128 feet	"
180 *chang*	make 1 *li* =	1895 feet	"
200 *li*	make 1 *tu*, or degree		

This was the table used by the missionaries in their survey of the Chinese empire in the year 1700, based upon the *ch'ih* used by *K'ang-hsi* in the palace, These *ch'ing* are figured in *Ta Ch'ing hui tien*, the Government Statutes of the reigning dynasty, as well as in several foreign books on Chinese music.* They are carved in the form of an obtuse-angled carpenter's square with two limbs, the longer one called the "drum," the shorter, the "limb"; and are perforated near the angle to be suspended by silk cords on the wooden frames, which are elaborately carved in the form of phœnixes and hung with silk tassels, the jade stones being decorated in gold with dragons in pursuit of pearls. They are modelled after an ancient design figured by Biot,† the different parts having a definite numerical proportion, so that if the breadth of the drum is represented as 1, the length of the limb is 2, the length of the drum 3, and the breadth of the limb 1 1/2. These *ch'ing* are used only in imperial ceremonies, and are of two kinds, the *t'ê ch'ing*, or "single musical stones," and the *pien ch'ing*, or "stone chime."

The *t'ê ch'ing* are twelve in number, giving the twelve notes of the Chinese diatonic scale. Each one is hung on a separate wooden frame and struck with a hammer of hardwood. They vary in size and thickness: from the largest, which has the drum 2.187 feet long, .729 broad, the limb 1.458 long, 1.0925 broad, and is .0729 thick, to the smallest, which has the drum 1.152 feet long, 0.384 feet broad, the limb .768 long, .576 broad, and is .1296 thick.

The *pien ch'ing*, or "stone chime," comprises sixteen pieces of jade of similar form, all of the same size, but of different thickness, and suspended on one wooden frame, in two rows of eight. They have the drum 1.0935 feet long, .3645 broad, the limb .729 long, .54675 broad, and

and Regis informs us that Parennin found the degree to contain 200 *li*, each measuring 180 *chang* of 10 *ch'ih*.

Afterwards the present rate of 250 *li* to a degree was adopted in order to make it one-tenth of a French league and one-twenty-fifth of a degree, and this last scale is found on the charts of D'Anville and in most modern Chinese maps (See *The Chinese Commercial Guide*, by S. W. Williams, LL. D. Chapter V. Moneys, Weights, etc., in China).

* *Chinese Music*, by J. A. Van Aalst. Publications of Chinese Imperial Maritime Customs. II. Special Series: No. 6, 1884, pp. 48, 49.

† *Le Tscheou Li*, ou *Rites des Tscheou*, traduit par E. Biot, 1851, Tome II, page 531.

range in thickness from .06068 to .1296 of a foot. The thickest gives, of course, the deepest note; and the jade chime includes four lower notes in addition to the ordinary twelve of the diatonic scale. Mr. van Aalst gives the scale in common musical notation, and adds that the special function of the jade instruments is to give one sound at the end of each word of the air, in order to "receive the sound" and transmit it to the next word. They are exclusively used in court religious ceremonies, but there are other musical stones carved out of jade for private use, like those in the form of a bat, symbol of happiness, and of two fish,* symbol of fertility, figured in the same paper. These are called *chi ch'ing*, propitious musical stones, and are often given as presents, like the *ju-i*, jade sceptres.

To return to our Chinese book on Turkistan. It relates further that in the forty-ninth year of *Ch'ien-lung* (1784) an official of the imperial household was dispatched to Yárkand with seventy workers in jade, who brought back five hundred large tablets of jade to be engraved with imperial patents of rank, etc., and fifty large square pieces to be carved into state seals, as well as three hundred smaller tablets and thirty small blocks for seals, the total weight of which amounted to four thousand seven hundred and fifty-two catties.

In the fifty-fifth year (1790) of the same reign there was a fire in the palace, in which all the musical instruments were burned and the Governor of Yárkand had sixty-four large slabs and eight smaller ones, for the manufacture of new *ch'ing*, mined from the Margulugh Mountains,† which produce a fine jade of green color, dark and

***Chi ch'ing yu yü*, "a propitious stone with fish," gives the punning meaning of "good luck and abundance," the second and fourth characters being replaced by others of the same sound.

† The Margulugh Mountains, which form part of the great K'un Lun range, pass into the Mirtái Mountains on the north and are continuous with the Nan Shan or Southern Mountains of Khotan towards the southeast. They are almost unexplored and are sparsely peopled by the curious Aryan race of Thakpo, photographed and described by Sir Douglas Forsyth in the Report of his Mission to Yárkand in 1873.

brilliant, marked with blood-red stains. This was brought to the city of Yárkand by the Mohammedan natives of the Yolarik Mountains, distant 270 *li* S. W. of Yárkand, and went therefore under the name of Yolarik jade.

The jade quarries in the Mirtái Mountains had been closed on account of trouble with the natives, but in the fourth year of *Chia-ch'ing* (1800) they were opened again, and there were quarried ten thousand catties of the finest green jade, eight thousand catties of onion-green and white of the second quality, and three thousand catties of white jade in smaller pieces. This immense weight was carted as far east as Karashár, but had to be left there on account of the difficulties of transport. "When I (Ying-ho) had passed the Ushaktal (Dwarf Willow) Military Station, which is 220 *li* N. E. of Karashár, the natives guiding me to the next stage showed it to me, lying in a heap on the northeast of the road, half buried under a pile of dust, more than two feet above the level of the ground."

Then follows an account of the more recent regulations for fishing for jade in the bed of the Zarafshán River, and of the six camps on its banks, occupied by the native Mohammedans in the autumn, when five hundred men were levied for the work, each ten under an *onbashi*, to get the yearly quantity of 18,500 catties requisitioned by the Emperor.

In addition to all of this jade levied from the Yárkand country, a supply was also still requisitioned from the district of Khotan, according to a memorial from the Governor dated the fourth year of *Chia-ch'ing* (1800), which stated that jade was obtained from five different places; but added that only that fished from the Yúrúng-kásh River was of good quality, and he accordingly proposed that the supply from the Karakásh River, Sangku, Shuya, and the Karango Mountains should be stopped, and that the first river only should be fished for fifteen days during the autumn, to supplement the supply of fine jade from Yárkand, as the largest pieces found there were also fit for the manufacture of the musical stones.

The Karakásh River, the name of which means "black jade," has always been one of the chief sources of the the mineral. Sangku is about 300 *li* southwest of Khotan, situated near the defile through which the Karakásh River pierces the K'un Lun range; Shuya, also on the northern slope of the range, lies to the east of Sangku, in the valley of a small tributary of the same river; Kárangoták, which signifies in Turki "Dark Mountains," is described as 200 *li* due south of Khotan, on the northern bank of the Yúrúngkásh River. The natives of Khotan have always fled for refuge to the rugged wooded glades of these hills when attacked by Turk or Tartar nomads from the north, as related by Rémusat.*

Afterwards the Mohammedan rebellion broke out in Eastern Turkistan and the jade quarries were closed, there being no further demand from China, and no more trade was allowed during the rule of Yakub Beg at Kashgar (1865–77).

It was during this reign that some of the deserted quarries in the upper part of the Karakásh River valley were visited by Dr. Stoliczka, the naturalist attached to Sir Douglas Forsyth's Yárkand embassy, who was there in the year 1873. He writes:

"The portion of the Kuenlún range which extends from Shahidula eastward towards Khotan appears to consist entirely of gneiss, syenitic gneiss, and metamorphic rocks, these being quartzose, micaceous, or hornblendic schists. On the southern declivity of this range, which runs along the right bank of the Karakásh River, are situated the old jade mines, or rather quarries, formerly worked by the Chinese. They are about seven miles distant from the Khirghis encampment, Belakchi, which itself is about twelve miles south-east of Shahidula. I had the pleasure of visiting the mines in company with Dr. Bellew and Captain Biddulph, with a Yárkandee official as our guide.

"We found the principal jade locality to be about one and a half miles distant from the river, and at a height of about five hundred feet above the level of the same. Just in this portion of the range a few short spurs abut from the higher hills, all of which are, however, as usually, thickly covered with débris and sand, the result of disintegration of the original rock. The whole has the appearance as if an extensive slip of the mountain-side had occurred.

"Viewing the mines from a little distance, the place seemed to resemble a number of pigeon-holes worked in the side of the mountain, except that they were rather irregularly distributed. On closer inspection we saw a number of

* A. Rémusat. *Histoire de la ville de Khotan.* Paris, 1820.

pits and holes dug out in the slopes, extending over a height of nearly a couple of hundred feet, and over a length of about a quarter of a mile. Each of these excavations had a heap of fragments of rock and jade at its entrance. Most of them are only from ten to twenty feet high and broad, and their depth rarely exceeds twenty or thirty feet; only a few show some approach to low galleries of moderate length, and one or two are said to have a length of eighty or a hundred feet. Looking on this mining operation as a whole, it is, no doubt, a very inferior piece of the miner's skill; nor could the workmen have been provided with any superior instruments. I estimated the number of holes at about a hundred and twenty, but several had been opened only experimentally, an operation which had often to be resorted to on account of the superficial sand concealing the underlying rock.

"The rock of which the low spurs at the base of the range are composed is partly a thin-bedded, rather sandy, syenitic gneiss, partly mica and hornblendic schist. The feldspar gradually disappears entirely in the schistose beds, which on weathered planes often have the appearance of a laminated sandstone. They include the principal jade-yielding rocks, being traversed by veins of a pure white, apparently zeolitic mineral, varying in thickness from a few to about forty feet, and perhaps even more. The strike of the veins is from north-by-west to south-by-east, or sometimes almost due east-and-west; and their dip is either very high towards north, or they run vertically. The mineral has the appearance of albite, but the lustre is more silky, or perhaps rather glassy, and it is not in any way altered before the blowpipe, either by itself, or with borax and soda. The texture is somewhat coarsely crystalline, rhombohedric faces being on a fresh fracture clearly traceable. It sometimes contains iron pyrites in very small particles, and a few flakes of biotite are also occasionally observed. This zeolitic rock is again traversed by veins of nephrite, commonly called jade; which, however, also occurs in nests. It is a white, tough mineral, having an indistinct cleavage in two directions, while in the other directions the fracture is finely granular or splintery, as in true nephrite. Portions of this mineral, which is apparently the same as usually called white jade, have sometimes a fibrous structure. This white jade rarely occupies the whole thickness of a vein; it usually only occurs along the sides in immediate contact with the zeolitic vein-rock, with which it appears sometimes to be very closely connected. The middle part of some of the veins and most of the others entirely consists of the common green jade, which is characterized by a thorough absence of cleavage, great toughness, and rather dull vitreous lustre. The hardness is always below 7, generally only equal to that of common feldspar, or very little higher, though the polished surface of the stone appears to attain a greater hardness after long exposure to the air. The color is very variable, from pale to somewhat darker green, approaching that of pure serpentine. The pale-green variety is by far the most common, and is in general use for cups, mouthpieces for pipes, rings, and other articles used as charms and ornaments. I saw veins of the pale-green jade fully amounting in thickness to ten feet; but it is by no means easy to obtain large pieces of it, the mineral being generally fractured in all directions. Like the crystalline vein-mineral, neither the white nor the green variety of jade is affected by the blow-pipe heat, with or without addition of borax or soda. Green jade of a brighter color and higher translucency is comparatively rare, and already, on that account, no doubt much more valuable. It is usually only found in thin veins of one or a few inches; and even then it is generally full of flaws.

"The Belakchi locality is, however, not the only one which yielded jade to the Chinese. There is no reason to doubt the existence of jade along the whole of the Kuenlún range, as far as the mica and hornblendic schists extend. The great obstacle in tracing out the veins, and following them when once discovered, is the large amount of superficial débris and shifting sand which conceals the original rock *in situ*. However, fragments of jade may be seen among the boulders of almost every stream which comes down from the range.

"A great number of the better-polished ornaments, such as rings, etc., sold in the bazaar of Yárkand, have the credit of coming from Khotan; possibly they are made there by Chinese workmen, but the art of carving seems to have entirely died away, and indeed it is not to be expected that such strict Mohammedans, as the Yárkandees mostly are, would eagerly cultivate it." *

Since the re-conquest of the country by the Chinese in the year 1877, pieces of jade in small quantities find their way again to Peking, but nothing fit to be carved into large vases such as were turned out from the imperial workshops in the reign of *Ch'ien-lung* during the second half of the eighteenth century. This emperor was an enthusiastic patron of art workmanship, and most of the elaborately carved pieces of artistic jade which have found their way to Europe and America date from this time, many having been taken from the summer palaces at Yuan Ming Yuan in 1860. He was a poet, too, and proud of his penmanship, and would often have his verses in honor of some temple or bit of pretty scenery engraved in facsimile on jade tablets, to be mounted in a screen, or perhaps on a pair of teacups, with the magic seal *Yü t'i*, "Imperial autograph," below. The round plaque of moss-green jade, a foot across, in the Bishop Collection, is an example of this, being inscribed with an imperial ode on the Buddhist monk Bôdhidharma, who is represented crossing the waves, standing on a reed plucked from the shore, with the pilgrim's staff across one shoulder, having a book slung from the end, and the alms-bowl in his other hand.†

* *Report of a Mission to Yárkand in* 1873, by Sir T. D. Forsyth. Calcutta, 1875. Chapter VIII, "Geological Notes by the late Dr. Stoliczka."

† Bôdhidharma, the twenty-eighth Indian and first Chinese Buddhist patriarch, the son of a king in Southern India, came to China in the year A. D. 520,

The inscription reads:

"Upon a single reed floating over the waves,
Whether coming or whether returning,
With rapt gaze and hands folded in sleeves,
He bides tranquil and undisturbed.
As a means to cross the broad river,
A reed was sufficient for his power.
No other could perform such a deed,
We bow in adoration to the holy monk.
Yü t'i—composed and written by the emperor."

On the other side of the same plaque we have a view of Golden Island (Chin Shan), near Chinkiang Fu, which stands out so picturesquely in the middle of the Yangtzĕ river near the mouth of the Grand Canal, covered with Buddhist shrines and monasteries.

The inscription, a rhyming verse of eight stanzas, reads:

"The summit of the pagoda, crowned with its pointed spire,
Has the azure vault of heaven above, naught else stands so high.
The pilgrim sees here a peerless evidence of the sacred law of Buddha,
Which he cannot approach without feelings of awe and reverence.
Although the picturesque scene, the river and the hill, are the same as of yore,
We will venture to add to our old verses yet another measure.
Though in scholarly lore we cannot come near the poetry of Tung-p'o,*
Whose old rhymes we have borrowed once more to compose these stanzas."

Below:

"In the cyclical year *yi yu* (A. D. 1765) in the spring, during Our journey to the south, We ascended the Golden Hill (Chin Shan), climbed to the top of the pagoda and composed for the third time these stanzas ending with the same old rhymes as before. We also drew a sketch of the view, which we presented on leaving to the Temple Hall Miao Kao T'ang, to be kept there as a memento of Our enjoyment of the prospect.

"Yü pi"—"Penned by the Emperor," whose name follows in two square seals in antique script (*Ch'ien Lung*), the first character engraved, the second cut in relief.

bringing with him the precious pâtra, the alms-bowl of Buddha, the prototype of the holy grail of Christian legend. He reached Canton on the twenty-first day of the ninth month, and after a short stay there came north to Loyang, the residence of the emperor of the Wei, a Tartar dynasty devoted to Buddhism. There he remained in silent meditation for nine years, hence receiving the name of the "wall-gazing Brahman," till his death in A. D. 529.

*Su Tung-p'o, one of the most celebrated statesmen and poets of the *Sung* dynasty, flourished A. D. 1036–1101. The practice of composing new verses with lines ending in rhymes borrowed from old poets is a common intellectual exercise in China.

The mines of Upper Burma are the chief source of the white jade flecked with bright green, called *fei-ts'ui* by the Chinese, which is so highly prized by them and largely imported for the manufacture of ornaments and articles of personal adornment. This is rightly identified by Pumpelly * with jadeite, which differs from nephrite, in its greater specific gravity, as well as in physical structure and in chemical composition. The Chinese, although ignorant of the scientific difference, always distinguish the two minerals, and our author devotes the last section of his *Discourse* to this precious mineral. With all due deference to his disclaimer, it seems to occur also in the province of Yunnan,† although more sparingly than in Burma; and I think that the bowl of Ou-yang, alluded to, might well have been of this material, which is certainly hard enough to rub down pure gold if the surface be not perfectly polished.

The Chinese imitate this, as well as white jade, so successfully in glass, that it is almost impossible to distinguish a false bangle or ring by mere inspection, although it will give a different tone when struck by the finger-nail. The glass is peculiarly dense and heavy, and contains nearly half its weight of oxide of lead.

Specimens of ancient jade are much sought after, and Section VIII is devoted to a description of the different varieties, of the curious conceits of the Chinese collector, and the affectionate way in which he cherishes the corroded piece, removes the rust, and brings to it a fine polish after months of patient effort. The idea that jade which has lain buried in the earth for over a thousand years becomes as soft as common stone, is, of course, taken advantage of by the maker of false antiques, who will soak an object carved out of steatite in some colored decoction,

* R. Pumpelly. *Geological Researches in China*, etc. Smithsonian Contributions, No. 202, 1866, pp. 117, 118.

† The *Yün Yü*, or "Yunnan Jade," of the modern Chinese, considered by them a variety of *fei-ts'ui*, is a dark mottled green, sometimes almost black, kind of jadeite, of high specific gravity. There are crude specimens in the London Museum presented by the late Col. Guthrie. The jadeite *ju-i* (No 3016) is an example, though not so dark in color as some specimens.

and produce the most *recherché* aubergine-purple, hibiscus-yellow, or other tint hardly to be seen in true jade, and imitate the crackle of the most ancient porcelain to deceive the unwary. If the buyer remonstrates because he can scratch it with the finger-nail, he is told that this is only a test of its great antiquity. So Rémusat * relates that M. Bertin, who had, after a lengthened correspondence with the missionaries in China, gathered together so many precious materials to illustrate the arts and products of that empire, ought certainly to have possessed some objects carved in jade; and yet all the things from his collection ticketed *yü* (jade) were really translucid steatites, a kind of soft stone that no one acquainted with the first elements of mineralogy could confound with jade.

Prehistoric jade implements are rare in China. I have seen only one arrow-head, which is in my collection in the Loan Exhibition at the South Kensington Museum. Jade celts of the perforated type are occasionally to be found in collections, and are known by the name of *yao chan*, medicine spades, being supposed to be relics of Taoist herbalists of olden times, and to have been used by them to dig up medicinal roots. They are often carved with an ornamental design in relief, to make ornaments to be worn on the girdle, not sufficiently to disguise the original form. Sometimes an ancient emblem of rank, such as used to be held in the hand of high officers at court ceremonies, is for sale at a prohibitive price.† Symbols were made of jade from

* *Recherches sur la Substance Minérale, appelée par les Chinois Pierre de Iu, et sur le Jaspe des anciens.* Suite de l'Histoire de la Ville de Khotan, par M. Abel Rémusat. 1820.

† Since the above was written I have received a water-color drawing of one of these ancient emblems, No. 13200 in the Bishop Collection. It represents a *kuei*, or baton, of oblong shape with pointed apex, such as used to be held in the hands of a high official in full court dress. The surface seems to be corroded and much discolored, to a clouded dark reddish-brown tint in some parts. This word *kuei* is a very ancient character in the Chinese language, written at first without the radical *yü* (jade), which is now usually prefixed to the ancient form. It means primarily a baton or sceptre, and was given by the sovereign when he conferred a fief as a symbol of feudal rank, distinguishing the rank of the noble to whom it was given by differences in its form and length.

the earliest times, for use in the worship of the powers of nature, heaven, earth, the four cardinal points, the sun, moon, and stars. They are still used in imperial worship, and there are six figured in the Government Statutes of the Reigning Dynasty quoted above. There are three round *pi;* the largest, Figure 1, over six-tenths of a foot in diameter, perforated in the middle with a small round hole, of mottled "sky-green"-colored jade, used in sacrificial worship on the Altar of Heaven and the altar for harvest prayers; the next, Figure 2, two-thirds smaller, made of clouded-reddish jade, for use on the Altar of the Sun, matching the porcelain sacrificial vessels and libation-cups, which are covered with red glaze; the third, Figure 3, thirty-six-hundredths of a foot across, pierced with a square hole in the centre, made of pure white jade, matching the white porcelain, for use on the Altar of the Moon; the yellow *tsung*, Figure 4, for use on the Altar of the Earth, is carved out of yellow jade, with square base four-tenths of a foot across, and rounded top, marked at one of the corners with natural lines in the form of a range of mountains. There are two *kuei*, each thirty-six-hundredths of a foot in diameter, of square section, with a small process (*ti*) projecting on either side; one, Figure 5, rounded above and below, of white jade, with a faint yellowish tinge; the other, Figure 6, flattened, made of green-colored jade—both used in sacrificial worship on the altar of the land and grain.

In ancient times these jade symbols used to be buried in the earth, offering a certain analogy to the round stone "whorls," with inscriptions, found in such large quantities by Schliemann, in the ruins of ancient Troy, the use of which has so puzzled archæologists. The peculiar "cash" of the Chinese, which has circulated some three thousand years, is said to be modelled on the same, its round circumference symbolizing the vault of heaven, its square hole in the centre, earth.

Jade has often been used in the manufacture of talismans and amulets, and in Chinese collections we find certain small round or octagonal cylinders, which have a remarkable resemblance to the ancient cylinders inscribed with figures and inscriptions of Babylonian, Assyrian, and Persian origin, like the well-known signet cylinder of King Urukh, of Chaldea, found by Sir R. Porter, and copied by Professor Rawlinson,* from his Travels.

It is recorded in the official annals of the period that signets of this kind were worn, attached by silk cords, strung with pearls and precious stones, to the girdle of the official costume of the mandarins during the *Han* dynasty, which flourished two centuries before and after the Christian era. The Annals of the After *Han* describe those of princes and nobles to have been made of white jade; those worn by officers with annual salary of 2000 to 400 piculs of rice, of black rhinoceros horn; officers of lower rank, private scholars, and students, wearing ivory signets. They were made on the cyclical day *mao* of the first moon, and were hence called *kang mao*. They were abolished temporarily by the usurper *Wang Mang*, in the year A. D. 11, for a superstitious reason, the character *mao* forming part of the character *Liu*, the family name of the *Han*.

The specimen before us, No. 13203 of Mr. Bishop's collection, is an octagonal cylinder, two inches long, engraved with four characters in antique script on each of its faces, the whole inscription being like this, when spread out:

> "May this amulet of the day *mao* of the first moon,
> With miraculous power pervade the four quarters,
> That the red, blue, white, and yellow,
> All four colors may be duly harmonized.
> May the charm recited by imperial order,
> To instruct the dread monsters and dragons,
> Be efficacious in all dangerous diseases,
> Which I could not dare to withstand."

The Chinese are so devoted to researches into antiquity, and have published so many books on numismatics, ancient bronzes, sacrificial vessels and implements, old inscriptions and kindred subjects, that we naturally

* Rawlinson's *Ancient Monarchies*, Vol. 1, page 94.

expect to find a series of special works on jade. The absence of such works would show the rarity of ancient specimens of jade. One of the most celebrated books on bronze antiquities is the *Po ku t'ou*, in thirty books, written by Wang Fu in the beginning of the twelfth century, in which several hundred vessels are figured, with a facsimile of the inscription upon each. A revised edition was published during the *Yuan* dynasty, in the *Chih-ta* period (A. D. 1308–1311), in large folio, the vases being represented of the original size. I have in my possession an incomplete copy of this last edition. New editions were issued during the *Ming* dynasty, in the seventh year of *Chia-ching* (1528) and in the cyclical year *kuei mao* (1603) of the reign of *Wan-li*. Of more recent editions one of the best is that edited by Huang Shêng, published in the eighteenth year of *Ch'ien-lung* (1753). The same scholar edited at the same time another illustrated collection of antiquities of about one-third of the extent of the *Po ku t'ou*, called *K'ao ku t'ou*, in ten books, by Lü Ta-lin, first published during the *Sung* dynasty, in the seventh year (1092) of the *Yuan-yu* period (1086–93). This is more interesting to us, because the eighth book comprises a small collection of jade in the possession of Li Po-shih, a native of Lu-chiang, including a tiger-shaped tablet, scabbard-guards, a round symbol, girdle buckles and appendages, a double-handled wine-cup engraved with spiral ornament, etc.

With this edition of the two books on ancient bronzes there is usually bound up at the end another work, entitled *Ku yü t'ou*, "Illustrations of Ancient Jade," in two books, by Chu Tê-jun, introduced by the same editor, Huang Shêng, in a Preface, also dated 1753. The original Introduction by the author, who flourished during the *Yuan* dynasty, is dated the first year of the period *Chih-chêng* (A. D. 1341). He says that "from the time he left college he used to visit the houses of the princes and celebrated men of the capital city of Yen (the modern Peking), as well as the collection in the imperial palace, and examine carefully the different objects, so as to appre ciate the excellency of the things worn and vessels fashioned by the ancients, and to figure a few examples of such as had survived, and which he had seen himself, to present to those who take an interest in the study."

The most curious relic of jade-carving figured in this volume is the first, entitled "Apparatus for South-pointing Chariot," Figure , which is described thus: "The chariot apparatus figured above measures in height 1.42 feet, and is .74 of a foot in length below. The man's figure, carved out of jade, has one hand constantly pointing towards the south, the bottom of the foot being drilled with a round hole, so that it turns upon a pivot, poised on the head of the fabulous monster Ch'i-yu.* In the period *Yen-yu* (1314-20) I succeeded in getting a sight of this at the Imperial Decree office of Yao Mu-an. The color of the jade had a yellowish tint, mingled with bright red of antique shade, and it had marks of erosion from having been buried in the earth." The south-pointing chariot is said by Chinese commentators to have been invented by the ancient Emperor *Huang Ti*, and to have suggested the invention of the mariners' compass, called by them the south-pointing needle.

The next figure is that of a round medallion, *pi*, a foot in diameter, with a round hole in the centre surrounded by a zone of spiral ornament, and, outside, a second zone of interlacing dragons. Next follow in order sword-clasps, round ornaments in the form of coiling lizards, and girdle buckles of varied designs.

The second book contains figures of insignia of rank, ornaments for the girdle and for the ears, a piece of jade in the form of a cicada, from the mouth of a corpse, a winged monster said to have been dug up by a peasant from the grave of the ancient king T'ai K'ang and bought

* A legendary being generally considered to be the first great rebel, who sought to overthrow the ancient Emperor *Huang Ti*, and the reputed inventor of warlike weapons. Some pretend that he was the head of a confederacy of 81 brothers, who had the bodies of beasts, but human speech, with foreheads of iron, and who fed on the dust of the earth. His spirit is believed to reside in the planet Mars, which influences the conduct of warfare. See Mayer's *Chinese Reader's Manual*, page 36.

from him by imperial command by Chao Tzŭ-ang to be used as a letter-weight, jade horses, girdle buckles, a wine-cup of form and design similar to the one in the other collection of Li Po-shih mentioned above, ornaments for scabbard, and a sword-handle.

These are, however, but meagre collections of small extent compared with that contained in the one special book on the subject, which is entitled also *Ku yü t'ou*, or in full *Ku yü t'ou pu*, "Illustrated Description of Ancient Jade." This is the catalogue, in one hundred books, with more than seven hundred figures, of the collection of jade belonging to the first Emperor of the Southern *Sung* dynasty, who had resigned the empire to his son in the year 1175, the year before it was published by an imperial commission of nineteen members, including one writer and four artists, presided over by the President of the Board of Rites, Lung Ta-yuan, the author of the original preface, which reads thus:

"His Majesty the Great Exalted Glorifier of *Yao*, the Sacred Emperor, endowed by Heaven with love for antiquity, and therefore fond of searching the ancient records, reposing from the toils of state, one day quoted to us the Annals of Ch'u, which say that, "The Ch'u State had nothing which they deemed precious, it was only virtue which they thought precious." Therefore what is there in old curios to be fond of? Yet to perfect knowledge it is necessary to study the real things, is what the sacred classics teach us most clearly. The sacrifical vases like the *ting*, *yi*, *tsun*, and *lei*,* are important vessels, and these have all been described in the *Po ku* and *K'ao ku* books. But the largest of these vessels are big enough to hold an ox, and even the smallest to contain a good-sized measure of grain, so that very few could be carried in the girdle pocket or placed upon the side-table. For those who like to take them away in their sleeves, handy to be caressed, and easily carried about, only pieces of ancient jade are available. Therefore from the complete collection of specimens preserved in the imperial palace, when resting from a myriad affairs, he orders his near attendants to bring some out to rejoice his eyes.

* These vessels were anciently cast in bronze. The *ting* is a caldron with two handles or ears, either of rounded body with three legs, or of oblong form with four legs; it was originally a cooking vessel. The *yi* is a flat-bottomed vessel without feet for holding sacrificial millet, the *tsun* a trumpet-mouthed vase for holding sacrificial wine, the *yi* also a vase for wine, engraved with cloud-scrolls and similar designs from which it got its name. The old forms are copied in the present day in porcelain, jade, etc., as well as in metal. The Buddhists have adopted the *ting* as an incense-burner and the *tsun* as a pair of flower vases for their altar set.

His Majesty the Great Exalted Sacred Emperor, of supernatural wisdom and celestial genius, and naturally endowed with knowledge of things, although he allows his mind some distractions in leisure hours, yet he is not lost in a mania for curios, but consults the classics as mirrors of antiquity to perfect his sacred scholarship.

"He has lately, wearied with the weight of affairs of state, resigned the throne, and stays highly reverenced in the celestial palace. His Majesty the Reigning Emperor, rivalling *Shun* of Yü in filial piety, and equal of *Yao** of T'ang in power, waits upon His Majesty the Great Exalted Sacred Emperor, a model to his family and state, holding the whole world in trust for his delectation, so that of all the precious things that can feast the eyes, there is nothing that he does not search out and reverently offer. So His Majesty the Emperor himself, when tired with toil, has rested awhile at the T'ang-t'ing pavilion, and during his visits there has compiled a full description of the rare pieces of precious jade belonging to various dynasties. Yet he is not satisfied with its completeness, and he has commissioned his officers to take silver and select more pieces, and has acquired altogether more than seven hundred specimens, which he has reverentially presented to the Tê shou kung, to be kept there as pure ornaments for the side-tables of His Majesty the Great Exalted Sacred Emperor.

"He has accordingly commissioned us his servants, Ta-yuan and his colleagues, to arrange them in proper order, to collect artists in color to draw the different forms, to state the exact dimensions, to make careful quotations from books, and to write a complete description of each piece.

"His servant has heard that the scholars of olden times likened jade to virtue, because dirt would not stain it, nor friction injure it, because it was of liquid aspect yet brilliant, of warm appearance yet strong. So from the Three Dynasties to the present day, all the important vessels of the Ancestral Temple and all the chief treasures of the imperial court have been fashioned out of fine jade. From the Son of Heaven down to the hereditary princes and high officers, all carried or wore jade in the form of *kuei*, *chang*, *huan*, *pi*,† and the like, each denoting a particular purpose and not used solely for ornament.

* *Yao* is the designation of the Great Emperor, who, with his successor *Shun*, stands at the dawn of Chinese history as a model of all wisdom and sovereign virtue. After occupying the throne for seventy years he set aside his unworthy son Tan Chu and selected the virtuous *Shun* as his successor, giving him his two daughters in marriage, and abdicating in his favor. *Shun* adopted the great *Yü* as his successor, the founder of a hereditary line, the first of the three ancient dynasties, whose reign is said to have begun B. C. 2205.

† The different forms of these jade antiquities are illustrated in the subsequent pages of the book. The *kuei* was an oblong tablet or baton of rank coming to a point above, the *chang* half a *kuei*, divided longitudinally. The *huan*, originally an armlet of stone, was a solid ring, the *pi* a circular tablet pierced with a hole in the centre. These last were most highly valued in feudal times in China and cherished as the palladium of the principality, so that a single *pi* would ransom several walled cities. When circular money was adopted as a metallic currency in China during the *Chou* dynasty, the first bronze coins were cast in the form of the ancient jade *pi*.

Learned scholars of after times carefully explore dark caves and search the recesses of mountains, sparing neither silver nor silks to buy these at large prices. As soon as a specimen is acquired they distinguish its workmanship and design and trace out its model and form, both telling of the different colors of the jade and of the details of the carving. Though buried in deserted ruins, or thrown away in old pits, yet they have not been lost, but after having long lain hidden during thousands or hundreds of years, have one day been recovered by the world, to be passed from hand to hand as presents, so that precious jade has also its periods of light and darkness fixed by fate.

"Your servant, reverently obedient to the special command, has collected a body of officers, who, after extensive research into antiquity, reference to the classics and other books, have figured the specimens, painted them in color, and written a description of each. The exact dimensions of the pieces and the presence or absence of spots and other colors are all duly described, so that it is only necessary to open the leaves to see everything at a glance, and to know the dynasty and the class of vessel. The jades in the collection have been enclosed, as it were, in a casket, where there is no fear of their being broken, and they can be seen by merely unrolling the scrolls, so that after readers may be appealed to, to attest the truth of my words.

"So your servants, Ta-yuan and his colleagues, though their knowledge is not sufficient to paint the whole ox, nor their scholarship to include the two sides of the leopard, have, reverentially honoring the imperial order, ventured to try to carry out the task, and have compiled this *Ku yü t'ou pu* in one hundred books, which they reverently offer in the imperial palace, in the fond hope that His Majesty, the Emperor, when free from the myriad affairs of state, may lend his light-giving glance, so that his servants may be honored with his unbounded grace and be rendered exceedingly joyful."

First day of third month of third year of *Ch'un-hsi* (A. D. 1176).

After the preface there is a list of nineteen names, giving the members of the commission with all their titles and honors, including one writer, and the four artists, Liu Sung-nien, Li T'ang, Ma Yuan, and Hsia Kuei, who are all included in the large catalogue of writers and artists published in the reign of *K'ang-hsi.*

The Second Preface by Chiang Ch'un, dated the forty-fourth year of *Ch'ien-lung* (A. D. 1779), relates how "a manuscript copy of the book had been purchased in 1773, when the emperor had issued a decree to search throughout the empire for lost books, and a copy sent to be examined by the library commission then sitting. This year I again read through the original manuscript and found the descriptions clearly written and the illustrations cleverly executed, so that it was worthy of being compared with the *Hsüan ho Po ku t'ou.* This book describes the ancient bronzes referred to in the Rites of the *Chou* dynasty, while our work describes the jade, so that we could not spare either. The *Po ku t'ou* was reprinted several times and gained a wide circulation, while this book remained in manuscript and attracted no notice, not being included in the Catalogue of Literature of the *Sung History*, nor quoted by older writers. Lung Ta-yuan, whose name is included in the chapter on Imperial Sycophants of the *Sung History*, died before the date of publication, but he is left at the head of the commission, in memory of the work done by him. His actions were not worthy, but that is no reason for suppressing his book. I again bring this book before the eye of the Emperor, that it may again be referred to the library committee for revision and be corrected by them, and have the honor of being reprinted under special imperial authority."

The verdict of the library committee seems to have been unsatisfactory, for they criticise the book most severely in the Imperial Catalogue (*Ssŭ ku ch'üan shu tsung mu*, Book 116, folios 7-9), on account of there being no references to it in later books, and of certain anachronisms in the list of members of the commission, and declare it finally to be a fraud and not even a clever one, without any examination, however, of the contents. In consequence of this adverse decision, the book, in spite of the appeal in the preface, was not reprinted with the imperial imprimatur, and it has now become very rare. The illustrations, at least, seem to date from the *Sung* dynasty and to represent the imperial collection of the period, several of the pieces being inscribed on the back as having belonged to the *T'ang* and *Southern T'ang* dynasties, which flourished before the *Sung*. The collection is distributed under the following classes:

1. State Treasures (*Kuo pao*), Books 1-42
2. Amulets or Talismans (*Ya shêng*), Books 43-46
3. For Chariots or official Dress (*Yü fu*), Books 47-66
4. For use in the Study (*Wên fang*), Books 67-76
5. For burning Incense (*Hsün liao*), Books 77-81
6. Drinking Vessels (*Yin ch'i*), Books 82-90
7. Sacrificial Vessels (*Yi ch'i*), Books 91-93
8. Musical Instruments (*Yin yo*), Books 94-96
9. Decorative Furniture (*Ch'ên shê*), Books 97-100.

The first class includes the tablets and insignia of rank worn in former times by the Emperor and high officers, symbols of worship, State seals, and medals. It begins with two oblong tablets over a foot long, with two undecipherable characters on the face of each, attributed to the ancient Emperor *Yü Wang*, from the resemblance of the characters to those of the inscription from the Ku-lou Mountains.* They are described as having been discovered in two bronze tripod urns, weighing about one hundred and fifty pounds each, during the period *Chih-ho* (1054–55), in the dried bed of the Chi River, and were supposed to have been put into the river during the *T'ang* dynasty as offerings to the river god, being inscribed on the reverse side in antique script—"Black kuei of *Yü Wang* when he removed the waters. Precious specimen preserved in the Treasury of *K'ai-yuan* (713–741) of the Great *T'ang* [dynasty]."

Many other tablets follow, but they have little pretension to the great antiquity assigned to them, and some of the inscriptions are evidently copied from pieces of ancient bronze figured in archæological books, and, in fact, many of the specimens in the later parts of the collection seem to be derived from a similar source—the fountain-head of almost all Chinese decorative art.

The symbols used in imperial sacrificial ceremonies come next, a long series of round, square, octagonal, and diverse form. The round symbol, *pi*, twenty inches in diameter, drawn in Book 14, folio 11, like that used in the *Han* dynasty when the Emperor prayed for rain in time of drought, has a three-clawed dragon coiled round the central hole, an antique model of the modern Japanese dragon.

In Books 25 and 26 are the tiger-shaped tablets worn by high officers in the *Han* dynasty, types of the gold and silver tablets of authority described by Marco Polo, and figured in Yule's beautiful edition of his travels. Books 27 and 28 contain libation ladles and ceremonial weapons copied from ancient bronze implements. The next two

*Given in Legge's *Chinese Classics*, Vol. III, page 73.

books, sword-hangers and mounts, scabbard-guards and ornaments, halberds and maces.

The eight following books are filled with a long succession of imperial seals, beginning with the famous palladium seal of the first Emperor of the *Ch'in*, the builder of the Great Wall of China in the third century B. C., the possession of which conferred succession to the empire, hence its name of *Ch'uan kuo hsi.* The seals of the *Han* dynasty, which succeeded him, are square, with elaborately carved handles in the form of dragons and other monsters, interlacing rings, elephants, and fabulous birds. The seals of the *T'ang* are of similar shape, surmounted by handles of spotted deer, elephants, tortoises, etc. Seals of the dynasty then reigning, the *Sung*, occupy Books 35–38, of varied form, with handles of ch'i-lin, fishes, lions, or intricately coiled dragons, sometimes decorated all over with engraved dragons and phœnixes. The description of two of these may be extracted. The first, a square seal figured in Book 37, folio 7, with well-designed horse standing upon it tied to a ring in a post, to serve as a handle; the inscription graven in relief on the lower face being illustrated separately. "The above seal twenty-four-hundredths of a foot square, thirty-one-hundredths high, with handle in the form of a dragon horse, is of jade of translucid white color without spot. The inscription in four characters of antique script reads: Seal of imperial autograph. This is the seal that was always used by the Emperor *Hui Tsung* (1101–25) when he wrote an autograph dispatch to one of the princes or nobles, or to a foreign country. The handle is said to have been carved by the clever craftsman Wang Yu; the horse is modelled with rare skill, and is instinct with life, an inimitable piece of work." The second, figured on folio 12 of the same book, is a square seal surmounted by a unicorn, and is described: "The above seal is twenty-five-hundredths of a foot square, twenty-six-hundredths high, with handle carved in the form of a fabulous unicorn. The color of the jade is pure green without flaw. The inscription in four characters of antique scripts reads: Seal of *Fêng hua t'ang.* This, meaning "Hall of respectful beauty," is the name of the abode of the Second consort of His Majesty the Great, Exalted, Glorifier of *Yao*, the sacred, long-lived emperor, a scion of the *Liu* family. This consort is learned, accomplished, and virtuous, and is known within the palace as Our Lady Liu.* She is a skilled writer and artist, and whenever the retired Emperor has occasion to reply to any official, he generally directs this lady to write the answer in the style of the Emperor's own handwriting. The seal is that usually used by the Second Consort upon her own private letters and paintings." The next book contains small private seals of the *Sung* Emperors, of curious design, one in the form of a round box with engraved scroll border, and a handle like a "cash" of the period, with a pair of birds and two fishes on its rim, inscribed *Hsüan-ho nien chih*, made in the period Hsüan-ho (1119–25). The seal of two characters, formed to look like a pair of dragons, reading *T'ien shui*, celestial waters, was used by the Emperor *Hui Tsung* on his autograph letters and paintings.

Books 39 and 40 contain a series of jade tablets, with inscriptions, belonging mostly to the *Han* dynasty. Books 41 and 42, a collection of jade medals with lucky inscriptions, "out of a box in the Treasury, over two feet long, half as much broad, and nearly a foot high, full of different kinds of jade medals, dating from the *Han* and *T'ang* dynasties. This box, made of solid silver, was inscribed on one side with the date *Shun-hua* (990–4), when it was got by the Emperor *Tai Tsung*, the second of the dynasty, after the conquest of Mêng, the ruler of Shu (modern Ssŭ-ch'uan)."

The amulets included in the second class are contained in Books 43–46, which comprise oblong pieces with Taoist

* There is a short biography of this lady in the official annals, *Sung Shu*, Book 243, folio 14, which tells us that she was promoted to be second consort in 1154, and died in 1187. She was fond of luxury as well as accomplished, and had a foot-stool made of rock-crystal for summer use which the Emperor took for a pillow, which so mortified her that she threw it away. That her seal should be included is evidence of the authenticity of the collection. Such hall-marks are still used to seal imperial verses written therein, as well as on porcelain services made for use in them.

deities and serpent handles, and others in the form of ancient sword-money, reproductions of ancient coins of different shape; medals with appropriate legends given to princesses on their marriage to hang on their bed-curtains, and others as gifts to babies at their first ceremonial bath; concluding with the signets worn at the girdle by high officials of the *Han* dynasty, with inscriptions of similar purport to that given above.

The third class begins with a jade figure from a "south-pointing chariot," followed by carved mounts for the end of shafts, tires of wheels, hooks for the reins, and other ornaments from imperial chariots. Books 49–51 give a selection of ceremonial caps or crowns, all transfixed by a jade pin to fasten them to the hair. The Empress' crown of ancient jade, figured last, reminds one in general outline of a European crown. It is described as over a foot high, made of bright green jade, with upright lobes carved in the form of cloud scrolls, inlaid with pieces of yellow, red, green, and white jade, and incrusted with pearls, corals, and precious stones, as well as divers colored glass, so that its brilliance is truly dazzling, and declared to be a rare and priceless relic of the *Han* or *Wei* dynasty. Other jade objects, worn on occasions of ceremony, follow in order. Girdles, inlaid with ornamental plaques of jade, the parures of jade ornaments, beads and chains, that used to be suspended from the neck, and detached ornaments from the same, girdle-rings, fasteners and buckles, pins for the hair, ornaments carved in the form of a pair of fish, phœnixes, or coiling lizards, a cicada, or tiger, ending with a well-designed Bignonia flower three inches long of natural-red jade, with leaves of green jade, carved out of one piece with such skill that "only a clever artificer of the *Han* could show."

The Furniture of the Scholar's Study, which forms the fourth class, fills ten books. Of the ink-pallets, the first one illustrated, with its scroll border and elephant engraved on the back, the outline of which is like that of a vase with loop-handles, is an exact counterpart of the ink-pallet of imperial porcelain of the *Sung* dynasty, No. 8, in the old album described by me.* Some of the others are of graceful design, like the double gourd, with leafy branch and tendrils for a handle, and a tiny gourd for a trench to hold the water, and the pallet, shaped like a lotus-leaf, with uptilted rim. A curious ink-pallet is drawn in Book 68, folio 9, a circular plaque of black and white jade over a foot in diameter, the two colors separated by a sharply-defined curved line, so as to form a natural symbol of the *Yin-yang*, the mystic female and male principles, separating as in the primordial chaos molecule. It has on the back an inscription of fifty-six words in verse, to the effect that it was sent to the Emperor as a tribute gift from the West.

Next come cylindrical handles and tubes for the hair-pencil, plain, with scroll borders, or engraved with dragons. One is inscribed on the handle "Upright heart makes upright pencil," on the tube "*Chien yeh wên fang*, the name of the study of *Li Yo*, the last sovereign of the Southern *T'ang*, who was dethroned in 975, so that it must have originally belonged to him.

Pencil-rests follow, in the forms of hills and natural rocks. Then water-bottles, little bowls, and water-droppers; some of the former of elegant design, like the dragon-handled vase in Book 71, folio 7, the body of which is decorated with cloud scrolls, the shoulder and neck with leaf borders, the foot and rim with pearls; others in the form of animals, a goat or duck, a toad or tortoise, or of plants, like the lotus or musk-melon. Then letter-weights, foot measures; and ornaments for the table, *ju-i* † set with rubies and other precious stones,

* *Chinese Porcelain before the Present Dynasty.* Page 13. By S. W. Bushell, M. D. Peking Oriental Society, 1886. A wine-pot of *Hsüan-tê* (1426–35), No. 40 of this album, of deep-red porcelain, and described as copied from a jade wine-pot of the *Han* dynasty used by the Emperor, is exactly similar in form and design to two of the wine-pots figured in the *Ku yü t'ou*, which are attributed to the same date.

† The *ju-i* is a magic wand often placed in the hands of Taoist divinities. It seems to have been originally a branch of the woody colored fungus, *Polyporus lucidus*, an emblem of longevity, often met with in Chinese art.

chowry- (fly-brush) handles, body-scratchers of quaint form and design, and lastly a Buddhist rosary with one hundred and eight beads.

The urns or censers for burning incense and fragrant wood, which constitute class 5, are distributed through five books, and are all modelled on ancient bronze designs. So are most of the wine-vessels and wine-pots, libation-cups and drinking-cups figured in the next nine books. An exception to this general rule is the wine-vessel in Book 90, folio 5, modelled in the form of a horned dragon of fierce aspect, with scaly body 1.65 feet long, hollowed out to hold the wine, which is poured in at the top of the head, and flows out when the cap is taken off from the end of a spout hidden under the tongue. "The hair and beard are carved fine as silk, the eyes are constructed so as to move in hollowed sockets, and the white translucid jade of the scales made so thin that the red color of the wine shines through. This rare and valuable present was sent by the king of Khotan as tribute in the period *T'ien-shêng* (1023–31), and has been placed among his greatest treasures by each successive emperor of our dynasty down to the present." The sacrificial vessels of class 7 include wine-receptacles of diverse form and tazza-shaped round dishes for other offerings, also made after antique bronze designs.

The Musical Instruments of class 8 include what may be described very closely as guitars, bells, sounding-stones, mouth harmoniums, pandean pipes and flutes, drums of different kinds, clappers of five pieces hung on a string, and stringed instruments of various shapes.

The ninth and last class opens with a short series of Buddhist and Taoist figures and scenes, engraved on oblong plates of jade between two and three feet long,

The name is composed of two characters meaning "as you wish," and must be distinguished from *jui*, a monosyllable meaning tablet or baton, which is used as a general term to include the *kuei* and other ancient badges of feudal rank. A jade *ju-i* mounted with jewels was included among the presents sent by the Emperor of China to Queen Victoria in the fiftieth year of her reign, and one is often sent to a high mandarin on his sixtieth birthday or other auspicious occasion.

including a carved image of the god of longevity. A representation of Amida Buddha, seated with staff and rosary, is engraved within a medallion on the first plate, dated *Pao-ta* (943–957).

The next, an irregular four-sided plaque of pure white jade over two feet in height and breadth, has upon it an image of Samantabhadra, one of the great saints of the Tantra school of Buddhists. The figure, seated on a mat, with a flower-vase on its left and an alms-bowl on the right, in the midst of rocks enveloped in clouds, is said to have been miraculously produced, not carved by mortal hand. The empress mother of *Shên Tsung*, the fifth ruler of the *Sung* dynasty, who was an ardent devotee of this saint and of the goddess Kuan-yin (Avalokiteshvara), commissioned one of the chamberlains named Kao K'an to burn incense to them in the cave Hu Yin Tung. From this cave, one day in the year 1068, came sounds of thunder and a torrent of water bringing with it this sacred image, which Kao K'an carried in all haste to the empress, who placed it with much ceremony in a shrine within the palace for her own worship.

Another medallion-picture carved on light green jade of "Samantabhadra washing the elephant" is inscribed as drawn after the artist Yen Li-pên of the *T'ang* dynasty, by the worker in jade P'êng Tsu-shou, to be presented by the imperial treasury of *K'ai p'ing* (907–910) of the *Great Liang* to the Buddhist monastery, Hung Ming-ssŭ. *Kai-p'ing* was the title usurped by Chu Wên, a rebel who flourished in the ninth century at the end of the *T'ang*, till he was stabbed by his son. The pictures of the god of literature and of the ancient emperor of the east with their attendants are inscribed with the names of the carvers, one of whom, Wang Yu, has already been alluded to, belonging to the Imperial Jade Manufactory of the *Sung* Emperor.

The former Wên Ch'ang Ti Chun, whose celestial abode is in the Great Bear, is seated on a mule riding upon the clouds, with two attendants on foot, one carrying the *ju-i* sceptre, the other a lyre wrapped in silk. Tung Wang

Kung, the Lord Sovereign of the East, one of the most famous divinities of Taoist legend, was the husband of Hsi Wang Mu, the Western Royal Mother, the queen of immortals, who dwells on the K'un-lun Mountains in a magnificent palace, on the borders of the Lake of Gems, beside which grows the peach-tree of the genii whose fruit confers immortality. In the *Sung* dynasty a mystical doctrine representing this pair as the first created and creative results of the powers of nature was elaborated. The god holding a scroll in his hand is seated here before a tripod urn preparing the *elixir vitæ* from vermilion, with two attendants standing near, one bearing the *ju-i* sceptre, the other a basket of peaches. Both of these works of art are dated the second year of the *Hsiang-fu* period, corresponding to A. D. 1009.

Then come jade pillows, one of four-sided oblong form two and a half feet long and nearly a foot across, with scroll borders made of translucent white jade with a slight tinge of green, engraved all over with dragons and phœnixes in clouds fine as silk, said to be a relic of the palace of the *T'ang*. Then shoulder-rests for the divan, like small tables, and boxes carved in openwork for holding fragrant flowers or perfumes.

Book 100 contains the largest specimen in the collection, an oval vase (*wêng*) figured on folio 3, and described as 4.4 feet high, 7.2 feet in circumference at the body, 3.6 at the mouth, of translucid white color, with moss-green marks and spots of brighter emerald-green. It is engraved with three-clawed dragons in pursuit of pearls emerging from sea-waves and surrounded by clouds, which show out the rare green tints of the ground. When filled with wine it holds about eighty pints. It is described as the largest known jade vessel and of perfect workmanship, a unique relic of the *Chin* or *T'ang* dynasties. Among the other pieces figured here are a large fish-bowl (*kang*), 3.6 feet high, 6.4 feet round, decorated with fishes and dragons, square flower-pots, round and foliated saucer-shaped dishes for holding flowers, a circular deep dish with four legs for iced melons or sliced fruit in summer, the last illustration being that of a plain round bowl of beautiful emerald-green jade without flaw, of simple antique design.

But it is time to turn to the consideration of modern artistic work in jade. The principal workshops are at Peking, where, however, only small articles of daily use, such as snuff-bottles, mouthpieces for pipes, beads for the mandarin's rosary, rings, and other objects of personal adornment are turned out in the present day. I persuaded a Chinese artist to visit some of them and take sketches of the different processes of work and of the tools employed in working into shape the rough material, carving and polishing it to its perfect form. He found much difficulty at first, as the suspicious craftsmen were convinced that he was only anxious to worm out their secrets for his foreign friends to improve the tools and gradually supplant their work. At last, however, he fell in with one more amenable to reason, invited him to the theatre and to a good dinner afterwards, at which he made his notes, and arranged for a tour of the workshops next day. The results of his visits are embodied in the twelve pictures, which, with my translation of the descriptions of the artist, Li Chêng-yuan, follow Mr. T'ang's Discourse on Jade, now to be given.

He calls his article *Yü Tso T'ou*, "Illustrations of the Manufacture of Jade," and introduces the water-color illustrations by a short preface accompanied by a table of contents, which I will translate. The preface occupies the middle of the page, and must be read in vertical lines, from right to left. The table of contents is written on the pink ground on either side. The first two processes: (1) "Pounding the Sand," and (2) "Grinding the Sand," are combined in the first picture, so that the thirteen in the list make only twelve illustrations altogether.

YÜ-SHUO

A DISCOURSE ON JADE

With Researches on the
History of Jade

By

T'ANG JUNG-TSO

styled

HSI-WU

Citizen of Peking

Graduate and Scholar of the Chinese Empire

Translated

by

STEPHEN W. BUSHELL

YÜ SHUO

A DISCOURSE ON JADE

Written by

KU YU HSÜAN CHU JÊN
Dweller in the "Hall of Ancient Rarities"

Sealed
With His Library Seal

"KU YU HSÜAN YIN"

In the Cyclical Year Kêng Yin of
the Emperor *Kuang Hsü*

TABLE OF CONTENTS

YÜ SHUO.

I. SOURCES OF JADE.

The magic powers of heaven and earth are ever combining to form perfect results: so the pure essences of hill and water become solidified into precious jade. Hence all the places which produce jade are situated in the midst of mountains and streams. A short account of these may be gathered from different books.*

The "Book of Annals" (*Shu ching*), in the *Tribute of Yü*,* records that the province of Yang Chou sent as tribute *yao* and *k'un* stones, bamboos small and large, etc. The Commentary says that *yao* and *k'un* were both precious jades. Also that the province of Liang-chou sent as tribute *ch'iu*, iron, silver, stone for arrowheads, and musical stones. The Commentary says that *ch'iu* were musical stones of jade. Also that the province of Yung-chou sent as tribute *ch'iu*, *lin*, and *lang* and *kan*, precious stones. The Commentary says that the *ch'iu* and *lin* were fine jades and could be used to make the symbols of rank called *kuei* and *chang*.

The "Rites of Chou" (*Chou Li*), in its Geographical Section, says that the region due west was called Yung Chou, and that its commerce was in jade and stones. The "Book of Rites" (*Li Chi*) says that rocks which contain jade have a vapor like a white rainbow beside them, its pure essence becoming visible in the mountains and streams. The *Po*

* *The Tribute of Yu*, which forms Part III of the *Shu Ching*, is the title of the First Book of the *Hsia* dynasty. It comprises the Division of the Empire of China, with the natural productions and revenue of the different districts as fixed by the Great *Yü*, the founder of this ancient hereditary line. It is generally considered to be an authentic document of the third millennium B. C., and may be called a "Domesday Book of China." The Commentaries quoted above are those written during the *Han* dynasty some two thousand years ago. (See *The Chinese Classics*, in 7 vols., translated by James Legge, D. D., Professor of Chinese at Oxford University.)

wu chih says that the hills on which millet grows produce jade; Huai Nan Tzŭ, that streams which have round bends contain pearls, those with angular bends jade. An illustrated book on jade mirrors (*Yü ching t'ou*) says that when in the second month the plants growing on the hills have a light hanging down from them, there is jade; the spirit of jade being like a beautiful girl. Another book on jade (*Yü Shu*) says that jade has markings on it like dark hills or like green waves; that when it occurs in mountains the trees are luxuriant; when it is produced in rivers the water is fertilizing; and that although hidden in the rock its mottled colors shine through.

From these various quotations it may be seen that there are two kinds of jade, the one found on mountains, the other in rivers. In China jade is generally found in the hills, while in Khotan (Yü-tien) it occurs usually in rivers. The Materia Medica (*Pên Ts'ao*), quoting Hung-ching (A. D. 452–536), says: "The best jade comes from Lan-t'ien, also from Nan-yang, and from the Lu-jung river in Jih-nan; that brought from the foreign countries of Khotan (Yü-tien) and Kashgar (Su-lê) is also good. If translucent and white as hog's lard, and resonant when struck, it is genuine. The counterfeits have many points of resemblance and must be carefully distinguished." The *Yi wu chih* says that jade comes from the K'un-lun Mountains. The *Pieh pao ching*, that rocks which contain jade must be examined with a lighted candle, and when it shows inside a red light bright as the newly risen sun, it may be known that there is jade. Sung (Su Sung, Eleventh century) says: "In the present day neither in Lan-t'ien, Nan-yang, nor in Jih-nan is there any mention of jade, and it is found only in the Khotan (Yü-tien) country." During the After *Chin* dynasty in the reign *T'ien-fu* (936–43) the superintendent of the banqueting court Chang Kuang-yi was sent on a mission to Khotan, and wrote a diary of his journey, in which he states that "The place where jade is obtained in this country is called Jade River, which runs outside the walled city of Khotan. Its source is in the K'un Mountains, and it flows 1300 *li* from the west before it reaches the Bull's Head Mountain in Khotan, where it divides into three rivers. The first, called White Jade River, is 30 *li* to the east of the city; the second, called Green Jade River, 20 *li* to the west of the city; the third, called Black Jade River, being 7 *li* west of the Green Jade River.* Although the source is the same the jade varies according to locality, and is of these three different colors. Every year in the fifth and sixth months a swollen torrent of water rushes down and the jade follows with the current, its quantity depending on the size of the flood. The water recedes during the seventh and eighth months, and it can then be collected, the jade fished for, as the natives say, according to fixed rules made by the State. For ritual vessels, ornaments, and food vessels they often use jade, and the jade which we have in the Central Kingdom (China) also comes from this country."

There are even fields where jade can be cultivated, according to the *Sou shên chi*, which relates that "Yung-po, when his father and mother died, buried them in the Wu Chung Hills. There was no water on these hills, and Yung Po founded a station there for the distribution of tea. A certain man as soon as he had drunk brought out a pint of stone pebbles, gave them to him, and told him to plant them, and that they would grown into fine jade. It was afterwards really so." In the present day even in the province of Chih-li, within the boundaries of Yü-tien-hsien, there are fields where jade is cultivated.

Coming to the mountains which produce jade, these are not confined to one district. The *Êrh-ya* in its Geographi-

*The account of the rivers of Khotan, as related here, is somewhat confused, and difficult to reconcile with more recent descriptions. The "Bull's Head Mountain" is described in the Annals of the *Tang* dynasty as having two very steep-pointed peaks, with a Buddhist monastery containing a celebrated statue of Buddha built between them. It is given there the name Ku-shih-ling-ka, the Chinese transcription of the Sanskrit *Gaushringa*, which means also Bull's horns, and stated to be situated 20 *li* southwest of the royal city of Khotan. The large river which now runs 50 *li* west of the modern city is known as Káráhásh or Black Jade River. The Yúrúngkásh or White Jade River, which runs northward, to join the other, passes 5 *li* east of the city. Both these rivers rise independently to south of the K'un-lun range, which they pierce.

cal Section says: "The finest productions of the Eastern country are the *hsün*, *yü*, and *ch'i* of the Yi-wu-lu Mountain"—Yi-wu-lu, according to the Commentary, being a mountain in the modern Liao-tung, *hsü*, *yü*, and *ch'i* different kinds of jade. Again: "The finest productions of the western countries are the many jewels and jade of Ho Shan"—Ho Shan, according to the Commentary, being in the modern P'ing-yang at Yung-an hsien. Again: "The finest productions of the Northwest are the *ch'iu*, *lin*, *lang*, and *kan* of K'un-lun Hsü"—*Ch'iu* and *lin*, according to the Commentary, being the names of fine jades,—*lang*, *kan*, in shape like pearls; K'un-lun the name of a mountain, *Hsü* meaning its base.

Some other historical jades, like that found at Lan-tien of the Chou, at Ho-shih of the Ch'u State, at Chieh-lu of the Sung State, and at Ch'ui-chi of the Chin State, were all the highly prized treasures of the different States.* Jade was produced in other places, but none to rival these.

Besides these there are the jade stones of Yárkand (Yeh'rh kiang), an account of which is extracted from the *Hsi Yü Wên-chien-lu*: "Yárkand is a large walled city of the Mohammedan country. In its territory there is a river in which are found jade stones, the largest as big as round dishes or square peck-measures, the smallest the size of a fist or chestnut, some weighing as much as three or four hundred catties. There are many different colors, among which snow-white, kingfisher-feather green, beeswax yellow, vermilion-red, and ink-black are all considered valuable; but the most difficult of all to get are pieces like mutton-fat with red spots, and others bright green as spinach with gold stars shining through, and these last two kinds are considered the rarest and most precious. Along the river-bed extends a deep layer of

* The period referred to here is that of the *Chou* dynasty. The sovereigns of the Chou, with their capital at Loyang, ruled over the Royal Domain or Central Kingdom, as suzerains of the surrounding feudal states, till their overthrow by the founder of the *Ch'in* dynasty in B. C. 255. The states mentioned above are the Ch'u on the southwest, the modern Ssŭ-ch'uan, the Sung on the east ruled by the descendants of the *Shang* dynasty which preceded the Chou, and the Chin of the north.

stones both large and small, the jade pebbles being mixed with the rest. When the time comes for collecting them an official takes up his station some distance from the bank, and a military officer is posted close to the river. Native Mohammedans who understand the work having been levied, they walk in rows of thirty or twenty, shoulder to shoulder, stretching across the river, with bare feet, over the stones. When they come to a jade stone the Mohammedan knows it by the touch of his foot, and stoops down to pick it up. The soldier on the bank makes a stroke on his gong, the official then makes a red mark on his list, and when the natives come out of the water he requires of them as many pieces of jade as he has made marks."

"At a distance of 230 *li* from Yárkand there is a mountain called Mirtái Tapan,* where the whole side of the hill is of jade of all the different colors. But the stone is so mixed with jade, and the jade so veined with stone, that to get a quantity of blocks of pure jade, without flaws, weighing from 1000 to 10,000 catties, one must go to the top of the highest precipices, which are inaccessible to men alone. There are, however, yaks bred in this country which are trained to climb, and the Mohammedans, taking their tools with them, ride upon these yaks. They then scale the precipice, dig out the pieces with the chisel, and let them fall down to be collected afterward. These are commonly known as 'stone pieces,' also called 'hill stones.' Twice every year, in spring and autumn, Yárkand sends as tribute from between 7000 and 8000 up to 10,000 catties of jade."

"Still farther south, 700 *li* distant, is the Mohammedan walled city of Khotan (Ho-tien), situated in the midst of a fertile plain, 1000 *li* broad, the whole of which produces jade pebbles even in greater abundance than in Yárkand."

In the present day Hsi-an-fu, in the province of Shensi, Kuei-lin-fu in Kuangsi, Hsü-chou in Honan, as well as the

* Tapan is the Chinese transcript of the Manchu Dabán, "mountain." The Mirtái Mountains are the same as the Belurtág, being the part of the great K'un-lun range to the southwest of Yárkand.

districts of So-chü-hsien * and Ho-tien-hsien in the New Dominion, all these places produce jade.

There is a dark green jade (*Pi yü*) † commonly called Yunnan jade, but there is no mention of the production of jade in this province ; this kind of jade really comes from Burma (Mien-tien). The dealers in jade coming hither to and from China must all cross this province, and from this circumstance the name of Yunnan has been given to distinguish this peculiar kind of jade.

II. CRUDE JADE.

By crude jade is meant unwrought jade. It has been collected, but not yet carved. From its own natural qualities and its peculiar solidity and pure color, with no addition of carved ornament, it is considered a thing of rare value.

The Book of Annals (*Shu*), in the Testamentary Charge (of King Ch'êng), says that the great jade, the *Yi* jade, the cærulean jade, and the river plan, were all spread out in the eastern chamber. The Commentary adds that the great jade came from Hua-Shan, the *Yi* jade from the north-east, and the cærulean jade as tribute from Yung-chou, its color being like that of the sky. These three must all have been of crude jade and uncarved, because there is no mention of utensils.

The *Fu jui t'ou* says: "Jade sprouts are rare and precious ; not worked, but growing spontaneously, they shine like white flowers. In the reign of *Wên-Ti* of the *Han* dynasty, jade sprouts were seen in Wei-yang. It is said that these jade sprouts are seen when the five virtues are cultivated." According to the dictionary *Yun-hui* all

* So-chü, anciently pronounced Sa-kü, is the old name of Yárkand ; Ho-tien is a modern Chinese transcription of Khotan. These are two of the principal districts of Chinese Turkistan, or Hsin Chiang, the "New Dominion" as it is called also by the Chinese, since its conquest by the emperor Ch'ien Lung in the middle of the last century.

† *Pi yü* is a general term applied to all kinds of dark green jade varying in tint from sage and olive-green to the colors of moss and spinach, down to an almost black opacity.

jade grows, and while being formed there are sprouts, stem, flowers, and fruit, just as in growing plants. The jade sprout is when it is first growing, like the first shoot of a plant; the stem the finest kind of jade, like the best-grown centre of the plant; the jade flower, when full-grown, like the flower of the plant; and the jade fruit, when its formation is completed, as in vegetable fruit. All these jades can be used. According to the *Hsiang yü shu*, jade six inches in diameter, which spontaneously emits light, is called ch'êng. The *Tao-tê-ching* says that jade must be broken up to make vessels.

Han Fei Tzŭ (third century B. C.) relates of Pien Ho, a native of the Ch'u State, that he found a piece of crude jade in the Ch'u mountains and offered it to Prince Li. The prince sent a man to examine it, who declared it to be common stone, whereupon the prince, thinking it a fraud, cut off his right foot. After Prince Wu had succeeded, Pien Ho again presented it. It was again examined and reported to be stone, and they cut off his left foot. Prince Wên succeeded in his turn, and Pien Ho, holding the jade in his hand, lay at the foot of the Ch'u mountains, weeping for three days and nights, till the tears were changed to blood. The prince sent his workers in jade to carve the rough stone, and got a priceless vessel. Thus it may be seen that the finest jade comes from this rough stone, and those who can distinguish the latter are real connoisseurs of jade.

This crude jade is also a substance of special efficacy as a medicine; it adds nervous energy and cures certain diseases. Hung-ching* says in the *Pên-T'sao* that jade powder is prepared by pulverizing jade, and that it is not a distinct substance. The *Hsien Ching* says that when jade is prescribed it must be pounded to the size of rice-grains, and then suspended in bitter spirit to the consistence of mud. Some dilute it till like rice-water. When jade is ordered by the physician, carved vessels must not be used, nor unwrought jade that has been buried in graves. Kung

*T'ao Hung-ching, who flourished A. D. 452–536, was one of the most celebrated adepts in the mysteries of Taoism.

says that when jade is taken it is best to reduce it to a liquid form. When roughly powdered to the size of small pulse, the essential part is dissolved in the intestines, the solid fragments passing away unchanged. It is also prescribed in fine powder in certain cases of constriction from stone and tumors, but the plan of pounding it to the size of small pulse is of most real value. In its pharmaceutical properties it is sweet, neutral, and not poisonous. It removes heat in the stomach, cures asthma and hot obstructions, and relieves thirst. When pounded to the size of small pulse and taken for a long time, it lightens the body and lengthens life, moistens the heart and lungs, helps the voice and throat, makes the hair glossy, and also aids to nourish the five abdominal organs. It is compatible with gold, silver, and the herb Mai-mên-tung, and is still more efficacious when boiled with these and given in combination. Other preparations of jade, like jade-water, jade-tea, and fine jade-tea, are all prepared from unwrought jade dissolved into fluid form in different ways. These various prescriptions are all contained in the Materia Medica books, in which the prescriptions are always taken from unworked jade. So highly is the best crude or rough jade valued. The same material when carved into vessels is not to be compared with it.

III. VALUE OF JADE.

Jade is a substance hard and strong, yet of liquid aspect; it is fine-grained, and beautifully marked, and yet brilliant. It is the choicest material found in the two kingdoms of nature, and quite unrivalled in value among the myriad substances.

The Book of Poetry (*Shih Ching*), in the Minor Odes of the Kingdom, says: "The stones of those hills can be used to polish jade. Ch'êng Tzŭ, in his Commentary, explains that though jade is of warm, moist aspect, and the finest production of the world, while stone is rough and coarse, and the worst of things, yet it is impossible to make vessels by rubbing together two pieces of jade, although when polished with stone jade may be worked and made into vessels. The *Rites of Chou* says that a cubic inch of jade weighs seven ounces (liang), a cubic inch of common stone six ounces. In the *Book of Rites* Tzŭ Kung asked Confucius: "May I venture to ask why it is that the model man values jade and despises steatite? Is it because jade is rare and steatite common?" Confucius replied: "The model man of old compared jade to virtue. It is of warm, liquid, and moist aspect, like benevolence; it is solid, strong, and firm, like wisdom; pure, and not easily injured, like righteousness; when suspended, it hangs gracefully, like politeness; when struck, it gives out a pure, far-reaching sound, vibrating long but stopping abruptly, like music; though faulty, it does not hide its good points, when superior it does not conceal its defects, like loyalty; its brilliancy lights up things near it, like truth; it gives out a bright rainbow, like heaven; shows a pure spirit among the hills and streams, like earth; symbols of jade rank alone as gifts to introduce persons, like virtue; and in the whole world there is no one that does not value it, like reason. The Odes (*Shih Ching*) say: 'When I think of my lord, He is soft-looking, like jade.' That is why the model man values it so highly."

According to the dictionary *Wu-yin-chi-yün*, when placed in a strong fire and it does not become hot, it is true jade. According to the *Shuo-wên*, the *p'an* and *yü* were precious jades of the Lu State. Confucius says: "How beautiful are the *p'an* and *yü*, when looked at from afar so brilliant, when closely inspected so finely marked, excelling both in material and in brilliance of surface." According to the *Pai Kuan*, fire jade is red in color, and can heat a copper cauldron; warm jade will counteract cold, cold jade will remove heat; fragrant jade has a sweet smell; soft jade is of soft material; sun jade reflects a visible picture of the palaces of the sun: these being all precious things of rare occurrence. The Life of Wang Mang in the Annals of the Former *Han* dynasty says that fine jade will remove scars. The Miscellanies of the West Capital (of the *Han*) relates that there were in the Hsien-

Yang Palace five lamps of green jade, seven and a half feet high, carved in the form of lizards, holding the lamps in their mouths, and that when the lamps were lighted their scales all moved and the bright light filled the hall. The *Tu Yang-tsa-pien* records that during the *T'ang* dynasty the Kingdom of Japan presented to the Emperor an engraved gobang board of warm jade, on which the game could be played in winter without getting cold, and that it was most highly prized. Also that the Emperor *Tai-Tsung* of the *T'ang*, went one day to the Hsing Ch'ing Palace and found there in the double wall a precious casket containing a jade mace with the characters "soft jade mace" inscribed on the end. This had been offered in the period *T'ien-pao* (A. D. 742–755) by a foreign state. It could be bent until the two ends met, and straightened out again as rigid and firm as a stretched cord. Neither fire nor strokes of an axe hurt it. The sovereign, delighted with it as a magic thing, ordered an embroidered case of fine silk to be made for it, and a scabbard of green jade. Again, that 30,000 *li* east of Japan* is the island of Chi-mo, and upon this island the Ning-hsia Terrace, on which terrace is the gobang player's lake. This lake produces the chess-men which need no carving, and are naturally divided into black and white. They are warm in winter, cool in summer, and known as cool and warm jade. It also produces the catalpa-jade, in structure like the wood of the catalpa-tree, which is carved into chess-boards shining and brilliant as mirrors. Again, that in the reign *Shun Tsung* (A. D. 805) an embassy from the west presented two pieces of jade, one round, the other square, both half a foot in diameter, of brilliant surface reflecting like a mirror. Yi-ch'i Yuan-chieh, who was seated at the time before the Emperor, after carefully examining them, said: "One is dragon jade, the other tiger jade. The round

* The book quoted here is by an author who is fond of the marvellous, and, as Mr. Wylie in his *Notes on Chinese Literature* (p. 155) says, many of his statements have the appearance of being apocryphal, so that we must not conclude from this passage that the Chinese at this time were in communication with America.

piece is the dragon, produced in water, and highly prized by the dragon, and if it be thrown into water it will emit rainbow colors. The square piece is the tiger, produced in precipitous mountain valleys, and highly prized by the tiger, and if it be rubbed with tiger fur, purple rays will proceed from it, and all animals will cower trembling." The Emperor praised his words. The Additional Records of the *T'ien-pao* period say that Yang-Kuei-Fei kept jade in her mouth and sucked it to relieve lung thirst. In the *Yu-yang-tsa-tsu* it is related that the chamberlain Ma prized highly a bowl of pure jade, far excelling common jade, because even in the heat of the summer flies would not enter it, and because when filled with water the water was neither spoiled nor diminished even after a month, and also because the application of the contents of this bowl to imflamed eyes immediately cured them. The *Yi-chien-chih* says that in the reign of *Hsüan Tsung* (A. D. 847–859), of the *T'ang* dynasty, the emperor had twelve chess-men, on which were inscribed the cycle of the twelve hours, and that when a bowl was filled with water and these men put in, as the hour came round the proper one floated to the top without making an error of a moment.

But all these things, although deemed precious, and of great rarity, are fit only to be regarded as toys and are of no real intrinsic value. It is different with the case recorded in the *Shih-chi* of the Ho-shih-pi of the Ch'u State, which was taken by *Hui Wên Wang* of the *Chao*, and for which *Chao Wang* of the *Ch'in* offered in exchange fifteen walled cities. The *Tso Chuan* says that when the Marquis of Wei was taken prisoner by the Chin State and sent to the capital, the king sent his physician Yen to poison the Marquis of Wei, but Ning Yu, an officer of the Wei, bribed the physician to dilute the poison so that he did not die, after which the Duke of Lu sent for his ransom a quantity of jade including ten *chüo* to the king and ten *chüo* to the Marquis of Chin, whereupon the king consented and released the Marquis of Wei. The commentary explains *chüo* to mean two pieces of jade. Again, when the Marquis of Chin attacked the Ch'i State and was about to cross the river, his officer, Hsien Tzŭ, tied together two *chüo* (pairs) of jade with red silk, and worshipped, throwing the jade into the water, after which they crossed over. These are instances of life and death to prince and state, and not to be compared with the fancy of a man fond of jade and thinking each piece of peculiar value.

We have also accounts of productions of human ingenuity seeking to rival the powers of nature, as in the *Han-Wu-Ku-shih*, which related how the emperor built a sacred temple and in the front hall erected trees of jade, with branches made of red coral, leaves of green jade, flowers and seeds blue and red made of precious stones hollowed out in the middle like little bells, tinkling as they hung.* Such things dazzle the eyes and please the fancy, but are of no other value.

Coming to the employment of jade as food, it is also valued by some for this purpose. The *Ho-t'ou-yü-pan* says that on the Shao-shih Mountains there is found a white jade-oil which, when eaten, confers immortality. The *Shih-chou chi* says that at Ying-chou is found a jade-oil like spirit, which is called jade-wine, and which, when some cups of it are drunk, intoxicates and gives to men long life. Pao Fu-tzŭ says that the mountains which produce jade have springs of jade-oil, which flows out clear and brilliant as rock-crystal, and which, when stirred with any hollow stem, instantly turns to water; and that one cup of this when drunk will give a thousand years. Tsang Ch'i says in the *Pên Ts'ao* that the water which comes from jade, when drunk, will confer long life and a youthful aspect. That jade so eaten should confer immortality is a test of its high value such as could hardly be surpassed!

* A pair of little trees of this kind is often presented as part of the trousseau of a rich Chinese bride of the present day, standing in flower-pots of jade, cloisonné enamel, or rare porcelain, filled with coarsely powdered lapis lazuli, or coral, instead of earth. Covered with glass shades, they make a brave show in the procession of wedding-gifts which is always carried through the streets of a Chinese city.

IV. OBJECTS MADE OF JADE.

The Book of Rites (*Li Chi*) says: "If jade be not carved the vessel cannot be made." Mencius says, "Now you have a piece of rough jade, and even if of the value of ten thousand pieces of silver, yet you will entrust it to the jade men to be carved." Therefore the employment of jade to make vessels is not a work of modern times. The Annals (*Shu Ching*) tell us that he (*Shun*) established the sphere and the jade transverse to regulate the seven planets. Again, in the Metal-bound Coffer that the Duke of Chou stood erect, having placed the *pi* (on the altar) and holding the *kuei* in his hand. Again, in the Testamentary Charge that after his (King *Ch'êng's*) attendants had put on his crown and robes, he leaned on the jade table.

The Book of Poetry (*Shih Ching*) in the State Odes says: "She grows old with her lord, wearing six jade pins in her hair"; the Commentary explaining it to mean six pins ornamented with jade. Again, "He presented to me a quince, I returned a *chü* of fine jade. He presented to me a peach, I returned a *yao* of fine jade. He presented to me a plum, I returned a *ch'iu* of fine jade." The Commentary explains that these things were all of the finest jade, the *chü* being girdle appendages, the *yao* and *ch'iu* worn also as ornaments. Again: "With woollen robes like red jade," *mên*, according, to the Commentary, being the red color of jade. Again: "When I know that you are coming, I will present you with all the jade ornaments," meaning, says the Commentary, the jade set worn on the left and right sides. Again, in the Lesser Odes:* "They (boys) will have jade sceptres to play with."

* The *Lesser Odes* form a section of the *Shih ching*. Our author is too concise, but he expects his readers to have the *Book of Poetry* on the tip of their tongue, so that one line is suggestive enough. This one is part of two verses often quoted to contrast the lot of boys and girls in China. Speaking of King *Hsüan* they run, according to Dr. Legge's translation: "Sons shall be born to him; They will be put to sleep on couches. They will be clothed in silk robes. They will have jade sceptres to play with." "Daughters shall be born to him; They will be put to sleep on the ground; They will be clothed in wrappers; They will have earthen tiles to play with."

In the Rites of Chou (*Chou Li*), the First Minister, when there is a great court reception of the nobles, aids the Sovereign with the jade presents, the jade offerings, the jade tables, and the jade libation-vessels. Again, the Chief of the Jade Treasury, when the nobles are summoned for a sworn convention, prepares the jewelled vessel and the jade dish (for blood). Again, the Minister of Rites, when there is a great sacrificial worship, laves the jade wine-vessels and hands the jade dishes ; the Commentary explaining *ch'ang* as vessels for wine, *tzŭ*, dishes for holding millet. Again, under the Minister of Punishment, the lesser envoy regulates the six symbols (*jui*) of rank, the symbol of domination (*chên kuei*) peculiar to the emperor, the pillar symbol (*kuan kuei*) held by princes of the first rank, the symbol of sincerity (*shên kuei*) by princes of the second rank, and the symbol (*kung kuei*) by princes of the third rank, the grain symbol (*ku pi*) by princes of the fourth rank, the reed symbol (*p'upi*) by princes of the fifth rank. He arranges the six precious offerings (*pi*) : horses with the kuei symbols, furs with the chang, plain silks with the pi, brocaded silks with the tsung, silks embroidered in colors with the hu, silks embroidered in black and white with the huang. These six offerings were used as presents for the cultivation of good relations with the feudatory princes.

In the "Book of Rites" (*Li Chi*), in the royal ceremonial hall, jade cups and large vessels were used for wine, jade tazzas and carved bamboo dishes for the food, and jade cups for libation. This book mentions also the four *lien* and the six *hu* of the sovereigns of the *Hsia* dynasty, described in the Commentary as jade vessels for holding millet and grain in the Ancestral Temples.

The *Tso Chuan*, in the seventeenth year (B. C. 524) of Duke Chou, records a speech of the P'i Tsao of Chêng : "If we use wine-vessels of jade and jade libation-cups, Chêng will escape the fire." Again, in the twenty-ninth year of Duke Chao (B. C. 512), the Duke presented to Kung Yen a robe of lambskin, and sent him to offer a *lung fu* to the Marquis of Ch'i. He also offered the lambskin robe, at which the marquis was pleased, and gave him Yang-ku.

The Commentary says that *lung fu* was the name of a piece of jade, Yang-ku a walled city of the Ch'i. The *Êrh-ya*, an ancient dictionary, in its section on apparatus, says that the horn bows of the time, ornamented at both ends with jade, were called kuei. Again, that *kuei* one foot and two-tenths long were called *chieh; chang* eight-tenths of a foot long were called *shu ; pi* six-tenths of a foot across were called *hsüan*. When the body (in circular pieces) was twice as large as the central hole, it was called *pi* ; when the hole was twice as large as the body, *yuan* ; when the hole and body were alike, *huan*.

The Miscellanies of the Western Capital of the *Han* dynasty (*Hsi-ching-tsa-chi*) says that in the Ch'in country, at Hsien-yang, they had a jade flute over two feet long pierced with twenty-six holes. When the Emperor *Kao Tsu* first went to Hsien-yang, and went round the treasuries there, he saw this, and played on it, whereupon mountains and groves with horses and chariots continued to appear in a mist, vanishing altogether when he ceased playing. He gave it the name of the "tube of beautiful visions."

In the "Han Annals" (*Han Shu*), in the life of *Wên Ti*, the emperor, in the ninth month of his sixteenth year (B. C. 164), is recorded to have acquired a jade cup on which were engraved four characters signifying "Long life to the sovereign of men!" Again, in the Life of *Wu Ti*, the emperor built the Têng-kuang Tower, and from the top of the tower resounded the bell made of bright-green jade.* Again, that the emperor, when his work was finished and rule established, announced the completion to Heaven, and engraved a record on stone tablets, with headings of jade painted with gold characters. Again, that the Wei-yang Palace had gates of jade.

* A jade handbell with tinkling tongue of jade is sometimes used to accompany the Buddhist priest when intoning his Sanskrit prayer. The handle is carved in the form of Buddha and the outside of the bell ornamented with Buddhist scenes and figures. The Tibetans and Mongols value these bells very highly. I tried to purchase a beautifully carved one for the Bishop Collection at the New Year's Fair at Peking in 1889, but a Mongol prince outbid me by an offer of twenty horses out of the drove he had brought down from his own country. S. W. B.

In the *San-fu-huang t'ou*, Tung Yen is described as lying in Yang-ch'ing hall on a couch made of variegated stone, with dishes before him of purple jade carved with coiling dragons, all inlaid with different kinds of precious stones; and he is also said to have had a round dish made of jade crystal filled with ice standing before him. The jade crystal and the ice were so exactly alike that an attendant one day, exclaiming that the ice, having no dish, would melt and wet the mat, threw it away, letting the dish drop, so that both ice and dish were shattered together. This jade crystal had been sent as tribute from the Khotan State, and the emperor *Wu Ti* had given it to Tung Yen.

In the Annals of the *Wei* Dynasty the emperor *Wên Ti* is said to have had a sword, the head mounted with a brilliant pearl, the hilt inlaid with blue jade, which he often handed to his attendants to destroy goblins.

In the Biography of Hu Tsung we read that during the *Wu* dynasty, when digging the ground, there was found a bronze casket, with the cover made of glass, and a second lid of mother-of-pearl, which was opened, and a white jade sceptre (*ju-i*) found inside. The sovereign questioned Tsung, who replied that Ch'in Shih-huang, on account of the existence of the spirit of the Son of Heaven in Chin-ling (Nanking), had buried precious things there in several places to keep down the sovereign spirit.

The *Yi Yuan* says that, under the *Chin* dynasty, Wang T'êng, when he was governor of Yeh, was travelling to the Ch'ang Shan, when there was a great fall of snow, covering the ground to a depth of several feet. Before the door of his tent, over a square space some ten feet broad, the snow all melted as it fell, whereupon he dug there, and found a jade horse more than a foot high. Also, that Yang Tzŭ-yang, when at Hung-nung, hearing a sound proceeding from the ground, dug there, and discovered a jade pig over a foot long. In the records of Liang-chou it is written that, in the second year of *Hsien-ning* (A. D. 276), a robber plundered the grave of Chang Chün, and found there a wine-vessel of white jade, a jade musical pipe, and a jade flute. The *Shih-yi-chi* says that, in the first year of *Tai Shih* (A. D. 265) of the *Chin* dynasty, natives of the Pin-ssŭ country came to court with clothes made of jade of different colors, like the armor of the time. Also, that the country of Po-te sent to the emperor a ring made of black jade, like lac in color. Again, that Wang Yen, during the *Chin*, made the handle of his fly-brush (chowry) of jade. Again, that the Yin Ch'in State, situated to the north of Turkistan (*Hsi-yü*), sent to the emperor, in the reign of *Wu Ti* of the *Chin*, a thousand strings of jade money, carved into rings, each ring weighing ten ounces (*liang*), with four characters engraved on it meaning "Celestial longevity, everlasting prosperity!"

The "Southern History" (*Nan Shih*) records that, during the *Liang* dynasty, in the sixth year of *T'ien-chien* (A. D. 507), the Khotan State sent envoys with offerings of the productions of their country, and that in the seventh year of *Ta T'ung* (A. D. 533) they again offered a jade Buddha carved in their country. According to the Rules of the Six Boards in the *T'ang* dynasty, in the worship of the gods of heaven and earth they used musical plaques of stone in the ancestral temple, and in the imperial palace they used musical plaques of jade. The *T'ang History* records that the Emperor *Kao-Tsung*, in the first year of the period *Ch'ien-fêng* (A. D. 666), when he worshipped T'ai Shan, had jade writings made on tablets carved out of jade, with gold characters incised, which were enclosed in a jade casket. The *Tu-yang-tsa-pien* says that T'ang Yuan-tsai had a fly-brush (chowry) made of red dragon's beard, with a ring carved out of red jade on the handle.

The "Sung History" (*Sung Shu*) records that, in the third year of the *T'ien-shêng* period (A. D. 1025), the Khotan (Yü-tien) State sent envoys to the imperial court with tribute of a jade saddle and harness and a girdle of white jade. The *Hsü-wên-hsien-t'ung-k'ao* says that during the *Yuan* dynasty the Commander-in-Chief Po Yen,*

* Po-yen is the Chinese form of the Mongolian Bayan, the celebrated military commander who conquered China for Kublai Khan. He died in the year 1294.

when he went to the Khotan country, while digging a well, discovered a jade Buddha between three and four feet high, of the color of freshly cut lard, which showed in a bright light all the sinews, bones, and blood-vessels, which he immediately sent to the emperor. There was also a block of white jade six feet high, five feet broad, and seventeen paces long, but this could not be transported on account of its weight. The Chin History (*Chin Shih*) records that, in the twenty-sixth year of the *Ta-ting* period (A. D. 1186), a great-grandson was born to the emperor, and that there was a banquet in the Ch'ing-ho Palace, at which the emperor gave him a set of mountains carved in jade with hares and tassels, while Chang Tsung (the heir-apparent) offered to the emperor a paper-weight of jade carved in the likeness of two camels, a jade instrument for playing the guitar, a phœnix hair-pin, and floral ornaments of jade.

As we come down to the present day we find larger things (carved out of jade), like flower-vases, dishes, large bowls, and cauldrons, as well as smaller objects, like girdle-ornaments, hairpins, and rings. For the banquet-table we have bowls, cups, and wine-vessels of varied form ; for congratulatory gifts, round money and oblong talismans. There are beakers and vases to be frequently replenished at wine-parties, wine-pots, and the three cups used at the wedding ceremony. There is the Buddha of longevity to pray to for life long as the southern hills, and the screen carved with the eight Taoist immortals. There are *ju-i* sceptres and mirror-stands as valuable betrothal presents ; hairpins, earrings, ornaments for the forehead, and bracelets as prized jewelry for personal adornment. For the scholar's study there are the set of vessels for burning the incense of a hundred ingredients, the tripod, vase, and box ; for more luxurious halls are flowers in pots, each pair filled with flowers appropriate to the season. There are combs of jade for dressing the hair and arranging the black tresses in the early morning ; pillows of jade for laying across the couch to snatch a dream of elegance at noon. There are rests for the wrist when the ink-pallet is being used; weights for the tongue of the dead arranged for the funeral. There are rouge-pots and powder boxes to give to the face of beauty the bloom of the peach; brush-receptacles and ink-rests to hold the weapons of the scholar before his window. There are the eight precious emblems of good-fortune for Buddhist temples; the wheel of the law, conch-shell, umbrella, canopy, lotus-flower, jar, pair of fish, and the endless knot; there are pomegranates bursting open, sacred peaches, and Buddha's-hand citrons—emblems of the all-prayed-for three abundances.* There are jade chains of round links, tokens of lasting friendship; jade seals for guaranteeing the authenticity of documents. There are beads for the rosary, to count the number of invocations of Buddha; paper-weights for the table of the scholar's study; tassel-ornaments for the fan-screen to shield the face of the coquette; jade keyless locks for fastening around the necks of children. Jade is used to carve a bracelet for the arm of the infant to give it something to suck; jade is also used to be interred with the body of the dead in the hope of preserving it from decay. Among other things are mortars and pestles for pounding drugs, and thumb-rings for protecting the hand of the archer. Lovers of tobacco-smoke prefer a mouthpiece of jade for their pipes, and gourmands like to use jade chopsticks. Jade rings are worn on the finger, to save from shipwreck in the pursuit of wine and pleasure; jade pipes used for inhaling clouds of smoke by those addicted to the opium of the west. In short, from the Son of Heaven down to the commoner, in adult, marriage, funeral, and ancestral ceremonies, for daily wear or when food is served, there is no one who does not on many occasions make use of jade.

* An abundance of sons, of years, and of happiness. The ripe fruit of the pomegranate, cracked open so as to expose the seeds inside, is an emblem of an abundant progeny; the miraculous peach is the fruit of the god of longevity; the Buddha's-hand citron the attribute of the god of happiness.

V. JADE USED BY THE SON OF HEAVEN.

The scholars of ancient times compared jade to virtue, because dirt could not soil it nor friction injure it. It is moist-looking, yet translucid; of warm aspect, yet hard. Hence, from the three ancient dynasties to the present day all the principal sacrificial vessels of the ancestral temple, as well as the most valuable objects in the imperial palace, have generally been fashioned of fine jade, so that it is necessary here to describe its use by the Son of Heaven.

The "Book of Poetry" (*Shih Ching*), in the Odes of Wei, says: "With his ear-ornaments of beautiful jade." The Commentator says that these ear-ornaments when made of jade were called *tien*, and that those worn by the Son of Heaven were made of jade. Again, in the Minor Odes of the Kingdom: "His scabbard studded above and below with gems." The Commentary says that *pi* was the scabbard, which was studded above with *p'êng*, below with *pi*, when worn by the Son of Heaven with his coat of mail; and that the *p'êng* was made of jade, and the *pi* of mother-of-pearl. Again, in the Greater Odes of the Kingdom: "On his right and left they held the libation-cups." The Commentary explains that the half-kuei was called *chang*, and says that during sacrificial worship the king poured the wine from a kuei-handled cup, the nobles in attendance offering a second libation from chang-handled cups, which were held by them on the right and left. And again: "He received the large and small sceptres (*ch'in*)." The Commentator Chêng explains that the small sceptre was the *chên kuei*, which was one foot and two-tenths long; the large sceptre, the large *kuei*, three feet long; and that both belonged exclusively to the emperor.

The "Book of History" (*Shu Ching*), in the Ta Ch'uan, says that *Yao*, when he resigned the empire to *Shun*, gave to him the T'iao-hua jade. Again, in the "Canon of Shun," that he called in the five jade symbols of rank, and on the same day of the next month gave audience to the Chief of the Four Mountains and all the Pastors, returning the symbols to the several princes. The Commentary explains these five symbols, *jui*, to be the jade symbols of the five grades of princes, the *kung*, *hou*, *po*, *tzŭ*, and *nan*, being the jade sceptres appertaining to each grade.

According to the Rites of the Chou dynasty (*Chou Li*), the Son of Heaven kept the *mao*, which was four inches long, for the reception of the several princes. The Commentator Chêng says that this *mao* was of jade, and that the jade was called *mao* to signify that the Son of Heaven enveloped the world with his virtue as with a canopy. When the nobles first received investment the emperor bestowed on them the *kuei* tablets. The angles and tops of these *kuei*, and the carved under surface of the *mao*, were made of corresponding size, length, and breadth, so that when the princes came to court, the Son of Heaven placed the carved surface on the top of the tablet, and if it did not fit it was proved not to be genuine. Therefore these symbols of rank were called *jui*. Again, it describes the Decorator of Chariots as taking charge of the five chariots of the king, of which the first was called the jade chariot. Again, it says that the king held the great tablet, and kept the tablet of domination; the Commentary explaining that the great tablet, three feet long, was held by the Son of Heaven, and that the tablet of domination, one foot and two-tenths long, was the one that used to be sent with the betrothal presents of the Son of Heaven.

The *K'ai shan t'ou* says that when Yü Wang received the command to remove the inundating waters, Yuan-yi Tsang-shui gave up to him the black tablet of jade, on which were inscribed characters from which he knew the high and low places of the nine provinces, and was enabled to dig channels and lead off the waters; and that when his work was finished he buried the black tablet on a celebrated mountain, the two characters being in an antique script, mysterious and most ancient, and quite unintelligible to ordinary scholars.

The "Classic of Rites" (*Li Chi*) says that the Son of Heaven wore in his girdle white jade with tassels of black silk. Again, in the section Yü Tsao, that the hat worn by the Son of Heaven had twelve rows of jade. Again, it says that the Son of Heaven held the sceptre (*t'ing*) straight and upright in the face of the world, the Commentary adding that this sceptre was called the great tablet (*kuei*); also, that the tablet (*hu*) of the Son of Heaven was of fine jade. Again, it says that when the sovereign summoned the officers, he used three *chieh* as tokens, two tokens to come hurriedly, one token at ordinary speed ; if at the office, they must not tarry to change shoes ; if outside, they must not wait for a chariot. The Commentator Chêng says that these tokens were made of jade, and that they were warrants to authenticate the commands of the sovereign. When the sovereign sent messengers to summon the high officers, he used sometimes two tokens, sometimes one (hence the general name of the three *chieh*), the number used being according to whether the occasion was ordinary or urgent : if urgent, two tokens to come quickly ; if not urgent, one token to come at ordinary speed. The "Illustrations of the Three Rituals" (*San Li T'ou*) says that the Son of Heaven had six tables, the jade table being the first. Also, that the red shield and the jade axe were the weapons wielded by the Son of Heaven in temple-worship. The *Lu p'u chi* informs us that when the Son of Heaven went to the audience-hall, and the hundred officers were collected, at three strokes of the jade mace they marshalled their ranks. The Life of King *Mu* (of the *Chou* dynasty) refers to the *hsüan-chu* among the valuables of the Son of Heaven, which the Commentator explains to be a kind of jade.

A Memoir of the State Seals says that when *Ch'in Shih-huang* had united the Six States, he gained possession of the jade of Pien Ho, and ordered the workmen to fashion it into a State seal, four inches square, with a handle carved in the form of a lizard, and commanded Li Ssŭ to write in the insect and fish script eight characters meaning "According to Heaven's decree may rule be everlasting!" which were engraved by the skilled workman Sun Shou, and it was called the seal of succession to the empire. Tzŭ Ying brought this seal as an offering to *Kao Tsu*, the founder of the *Han* dynasty. Wang Mang, when he usurped the throne of *Han*, tried to compel the empress to give up the seal, when it fell to the ground slightly injuring one of the horns of the lizard. Subsequently this seal came into the possession of the Emperor *Kuang Wu*. After the rebellion of Tung Cho, Sun Chien found it when digging a well, and sent it back to *Hsien Ti*, who soon after resigned it to the *Wei*. The *Wei* resigned it to the *Chin*, from whom it passed to the *Sui*. After the assassination of *Yang Ti*, the Empress *Hsiao* fled with it to the north, till in the fourth year of *Chên-kuan* (A. D. 630) the Empress *Hsiao* sent the seal as an offering to the *T'ang*. When *Fei Ti* (the last emperor of the After *T'ang*, A. D. 935) burned himself it is not known what became of the seal. The Old Rules of the *Han* dynasty says that there were in the *Han* palace six State seals, all made of white jade, with handles in the form of horned lizards, the inscriptions on which were: "The despatch-seal of the Emperor"; "The seal of the Emperor"; "The true seal of the Emperor"; "The despatch-seal of the Son of Heaven"; "The seal of the Son of Heaven"; and "The true seal of the Son of Heaven." Of these six seals the first was used on imperial despatches sent to the nobles and princes, the third to summon the high officers for a military expedition, the fourth on despatches sent to foreign countries, as well as in the worship of heaven, earth, and the gods.

The Book on Official Robes (of the "Han Annals") says that, according to the rules of the *Han*, the Son of Heaven wore a seven-lobed hat of jade. The Book on Imperial Equipage says that the seal of Lan-t'ien jade of the *Ch'in* dynasty, with lizard handle, was not included among the six seals. It was worn by the Emperor *Kao Tsu*, and was known afterwards as the seal of succession to the empire. Again, that the Emperor *Kao Tsu*, when he ascended the throne and offered worship to Heaven, used jade tablets, of brilliant white color, flecked with spots, and with moss-like markings of red, green, brown, and with black tints shining brightly through three leaves in number, inscribed with a hundred and seventy characters, in the official script of the *Han*, written in clear and strong style. The "Han Annals," in the Memoir of *Kao Ti*, record that the sovereign had wine set out in the front hall of the Wei-yang palace, and offered a jade cup filled with it to his imperial father, wishing him long life. Again, that the Emperor *Kao Tsu* sent Chang Liang with a present of a square vessel of jade to Fan Tsêng.

The Imperial Annals of the *T'ang* record that the founder of that dynasty was the first to fix rules for girdles, and from the Son of Heaven down to the hereditary nobles and princes, the three chief ministers, the presidents of the boards, generals and officers of the first and second grade, all these were allowed to wear girdles of jade, that of the Son of Heaven being set with twenty-four plaques. The Chronicles of the reign of *Ming Huang* relate that the Empress, having sent one day for the Imperial grandsons, and seated herself in the palace to look at their games of play, had the jade rings, bracelets, wine-cups, and dishes, that had been sent as tribute from western countries, brought out and arranged so that each one might take whatever he pleased, when they all crowded up and took as much as they could, the sovereign alone sitting still quite impassive. The Empress marvelled greatly and stroked him on the back, exclaiming: "This child will grow up to become a most peaceful Emperor," and ordered a jade dragon to be brought, which she gave to him. This jade dragon was several inches long, and had been originally found by the Emperor *Tai Tsung* in the Chin-yang palace, and the Empress *Wên Tê* used to keep it in her box with her robes, and now that it was given to the emperor, he valued it most highly. It was afterwards placed in the Treasury, and although only a few inches in size, its warm liquid body and cunning workmanship made it absolutely unique. Whenever no rain fell in the capital it was reverentially brought out, and prayers were offered; and if an abundant rain was about to fall, the horns appeared on close inspection to be raised. A Record of the reign of *K'ai-yuan* relates that whenever under the *T'ang* dynasty an imperial child was born in the palace, the emperor sent jade money with the sliced fruit as "baby washing gifts" * of good augury, the money being inscribed with prayers of prosperity. The Miscellanies of Tu-yang relate that the Emperor *Su Tsung* bestowed on Li Fu-kuo two unicorns carved in fragrant jade, which could be smelt several hundred paces off, and that Fu-kuo used to keep them beside his seat.

The Regulations of the Imperial (*Sung*) Dynasty say that when the dynasty was re-established there were kept in the Imperial Treasury eleven jade seals. The first, called the "State-protecting sacred seal," was inscribed "Endowed by Heaven with prosperity for myriads and tens of myriads of years everlasting." The second, called the "seal of appointment," was inscribed "Having received the appointment from Heaven for everlasting time." These two seals were used in the worship of the mountain T'ai Shan. The third, called the "seal of the Son of Heaven," was used in replies to foreign countries. The fourth, called the "true seal of the Son of Heaven," was used for the levy of a great army. The fifth, called the "despatch-seal of the Son of Heaven," was used to seal the appointments of nobles, etc. The sixth, called the "seal of the Emperor," was used in replies to border kingdoms. The seventh, called the "true seal of the Emperor," was used on despatches accompanying presents to border kingdoms. The eighth, called the "despatch-seal of the Emperor," was used to seal imperial autographs. The above were what were called the eight state seals. The ninth, called the "seal of appointment," had an inscription written by the founder of the dynasty, reading: "The seal of appointment of the Great Sung." The tenth, called the "seal of established rule," has an

* It is the custom in China to wash the child for the first time on the third day after its birth, the function being performed with certain religious ceremonies and oblations of fruit and wine. Charms of ancient cash, silver talismans, or such-like gifts of good omen are provided, one of which is bound round the wrist of the child by a red string and kept on till the wearer is fourteen days old.

inscription written by the Emperor *Hui Tsung*, reading: "Rule encompassing heaven and earth, and aiding the spirits in dark places; power equal to the great creator for a myriad ages everlasting." The eleventh, called the "seal of re-established appointment," was inscribed the "seal of appointment of the re-established Great Sung." Including the above, there were in all eleven seals.

Under the reigning Manchu dynasty the court girdle worn by the Emperor is of yellow color, with four square plaques of gold engraved with dragons. The ornaments are lapis lazuli for the services at the Temple of Heaven, of yellow jade for the Altar of Earth, of red coral for the Altar of the Sun, of white jade for the Altar of the Moon. The jade palanquin and jade chariot (which the Emperor rides in) are both made of wood lacquered red, each one decorated with four round panels of jade. The State seals are kept in the Chiao-t'ai palace, and there are twenty-three jade seals, inscribed: "The seal of appointment of the Great *Ch'ing* dynasty," "The seal of the Son of Heaven," "The seal of honor for kindred of the Emperor," "The seal of love for kindred of the Emperor," "The true seal of the Emperor," "The seal of reverence to heaven and zeal for the people": all made of white jade. "The seal of the Emperor for the worship of heaven," "The despatch-seal of the Emperor," "The despatch-seal of the Son of Heaven," "The seal of Imperial order," "The seal of gracious instruction," "The seal of promulgation of the classics and history": all made of dark-green jade. "The seal of the Emperor," "The true seal of the Son of Heaven," "The seal of Imperial patent," "The seal of reward of valor," "The seal of control of Empire," "The seal of punishment of crime and quiet of the people," "The seal of Imperial regulation of the myriad regions," "The seal of Imperial regulation of the myriad people": all of clear-green jade. "The seal of Imperial autographs," "The seal of Command of the Six Armies," and "The seal of wide region": all made of black jade. Besides these, there are the State seals reverentially kept at Shêng-king (the capital of Manchuria), including the six jade seals, inscribed: "The seal of appointment of the Great *Ch'ing* (dynasty), "The seal of the Emperor," "The seal of reverence of heaven, respect of ancestors, affection for scholars, love of the people": all three made of dark-green jade, "The seal of the Emperor," "The vermilion seal of examination of the four quarters," and "The seal of Imperial command": all made of clear-green jade.

Again, when sacrificial titles are conferred in honor of deceased Emperors and Empresses, jade seals and jade tablets are always used, and reverentially placed in the Ancestral Temple. These are all carefully made in the Imperial household, and presented in the first place to be inspected by the Emperor.

The above are some clear examples of the use of jade by Emperors of successive dynasties.

VI. JADE USED BY THE STATE.

The use of jade by the Son of Heaven has been shown to be most constant, and in like manner it has always been as highly esteemed by the State, as may be proved by consulting the records still extant and searching the official writers. In the "Book of Annals," in the second entitled *Hounds of Lü*, the precious jades were distributed among the uncles of the King ruling over States. In the "Rites of Chou," the Superintendent of the Magazine of Jade, looked after the gold and jade of the king, made ready the jade worn by the King on his robes, girdle, and as jewels, prepared the jade eaten by the King when fasting,* and furnished the jade placed in the mouth of the royal corpse. Also, the second minister superintended the officer in charge of the tablets, who distributed them to the States and explained their use to help the commands of the King, the rulers of the States using tablets of jade.

* The emperor fasts before important religious ceremonies, such as in the annual sacrifice to heaven, spending the night in the Hall for Fasting, one of the temple buildings, and during his fast the only thing permitted to pass his lips is a kind of *purée* made of finely powdered jade stirred up in hot water.

Again, under the third minister (of Rites) the Grand Director of Sacrifices made of jade the six objects used in worshipping heaven and earth, and the four quarters, the dark-green round tablet (*pi*) to worship heaven, the yellow octagonal tablet (*tsung*) to worship earth, the green pointed tablet (*kuei*) to worship the east, the red tablet (*chang*, in the form of a half-*kuei*) to worship the south, the white tiger tablet (*hu*) to worship the west, and the black semicircular tablet (*huang*) to worship the north. The Commentary, quoting the *Êrh-ya*, says that the *pi* had the body twice as broad as the central hole, that the *tsung* had eight sides like the earth, that the *kuei* had the top corners on the right and left truncated half an inch, that the *chang* was the *kuei* halved, that the *hu* was fashioned like a tiger to symbolize the fierceness of autumn, and that the *huang* was the *pi* cut in halves. Again, the President of the Celestial Magazine (*T'ien-fu*) kept the royal jade tablets and the great sacrificial vessels of the State, and when there was a grand sacrificial ceremony or a royal funeral, he brought them out and arranged them, and put them by again when the service was finished. The Commentary says that these things included the jade tablets of rank as well as the most beautiful vessels of jade, which were set out during the sacrifices to heaven and to the royal ancestors, as well as the grand funerals, to attest the splendor of the State.

So the "Book of Annals," in the Testamentary Charge (of King *Ch'êng*), records that they set out the precious things, the red knife, the great lessons, the large *pi*, and the jade tablets of rank, all in the western chamber, the Commentary explaining the *pi* to be large round symbols of jade, the two kinds of tablets both one foot and one-fifth long. Again (in the "Ritual of the *Chou*"), the *T'ien-fu* says that the President, in the last month of the winter, arranged the jade to determine whether the coming year would be good or bad. The Commentator explains that the jade arranged was the jade for sacrifice to the gods. Again, the Conservator of Tablets (*Tien jui*) has charge of the preservation of the jade tablets of rank and the jade vessels. He distinguishes the names, the things, and the ceremonies in which they are used, and furnishes the proper appendages to be worn. The Commentary says that the tablets held in the hand were called jui, which included the royal tablet as well as the rest, and that the jade used in the sacrifice to the gods, called here vessels, included the fourfold kuei, etc. The appendages included the mounting, the silk cords and tassels, bearing the same relation to the jade as robes to men. Again, that the *chuan*, *kuei*, *chang*, *pi*, and *tsung* were each suspended by a single loop of two colors and worn by officers at the royal receptions. The fourfold kuei, with round body, was used in sacrifice to heaven, and in the worship of the supreme ruler. The Commentary says that this was fashioned round in the centre, a large tablet being taken and carved in the middle in the form of a round *pi*, with the body twice as broad as the hole in the middle, and on each of the four sides a *kuei* carved projecting from each, the central body being also called *ti*. Also: The twofold *kuei*, with central body, used in sacrifices to earth, and in the worship of the four quarters. The libation *kuei*, with ladle (*tsan*), for sacrificing to the ancient kings, and for the entertainment of guests; explained in the Commentary to be a tablet carved at the top into a vessel, from which the wine could be poured out in sacrificial worship, and called ladle (*tsan*). Again: The round tablet, with one projection, (*kuei pi*), was used in sacrificing to the sun, the moon, the planets, and the fixed stars. The half-tablet, with point projecting (*chang ti shih*), was used in sacrificing to the mountains and rivers, and in ceremonial banqueting of guests. The measuring tablet (*t'u kuei*), to measure the shadows of the sun and moon in the four seasons. The precious tablet (*chên kuei*), to summon garrisons, and to relieve in times of trouble and famine. The toothed half-tablet (*ya chang*), to levy armies, station soldiers and frontier guards; the Commentator explaining that this was furnished with carved teeth as emblems of war. The oval tablet (*pi yen*) was used for regulating measures; the

Commentator saying that this tablet was one foot from above downwards, eight-tenths of a foot broad, being a *pi* made not round for regulating measures of length. Again: He ties silk cords through the holes pierced in the *kuei*, half-*kuei*, circular, octagonal, tiger-shaped, and semicircular tablets, and lays aside the round and octagonal tablets placed in the coffin; the Commentator explaining that channels and holes were driven through the jade of all six kinds, through which strings were passed to tie them to the corpse; the *kuei* being tied on the left side, the half-*kuei* at the head, the tiger tablet on the right, the semicircular one at the feet, the circular tablet under the back, and the octagon on the abdomen; a cube figuring a microcosm, emblem of the god of the universe. The grain tablet (*ku kuei*) was used to arrange disputes, and as a betrothal present. The rounded tablet (*wan kuei*), to reward virtue and to cultivate good relations; the Commentator Chêng observing that this tablet had no sharp edge or point in symbolism of its uses. The pointed tablet (*yen kuei*), to change men's conduct and to punish wickedness; Chêng saying that it had a sharp edge and a point, in token of its use to punish crime and to extirpate rebellion. Whenever there are ceremonies for the entertainment of guests, he prepares the jade objects and brings them. These are all regulations for the proper use of the various jade symbols, and we find, also, in the *K'ao-kung-chi*, a section on the jade workers whose sole duty it was to make these jade tablets.

The "Classic of Rites," in the section *Yü tsao*, says that dukes and marquises wore in their girdles black jade with hills engraved upon it tied with red silk cords; the chief officers wore dark-green, wavy jade with black and white silk cords; the scions of the royal house wore jade-like jasper with blue and white silk cords; the scholars wore another stone resembling jade with red and yellow silk cords.

The Book on Sacrificial Worship in the "Former Han Annals" describes the officers in charge as offering the jade *hsüan*, explained by the Commentary to mean round tablets of jade (*pi*) six-tenths of a foot in diameter. The *Han Chün* says that the emperor *Wu Ti* in the first year of the *Yuan-shou* period (B. C. 122) ordered to be made by the government the tiger tablets for military officers. Princes of the blood and nobles used jade tablets; State governors, copper tablets. These were numbered with the characters of the cycle of ten; the left half was kept in the capital, the right half given to the officer in command; and whenever an expedition was sent to put down a rebellion, they first compared the two pieces of the tablet. The Book on Official Robes says that, according to the *Han* regulations, princes and dukes wore caps of jade in eight lobes; marquises, barons, the sons-in-law of the Emperor, and mandarins of the first grade, seven-lobed jade caps; of the second grade, six-lobed jade caps; of the third grade, gold caps (or crowns), or five-lobed caps of dark-colored jade. The Miscellanies of the Western Capital say that, according to the *Han* regulations, princes and dukes were both buried in jewelled robes and jade chests. A book on events in the "Annals of the *Chin* Dynasty" records that when the heir to the throne first had audience the Emperor presented him with a jade unicorn tablet. The Memoirs of the *T'ang* Emperors record that *Kao Tsu* first fixed the official rules for girdles. The girdles of the hereditary nobles, the princes and dukes, of commanders-in-chief and ministers of State, were mounted with thirteen plaques of jade, and had two additional pieces hanging down behind.

Under the Manchu dynasty at the sacrifices in the Ancestral Temple and in the second hall of the Ancestral Temple, as well as in the principal ceremonies at the altar of the gods of the land and grain, libation-cups of jade are always used. The Government Statutes of the Great *Ch'ing* include among the jade objects used in sacrificial worship round tablets (*pi*), octagonal tablets (*tsung*), and *kuei*. In the principal ceremonies at the Temple of Heaven dark-colored *pi* are used; in the principal ceremonies at the altar of earth are used yellow *tsung;* on the altar of the gods of the land and grain, in the worship of the chief god, white *kuei* sprinkled with yellow; in the worship of the chief god of grain, green *kuei;* on the altar of the sun, red *pi*, and on the altar of the moon, white *pi*. All the carefully designed patterns of jade objects used by the State are here published, so that the ritual may be established.

VII. THE COLORS OF JADE.

Jade is naturally one of the most beautiful substances created by heaven, and it is highly prized by scholars. There are many different kinds described, the colors being distinguished according to their high or low value. The Encyclopædia *Ch'ien-ch'o-lei-shu* describes jade as being of five colors. "The three colors, white, yellow, and green, are all highly valued. The white of fresh lard is the most valuable; that like rice-water, with oily stains, and that with marks like snow, being inferior. Of the yellow, the most precious is of the color of chestnuts, which is called pure (lit., sweet) yellow, the smoky yellow being inferior. Of the dark-green color, the best is of deep bluish-green tint; if sprinkled with fine black stars, or if pale in shade, it is less valuable. There is also a red jade, red as a cock's comb, which is construed the most valuable kind of all, but this kind of beautiful jade is of extremely rare occurrence. Green jade, when of a deep-green color, is considered precious, the pale being inferior; transparent-green jade is of a pale-green color, with a tinge of yellow; spinach jade, being neither transparent nor of rich-green color, but of the shade of the leaves of the vegetable, is the least valued of all. The ink-black jade is also of no great value." It says again, that "red jade is called *mên*, and is also called *ch'iung*, the last name conveying the additional meaning of translucid; that brown jade is called *tzŭ;* half white and red, *juan;* bright-green jade, *lu;* dark-colored, *yi;* black jade, *chioh;* black jade of which mirrors can be made, *chin*." Again, Wang Yi's book on jade, *Yü-lun*, describing the colors of jade, includes red as the cock's comb, yellow as boiled chestnuts, white as freshly cut lard, black as pure lac; these being called jade tests, but there is no mention here of green jade. In the present day the green and white colors are very common, and black is occasionally met with, but the red and yellow hardly exist; so that, even for the six vessels of sacrificial worship, it is impossible always to find genuine pieces.

Yi-chou produces a kind of stone of the color of boiled chestnuts, which is called by the natives chestnut jade, and is supposed by some to be a kind of yellow jade, but it is wanting in brilliance and translucency, and fails to give out a clear, resonant sound when struck, so that others say that this chestnut jade of Yi-chou is only a brilliant, translucid kind of common stone, not really jade. Jade is hard, and its polished surface cannot be hurt by fire or edged weapon, whereas this kind of yellow stone can be easily carved by a small knife, and it is similar in structure to the white stone of Chieh-chou, though different in color.

Shih-chên (in the *Pên-ts'ao*) says that, according to the *T'ai-ping-yü-lan*, white jade came from Chiao-chou, red jade from Fu-yu, green jade from Yi-lou, spinach-green jade from Ta-Ch'in, black jade from Hsi-Shu, fine jade, in color like indigo, from Lan-t'ien, whence the place derived its name. Huai Nan Tzŭ says that the jade of Chung Shan could be heated in a charcoal stove for three days and nights, without any change of color, because it was endowed with the pure essence of heaven and earth. In the Ancient Rites, the green tablet (*kuei*), the dark cærulean *pi*, the yellow octagonal *tsung*, the red *chang*, the white tiger-shaped *hu*, and the black, semicircular *huang*, all derived their names from the symbolism of heaven, earth, and the four quarters.

In the present day white is the color most sought after in jade, and modern amateurs of jade generally keep a set of patterns for comparison. These patterns are little oblong tablets carved out of the purest and finest jade, arranged according to their colors by a clever connoisseur, in a set of ten, numbered in correspondence with their respective values. Whenever a piece of jade is added to the collection, these patterns are brought out and compared with the color of the piece, so that it may be put into one of the ten classes. The rarest kind of all is white and translucid, like mutton fat, tinged with faint pink throughout, and this is called the tenth grade of the colors. This is, however, of the greatest rarity and very seldom seen, so that a dealer in jade, in his whole lifetime, may not succeed in getting a single specimen, and should one piece be found out of ten thousand, it is cherished as a jewel of rare price and of inestimable value. The next in value are placed in the ninth grade, then come the eighth and seventh, down to the least valuable pieces, included in the second and first grades. The pieces of fine white jade in ordinary collections belong generally to the fifth and sixth grades, for not only is it difficult to become the fortunate possessor of a specimen of the tenth grade, examples even of the ninth and eighth grades are not easily found.

Ink-black jade is black throughout like ink. When its substance is entirely translucid and shines brightly like a mirror, without brain-like marks or spots of any other color, it is good ; if the color be pale or not uniform, or dull and not brilliant, it is inferior. There is another kind of sprinkled ink-black jade, commonly known as ink-spot jade. This is of white body, with black spots, as if made by sprinkling with a brush dipped in liquid ink, and when the spots are clearly defined and regularly distributed through the mass it is valuable ; but if the darker portion be not broken up into spots, or if the lighter part be surrounded by a halo, in neither case is it worth having. There is another kind of jade which is half black, half white, the two colors united in one piece with lines of demarkation sharply defined ; the one white as lard, the other black as ink, not mixing with each other. When this comes into the hands of the worker in jade he plans a special design according to the size and color, and carves the piece, and often succeeds in producing a clever work of art, imitating a spontaneous growth of nature. Thus are found rare pieces of unrivalled skill, and this peculiar kind of artistic work is worthy of a collector of culture.

Among white jades there is one special variety invested with a skin. This kind comes from Ho-tien (Khotan), and is found in the rivers among the best jade pebbles produced there. It seems that the stones which are found in the river have been rolled down by the current, and after the water has subsided they lie exposed in the bed of the river, to be burnt by the sun and blown about by the wind, acted on by the water and rubbed by the sand, till after a long time a coat is formed on the jade, a kind of light-reddish skin, the color of an autumn pear, which is called russet pear-skin. This skin may enclose a jade of either good or bad quality. In the present day, snuff-bottles, thumb-rings for archers, tubes for peacock's feathers, mouth-pieces for tobacco pipes, etc., are often carved out of this kind of jade, and are twice as valuable as those made of the ordinary varieties. But the color of the skin must be exactly like that of the rind of the russet pear; if deeper or lighter in the tint it is not esteemed.

The dark-green jade (*pi-yü*) which comes from the southern border (of China), is of a very strong and hard body but dull in color, and it is also often variegated with brain-like marks. It occurs, however, in very large and heavy pieces, like the fish-bowl (*wêng*) of jade which stands in the Prohibited Grounds in front of the Chêng Kuang Palace,* which is between six and seven feet in diameter, so that a man can lie down at full length inside. This is only considered valuable from its unusual size.

With regard to yellow jade and clear-green jade, good specimens are seldom seen, and they are generally valued

* This palace is in Peking, within the imperial city, on the eastern bank of the lake, where it is spanned by a marble bridge. The foreign envoys have had their audience of the emperor of late years in one of its halls. The immense bowl referred to stands in the grounds, outside the audience hall. It is of oval shape and rounded section, with a round mouth, the diameter of which is about two-thirds of that of the middle of the bowl. It is said to date from the *Yuan* dynasty (1280–1367), when the palace was founded, and to have occupied the same place ever since.

in proportion to the purity of the color and bright translucency, the inferior kinds being dull and mixed with other shades. Vegetable jade is a variety of green jade, of deep-green color like spinach, from which it derives its name. The dealers call this kind Ma-na-ssŭ. Ma-na-ssŭ (Manas)* is the name of a Mohammedan walled city in the New Dominion (Turkistan), which gives its name to jade, because the spinach jade is a product of that place, and hence it is called by the same name as the city.

VIII. ANCIENT JADE.

Scholars of the present day who love antiquity and learned research all consider ancient jade to be the rarest of treasures. Ancient jade is jade that has lain buried in the earth and been discovered again. The jade has lain buried in the ground, either lost in times of famine, or sunk in water during an inundation, or when lakes were being planted with mulberry trees and reclaimed. Sometimes it has been purposely buried and subsequently forgotten, at other times overwhelmed by falling mountains or fallen into earthquake cracks. It may have remained hidden in the bowels of the earth for centuries until it be found again, when it is submitted to skilful manipulation and becomes a valued specimen of ancient jade. The process of manipulation of ancient jade is to put it into a cotton bag filled with bran and to submit it carefully to daily friction for some months or even years, till the old

* The city takes its name from the river Manas, which has its fivefold source on the northern slopes of the lofty Khatun Bogda Mountains and runs north to the lake Ebi Nor. Gold as well as jade is found near its source. This river is also called by the Chinese Ch'ing Ho, or Clear River, on account of the transparent purity of its current. The jade found here, according to Ying-ho (*Hsi-Yü Shui-t'ao-chi*, bk. III, fol. 34), is of a translucid, very dark-green color with mottled stains. It is described by him as obtained from the river-bed, where it occurs in blocks, the largest of which weigh several tens of catties. A similar kind of jade is found at Botugol, near Irkutsk in Siberia, specimens of which have been sent to all the museums of Europe by M. Alibert. One of these, an immense water-worn block of irregular ovoid form in the British Museum, is 4 feet long and weighs 1156 lbs. There is a small polished bowl (No. 3129) in the Bishop Collection.

substance of the jade shall appear, when the work is finished.

Han yü, literally jade held in the mouth, was originally used for the jade that in ancient times used to be put into the mouth of the corpse when laid out for burial.* Some scholars of the present time, however, apply this term not only to jade found in tombs, but also include under it all ancient jade that has been buried in the earth; others err more deeply still, in writing it as jade of the *Han* dynasty; but both these views are, in my opinion, wrong. In ancient times they often buried jade with dead bodies because of its beauty and high value. It was also used in former times because when mercury was used to preserve the dead, the quicksilver being liquid tended to flow out, and had to be sealed up by the addition of jade, so that jade was employed to close up all the orifices of the body to prevent the mercury injected into the corpse from escaping. But the jade thus put into dead bodies must get stained by them. In this way the material, as it lies buried in the ground for long years, becomes gradually decomposed and rotten, so that other substances can penetrate and discolor it—that is what is called "staining." The jade, originally of pure-white color and perfectly translucid, after having been stained in the corpse, cannot but have its purity soiled, so that this kind is not so highly valued as other ancient jades. When jade has been buried for over 500 years the stains penetrate its substance; after 1000 years it becomes as soft as common stone; after 2000 years, as soft as lime; after 3000 years, as soft as decayed bone, this being the extreme limit of the life of ancient jade, so that it is no use looking for jade anterior to the first three dynasties. Ancient jade when first dug up from the ground is called "salt-meat bones"; after it has been handled for a long time the jade recovers

*The custom of placing something precious in the hand or mouth of the corpse is ancient and widespread. The Romans used to put an *obolus* under the tongue of the deceased as a fee for Charon for his ferry over the river Styx, and even in the present day, at an Irish wake for instance, the dead has a piece of money put in his hand to pay his way with.

its old translucency, and it is called "salt-meat skin," these two names being derived from its color and general aspect. When it has been still further manipulated in the bran bag it is known as shelled ancient jade; this name meaning that the jade, which while buried in the ground for some thousands of years has been corroded by the earth and stained by other things, till it is as rotten as decayed bone, after having been dug up and submitted to friction and manipulation becomes once more translucid and brilliant, and the impurities all cleared away, till it comes out of the bran bag as brilliant and pure as a precious stone, the rottenness being at one stroke all "shelled" off.

Jade which has been corroded by the earth becomes loose and rotten in texture, so that mercury is able to soak through the skin and stain it. In every place there is always some mercury in the ground, so that it is not only that put into the body in ancient times. Once the mercury has soaked in, lime, earth, and various other substances can in their turn soak through and penetrate the interior. Many substances thus gradually soak through and make stains of many different colors. Some stained by yellow clay becomes yellow in color; some stained by turpentine, of a still deeper tint, and this, after manipulation, comes out of the color of amber and is known as "old dry yellow." Some stained by lime is red in color, and this by friction becomes like the blossom of the double peach, and is known as "child's carnation." Some stained by indigo is blue in color, from the dye of the clothes having soaked through, and this, which may be either light or dark in tint, is known as "old dry blue." Some stained by mercury is black in color, but it can acquire this color only when a large quantity of mercury has soaked in—meaning by a large quantity of mercury, so much as used to be put in the corpses of ancient kings and princes, not the mercury naturally present in the ground and the effect of which must be distinguished. After friction this color comes out like the blackest metallic paper, and is known as "pure lac black." Some stained by human blood is crimson in color, that found in dead bodies for instance, which may be dark or light in tint, and which is known as "jujube red." Some stained by bronze objects is green in color, because bronzes when buried for long years become green and blue, and stain the jade lying beside them of the same colors, like the tints of the kingfisher's feathers, and this when it has been submitted to friction in the bran bag comes out of yet more beautiful colors, not to be surpassed, and is known as "parrot-green." Specimens of this beautiful variety are rarely seen in collections, and are most highly prized. In addition to these there are other colors, caused by the staining of different substances, of so many kinds that they cannot be separately described. Among the names of the colors are vermilion-red, cock's-comb red, grape-purple, aubergine-purple, hibiscus-yellow, chestnut-yellow, pine-green, salisburia-green, mutton-fat white, rice-husk white, shrimp-spawn green, and mucus-green, these last two greens being only found from staining in ground of the South. These rare kinds of different colors are all included under the general name of "the thirteen colors."

There are other cases of staining producing peculiar transformations like the mottling of a toad's skin, like cloud masses, like crackle porcelain, like bullock's hair, like crab's claws, or like scattered pearls. The origin of all these different stains is truly most difficult to distinguish precisely. Ranging in space through myriads of miles, and in time some five thousands of years, over a vast territory with all kinds of productions, and buried, moreover, in the depths of the earth to be transformed under the source of the water-springs; even though a scholar were learned in physics, yet all his knowledge would not suffice, nor would his cleverest guesses be able, to solve the problem, and there would be places that would not be reached.

IX. FEI-TS'UI.

Fei-ts'ui is originally the name of a bird (a kingfisher, *Alcedo halcyon*, or *ispida*) found in Yü-lin (in the province of Kuangsi), the cock being reddish and called *fei*, the hen bright green, called *ts'ui*. In the present day the name is applied to green jade on account of the similarity of the color, but it is not known from which dynasty it starts. In the *Ku'ei-t'ien-lu* we read that "Ou-yang Hsiu * had in his house a large jade bowl (*wêng*) of most antique aspect and workmanship and artistically carved, which, when he first got it, was pronounced by Mei Shêng-yü to be of ordinary green jade (*pi-yü*). While living at Ying-chou he often showed this bowl to his visitors, and there happened to be sitting there one day a military officer named Têng Pao-chi, an old eunuch of the court of the emperor *Chên Tsung*, who knew what it was and said: 'This is the precious jade which is called *fei-ts'ui*. Among the precious things preserved in the palace of the Yi-shêng Treasury there was a *fei-ts'ui* wine-cup (*chan*), from which I first came to know it.' Happening one day afterwards to rub lightly a gold ring along the interior of the bowl, the gold was gradually rubbed off, just as a cake of ink is rubbed down on a stone pallet, whereby it was first known that *fei-ts'ui* could reduce gold to powder. Thus we see that the name of *fei-ts'ui* was applied to green jade as early as this time (eleventh century A. D.).

The *fei-ts'ui* of modern times is found in Burma (Mien-tien kuo) in the midst of high mountains. It occurs in the middle of the rocks, and natives first chisel out of the rocks the rough jade, which is found in masses varying in size, up to the weight of a thousand, or even ten thousand, catties. These are very coarse in appearance and color, brownish-yellow like the outside of a salted ham, and would be taken by an ignorant man for blocks of common stone. The places have long been worked, and the superficial and easily worked parts are exhausted, so that the finest jade is inside, and it is necessary to dig deep down to extract any. But mining so deeply and groping in the dark are hard tasks for the laborers, and recently the novel method of blasting the rocks by gunpowder has been introduced and has taken the place of other manual labor.

* Celebrated among the foremost statesmen of the *Sung* dynasty, and author of many historical and critical works. Flourished A. D. 1017–1072.

By this method, when the overseer has discovered a place containing pieces of *fei-ts'ui*, he directs the miners to drive in tunnels below the mountain to the depth of some five or ten feet, and to fill them with blasting powder. The mouths of the tunnels are then sealed, and the powder exploded in the ordinary way. The mountain falls and the rocks are split, and the *fei-ts'ui* can be afterwards picked out. But the jade got in this way is generally much scarred and cracked, so that large perfect pieces are rarely obtained; and the new material of modern times is very often marked with willow-like scars for the same reason.

After it has been mined it is necessary to examine closely the texture and veins, and to look carefully for traces of color, holding it up to the light of a lamp or the sun, to see if any shade of green can be reflected from the interior, a sign that there is hope of its containing *fei-ts'ui*. It is then given to the workers in jade to be split open, and if of pure emerald-green color, clear and translucid, neither oily nor dry and without spots and scars, of wholly translucid body, and color both deep and full, it is considered to be of the highest value. When on a ground of pure white there are sprinkled some spots of deep green, instinct, as it were, with life and movement, sharply defined and not shading down, of clear translucency without flaw, it is known as "pretty green," and is also of high value. When, on the contrary, the green color is either pale or clouded, or although deep yet approaching black, or when the white color is grey like the ashes of a joss-stick, or cloudy like a bad stone, all these varieties are not worth collecting. There is another kind where the whole body is pale emerald-green, which at first sight appears to be valuable, but on more careful examination the color disappears and leaves no clear trace behind, so that it is impossible to define exactly the green part. When the green color is strewn with black spots, or when it is mixed with white powder, it is also included in the category of common stuff.

There are other differences in the rough ore, depending on its coming from old mines or from new mines. The *fei-ts'ui*, growing in the bowels of the rock, becomes gradually formed inside and develops in the dark its brilliant color during an unknown succession of years, till it becomes fully formed into perfect jade. When the full time has elapsed, the power of growth being so great, it is organized into a perfectly formed specimen. Hence, when weighed in the hand, it is of heavy specific gravity, and when tested by the eye, its colors are fully developed. The innate power of growth has produced a kind of deep, full, and rich tone, penetrating and veining the whole substance; and this is known as "old mine ore." But when the green is only of some days' growth and not fully formed, and it is dug up prematurely and so prevented from attaining its perfect development, the color, even if fairly good, fails to show the full rich brilliance, the texture is light and loose, and the body wanting in strength and firmness; and this is known as "new mine ore." To determine whether a piece be of new or old ore, and to distinguish accurately the rich and the immature state, require the practiced eye of a connoisseur, and the distinctive points can only be generally sketched, as it is impossible to describe them exactly by the pen or by word of mouth. When, however, the worker in jade comes to carve the piece, it can easily be distinguished as new or old, because the old, being of hard substance, requires much labor; whereas the new ore, being of soft body, is more easily worked, so that the mere act of splitting it open is sufficient to determine its real nature.

After it has been carved into a work of art and polished to a brilliant surface, the color shines out in its full beauty, and gives the artistic work a rare value, so that it excels in color the waves of spring and in brilliance the precious emerald. Put into water, its green color permeates the whole mass; placed on the table, its powerful brilliance dazzles the eyes. This is the most precious kind of *fei-ts'ui*; its beauty is such that an ordinary man hardly ventures to keep it in his private possession.

With regard to the various things made of it, there may be seen in the imperial grounds melons carved out of *fei-ts'ui;* and there are exhibited in the rooms of the palace vegetables (cabbages), as if growing there. There are flower-vases, fruit-dishes, bowls, and wine-cups for the decoration of the banqueting table; ear-jewels, hairpins, and rings for the daily adornment of beloved beauty. For appendages to be worn with the official robes there are tubes for the peacock's feather and beads for the rosary; for personal adornment there are pins for the hair and rings for the archer's thumb. Rests for the pencil-brush and cylindrical vases for holding paint-brushes light up with their beauty the study of the scholar; tobacco pipes and snuff-bottles are carved for the rich and luxurious. The value of a pair of bracelets to encircle the arm will exceed a thousand ounces of silver; the price of a single buckle for a girdle round the waist will amount to several hundreds. The eighteen beads (of the small rosary), the number of the Buddhist Arhats (Lohan), are rich jewels for the breast; the two-headed pins, for winding the hair round, make bright ornaments for the crown of the head. Other things, like the ornaments and Buddha's heads hung as appendages upon the rosary, the flower-petals and butterfly-wings sewn upon velvet on the headdress, although of very minute size, are valuable when of brilliant color. Specimens of the highest class are really equal in value to "several walled cities"; they are the special product of the miraculous creative power of hills and rivers, and are cherished as precious jewels by rich men of the present day.

Some say that jade when red in color is called *fei*, when green in color *ts'ui*, after the names of the differently colored kingfishers; but the red jade is of very rare occurrence, and so the general name of *fei-ts'ui* is applied to green jade. In former times, however, there existed a kind of jade, each piece of which exhibited the two colors, red and green, both so pure and bright as to dazzle the eyes, and this was really worthy of the name.

With regard to the green bowl in the possession of Ou-yang Hsiu described in the *Kw'ei-t'ien-lu*, which was able to reduce gold to powder, the *fei-ts'ui* of modern times, when carved and polished, is bright, smooth, and of fine surface, and therefore incapable of pulverizing the different metals, from which it may perhaps be inferred that the precious jade called *fei-ts'ui* at that time may be different from that known as *fei-ts'ui* in the present day.

APPENDIX.

TITLES OF SEVENTY-ONE BOOKS QUOTED IN THE DISCOURSE ON JADE.

1. *Shu Ching.* Classical Book of Annals. Compiled by Confucius about 500 B. C. Translated by Dr. Legge, *Chinese Classics,* Vol. III, Parts 1, 2.
2. *Chou Li.* Ritual of the Chou dynasty (B. C. 1122–249). With an appendix, *K'ao-kung-chi,* on various handicrafts. Said to have been written about 1100 B. C. Translated into French by Biot, 1851.
3. *Li Chi.* Book of Rites. One of the Five Classics.
4. *Po-wu-chih.* Records of Remarkable Objects, by Chang Hua, A. D. 232–300, a native of Fan-yang (near the present Peking).
5. *Huai Nan Tzŭ.* A Taoist work by a descendant of the first emperor of the *Han* dynasty, named Liu An, Prince of Huai Nan, who died 122 B. C.
6. *Yü-ching-t'ou.* Illustrated Book on Jade Mirrors. Author unknown.
7. *Yü Shu.* An old Book on Jade. Author unknown.
8. *Pên Ts'ao.* Standard works on Materia Medica collected in the well-known *Pên-ts'ao-kang-mu,* in 52 books, by Li Shih-chên of the *Ming* dynasty. Sixteenth century A. D.
9. *Yi-wu-chih.* Record of strange things by Yang Fu of the *Sui* dynasty, A. D. 581–618.
10. *Pieh-pao-ching.* Classic of various precious things.
11. *Chang Kuang-yi Hsing-chêng-chi.* Record of the itinerary of Chang Kuang-yi, who was sent on an embassy to Khotan by the first emperor of the After *Chin* dynasty in the year 938. He was sent again to Khotan by the founder of the *Sung* dynasty in 961. (*Histoire de Kotan,* par A. Rémusat, pp. 74–83).
12. *Sou-shên-chi.* A Collection of Legends by Yü pao, who lived in the early part of the fourth century.
13. *Êrh-ya.* An ancient Dictionary of Terms used in the Classics, divided into 19 sections, each treating of a different class of subjects.
14. *Hsi-yü-wên-chien-lu.* A description, in 8 books, of Eastern Turkistan and neighboring countries, by Ch'i Shih-yi, a Manchu officer, published in 1777.
15. *Fu-jui-t'ou.* An illustrated book on Jade Talismans, etc., by Hsü Shan-hsin of the sixth century.
16. *Yün-hui.* A dictionary compiled by Hsiung Chung of the *Yuan* Dynasty, thirteenth century.
17. *Hsiang yü shu.* A book on Jade. Author unknown.
18. *Tao-tê-ching.* The famous classic of the Taoists, by Lao Tzŭ, written at the close of the sixth century B. C.

19. *Han Fei Tzŭ.* The works of Han Fei, a philosopher of the third century B. C.
20. *Hsien Ching.* A Taoist book of medical prescriptions, quoted in the *Pên-ts'ao.*
21. *Shih Ching.* The Classic Book of Odes, compiled by Confucius about 500 B. C. Translated by Dr. Legge, *Chinese Classics,* Vol. IV, Parts 1, 2.
22. *Wu-yin-chi-yün.* A dictionary by Han Tao-chao of the *Chin* dynasty, twelfth century.
23. *Shuo-wên.* The celebrated ancient dictionary by Hsü Shên, written at the close of the first century A. D.
24. *Pai Kuan.* By Ch'ou Yuan, *Yuan* dynasty, twelfth or thirteenth century.
25. *Ch'ien Han Wang Mang Chuan.* The life of the usurper Wang Mang (A. D. 9–23) in the History of the former *Han* dynasty.
26. *Hsi-ching-tsa-chi.* A record of incidents at Ch'ang-an, the metropolis during the *Han* dynasty, by Liu Hin, who lived about the beginning of our era.
27. *Tu-yang-tsa-pien.* A record of rare and curious objects brought to China by Su O from A. D. 763–872. Latter part of ninth century.
28. *T'ien-pao-yi-shih.* Matters omitted in the annals of the *T'ien-pao* period (742-756). By Wang Jên-yu. Tenth century.
29. *Yu-yang-tsa-tsu.* Essays on the productions of China and foreign nations, etc. In 20 books. Written by Tuan Ch'êng-shih, towards the end of the eighth century.
30. *Yi-chien-chi.* By Hung Mai, a celebrated writer of the *Sung* dynasty, who lived A. D. 1123–1203.
31. *Shih-chi.* Historical records, by the famous historiographer Ssŭ-ma Ch'ien, B. C. 163–85.
32. *Tso Chuan.* Amplification of the ancient annals of the State of Lu, in the present province of Shantung, extending from 722 to 484 B. C. By Tso Chiu-ming, one of the disciples of Confucius.
33. *Han Wu Ku-shih.* A record relating to the time of the Emperor *Wu Ti,* B. C. 140-86, attributed to Pan Ku. Others believe it to be a compilation of the *T'ang* dynasty.
34. *Ho-t'ou-yü-pan.* Seems to be a production of the *Han* period. It is quoted in the *Po-wu-chih.*
35. *Shih-chou-chi.* A fabulous description of ten insular kingdoms attributed to Tung-fang-so. Second century B. C.
36. *Pao Fu-tzŭ.* A work on Taoist philosophy, alchemy, charms, etc. By Ko Hung. Third and fourth centuries A. D.
37. *Mêng Tzŭ.* The works of Mencius, fourth century B. C. Translated by Dr. Legge, *Chinese Classics,* Vol. II.
38. *Han Shu.* History of the (Former) *Han* dynasty, 202 B. C.–25 A. D. Compiled by Pan Ku, who died 92 A. D.
39. *San-fu-huang-t'ou.* An ancient description of the public buildings in Ch'ang-an, the metropolis of the *Han.*

40. *Wei Shu.* History of the *Wei* dynasty. A. D. 386–558. Compiled by Wei Shou.
41. *Hu Tsung pieh-chuan.* Biography of Hu Tsung in the *San Kuo-chih*, or History of the Three Kingdoms (A. D. 220-280), book 62.
42. *Yi-yuan.* By Liu Ching-shu, of the Liu *Sung* dynasty. Fifth century.
43. *Liang-chou Chi.* Description of the province of Liang-chou (the modern Kansu). Fourth or fifth century.
44. *Shih-yi Chi.* Record of things omitted in the annals of the empire, by Wang Chia. Fourth century.
45. *Nan Shih.* Southern History. A. D. 420–589. Compiled by Li Yen-shou.
46. *T'ang Liu Tien.* Canons of the Six Boards of the *T'ang* dynasty, in 30 books, drawn up by the Emperor *Yuan Tsung* in the early part of the eighth century.
47. *T'ang Shu.* History of the *T'ang* dynasty, A. D. 618–907, by Ou-yang Hsiu.
48. *Sung Shu.* History of the *Sung* dynasty, A. D. 960–1280. Compiled by T'o T'o.
49. *Hsü Wên Hsien T'ung K'ao.* Supplement to the *Wên-hsien-t'ung-k'ao* of Ma Tuan-lin, compiled by Wang Ch'i in 1586, in 254 books.
50. *Chin Shih.* History of the *Chin* dynasty, A. D. 1115-1234. Compiled by T'o T'o.
51. *K'ai Shan T'ou.* An old book quoted in the *Ku-yü-t'ou*, describing how Yü Wang opened the country after the inundations.
52. *San-li T'ou.* Illustrations of the Three Rituals, by Liu Ling, fifteenth century.
53. *Lu-p'u chi.* Description of the imperial travelling equipage.
54. *Mu T'ien-tzŭ Chuan.* A narrative of the adventures of the Emperor *Mu Wang* (1000 B. C.), on his journey to the West. Said to have been found in the tomb of one of the *Wei* princes in A. D. 281.
55. *Ch'uan Kuo-hsi K'ao.* Researches on the seals of succession to the empire.
56. *Han Chiu-yi.* Old usages of the *Han* dynasty, quoted in the *Ku-yü-t'ou.*
57. *Han Shu Fu Chang-chih.* Description of official robes in the *Han* History.
58. *Han Shu Yü-fu chih.* Description of the imperial carriages and equipage in the *Han* History.
59. *T'ang-shih Lu.* Lives of the Emperors of the *T'ang* dynasty. A. D. 618–907.
60. *Ming-huang Tsa-lu.* Records of the reign of *Ming-huang* (713–755). By Chêng Ch'u-hui, *T'ang* dynasty.
61. *Kai-yuan Yi-shih.* Matters omitted in the annals of the *K'ai-yuan* period (A. D. 713–741), by Wang Jên-yü, tenth century.
62. *Huang Ch'ao Hui Tien.* Statutes of government of the imperial dynasty. *Sung* dynasty, A. D. 960–1280.
63. *Ch'ien Han Chiao-ssŭ chih.* Description of the sacrificial rites in the Former *Han* History.

64. *Han Chün.* Discourses on the *Han* by Lin Yueh of the *Sung* dynasty.
65. *Chin Shu Chin-shih.* Ancient events in the History of the *Chin* dynasty, A. D. 265–419.
66. *Ta Ch'ing Hui Tien.* Statutes of government of the Great *Ch'ing* dynasty (1644–).
67. *Ch'ien-ch'o-lei-shu.* A cyclopædia in 120 books by Ch'ên Jên-hsi, who completed it in 1632.
68. *Wang Yi Yü Lun.* Description of Jade by Wang Yi.
69. *T'ai-p'ing Yü Lan.* The vast encyclopædia in 1000 books, finished in 977, by command of *Tai-Tsung*, second emperor of the *Sung* dynasty.
70. *Ku Li.* Description of the Ancient Ritual in the Book of Rites.
71. *K'uei T'ien Lu.* A small collection of incidents chiefly relating to the imperial court, written by the historian Ou-yang Hsiu after his retirement from office, and published in 1067.

ILLUSTRATIONS

of the

MODERN MANUFACTURE OF JADE

With

INTRODUCTION

and

TABLE OF CONTENTS

BY

LI SHIH-CH'ÜAN

styled

CHÊNG-YUAN

ILLUSTRATIONS OF THE MANUFACTURE OF JADE.

PREFACE.

The Classic Book of Rites says: "If Jade be not carved it cannot make a vessel." This means that jade which is brought from the mountains or rivers a crude, formless mass requires the skill of clever workmen to select the best part and carve and polish it properly, before it can be made into a finished vessel.

Doctor Bushell, an Englishman, who has spent over twenty years of his life in the Central Kingdom,* being naturally fond of ancient works of art, has gathered together a large collection of specimens of Chinese work in porcelain, bronze, and jade, which, during moments of leisure from official work, he takes much interest in studying. Of the different kinds of jade he has picked out some of the choicest and most beautiful of the pieces,† and offered them to the photographer, who has made a series of illustrations. He has also invited the learned T'ang Jung-tso to write a Discourse on Jade, to be printed and published for the benefit of those interested in the subject. Only fearing that in the absence of plates to illustrate the art of carving and polishing jade, it could hardly be found that the description was altogether clear, he has instructed me to go personally to see the various processes of carving and polishing, and to make pictures of them, in the hope

*The name "China" is unknown to the natives of that country. Their name for the country is *Chung Kwoh*, "Central (or Middle) Kingdom."—*Editor's note.*

†The artist is wrong here, my own Collection being only of porcelain and bronze. The illustrations he refers to are those of Mr. Bishop's beautiful series of jades, some photographs of which I had once shown to him. S. W. B.

that those who may consult the book may be more thoroughly satisfied.

This work of Dr. Bushell, although only a leisure occupation, will yet fill a small unknown gap in the exact knowledge of handicraft work.

This Preface was written in the cyclical year *kêng yin* of the reign of *Kuang-hsü*, in the last ten days of the fouth month, at Yen Tu (Peking) by the artist Li Shih-ch'üan, styled Chêng-yuan.*

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I. POUNDING THE SAND.

There are many kinds of tools used in working jade, but they do the work not by their own strength, but by the help of the stone sand. I am informed that the black, red, and yellow sands employed all come from Huo-lu Hsien, in the province of Chihli, and that some is also brought from the province of Yunnan. It comes in pieces like the small anthracite coal used by blacksmiths, and requires to be pounded with pestle and mortar to the size of broken rice. This is then passed through a very fine sieve, washed

*The Preface is stamped at foot in vermilion with two seals, the first inscribed with the author's personal name, "Shih-ch'üan," the second with his literary, or artistic, name, "Li Chêng-yuan."

to separate impurities, and then when water is added it is fit for use.

2. GRINDING THE SAND.

The yellow sand used for the polishing wheel requires to be ground down very finely and evenly, after which it is washed and mixed with water, ready for use.

N. B. These two operations are combined in the first picture, and the tubs below contain the black sand, characterized as very hard; the red sand, as a little softer; and the yellow sand, as still softer than the red; the tub on the left being filled with a fourth kind, called *pao liao*, "precious-stone dust," for use on the leather wheel, which gives the final polish to the jade.

3. SAWING OPEN THE CRUDE JADE.

The tool used is a two-handled steel saw, kept moist with black sand mixed with water. If it be a very large, heavy block of jade, it is sawn open, as illustrated in the picture. If the block of jade be only 20 or 30 catties in weight, it is suspended on a steelyard, and sawn open with a large plate-saw 20 inches in diameter. The jade is found in nature generally enveloped in stone, and to get at the jade this skin must first be stripped off, just as a fruit is peeled to get at the kernel. This is the first process in working jade.

4. THE SLICING SAW.

This saw is mounted on a wooden axle, and consists of a round plate of steel with an edge as sharp as that of a knife. It is called the slicing saw, and is moistened with red sand mixed with water to saw up the jade, from which the envelope has been stripped into square or oblong slabs, of a size corresponding to the object to be made, ready to be fashioned by the shaping wheel. If the piece of jade be large and heavy it is suspended on the end of a steelyard, as in the picture; if it be small and light it is held in the hand, the steelyard not being required.

N. B. The plate-saw, the axle, and the treadles, with which it is worked, are figured in detail below, as well as an iron hammer and block for keeping the plate hammered, in shape. Saws of different sizes are placed ready on the table, and wooden guards to protect the workmen hang on the wall.

5. THE SHAPING WHEEL.

These wheels are rings of steel from half an inch down to two or three lines in thickness. The axis of the ring is mounted with a thick slab of bamboo, with a depression in the centre, into which the wooden axle-rod is stuck with red glue. This wheel is used to remove the sharp edges and corners from the square or oblong piece of jade, hence its name of shaping wheel. When the edges have been thus removed, the object is shaped, but the jade is still rough and uneven, so that it requires the grinding wheel to smooth it, and the wooden wheel, glue wheel, and leather wheel to give it a final bright polish.

6. THE GRINDING WHEEL.

The grinding wheels are steel plates two or three lines in thickness, turned on a wooden axle. These grinding wheels are of six or seven different sizes. They are used to grind the piece that has been fashioned by the shaping wheel, till the surface is uniformly smooth. When this work is finished the piece is ready to have ornamental designs carved upon it, to be bored with the diamond, to be hollowed out or pierced, whenever such work is required.

7. HOLLOWING THE INTERIOR.

By hollowing the interior is meant "removing the core." Whenever a hollow space has to be left inside the jade object, it must be first bored with the round steel cylindrical borer, which, after the boring is finished, leaves a round core inside. This core has to be dug out with a steel chisel struck by a small hammer. If the mouth of the jade object is to be left small and the chamber larger, flat steel gimlets, like corkscrews, are used to hollow out still more the interior of the piece.

N. B. The borer is mounted, as figured below, on an iron rod, and is channelled twice or three times, to allow the sand to get in. The gimlets are fixed into a hollow in the end of the similar iron rod. The revolving strap attached to the treadles is made of leather.

8. CARVING ORNAMENTAL DESIGNS.

When the jade has to be decorated with ornamental designs the tools used are of two kinds. The first are small round plates of steel, with sharp edges like knives, called nails (*ting-tzŭ*), because they are somewhat like round-headed nails in shape. The others are small steel plates with thicker edges, called *ya t'o*. These tools are made of many different sizes and shapes, according to the fancy of the workman, and according to the nature of the work required. All jade objects, of square or round form, of large or small size, which are to be ornamented outside with different designs, must have the patterns carved with these tools.

N. B. Some of these small plates are figured below, with the iron rod on which they are mounted, a little hammer to drive them into the hollow end of the rod, and another tiny hammer to straighten the plate of the "nails."

9. THE DIAMOND BORER.

When the jade object has to be carved in openwork (*à jour*), holes must first be pierced with the diamond, following the pattern of the design. This work is called diamond-boring, and only after it is done can the wire bow-saw be introduced and worked round the outline of the pattern. The pieces carved in openwork and decorated with ornamental designs have still to be polished to finish them off.

N. B. The lever which presses down the diamond is figured below, a weight being suspended to the arm by a string which passes through a round hole in the middle of the table, while a small cup is fixed underneath the end of the arm to hold the rod in which the diamond is fixed, which the workman turns, with the bow in his right hand, holding the piece of jade with his left.

10. OPENWORK CARVING.

When a slab of jade has to be carved in openwork it must be pierced with round holes by the diamond borer and afterwards sawn with a steel wire stretched on a bow. When this is used, one end of the wire is first loosened, so that the wire may be passed through one of the holes, after which it is fastened again to the end of the bow. It is then moistened with sand and water, and the jade sawn out following the outline of the pattern. An upright piece of wood is fixed in the table, or a horizontal piece nailed on, with a vise attached, to grasp the jade object firmly.

N. B. The apparatus is figured in more detailed form below, with bow both strung and unstrung.

11. PIERCING HOLES.

Small objects, such as snuff-bottles, thumb-rings, mouthpieces of tobacco pipes, and the like, which cannot be held in the hand, are placed in a large bamboo cylinder about nine inches high, filled with clear water, on which float pieces of wood pierced with holes or hollowed into nests, corresponding in size to that of the jade articles. The jade having been fixed in one of these cavities, the left hand of the workman is left free to press the diamond borer with a little iron cup held in the palm, while his right hand wields the bow which pierces the holes.

12. THE WOODEN POLISHING WHEEL.

When the grinding wheel has done its work, although the surface of the jade is smooth and uniform, yet it has no bright gloss, and the wooden wheel must be used, with yellow diamond dust or with a paste made of one of the colored sands, to give it a polish. If the jade article is too small to be polished on the wooden wheel, or if the pattern of the design is very small and complicated, so that the wooden wheel cannot be used, then a small wheel is made of a piece of dry gourd-skin to polish it.

N. B. Two wooden polishing tools, adapted to be mounted in an iron rod for polishing the interior of vases, etc., are figured below, in addition to the wheel described above.

13. THE LEATHER POLISHING WHEEL.

This is a picture of the leather wheels which give the bright polish. These wheels are made of four or five layers of ox leather sewn together by hempen cord. They vary in size from over a foot in diameter down to two or three inches, and are all used with a paste made of the "precious-stone dust" mixed with water for polishing the jade. After it has been polished on the leather wheel, the jade acquires a bright glossy surface of warm, uniform color; such as is most highly appreciated by cultured collectors. This is the finishing touch of artistic work in jade, and completes the cycle of work.