THE ECONOMIC GEOLOGY OF THE NON-METALLIC MINERALS, BASED ON AMERICAN EXAMPLES.

BY

JAMES F. KEMP, A. B., E. M.

Professor of Geology in the School of Mines,
Columbia College, New York City.

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CHAPTER I. THE CARBON SERIES.

THE PHYSICAL CONDITIONS IN WHICH VEGETABLE TISSUE ACCUMULATES. The necessary conditions that must surround vegetable tissue in order to render its accumulation possible are those of retarded oxidation. They are supplied by a protecting layer of water. If exposed on the surface, vegetable tissue, as in the case of fallen leaves in a forest, gradually consumes and passes away in gases, leaving a small mineral residue or ash behind. But if deposited under water as in the accumulations of a delta, a lake or a swamp, the increments of fresh material may so much exceed the loss from oxidation that great accumulations result. For comparative purity of deposit, i.e., small mineral residue or ash, much sediment must be necessarily absent. Such conditions are best supplied by swamps in which trees and smaller growth project above the quiet, standing water so that whenever trunks, branches, leaves, etc., fall they are preserved. Roots and subaqueous plants add their quota, and if subsidence of the area accompanies and keeps pace with accumulation the final result may be very considerable. Little if any sediment reaches the recesses of swamps because under ordinary conditions any inflowing water as was shown many years ago for the inundated lands of the lower Mississippi, is filtered of its load in the outer margins. Severe floods are then the only agent for the introduction of foreign material.

Inasmuch as in this connection the subject of the accumulation of vegetable tissue is treated with a view of throwing light on the formation of coal seams, the following types of deposit alone are mentioned and smaller forms are omitted.

1. MARINE DEPOSITS both submarine and salt water swamps.

2. FRESHWATER DEPOSITS in deltas, transient lakes, swamps and tundras.

It is a mooted question whether the vast results of submarine, vegetable growth in the form of algae, etc., ever accumulate in permanent amount and notable purity. Their substance is largely soft and readily decomposes even though protected by water, and the circumstances of their growth in a medium which down to great depths is never wholly quiet and whose specific gravity approximates their own, militate against such a result. The actual evidance from soundings

and observations in shallow water is as yet quite negative, and although they are swept into inlets and upon beaches in considerable quantities, experience thus far available fails to reveal deposits in sufficient amount to give them great claims to be considered as possible sources of coal. Nevertheless as will be later shown some writers have referred coal seams to them.

The seacoast swamps are of greater importance. They cover extensive areas in many parts of the world and especially along the Atlantic coast. In the warmer climates the mangrove pushes its arching stems seaward, aids deposition and facilitates the growth of vegetation in its rear; while in the north the sedges and shore plants soon give rise to a black boggy turf, high in carbonaceous matter, but also high in mineral admixtures as well. Observation shows, however, that the number of land plants that can flourish near salt water or with roots more or less immersed in it is not great and that it is made up of those with but little woody tissue such as grasses, sedges, etc. As sources of rich and fairly pure carbonaceous residues they cannot be said to equal land plants in any degree.

The principal sources of vegetable accumulation so far as the experience of the present throws light on the conditions of the past are thus reduced to those in fresh water.

DELTAS. With other sediments brought down by rivers to their mouths are vast amounts of drift wood and more or less water-logged and macerated vegetable tissue. These become buried in the delta deposits which are always, when formed by large rivers of low gradient, black and bituminous. Such is the case off the mouth of the Mississippi and to such deposits have been referred many coal seams. Traces of carbonized logs, tumbled irregularly in the coal seam, have given rise to this view. For very high ash coals this suggestion of origin may be of value but for the vast majority of those worked, which contain fairly low amounts of ash, condition so favorable to the abundant introduction of sand and silt cannot be seriously considered. Of somewhat analogous origin are the great rafts of logs and other floating debris, which sometimes gather agianst an obstruction until they form vast masses of floating and water-logged wood. Upon this a heavy, plant growth springs up, and leads to very extensive and fairly clean accumulations. The Red River raft of Louisiana has furnished for many years a striking illustration, being some miles in extent and practically like solid land.

LAKES. Geologically considered all lakes are transient phenomena, although in the cases of enormous bodies of fresh water, like the Great Lakes, the statement is less applicable than to smaller ones, but it is none the less true that numerous small bodies of standing water indicate a young topography, whereas those portions of the earth's surface that have been land have passed the lake stage. Lakes are cut down and drained at the outlet and filled up at the inlet. The process is aided by the growth of aquatic plants and in the end what was once a body of water becomes a swamp and later a bog. In the northern portion of the United States and in Canada there are innumerable illustrations of this process in all stages, and not a few bogs are clearly old lake basins now filled with sphagnum and other related varieties of vegetation together with some trees. Under such swamps there is usually a bed of shell marl and diatomaceous earth where the middle portion of the former lake stood and a layer of bog

ore around its edges. Still larger swamps form upon the surface of the land without necessarily requiring a preexisting lake, provided the rainfall is quite high and the general gradient of drainage is low. Thus along low coastal plains, such as now exist on the Atlantic seaboard, the conditions are favorable and some very extended swamps have formed. The Great Dismal Swamp of Virginia and North Carolina is of this character and not a few others of smaller size are known. They differ from the saltwater swamps earlier referred to, in being fresh and thus letter adapted to plant life. None the less they are close to the coast line of a great and slightly elevated plain and would require but little submergence to bury up their vegetation beneath encroaching sediments. Although less extended than the swamps that yielded the coal of Carboniferous and Cretaceous periods, they doubtless furnish our best illustration of the conditions prevailing in those times. It is also to be noted that the elevation of a low and shelving coast may develop on the landward side of its former fringing bars and especially if mangroves are present, lagoons of very considerable size, that will pass from a brackish water condition to that of freshwater swamps.

TUNDRAS. The researches of Dall, Russell and others in Alaska have been fruitful in showing the great extent and the rank, luxuriant character of the vegetation in those cold latitudes. In the interior of Alaska the surface is unglaciated, because although the climate is cold, the rainfall is insufficient for the great accumulation of snow. The short summers are hot and develop a very vigorous growth of mosses and stunted higher types of vegetation, while a foot or so below the surface the ground is frozen in perpetual ice. Innumerable pools of standing water dot the fairly level surface, and with the soft mossy growth into which the traveler on foot sinks nearly to the knees, impede advance. Conditions are thus favorable for great accumulations of fairly pure vegetable matter and may be analogous to those which in some localities have led in the pass to the formation of coal seams; but the general character of the coal flora as yet studied, suggests a warm rather than a cold climate. Russell has also described very dense growths of forests even on the moraines which rest upon the ice of the Malaspina glacier.

In summary it may be fairly stated that so far as our knowledge today gives us an indication, land growths as distinguished from marine are the more important sources and freshwater salts are superior to saltwater. The most favorable conditions of all are met along low coastal plains, in regions of abundant rainfall and low drainage gradient. If to this is superadded a progressive submergence with extended periods of interuption which allow of great swamp development , the conditions are all present for the repeated formation of beds of plant tissue and for their periodic burial and preservation in a sedimentary series. The application of these preliminary descriptions to the interpretation of coal formations in particular areas will later follow.

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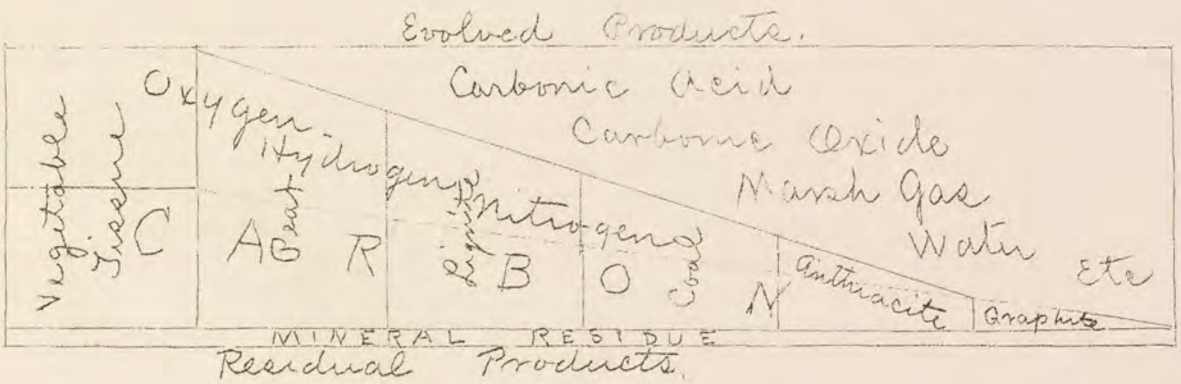
The Chemical Composition of Plant Tissue and the changes involved in its passage to coal.

A vast number of analyses of dried, woody tissue agree in showing that it contains very nearly Carbon, 50., Oxygen, 44., Hydrogen, 6., a little Nitrogen and still less Sulphur. An average of European forest woods is given by E. Gottlieb at C. 49.57, O. 43.83, H. 6.11, N. .07 and ashes, .42. The ashes vary somewhat and are stated by others to evan reach 2 %. In the drying much water, of course, was driven off, that belonged to the fresh plant,in part at least in complex but easily broken molecules. With the above which is largely cellulose, $C_6 H_{10} O_5$, there is also deposited more or less of gums and resins and of animal substance, but probably not enough to be a very serious factor in the total result. Albuminous matter in the seeds of plants,and in animals supplies Nitrogen, and sulphur is derived from similar compounds which are different from the woody fiber that is the main source of carbon. As this mixture of tissues is exposed in nature to even very retarded oxidation, portions of both the carbon and the hydrogen combine with the oxygen and to a much smaller extent with each other and pass off, so that the result is a great relative increase in the carbon present, and a great decrease in the oxygen. The tissues become brown and finally, quite black. J. S. Newberry has summarized these changes graphically by a diagram which marks the several stages quantitatively as well as qualitatively, and which slightly changed so as to express more closely percentage ratios is reproduced below-.



The earlier stages of the process are illustrated in a single peat bog- from the upper and growing layers downward to those more carbonized. It is important to bear in mind during the discussion of origin that coals- are true although very complex hydrocarbons and up to the last stages of metamorphism into graphite are never mixtures of pure carbon with socalled bitumen as was the old conception still retained in our name bituminous coal. The old conception was first controverted by Baltzer of Zurich in 1873, since which date the later view has been almost universally held. All coals, however metamorphosed, show some hydrogen and oxygen, enough to form for instance, the higher members, of the benzole series, but there is no doubt that every coal represents such a complex aggregate of a number of molecules, that no one formula could express them. It is also important to appreciate that the great chemical change through which woody tissue passes on the way to coal is oxidation, and that the main results are water and carbonic oxide and acid, marsh gas or CH_4 being the principal remaining product. It is significant that the three gases last named are the dangerous ones in the coal mines, and it is well established that the deterioration that freshly mined coals suffer on exposure is also due to oxidation.

While the series of products derived from plant tissue is a practically unbroken one it is customary to place emphasis on these four substances as marking important stages; viz. peat, lignite, bituminous coal, anthracite. By peat we understand the mass of stems, leaves, etc. that mats down under the growing plants on the surface; that still preserves the structure of the woody tissue; that is quite incoherent, but yet brown to blackish brown and notably carbonized. If the tissue is macerated before deposit the vegetable structure may be more or less obscure. As the subsequent analyses will show, peat is high in oxygen and always contains a large amount of water unless kiln-dried. The next stage is lignite or brown coal (Braunkohle of the Germans). The lignites are variable but in general they are much more compacted than peat; the origin structures are more obliterated although often visible; the color is dark brown to nearly black, but in the last case the powder is brown. Chemically the oxygen has notably decreased, the hydrogen considerably, and as freshly mined the percentage of water is always much higher than the true coals. Lignites are inclined to air-slack on exposure and slough away to a black mud. It was formally customary to describe all past-Carboniferous coals as lignites and make the distinction a geological one, but the development of Cretaceous and Eocene coals in the West, which are quite as good as those of the Carboniferous in the East, has rendered the geological distinction of no value.

The next stage is that of bituminous coal, called also stone-coal (Steinkohle, Schwarz kohle of the Germans). The name bituminous is perhaps unfortunate suggesting as it does the admixture of a "bitumen" with pure carbon, according to the old conception, but it is in such general use as not to be advantageously replaced. These coals we also call soft coal as against the hard anthracites so much used in America. In them the evidence of vegetable structure to the naked eye, has mostly disappeared, although more or less preserved and specially evident in the cellular layers which we usually call "mineral charcoal" ("Faserkohle" of the Germans.) The color is a good black. The oxygen has very much decreased and the hydrogen notably so; the percent-

age of water is low and the tendency to air-slack much less marked than in the lignites. In anthracite the vegetable structure is but rarely apparent; the coal presents shining,lustrous surfaces and compact, homogeneous texture. The decrease in oxygen and hydrogen is very marked and the carbon has mounted to above 90 %. The nitrogen has almost diaappeared and the water in the freshly mined coal is low. The anthracites resist air-slacking much the best of all.

The general course of these chemical changes is shown in the subjoined table which is practically accepted by all authorities. All these analyses are reckoned on an ahs-free basis, and are selected from a widely varying series so as to be as representative as possible. Under each kind of coal, etc., later on will be given many actual analyses.

	C	H	O	N	Total
Woody Tissue - - - -	50	6.	43.	1.	100.
Peat - - - - - - - -	59	6.	33.	2.	100.
Lignite- - - - - - -	69	5.5	25.	0.8	100.3
Bituminous Coal- - -	82	5	13.	0.8	100.8
Anthracite - - - - -	95	2.5	2.5	Trace	100.

The further stage in the process would be the elimination of oxygen and hydrogen and the change of the carbon to graphite. In the Rhode Island-Massachusetts coals this is in part accomplished, for there apparently is much graphite substance through the coal, and in many graphitic schists and quartzites we doubtless have the pure metamorphosed carbon. Some close chemical analysis is necessary, however, to make sure that in the Rhode Island case we have not still some hydrocarbons, very high in carbon, for in the published analyses hydrogen and oxygen still appear in considerable amount. The last stage of the cahnge leaves only the mineral residue or ash behind.

All the reactions in the alteration from plant tissue to coal we do not fully understand notwithstanding the fact that the main features are sketched above. The conditions that have surrounded these great beds of vegetable products while buried in the earth, cannot be reproduced in the laboratory although many attempts have been made. In some cases it doubtless occupied vast periods of time, yet in instances timbers buried in old, abandoned chambers of coal mines, especially if such have been temporarily on fire, have changed in a few years to coal, and may even be coal at one end of a stull and wood at the other.

E. S. Moffatt,(M. E. Feb.1887)described such a case from Scranton, in which a stull, 10 ft.long, and somewhat crushed at the upper end was buried in refuse and gob in a burning mine for thirty years, On being excavated it was found to graduate from unchanged wood at the base, through charcoal to a true bituminous coal at the top. Similar cases have been met abroard-(Mietzsch. Geol. der Kohlenlager, p.234).

The condition of the woody tissue at the outset of the deposition may have exerised an important influence. If more fully oxidized in some deposits than others by reason of longer exposure to the air, the subsequent result might be more or less modified. Thus J. J. Stevenson regards such an original, specially oxidized material as the chief cause of the formation of anthracite in the coal series of Pennsylvania. It is conceivable also that variation in the character of vegetation might exercise some, though probably not great influence. The compos-

ition of the ash of coals has been appealed to as throwing light on the original character of the deposit when it is compared with the composition of wood-ashes. In all such comparisions the mechanical sediments mostly free silica and silicates of alumina and lime and the infiltiations chiefly quartz, calcite and gypsum, must be left out and this involves difficulties. After making such allowance, it is than apparent that alkalies are less abundant in coal-ashes than in wood-ashes, and the inferance is that in the course of carbonization the alkalies have been leached out by percolating waters. In the end so many variables enetr into the problem and so many chances of error present themselves, that but little encouragement is afforded, of reaching reliable results.(See Dana's Manual of Geology, under the Carboniferous Age- for an attempt). Fossil plants either in the coal itself or in the shales of the roof and floor or in shale-partings and mining-slates in the seam itself give us a better indication of the general character of the vegetation, than does any other form of data.

The great increase in density which has taken place in the alteration of peat to coal(the specific gravity of the latter ranges from 1.25 to 1.45 for bituminous, and from 1.55 to 1.65 for anthracite. It is 2.08 for graphite.)has given ground for thinking that the deposits have been much compacted and that a coal seam of six feet represents many times thatthickness of fresh vegetation. Allowance must also be made for the evolved products during the change, and for the fact that the fossil coal plants indicate that the carboniferous vegetation, at least, was largely endogenous and of soft, spongy tissue. Calamite and lepidodendron logs that must have been two or three feet in diameter we often see in coal seams flattened to a thickness of an inch or less and represented by this thin layer of coal. Aside from chemical change the overlying weight of rocks would compact many such beds in a very appreciable manner. It is justifiable to infer, therefore, that a coal seam a few feet thick represents several,certainly two or three times,that thickness of uncompacted peat and that the original growth was correspondingly luxuriant. Where seams reach great thickness as in the case of eastern Pennsylvania in the Mammoth bed, and in Southwestern Colorado, the growth was correspondingly heavy, unless it was increased by material transported from a distance

The vast amount of carbon represented in coal seams, all of course extracted from the atmosphere, has led many to expatiate on the greater richness in carbonic acid. Whcih must have been characteristic of the air in Carboniferous times. As the Cretaceous and early Tertiary periods are hardly inferior to the Carboniferous as coal producers the same argument applies to them. If it were possible to obtain an estimate of the amount of coal in the world and to assume its composition and turn it into the corresponding amount of carbonic acid, it would then be possible to see how great a change in the composition of the earth's atmosphere(whose present weight in composition are very well known)this addition would involve. It is very probable that the increment would be practically lost in the vast bulk of the atmosphere, and that the change would be but slight. For instance if we assume a layer of coal 1 ft. thick and 75% C. over all the known land, it would contain about three fourths as much carbon as is in the atmosphere to-day. But as all the coal of the world is probably not a fifth of this, the increase of the total CO_2 in the atmosphere, were all the coal

turned into this gas, would bring about no greater differences between the atmosphere of today and of Carboniferous times, than between that now found in the country and open squares in the city, or say between .035 % and .040 %. Whether this slight difference would have any appreciable stimulus on plant growth is very problematical.

It should be added that there are forms of coal, that we may best call asphaltic coals, and take up under petroleum which fill fissure veins and are clearly derived from some form of hydrocarbon analogous to oil or bitumen and which have been deposited by infiltration precisely like a mineral vein. Coal seams have even been referred to tarry residues left by the evaporation or polymeric change of petroleum lakes; to the separation of the carbon in some extraordinary alteration of limestone and to various other change sources, but such theses have limited foundations in reason, and belong rather to the curiosities of literature than to science. Many other more grotesque views have been advanced in the past a brief review of which may be found in Muck's Chemie der Steinkohle- p.135.

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GEOLOGICAL DISTRIBUTION. Peat is limited to deposits of recent geological time, none dating back of the Quaternary, or at most, latest Tertiary. Lignite or brown coal is chiefly derived from Tertiary beds, some however, being as old as the Cretaceous. Abroad it occurs even in Jurassic, Triassic and Carboniferous strata. The principal horizons in America are the Laramie at the close of the Cretaceous and in the Eocene of the early Tertiary. The latter of those formations is called the "Lignitic" in the Gulf States. But the same horizon, as in the case of the Laramie, may yield lignite in one part of the country and in another, where metamorphism has occurred, may furnish excellent bituminous or even anthracite coal. Coals proper of both principal varieties are mostly limited to two great series of strata, the Carboniferous in the East, and the Laramie of the upper Cretaceous in the West. There are minor deposits in the Jura-Trias of Virginia and North Carolina; in the Dacota of the Lower Tertiary on the Pacific Coast. Anthracite is in far the greatest quantity in eastern Pennsylvania, of Carboniferous age, but local metamorphism due to igneous intrusions has caused its formation from Laramie coals, near Santa Fe, N.M; Crested Butte and elsewhere in Colorado, and in one or two less developed places, as Queen Charlottes Island from earlier Cretaceous Coals etc. Graphite is chiefly limited to Archaean rocks but it may be a result of contact metamorphism in rocks of any age. It is also found in fissure veins.

CHEMICAL ANALYSES and their INTERPRETATION. There are two methods of chemical analysis practiced, the complete or elementary and the proximate. In the former the absolute, elementary amounts of carbon, oxygen, hydrogen, nitrogen, sulphur,etc.(all but the ash,) are determined without regard to combinations. This is the older method and has largely fallen into disuse on account of its relative difficulty and because it does not give the information about a fuel that is desired in practical adaptations so well as the simpler, proximate method. It does however afford data for scientific deductions about the chemi-

cal nature of coals, and about their calorific powers not given by the proximate method. These analyses are calculated for ash-free substance when used for general purposes of classification and comparision, and are based on material dried at 212 degrees F. The following table will serve as a basis of illustration.

Peat.	H_2O.	C.	H.	O.	N.	S.	Ash.
1. Sphagnum (dried)		49.88	6.54	42.42	1.16		
2. Condensed Peat	20.0	47.2	4.9	22.9			5.0
Lignites.							
3. Carbon. Wyo.	7.35	63.65	4.60	19.44	1.40	0.76	2.80
4. Morrison Col.	8.20	64.05	4.80	17.24	0.70	0.51	4.50
5. Kanawah Ut.	7.45	53.95	8.30	23.57	0.98	0.90	4.85
6. Ft. Berthold N.D.	8.00	57.20	5.22	25.52	0.70	1.88	1.48
7. Robertson Co.Tex.	16.40	54.46	4.41	16.07		0.96	7.70
8. Coos Bay Ore.	13.28	56.24	3.38	21.81	0.42	0.81	4.05
9. Alaska	16.52	55.79	3.26	19.00	0.61	0.63	4.18
Bit. Coal.							
10. Whiteside Tenn.	1.04	78.83	5.51	4.00	1.12	2.61	6.89
11. Briar Hill O.	3.28	77.88	6.20	7.65	1.51	0.64	2.84
12. Brazil Ind.	5.45	76.05	5.88	8.13	1.37	0.80	2.32
13. Connelsville Pa.	0.89	82.48	4.50	5.61	1.45	0.94	4.13
14. Crested Butte Col.	1.00	74.29	7.49	9.17	1.40	0.61	6.04
15. Blossburg Pa.	0.69	81.15	5.21	2.24	1.30	0.68	8.73
Anthracite.							
16. Spring Mountain Pa.	1.97	91.40	2.59	0.08	0.21	0.71	3.04
17. Lykens Valley Pa.	0.73	82.89	4.53	0.40	0.64	0.68	10.13
18. Crested Butte Col.	0.72	82.50	5.15	4.55	1.12	0.85	6.04
19. Santa Fe N.M.	3.19	74.37	2.58	8.71	1.76	0.73	6.05
20. Queen Charlottes Is.	1.90	75.95	6.03	6.81	1.40	0.95	7.96

Analyses Nos.1&2 are from Johnson's Peat and its Uses, p.24 and p.100. No.1. is unfortunately reckoned ash-free and dry. There were 2-3% ash present. No.s 3.4.5.6.14.18.and 20. are by C. E. Munsell, from specimens in the Museum of the School of Mines, Columbia College. See Jour. Amer. Chem. Soc. XIII.No.4. Munsell also gives two complete analyses of peat, but too low in H_2O to be typical. No.s 8.& 9. are by H. S. Munroe,-on specimens from the same source-and are quoted in Macfarlane's Coal Regions of America-p.557. No.s 10.11.12.13.15.16.17.are by J. L. Lilienthal and were made in 1871 on specimens from the same source-furnished, like the others, by Prof. J. S. Newberry. They are taken from the records of the Geological Department of the School of Mines. No. 8 is from E. T. Dumble's Report on Brown Coals etc.-Texas Geol. Survey. 1892. p.217. In each of these references are numerous other similar analyses.

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These analyses bring out strongly the general relations of the elements which were mentioned earlier. The progressive decrease in oxygen and hydrogen from peat to anthracite; the small but variable amounts of nitrogen and sulphur, and the inconstant quantity of ash are shown. In close comparasions allowance must be made for the variability of samples and for the position of the same whether near outcrop or well underground, as stated above.

When the discussion of chemical composition is carried to its completeness, it is customary to recalculate, excluding the ash. The relations of oxygen and hydrogen are then brought out by speaking of the latter as combined and disposable. It is assumed that the hydrogen will combine with the oxygen to form H_2O until the latter is exhausted, and the amount required is the "combined" hydrogen; the excess is then the "disposable". The latter may be obtained by subtracting one eighth the percentage of oxygen from the total hydrogen. There is always some disposable hydrogen and in true coals (bituminous or stone coals and anthracite) the disposable is always in excess of the combined. It is further often customary to calculate the number of parts of oxygen and hydrogen per thousand parts carbon, and on the ratios of these results to base discussion. If No.s 2,3,11,13,15, and 17, all of which are representative numbers of their several classes are recalculated, we obtain the following table, in each case eliminating the water and ashes. In No.2- in order to obtain the disposable and combined hydrogen, 2 % of supposed nitrogen, as a fair average value, have been subtracted from the combined O and N. In the hydrogen, the error could be but one-eighth of the excess or deficiency in the assumption.

Peat.	C.	H.	O.	N.	S.	HDisp	HComb
2. Condensed Peat	62.93	6.53	30	.53		2.97	3.56
Lignite.							
3. Carbon. Wyo.	70.84	5.12	21.63	1.56	0.85	2.42	2.70
Bit. Coal.							
11. Briar Hill O.	82.96	6.60	8.15	1.61	0.68	5.58	1.02
13. Connelsville, Pa.	86.83	4.74	5.91	1.53	0.99	4.00	0.74
15. Blossburg Pa.	89.60	5.75	2.47	1.45	0.75	5.44	0.31
Anthracite.							
17. Lykens Valley Pa.	92.98	5.09	0.45	0.72	0.76	5.04	0.05

If the above values are recalculated so as to give ratios on the basis of 1000 parts carbon, the following table is obtained. The disposable and combined hydrogen is usually expressed in this way.

Peat.	C.	H.	O.	Disp. H.	Comb. H.
2. Condensed Peat	1000	103.76	453.3	47.19	56.57
Lignite.					
3. Carbon. Wyo.	1000	72.27	305.3	34.16	38.11
Bit. Coal.					
11. Briar Hill. O.	1000	79.55	98.24	67.26	12.29
13. Connelsville Pa.	1000	54.58	68.06	46.05	8.52
15. Blossburg Pa.	1000	64.17	27.56	60.71	3.45
Anthracite.					
17. Lykens Valley Pa.	1000	54.74	48.39	54.21	0.53

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The proximate analysis is now performed by general agreement, by first drying about 1 gram of the coal in a weighed platinum crucible at 100-115 C.until it reaches a constant weight or begins again to slightly increase. It is then heated in a good bunsen burner 3 minutes and in a blast lamp 3 minutes, cooled and weighed. The loss gives the volatile hydrocarbons, and the residue indicates whether the coal cokes or not. Foreign practice requires a bunsen flame of at least 18 c m (about 7 in.) height and that the crucible, set in a fine platinum wire triangle be placed in it with the bottom not over 3 c m(1 1/5 in.)from the top of the lamp. The coal is then ignited until flames cease to come off- no time limit being set. After determining the loss, the remaining "fixed carbon" is entirely burned off, and the residue is the ash. Sulphur is the most frequent element estimated, but in metallurgical practice of course all the elements of the ash are needed. The proximate analysis indicates the behavior of the fuel in practice, whether rich in gases or poor, whether with a long flame or short, whether coking or non-coking etc. In the classification of coals in America we calculate the ratio of the fixed carbon to the volatile hydrocarbons and use this as a short numerical indication of the character of the coal. All this will be taken up later in speaking of the classification of coals-but as illustrating proximate analyses the following table is appended-standard fuels being selected so far as possible.

Peat.	H O.	Vol.Hyd.	Fx'd. C.	Ratio	Ash	S.
1. Dismal Swamp	20.22	52.31	24.52	0.47	2.95	
Lignite.						
2. Vogel Mine Texas	17.75	37.85	37.40	0.99	6.20	0.80
3. Golden Col.	13.43	37.15	45.57	1.23	3.85	
4. Rock Spring Wyo.	7.00	36.81	54.46	1.48	1.73	
Bit. Coal.						
5. Clay Co.Ind.	4.0	40.0	52.0	1.30	3.0	1.0
6. Briar Hill O.	3.60	32.58	62.66	1.92	1.16	0.85
7. Connellsville Pa.	1.26	30.11	59.62	1.98	8.23	0.78
Semi-Bit. Coal.						
8. Cumberland Md.	1.23	15.47	73.51	4.75	9.09	0.70
Anthracite.						
9. E. Mid. F'd. Pa.	4.12	3.08	86.38	28.04	5.92	0.50
10. N. Field Pa.	3.42	4.38	83.27	19.01	8.20	0.73

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No.1. is by B. Stillman in Leavitt on Peat- p. 148
No.2. Dumble's Rept. on Texas Brown Coals. p. 182
No.3. Mineral Resources U. S. 1883-84 p. 101. No.4. Idem 26.
No.5. do. 1887. 240; No.6.Idem.60; No.7 do. 1883-84-177; No.8. do. 1885-54.No.s9 and 10, do. 1883-84, 69.

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Other methods of assay are employed to determine the calorific power of the coal as indicated by the amount of litharge a grain

will reduce. The best method is that of R. C. Hills, as referred to below. It is also customary to speak of the sum of the volatile hydrocarbons and of the fixed carbon as indicating the fuel value-or fuel percentage (see paper by H. M. Chance cited below). All these questions are metallurgical rather than geological but they are necessary to the true estimate of a fuel. Some additional discussion of coals is given further on in speaking of their classification.

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Note. All the standard treatises on Metallurgy and technical Chemistry discuss this subject.

H. M. Chance. Relative Value of Coals to the Consumer-M.E. XIV. 22.

P. Fraser. Classification of Coals- M.E. 6. 430. Penn. 2nd. Geol.Surv. M.M. p.144.

F. A. Gooch. Analyses of Coals and Lignites of the Northwest. 10th Census XV.775.

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A. S. M'Creath. Much valuable information in Reports of Chemist of 2nd Penn. Geol. Surv. M.MM.M3.

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P. Schweitzer. True Composition of Coal and the Methods of arriving at it,etc.- Catalogue of the Univ.of the State of Mo.1871.App'dixA.

T. O'C. Sloane. Notes on the Analysis of Bituminous Coal. - A.J.S. III. 14. 286.

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CHAPTER II. THE CARBON MINERALS CONTINUED

Peat, Lignite or Brown Coal, and Post Carboniferous Coals.

PEAT.- Peat is of greater scientific interest than practical importance in America, although in many foreign districts, such as Ireland, and southern Germany, it is the chief local fuel. The general conditions of its growth were mentioned above. It requires a cool, and fairly moist climate for its best development, and is therefore found in temperate to cold latitudes. The principal peat maker is Sphagnum, a moss which has a great avidity for moisture and grows continually upward from its decaying stems. With it there occurs abroad much heather (Calluna) that is lacking in this country, but with us many grasses, aquatic plants, and even shrubs and trees contribute to the accumulation. The lakes of the glaciated region that are gradually filling with vegetation are prominent sources, as are beaver-meadows,

and for saltwater accumulations are sea coast swamps. All of our central and northern states, and all the provinces of Canada are abundantly supplied. The American peat is principally used as a fertilizer under the name"muck". It is often advantageously spread on land, or mixed with compost heaps. As a fuel it is now of no practical account because of our abundant and cheap supplies of coal with which it cannot compete in any degree. But in the decade of the sixties before this was demonstrated so completely there was a great deal of interest in the subject and a mild craze for the preparation of this fuel swept over the country, leaving a trail of financial wrecks in its rear. Machines were invented to dig and compress it and many attempts were made to place it on the market, but its property of absorbing water to the average amount of 20 % which must be evaporated in its combustion, with the loss of just that amount of calorific power, is the most serious drawback, added to which are its pungent and penetrating odor when burned, and its frequent high percentage in ash.

Peat bogs (English term"mosses") grow with great rapidity, 3-6 ft. being recorded in Germany in 20-30 years (See Geikies Textbook of Geology 1st Edition p.460). They may climb beyond the immediate location of moisture (climbing bogs) as they draw after them the necessary supplies of water by capillary attraction. They may invade forests from changes in topographical relations and from their antiseptic properties, preserve fallen timber for long periods. Such logs have been dug up and utilized in southern New Jersey and abroad. The same antiseptic influences have preserved the remains of animals and even of man. In the town of Montgomery, Orange Co.,N.Y. the bones of nine mastodons have been dug from the peat within a range of eight miles. Peat bogs enclosed in deposits of glacial drift have proved of considerable geological interest in their bearing on the question of one or more glacial epochs and the advance and retreat of the ice. Extended ones called "forest beds" are known in these relations in Iowa. The frequent association of shell marls and bog iron-ores with peat has already been mentioned.

Elementary Analyses.

	C	H	O	N	S	Ash	H_2O
1. Oswego N.Y.	44.11	6.14	33.39	0.78		15.57	10.30
2. Ravenna O.	57.84	7.10	21.12	0.84	0.20	4.95	7.95
3. " "	41.81	6.95	16.48	2.24	6.26	13.66	12.60
4. Condensed Peat	47.2	4.9	22.9			5.00	20.00

Proximate Analyses.

	Water	V. H.	F. C.	Ash.
5. Dismal Swamp	20.00	50.05	24.97	4.98
6. " "	20.00	52.59	25.44	1.97
7. " "	78.89	13.84	6.49	0.78
8. " "	20.22	52.31	24.52	2.95
9. " "		65.53	30.82	3.65
10. " "	10.00	58.08	28.59	3.33

Analyses of Peat Ashes.

	11.	12.	13.	14.
Potash	0.69	0.80	3.46	13.04
Soda	0.58		to-	6.36
Lime	40.52	35.59	6.60	10.31
Magnesia	6.06	4.92	1.05	5.15
Oxides of Iron and Alumina	5.17	9.08	15.59	17.16
Phosphoric acid	0.50	0.77	1.55	4.12
Sulphuric acid	5.52	10.41	4.04	4.47
Chlorine	0.15	0.43	0.70	4.23
Soluble Silica	8.23	1.40		9.02
Carbonic acid	19.60	22.28		
Sand-or Insoluble	12.11	15.04		25.83
Total	99.13	100.74	32.99	99.69

No.1.N.Gowenlock.Cultivator and Country Gentleman-1875, 275. No.s 2 & 3 C.E.Munsell Jour.Amer.Chem.Soc.XIII.No.4. The water is low for air dried peat-and in 3, the sulphur is unusually high. No. 4.Johnson-Peat and its uses-p.100.- No.s 5 and 6 Leavitt. Facts about Peat-p.147.S.W. Johnson Analyst.No.s 7 to 10 Idem.p.148. B. Silliman.Analyst. No.s 11,12 and 13. Johnson-l.c. p.47. No.11. from Poquonnock Ct. G.F.Barker Analyst. No.12 Colebrook Ct. O.C.Spanow Analyst.

No.13 Guilford Ct-P.Collier,Analyst. No.14. Ash of Sphagnum palustre Websky Anal. from Senft Humus etc. p.136. The total percentage of ash was 3.88. Comparatively few analyses of American samples have been made, but many foreign ones will be found in the citations below.

LITERATURE ON PEAT.

Note. Textbooks of Metallurgy and technical chemistry treat of peat as a fuel-as a general thing, with analyses of both fresh peat and ashes.

Brande. On Peat and its Products. Proc. Roy Soc. Jan.31.1851. Atheneum 1217- A.J.S. II. 11. 440.

G. H. Cook. Peat in New Jersey. N.J.Geol.Surv. 1868-698. A number of partial analyses are given

S. L. Dana. Muck Manual- Lowell 1842.

S. W. Johnson. Peat and its Uses as Fertilizer and Fuel-N.Y.1866. An earlier and shorter report was published in Hartford about 1858. The later work sums up the peat question as regards this country, quite satisfactorily even to this day. Rec.

N. Gowenlock. Peat and its Uses. The Cultivator and Country Gentleman 1875. p. 275.

T. H. Leavitt. Facts about Peat.1867. A pretty complete compilation in the interest of the authors peat machine.

L. Lesquereux. Sphagnum as a Peat Maker. Haydens Rep.1872. Quoted in A.J.S. iii. VI.383. See also-Paper on Origin of Coal-Ann.Rep.Penn. Geol.Surv.1885. p.109. and his classic essay Quelques Recherches sur les Marais Tourbeux-Neufchatel.1844.

Sir Chas. Lyell. Principles of Geology-II.502. Antiquity of Man.

W. J. Mc.Gee. Interglacial Peat Beds in Iowa-Eleventh Ann.Rep.Dir.U.S. Geol.Surv. p.486. The same subject is treated in general works on the Ice Age. For one in Ohio see A.J.S. ii. L.54.

J. Roth. Chem. und Physik.Geologie. Vol.II. p.539.A valuable bibliography is given.

F. Senft. Humus-,Marsch-,Torf-, und Limonit-Bildungen Leipzig 1862. Rec. Gives a bibliography somewhat antiquated.

N. S. Shaler. On Peat and Swamp-Soils. Twelfth Ann. Rep. Dir. U. S. Geol. Surv.- 311. Also reference given on p .
R. C. Taylor. Statistics of Coal- 1848. Contains many local data onPeat
F. Zirkel. Petrographie 1894. Vol.III p.626. A very valuable bibliography is given.

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LIGNITES or BROWN COALS.

The term lignite is mostly used in America whereas brown coal is chiefly employed abroad. No distinction is made between the two terms by most of our American writers, but E. T. Dumble in the recent report cited below restricts as do the Germans, lignite to those varieties which still preserve the structure of the original wood, while brown coal is applied to those which have it but feebly if at all developed. In these pages the terms are used interchangeabl , the term lignite in accordance with the French and earlier American usage being preferred.

No very sharp line can be drawn between lignites and peat on the one hand and between lignites and true coals on the other. The amount of water present is less than in peat, and greater than in coals. The same is true of oxygen. In true coals the disposable hydrogen is always in excess of the combined, not always in lignites . Lignites are more or less brown, certainly in powder, whereas true coals are usually black. The plant structure is as a rule more evident in the former, and the individual stems and twigs may be even apparent. Lignites do not bear exposure well but tend to slough away to mud. This was true of those first opened in the prairie and Rocky Mountain states, and created an early and somewhat unfavorable impression about their fuel resources that later mining has dispelled. The older practice, based on this early experience with the fuels of the Laramie, of calling all post-Carboniferous coals lignites has now become properly obsolete and the distinction is a physical and chemical one as it should be. Nevertheless it is a general rule that the lignites are in a comparatively late geological strata (chiefly Tertiary) and that they are found in relatively undisturbed and unaltered sediments. As soon as any notable change or incipient metamorphism show themselves, the carbonaceous deposits are among the first to feel the effects, but even to this rule there are exceptions, for the mines north of Denver, in Colorado are on seams which dip at a high angle and yield a lignite rich in water, whereas near Trinadad the same geological horizon yields excellent coking coals from flat seams. Some other factor must have entered in this case, such as the presence of igneous rock or a difference in the chemical composition of the original deposit such as greater oxidation, which will account for the difference.

Lignites vary widely in specific gravity. Certain fossil resins often classed with them are less than 1., while high ash lignites run above 1.5. 1.20--1.30 is about the avergge of good ones, being somewhat under that of bituminous coals. The determination of the specific gravity present some difficulties on account of contained gases and it is advisable to exhaust these from the powdered sample with an air pump. The hygroscopicity is a serious matter for as a general rule, even though the water contained in freshly mined material (5-20%) is partially exhausted it is reabsorbed with considerable avidity.

Lignites lend themselves to certain processes of chemical manufacture abroad, as for instance the production of paraffine, some oils etc., but the general remoteness of our deposits from centers of population and our other cheap sources of these articles make such adaptation of no serious moment. Our lignites are only to be viewed as sources of fuel, and only of this in regions remote from true coals.

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LITERATURE.

G. H. Cook & J. C. Smock. New Jersey Lignite. Geol. N. J.1868. p.696. A bed on Cheesequakes Creek reaches 4 ft. Rept. on Clays.1878. 73. Anals.Vol. Hyd.& water 50.2-Fixed Carbon 34.6-Ash 15.2 .

E. Hitchcock. Description of a Brown Coal Deposit at Brandon Vt. etc.- A.J.S. ii.XV.95- Geol.of Vt. I.233.

J. P. Lesley. Mont Alto, Penn. Lignite. Proc.Amer.Acad.Sci. 1864. 463.

L. Lesquereux. Fossil Fruits at Brandon Vt. A.J.S. ii. XXXII. 355.

N. S. Shaler. Geology of Martha's Vineyard. 7th Ann. Rep. Dir. U.S.Geol. Surv. 357.

EASTERN STATES. Many years ago a pocket of lignite was found at Brandon, Vt. which attracted some attention in connection with the associated Siluro-Cambrian limonites and because it contained Tertiary fossil fruits. It has been used to a very small extent as a local fuel. Lignite deposits occur in the Tertiary beds at Gay Head, Martha's Vineyard, and are not infrequent in the Cretaceous clays of Long Island, New Jersey and southward. They are usually associated with marcasite and are of no practical importance. A deposit somewhat like the Brandon one has been discovered at Mont Alto Penn.

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When the lignites in the country west of the Mississippi are taken up, if the attempt is made to differentiate them from the true coals of much the same great regions and stratigraphic horizons, such objectionable geographic and geologic confusion results that it is much more advantageous to describe them in connection with the vastly more important true coals. Even when the fuels show the higher percentages in water and the chemical composition, characteristic of the lignites, if they have a standard reputation as coals, they will be called coals, and regarded as such without reference to the strict scientific definition, for this has grown to be the customary commercial practice. At the same time where the lignitic character is well shown and known as such it will be emphasized. After some preliminary discussions regarding coals the districts will be taken up in this order- The Pacific Coast-the Great Basin-The Rocky Mountains-and The Great Plains.

GEOLOGIC and TOPOGRAPHIC RELATIONS of COAL SEAMS. Coal seams are almost without exception associated with shallow water deposits, chiefly fire clays, shales and sandstones. Limestones are subordinate in such series and when found are very valuable datum-strata from which to identify the neighboring coal beds. Such is the case in the Lower Productive Measures of central Pennsylvania as will be later brought out. Limestone in immediate association with coal is rare although not unknown, for G. K. Gilbert has observed such a case in one of the Utah fields. Still the swamps of Florida today are reported by N. S. Shaler as growing in depressions in limestone and might give rise tosuch a coal seam in time.

Fire clay often underlies the coal and is the result of the stage of quiet waters next preceding the swamp growth. From such beds some of the standard fire brick of the country are manufactured, as at Woodland, Penn. and St. Louis, Mo., Where a coal seam is too thin to be worked for itself alone, it may be taken out along with the underlying clays and used with profit as a fuel, to turn the latter into brick, tile etc. This is a growing practice in Iowa. The fire clay not infrequently contains plant remains, chief of which are the so-called stigmaria, which were the roots of some of the earliest swamp plants that lead to the formation of the coal. Although these underlying beds are spoken of as clay, it is not to be inferred that they are always soft and plastic,; on the contrary they are often dense, firm rock, and are ground before being used. When, however, the underlying clays are more or less soft or plastic, they sometimes bulge up into the drifts and headings of mines with a so-called "creep", that gives the engineer great annoyance. Shales and sandstones are the other rocks most frequent in the floor and are the usual ones present in the roof of a seam. A good firm roof is a great desideratum and if this is a solid sandstone it is an immense aid to mining. With tender shales it is at times necessary to leave an upper thin bench of coal as a precaution. Shales in connection with coal are usually called slate, but in strict geological use a slate is a metamorphosed shale or clay with a new cleavage, induced by pressure and shearing. The coal beds are themselves sometimes called veins, and this is also contrary to good geological usage, but of course in every day affairs one is not over-particular in these matters. These shales are often found serviceable as a material for vitrified brick. It is rare that a coal seam of several feet in thickness is devoid of thin layers of shale, often of great persistency, that divided into two or more benches. If such shales are thin and tender they cannot be separated in mining and are a grievous source of ash, making the coal "bony", but if sufficiently thick and solid they may be culled out (mining slate) and thrown on the dump or used as gob. At times such a parting along a seam, may gradually increase in size, until it splits the seam into two with an interval of several feet between. Even thin beds of limestone have been met in the thickest portions of such a parting and clay ironstone may do the same.

Coal seams are sometimes cut abruptly by bodies of shale or sandstone that the workings show to be somewhat sinuous and of great length though of comparatively limited breadth. They are due to the filling of old stream channels through the original swamp. Such a one has been described from the Northern Anthracite Field of Pennsylvania by H.A.Wasmuth, (Jour. Franklin Institute, see XXXIV. 354.) and they have been occassionally met elsewhere. Old stream channels have also been formed and filled in later Carboniferous time than that of the coal formation and after the latter had been long buried up, as at Avery, Iowa, (see Keyes Report on Iowa Coals, 1894. p.182.)and old pre-glacial and drift filled channels are met within the limits of the drift, both East and West. Such a one caused a bad disaster at Nanticoke, Pa.in 1885. (C.A.Ashburner M.E. May 1886.) Cracks of smaller size filled with clay and sand are also met cutting seams and a number of these have been figured from Iowa by Keyes.

The frequent association of beds and nodules of spathic ore(clay ironstone and blackband)with the shales of a coal bearing series(is one of the most widely observed phenomena. These ores are best developed in this country in western Pennsylvania and Ohio, and in former years were will they occur anywhere the soil and in the growth of the stage of [illegible] nature seen preceding the young growth. [illegible] of the greatest fine soils of the country are [illegible], as at [illegible], and St. Louis, Mo., Where a soil such as this is to be worked the [illegible] [illegible], it may be taken out along with the [illegible] and used with profit as a fuel, to turn the latter into brick, [illegible]. There is a growing practice in [illegible]. The first gave and [illegible] [illegible], chief of which are the so-called [illegible], which have the power of some of the earliest [illegible] given that [illegible] of the soil. Although these underlying [illegible] the [illegible] of it as ... of no interest that they are simply [illegible] and [illegible] [illegible], stone, fire rock, and [illegible] [illegible]. This, however, the [illegible] [illegible] [illegible] sometimes [illegible] up into the drifts and [illegible] [illegible] called "Group", that gives the [illegible] [illegible]. [illegible] around and the other [illegible] [illegible] of the [illegible] [illegible] [illegible] is the [illegible] of a [illegible]. A [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] is a [illegible] [illegible] it [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

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The [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] extremely important but today their output has been rendered insignificant by the influx of hematites from Lake Superior. Nodules of clay iron-stone often weather to limonite and in this form are mined.

While coal seams are as a rule quite uniform in thickness and quality, so much so as almost to justify J. P. Lesley's comparasion of a short drift from the outcrop, to a sample off a roll of broadcloth, yet they do pinch and swell, more or less, and become bony in places, to such an extent, that on a new territory considerable drilling or drifting is often advisable, and lean streaks need not cause undue surprise. Such experience has been met in the Loyalsock basin in anthracite and in the Reynoldsville basin in bituminous in Pennsylvania and often elsewhere. Nevertheless, coal seams are incomparably superior to metalliferous deposits in uniformity of quality and regularity in thickness.

The outcrop of a coal seam is marked by a black carbonaceous soil called "blossom" or "flower" or "smut" and this furnishes one of the most useful indications of its presence. If the wall rocks are firm this outcrop is thinner than the true seam because of weathering softening and squeezing. A drift in under good cover will generally show a notably greater thickness, but if coal and walls have all softened and sloughed off together and especially if on a hillside, the smut may give very exaggerated ideas of thickness, unless it is cut by careful ditches and drifts. Thus in 1851, J. Dill reported a coal seam at Straitsville, Perry Co. Ohio at 112 to 138 ft. thick, (A.J.S. ii. XII.282) which proper prospecting showed to be but 17 ft. (W. W. Mather, A.J.S. ii. XV. 450). The outcrop coal is tender, earthy, rusty from the decay of pyrites and relatively high in ash and moisture, and yet the increase in ash is less than one would often suspect. Aside from physical changes, greater oxidation seems to be the chief chemical change. If the smut comes from an inclined seam outcroping on a hillside it must be borne in mind that it may dip in a direction opposite to that of the coal. In order to have preserved their good qualities against weathering coal seams ought to be beneath at least 50 ft. of cover, but it does not follow that serviceable fuels for local use may not be met under much less; for innumerable country banks all through our coal regions have but slight thickness of rock above them. In regions of forest, the presence of coal has been indicated by the upturned soil on the roots of fallen trees; and indeed the discovery of anthracite in Pennsylvania is said to have been made in this way by a hunter; but today the eastern portion, at least, of the country is so generally mapped in a geological way, and methods of prospecting with the oil rig and the diamond drill have been carried to such perfection, that these more primitive means are of less importance than formerly.

The presence and situation of coal seams are also indicated by very characteristic and significant tppographical features, as was stated many years ago (1856) by J. P. Lesley in his classic little work "Manual of Coal and its Topography". Where the general dip is flat, the hills are due to erosion and on their sides the coal seams appear at the foot of terraces or benches that are beautifull y marked in the farming and cleared regions of central Pennsylvania. One at tines can follow the bench of a coal seam with the eye for long distances. It appears that the coal has softened and weathered more readily than its roof and floor, and caving down has caused the bench above it. In inclined measures, especially if the dip is steep, the easy erosion of the coal often makes a

small depression along the outcrop.

The frequent presence of impervious beds of fire clay or tight shale below the relatively open and jointed coal seam, directs subterranean drainage along this horizon in an important way; and as all coals are more or less provided with pyrite, which readily yields to the oxidizing action of these waters, the subterranean streams become charged with sulphate of iron, which is deposited as limonite around the springs and seepage at the outcrop. These wet spots, stained yellow by the iron oxide, are also important indications of coal, especially when taken with the benches or terraces just described.

Coal seams are often repeated many times in a series of strata with varying thicknesses of shales, sandstones, conglomerates and perhaps thin limestones in between. Some may be too thin or bony to be ever worked; some may be too thin for present conditions, yet of promise in the future. In fact, in Pennsylvania today, 30-36 in. seams are mined which were rejected ten years ago, when 4 or 5 ft. were esteemed a minimum. In Kansas 20 in. seams are exploited and abroad even less. The Alabama sections record 50 seams and in the Joggins of Nova Scotia 81 have been identified of which 30 are 1 inch and less, and many more not over 3 inches. In Pennsylvania there are 14 or 15 well recognized seams, but of these, and the same is true of Alabama, seldom more than 3 or 4 are workable in a given area and often only one. These individual seams hold their own peculiar properties over distances that are really surprising, but at the same time, display among themselves, quite marked differences of composition and structure. As a guide to prospecting, it may be said that if a number of openings well distributed show a bed to be poor, the chances are, it will not change for the better.

While the correlation of seams in basins separated by intervals of erosion, is in general to be made with a fair degree of accuracy, by means of associated and persistent beds, especially of limestone, or by means of fossil plants, or the peculiar properties of the seams themselves, yet caution is to be observed. The very circumstances of coal formation, indicate that however extended the original swamp or estuary, it might have changed from point to point, might have advanced its growth on a delta and have failed on neighboring shores; might cease and be buried in one place and spring anew in some favoring depression at a distance, etc. all of which would render the correlation difficult. The recent work in Iowa, of C. R. Keyes has brought out this feature strongly, and too much uniformity is not to be expected elsewhere. The whole trend of recent geological work is toward caution in these matters.

A most troublesome irregularity in the practical development of coal mines is met in the faults that in some parts of the country display themselves. They are less shown in the northern Allegheny fields than in the southern, and on the whole less extensively developed in the East than in the West. So far as records are available they seem to be much worse in the Belgium and French fields than in any of ours. Normal faults are much the most common; reversed faults being rare. Two intersecting ones may cause a wedge-shaped intrusion of the hanging, and various other more or less complex combinations result. Diamond drill cores, giving an accurate knowledge of the succession of the strata are the best aid in remedying the difficulties. Rolls and heaves and certain other minor forms of disturbance are more frequent.

The general grouping of coal seams, in basins of synclinal type, is

a striking structural feature. It is no doubt to be explained by the location of the valleys of erosion along the anticline as in all areas of folded stratified rocks the world over; but it is so wide spread in coal regions that we customarily speak of a coal area as a basin. Some synclinal basins rise to the dignity of geosynclinclines as in the case of the lower peninsula of Michigan, but the greater number are more limited. The basins too have a pitch of their own along the strike of the axis and although at times spoon bowl shaped as in the anthracite fields, they usually pitch gradually down into the earth for long distances on the strike, perhaps to rise again, or perhaps to be hopelessly buried under later rocks. In one rare case, Coal Basin, in northwestern Colorado, the seams dip away on all sides from a valley that has been eroded on the crest of a dome.

THE VARIETIES of COAL and their CLASSIFICATION. The varieties of coal may be spoken of in a large way or in a small way. Thus the run of the mine or total output in a workings or a district may yield a well marked variety in the large way, such as bituminous, semibituminous etc. but when a working face is examined closely, it is seen to be made up of several contrasted varieties in a small way. There is bright, shining coal which usually constitutes the greater part and rarely all of the seam. It is brittle, has a well marked cleavage across the bedding, and breaks in small cubes and prisms. It is the lowest in ash of the lesser varieties, and gives the best yield in coke, when the seam is coking. It is found in all the large varieties of coal except cannel. Plant remains are not entirely undistinguishable, but are less evident than in the others. In some of our anthracite seams, especially in the upper bench or "rider" , there is sometimes met a subvariety of the shining coal, that breaks with a kind of conchoidal fracture like a checker, and has led to its name "checkercoal". The same thing is known abroad, and is called by the Germans "augenkohle". Various explanation have been advanced for it but it is probably much the same as conchoidal fracture. Very curious rounded spheroids of coal of a size from 1/4 inch to 10 inches diameter have been met in the Mammoth seam of Pennsylvania, which are called "coal apples". They do not differ essentially in composition from the rest of the seam,and are regarded by W. S. Gresley, who has described them, as due to jointing. (M. E. Feb.1893.). The lustrous shining coal seems to have no special name in American practice which is unfortunate. It might best be called "glance-coal" (German glanzkohle) even though this name has been used in the large way and in a different sense by Ure. (Dict.of Arts etc. 1845).

In contrast to the more abundant glance coal is the dull, lustreless variety (German Mattkohle) that forms thin layers in almost every seam. Cleavage is lacking and the layers perform the part of a bond for the glance coal. It seldom makes up an entire seam, unless this latter is a thin and very subordinate one. It is practically the same as the large variety, called in the older works, splint-coal. It runs higher in ash than glance coal, contains more oxygen and hydrogen and especially disposable hydrogen, and has indifferent , if any, coking properties. Its relations to cannel coal are close. Bituminous coal seams contain frequent layers of a third variety of coal that is open and porous in structure, that shows abundant traces of plant remains, especially calamite stems and that is usually called mineral charcoal. (Faserkohle). It is tender, breaks up readily to dust, is relatively high in ash, and doubtless be-

cause of its open texture is prone to be rich and pyrite. Mineral charcoal is especially common in our Central Coal Fields. Comparative analyses of the above three varieties would only be significant when taken from the same seam, and such from any of our American coal beds, are not available; but a considerable series of analyses of mineral charcoal are given by A. S. M'Creath in Rept. MM. Penn. Geol. Surv. p.105.

The classification of coals in the large way is not a simple matter. In earlier times physical properties were appealed to and upon these the subdivisions were based. Ure in 1845 made the following; Cubical coal, Slate or Splint coal, Cannel Coal, and Glance Coal. Later on, terms more like those in use today appeared. Watts (Dict. of Chem. 1863) speaks of a Lignite or Brown Coal, Bituminous or Coking Coal, with many subvarieties , Anthracite and Steam Coal. Others as R. C. Taylor (1843) grouped on the basis of their relations to the metallurgy of iron, (statistics of Coal, p.1. Taylor's book is a very valuable one and to be highly recommended) but such schemes are properly metallurgical, and the object at this point is to establish the varieties which will make later descriptions intelligible.

The essentials of the classifications most in use in America today were established by Prof. Walter R. Johnson, whose name cannot be held in too high respect by all engineers. They are set forth in his invaluable report to the Navy Department in 1844 on the qualities of American and foreign coals. The proximate method of analysis was used by him as early as 1839. (See Jour. Franklin Institute XXIV. p.73.1839) and perhaps by others earlier; but the ratio of the fixed carbon to the volatile combustible matter was specially emphasized in 1844. Later on, in 1858, H. D. Rogers in Vol.II.of his Report on the Geology of Penn. p.983. established the commonly accepted different varieties on a percentage basis; being led thereto by his experience with Pennsylvania coals, and by the broad differences they exhibit in Geographical realtions. Rogers made:

1. Anthracites, Volatile matters below 6 per cent
2. Semianthracites, " " " 10 " "
3. Semibituminous, " " between 12-18 " "
4. Bituminous, " " above 18 " "

But then under the heads of anthracites, common bituminous and hydrogenous, he carried out a more minute scheme that has never been much used. If we add to this-

5. Cannel, Volatile Matters- - - - - - -40-65 percent.

we have our principal varieties as today regognized. But percentage numbers as thus expressed are open to the objection that they are much affected by the amounts of ash and of moisture, and hence the ratio of fixed carbon to volatile hydrocarbons is a much fairer expression. At the same time we are not forced to reckon out an ash-free, water-free analysis. These points are well set forth by Prof. Persifor Frazer, in his valuable paper on the Classification of Coals, M. E. VI. 430. Rept. MM. Penn. Geol.Survey p.128, where will be found appended an interesting discussion by J. P. Lesley. Calling the ratio of fixed carbon to volatile hydrocarbons, the "Fuel Ratio", Frazer sums up with the following table

Classes of Coals.	Fuel Ratio.
Hard-dry Anthracite- - - - - - -	100 to 12
Semi-Anthracite- - - - - - - - -	12 to 8
Semi-bituminous- - - - - - - - -	8 to 5
Bituminous - - - - - - - - - - -	5 to 0

The 100 and the 0 at the extremes are of course theoretical limits. Prof Lesley shows that there are some slight exceptions to these figures when applied to accepted analyses, and Mr. M'Creath urges that the volatile sulphur in a coal should be subtracted from the "Volatile Hydrocarbon", and added to the "Fixed Carbon" and on recasting some fifteen analyses, it is shown that this will make a slight difference in the ratio. But while sulphur volatilized in coking is not strictly speaking a volatile hydrocarbon, it is not evident that it is therefore fixed carbon, and no serious error is made in leaving Frazer's ratios as they stand. In addition to the above, we need to know the percentage of ash and sulphur, and the character of the coal whether coking or not.

Trade classifications of coal depend on size of lumps, color of ash, locality of mine, etc. many of which are only local importance.

To illustrate the range in composition of the varieties in Frazer's table, the following analyses of a few standard coals will serve, but while they are selected so as to be as representative as possible, it must be appreciated that analyses vary more or less. All the varieties of coal are here represented, as may be readily seen by running dow n the column of ratios.

Post-Carboniferous.	H_2O	V.H.	F.C.	Ratio.	Ash	S.
1. Cooks Inlet, Alaska	9.31	46.14	40.85	0.88	3.70	
2 Nanaimo, Vancouvers Island	1.70	38.10	48.48	1.27	11.72	
3. Carbonado, Wash.	1.74	30.70	58.30	1.90	9.26	
4. Great Falls, Mont.	5.53	18.40	64.33	3.50	11.41	0.43
5. Rock Springs, Wyo.	7.00	36.81	54.46	1.48	1.73	
6. Trinadad, Col. Coal.	1.15	30.20	58.04	1.79	10.61	0.595
7. " " Coke.	1.54	6.35	74.85		17.26	0.655
8. Crested Butte, Col.	1.56	5.93	88.71	14.96	3.75	0.48
Jura-Triassic.						
9. Richmond, Va.		32.00	59.25	1.85	8.75	
Carboniferous.						
10. Krebs, Ind. Terr'y.	1.80	37.17	53.40	1.44	6.73	0.90
11. Hackett C'y, Ark.	0.85	14.92	73.87	4.95	9.04	1.32
12. Cherokee Seam, Kan.	1.94	36.77	52.45	1.43	8.84	
13. Rich Hill, Mo.	6.50	36.87	52.99	1.44	3.65	2.69
14. Rose Hill, Iowa	4.91	41.69	43.01	1.03	10.39	5.09
15. Peru, Ills.	10.30	33.90	51.26	1.51	4.54	
16. Hocking Valley, Ohio	5.95	36.48	52.41	1.43	5.13	1.09
17. Connellsville, Pa.	1.26	30.11	59.62	1.98	8.23	.784
18. " " Coke.			87.25		12.00	.746
19. Conemaugh, Pa.	.67	14.53	74.80	5.14	9.37	.63
20. Bernice, Pa.	1.29	8.10	83.34	10.28	6.23	1.03
21. Lehigh C.&N.Co. Pa.	1.72	3.52	88.49	25.14	5.56	0.61
22. Cumberland, Md.	0.96	19.14	72.71	3.80	6.41	0.79
23. Pocahontas, Va.	0.69	18.83	74.07	3.93	5.65	0.76
24. " " Coke.	0.55	0.76	92.55		5.75	0.60
25. Sewanee, Tenn.		27.81	61.52	2.21	10.37	1.22
26. Pratt Seam, Ala.	1:00	32.17	63.37	1.97	3.34	1.04
27. " " " Coke.	0.16	0.80	87.30		10.55	1.20

(1) M.R. 1891. 210. (2) M.R. 1886. 369. (3) M.R. 1887. 373. Average of 9 seams. (4) M.R. 1886. 291. (5) M.R. 1886. 375. (6) and (7) W.B. Potter Lignite Coals of Col. M.E.V. The vol.hyd. are extremely high for coke. (8) Anthracite. J.S.Newberry, S.of M. Quarterly July 1883. 341. Contains Phosphorus 0.067. (9) M.R. 1882. p.82. (10) H.M.Chance M.E. Feb.1890. (11) M.R. 1889-1890. 176. (12) M.R. 1888. 275. (13) M.R. 1883 52. (14) C.R.Keyes.Rept.on Iowa Coal. 507. (15) M.R. 1882. 51, and 1883 42. (16) N.W.Lord. Econ.Geol.Ohio. V. 924. (17) and (18) M'Creath calls them typical. M.R. 1883. 177. (19) Semibituminous M'Creath. Rept.MM. Pa. Geol.Surv. 59. (20) Semianthracite. M'Creath Rep. MM. 82. (21)Hard dry Anthracite. M.R. 1885. 54. (22) M'Creath in Mineral Wealth of Virginia, 119. (23) M'Creath. I bid. 119. Average of 10 samples. (24) M'Creath and d'Invilliers. Comp. Southern Cokes etc. M.E. 1887. (25) H.S.Fleming, M.R. 1888. 366. (26) E.Ramsey. Pratt Mines etc. M.E. 1890. (27)M'Creath and d'Invilliers M.E. 1887.

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The composition of the ash is important in metallurgical applications and a few are appended to show the general range-

	1.	2.	3.	4.
SiO_2	47.90	50.65	65.70	43.69
Al_2O_3	47.76	44.83	23.23	35.79
Fe_2O_3	1.43	2.72	5.46	14.74
CaO	1.48	0.32	4.15	3.52
MgO	0.53	0.11		1.21
K_2O, Na_2O	0.49	.768		
S.	tr	0.53		
P_2O_5	0.21	0.072		0.34
Loss	0.20			
TiO_2		tr		
	100.00	100.000	98.54	99.29

(1) Ash of Connellsville coke-J.B.Britton quoted by W.W.Bowron, M.E. May 1885. (2) Ash of Tracy City Coal, Sequachee Valley Tenn. I bid. (3) Ash of Trinadad Coal, Colorado- see No.6 of previous table-W.B.Potter. M.E.V. (4) Eureka Mine Houtzdale Pa. M'Creath. Rept. M. Pa. Survey. p.27. The analysis is given in percentages of coal and reduced here to parts in a hundred.

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SUMMARY.

The important points for an engineer or chemist to bear in mind regarding the composition of coals may be condensed as follows:

MOISTURE. The less moisture the better. Each per cent means 20 lbs of water per ton to evaporate before the heat of the coal is available. All coals have some. The average of 149 Ohio coals gave T.G.Wormley-4.65 %; of Iowa coals, 64 afforded C.A.White an average of 8.57 %; 112 Missouri coals analysed by R. Chauvenet-gave- 3.40 %; 97 Pennsylvania coals yielded an average of 1.03 %.

Iowa. C. A. White- Geol.of Iowa 1870. II. 357. Analyses by Rush Emery.
Missouri. Regis Chauvenet- Iron ores and Coal Fields 1872. p.31.
Ohio. T. G. Wormley- Report of Geol. Survey for 1870. p.403.
Pennsylvania. A. S. M'Creath. Geol. Surv. Penn. Rep. M. 28.

ASH. The less ash the better. First class coals ought not run over 6 or 7 %; second class not over 12 %, but the location may make a difference. For ordinary firing white ash coals are to be preferred, and the nearer the ash is to pure silica and alumina the better. Iron oxide, lime, magnesia and the alkalies make clinkers.

VOLATILE HYDROCARBONS. Semibituminous coals are preferred for steaming. In coking coals the less volatile matter, the more coke. In gas coals, provided a good coke is yielded, the more volatile matter the better. To be a good "gas coal" in New York a coal should yield at least 10000 cu.ft. of gas per ton, and extra good ones yield 12000- Elsewhere local coals may be employed yielding less. At the same time sulphur should be low, 0.5 % in New York, which is severe. It depends largely on the condition of the sulphur in the coal, see below under sulphur. A good discussion is given by E. Mc.Millin. Econ. Geol. of Ohio. V. 722.

FIXED CARBON. gives the great heat in steaming. In coking in the large way, the percentage of yield given by crucible experiment will not be realized by several units.

SULPHUR. The less the better for all purposes. It is present in three forms, sulphurous organic compounds(often called free sulphur), pyrite or marcasite and calcic or other sulphate. The important feature lies in its relation to coke. Despite the general impression all the free sulphur does not go off in coking, as was shown by Wormley in 1870. M'Creath gives as a general rule, that the percentage of sulphur in the coke, will be a little less than in the original coal but for practical purposes may be considered the same-(Compare analyses 17 and 18 in table above). The pyrite loses some, but the calcium sulphate holds its sulphur even to the ash. Many more points are developed in the references given below-

J. P. Kimball. Relations of Sulphur in Coal and Coke- M. E.Sept.1879.Rec.
A. S. M'Creath. Penn.Geol.Surv.Rep.M.30. MM.123.Rec.
F. Muck. Chemie der Steinkohle. 88.
J. D. Pennock. Investigation of Coals for making Coke etc. M.E. Feb.'93.
P. Schweitzer. Univ.of Missouri.Catalogue 1875. Paper on the true composition of Coal-etc.
T. G. Wormley. Geol. Survey of Ohio. 1870.

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PHOSPHORIC ACID is present in all coal-ashes-but it seldom reaches the hundredths place of decimals and very rarely the tenths. It is only of moment in cokes used for Bessemer pig-(See A.S.M'Creath Rep.MM.126. M3 78.)

THE WEATHERING OR WEATHERWASTE OF COAL. It has been long recognized that coals deteriorate on exposure and are even subject to spontaneous combustion. The changes are less marked in anthracite and splint coals and may be almost nothing for reasonable periods, but for more tender bituminous the result is serious and may impair the coking properties. The evil effects were formerly referred in large part to the sulphur compounds present, especially the spontaneous combustion ,but it is now generally understood as being chiefly due to the oxidation of the carbon and hydrogen present although of course the change in the sulphur compounds especially the sulphide of iron is no small additional factor. These last named changes are aided by dampness, while the oxidation of the carbon and hydrogen proceeds more rapidly in a dry place. Pyritous coals

should thus be stored amid dryness, while dampness does not injure non-sulphurous. The change in physical properties is no less marked. The swelling of the little films of sulphide of iron while changing from sulphide to sulphate or hydrous oxide is very destructive. The close parallel between all these changes and the production of smut and outcrop coal is close. These questions are quite fully discussed in the citations below, especially that of J. P.Kimball.

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J. P. Kimball. Oxidation or Weathering of Coal. M.E.Sept.1879. Rec-Gives many references.

A. S. M'Creath. Report M.33. MM.113.

F. Muck. Chemie der Steinkohle-104.1891. Gives many references to European literature. Rec.

J. D. Pennock. M.E.Feb.1893-Gives a good illustration on Reynoldsville Pa. coal.

A. P. Rockwell. Effect of Exposure on Coal. Amer.Jour. of Mining. Dec. 15th 1866. 185.

R. P. Rothwell. Alabama Coal and Iron. M.E.II.144- E.& M.J.1874.51.

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FIELD-RULES for AREAL YIELD. Coal lands are usually sold by the acre. It is well to note that an acre is 208.71 feet square; that about 25 acres in linear order extend a mile- and that a square mile has 640 acres. As coal ranges from about 1.25 to 1.55 in specific gravity, with bituminous near the lower limit, say about 1.30, it is safe to reckon as a good round number 80 lbs. of coal to the cubic foot. With 43560 sq.ft. per acre this makes a one foot seam of coal good for 3.484.800 lbs. or 1742 tons. As it cannot be all removed in mining it has become a general rule of thumb to reckon 100 tons of coal per acre per inch of seam, a convenient number that can easily be multiplied. All this assumes flat seams and reference may be made to the earlier remarks on available thickness of seams, variations,etc. An engineer should be conservative in estimates.

SAMPLING. Great judgement is necessary in the fair sampling of coal seams, and the endeavor should be to reproduce the character of the run of mine product that will be later developed. As earlier noted there are varieties of coal in each seam; there are benches, shale or slate partings, layers of mineral charcoal,etc. Different benches may have different qualities, an upper bony one being often left for a roof, or a bottom one for a floor. Good coals of contrasted properties may be even kept separate in the mining. Shale partings sufficiently large are thrown out. Hence a sample straight across a seam may not represent true running conditions, and while an engineer must not select the cleanest lumps, he should also not include slate-seams that will be culled out. Where samples are in the nature of drillings from an oil rig, they should be washed in a basin like the gold seekers pan, to rid them of all sorts of rock that fall into the hole from above the seam. In this case it is very difficult to get a fair result- and, where possible, diamond drill cores are to be preferred. But even these churn up more or less. The method of taking a sample should be carefully noted when the analysis is given.

Now that great numbers of analyses are becoming available, and our beds are being accurately correlated, the analyses are being more and more grouped by coal beds, especially in limited basins. This has many

advantages on account of the general uniformity of seams- and where an engineer can get points on an unopened tract from experience met elsewhere in the same basin they are of the greatest service, for it is to be well appreciated that established reputations count for a great deal in the marketing of coals, and often new fields have great difficulties in making their way against prejudices.

J. P. Kimball. Differential Sampling of Bituminous Coal Seams.
M. E. October 1883.

The analyses in Rept. MM. 2nd Geol. Survey of Penn. are all arranged by seams. The same is true of Edwards Coals and Cokes in West Virginia- and the general plan is strongly urged in Kimball's Quemahoning Coal Field, etc. M. E. XII. and Ashburner's, Classification and Composition of the Pennsylvania Anthracites, M. E. XIV. 706.

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CHAPTER III. GENERAL GEOLOGICAL LITERATURE on COAL.

POST-CARBONIFEROUS COALS.

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LITERATURE of more than Local Importance.

Daddow and Bannan. Coal Iron and Oil. Pottsville 1866.
J. H. Jones. Coal in the United States- Mineral Industries. Eleventh Census. 1892 343-422.
J. P. Lesley. Manual of Coal and its Topography. Philadelphia 1856. Most highly to be recommended.
T. Mac Farlane. Coal Regions of the United States. N. Y. 1873. Rec. (Out of print).
Mineral Industry. Annual Statistical Volume of the E.& M.J. Gives a statistical and market review of coal- Begun in 1893.
Mineral Resources of the U. S. Geol. Survey. A valuable annual review since 1882 with many local details of geology.
P. Prince Jr. Rep't on the Coal Exhibits at the Centennial Exposition
" Judges Reports and Awards. GroupI. pp.50-107. Gives many analysesRec.
" The Coals of the United States. Tenth Census.XV.605. Rec.
Andrew Roy The Coal Mines- including a sketch of the Coal Fields of the Globe. Cleveland. 1876.
R. C. Taylor. Statistics of Coal- Philadelphia. 1848. Hist.

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The post-Carboniferous coals will be taken up in the following order. I. The Pacific Slope-II. The Great Basin-III. The Colorado Plateau and the Rocky Mountains-IV.The Great Plains-V.The Jura-Trias coals of the Atlantic Slope-

I. The Pacific Slope.

ALASKA. Miocene strata are abundantly developed along the south coast of Alaska. They contain lignite beds, often of a quality to yield good coal and in not a few places. Many years ago such were announced from Admiralty Island, in the northeastern archipelago, and from St. Johns Bay

17 miles from Sitka (reported as anthracite M.R.1884.p.19). More recently the greatest interest has been directed to Unga Island, one of the Shumagins, south of Aliaska Peninsula, and to various localities in Cooks Inlet, about the middle of the southern Alaskan coast. At Unga- several seams 5-6 ft.thick and 2 miles long are reported. A train and bunker have been built and some mining done. On Kachemak Bay, on the Kenai Peninsula, southwest side of Cooks Inlet, other serious operations have been begun. An analysis is given in a preceding table. A 6 ft. seam is recorded. The importance of these coals lies in their availability for the cities on the Pacific, especially San Francisco and Portland. At present these markets take coal from all quarters of the globe, (Penn. England, Japan, Australia, Oregon, Washington and Van Couver's Island).

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BRITISH COLUMBIA. The importance of the coals of British Columbia, or more definately of Vancouvers Island is more than local. The mines furnish what is regarded as the best of the fuels mined on the Pacific coast and ship over half a million tons yearly to Californian ports. There are two basins or fields on Vancouvers Is., all situated along the eastern side. The southern is the Nanaimo, with a town of the same name about 75 miles north of Victoria. The northern is the Comax about 60 miles beyond Nanaimo. In the Nanaimo field the oldest openings are at the town of the same name. They were begun in 1863 and now consist of five shafts from 500-700 ft. deep- one of which is on a small island (Protection Island) off the coast-and needed as a means of continuing the mines out under the straits of Georgia, they having already penetrated two to three miles. The coal as worked is 5-12 ft. thick, coking and an excellent gas coal. Two seams are mentioned by J. Richardson. Six miles north of Nanaimo another large plant is in operation at Wellington, which furnishes the best of the Pacific fuels. The shafts are under 400 ft. and the seam is ten feet or even more in places, and is called the "Newcastle". A mile and a

half south is East Wellington with coal 2 1/2-6 ft. and a smaller plant. In the Comax field the one company as yet operating is the Union, whose mines are eleven miles back from the coast. The coal as worked is 5-8 ft and much prized. Richardson states that 10 seams are known with a total of 29 ft.3 in. coal. (C.G.S. 1871 & 72.) Recent explorations with the diamond drill have been made at Oyster Harbor and Tumbo Islandfinding in the last locality 5 ft. of good coal.

In the above fields the coal lies flat as a general thing, dipping 5 degrees and upward. The stratigraphical position is upper Cretaceous equivalent to the Chico of California but below the Laramie of Washington. Collectively viewed the fields form a narrow trough about 130 miles long but separated into two parts as stated.

On Queen Charlottes Island-further north- and about the middle of the island, lower Cretaceous strata appear resting on the Trias. They have been known to contain anthracite but the seams, although somewhat explored, have not yet proved remunerative. Some Tertiary lignites are known on the mainland but only at Sumas Mountain are they altered to coal and there only a two-foot seam is reported. For coal east of the Rocky Mountains in Alberta, see under the Rocky Mountain division later on.-

	H_2O.	V. H.	F. C.	Ash	S.
1. Nanaimo	4.6	33.7	54.7	7.	
2. " "	1.70	38.10	48.48	11.72	
3. Wellington	4.	32.6	59.6	38.	
4. "	2.75	30.95	59.72	6.58	
5. Comax Field	1.47	28.19	64.05	6.29	
6. Queen CharlotteIs.	1.60	5.02	83.09	8.76	1.53
7. " " "	1.89	4.77	85.76	6.69	0.89
8. Sumas Mountain	4.62	35.68	42.00	17.70	

1and 3. Reported by T. W. Myers.see below. 2. Reported by J.F.Jones, see below. 4. G.C.Hoffmann, C.G.S. 1884.M. 5. B.J.Harrington, C.G.S. 1876-1877. 465. 6 and 7. B.J.Harrington, C.G.S. 1872-73. 80. 8. W.H.Merritt M.E. Oct.1889.

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WASHINGTON. The coal fields of Washington, are much the most important of those in the United States on the Pacific Coast. They occur for the most part on the east shore of Puget Sound and from 10-35 miles back from the water front, along the streams that head in the Cascade range and flow westward. One field, the earliest worked, is near the water at Bellingham Bay on the north, but is of comparatively small importance to-day. One very important region is on the east side of the Cascades on the Yakima river, a tributary of the Columbia. All the coals are of Laramie age and later than those of Vancouver. The country is heavily wooded, in large part deeply buried in drift, and in the foothills and mountains much cut up by basaltic intrusions. To the upheavals, and igneous rocks it seems pretty well established that the change of the lignites to good bituminous coals is due. Even anthracite is known and, in the Wilkeson field, natural coke is frequent next dikes. From north to south the productive fields are the following; Bellingham Bay, Whatcom Co; Skagit River, Skagit Co.; Raging River, Squak Creek; Newcastle or Washington, and Green River fields in King Co. which is the chief producing co county; the Wilkeson field in Pierce Co.; the Yakima and Wenatchee fields in Kithtas Co.; a minor field near Seatco in Thurston Co. and a reported field in Okanogan Co. S ome coke is made at Skagit river from thin seams but aside from this, on the north, the Bellingham Bay, Squak creek, and Washington fields afford a lignite coal. Of these at present the last named is the chief producer from the mines at Newcastle, and furnishes what is known as Seattle coal. One bed 10-11 ft. thick, with good roof and floor and a dip of 40 degrees is mined. Seven others are known, one with much bone, being 24 ft. Newcastle is 18 miles east of Seattle. A mile further are the Cedar river mines, on two ggod seams of which one 11 ft. thick, is now productive. The coal is the same as at Newcastle. Ten miles from Seattle are the Talbot and Renton mines formerly worked but now abandoned. On Squak creek seven seams are known, five of which are workable. The Raging river area has six or seven of good bituminous coal, standing at 80 degrees and with much of the coal above the water. Both of these are of recent development. The Green river field whose largest mines are the Blawk Diamond, the Franklin and the Kirke supplies a good bituminous, but not strongly coking coal. Three beds 4 ft. to 7 ft are worked at Black Diamond; five are known at Franklin and Kirke, of which two are mined. One seam at these mines reaches 47 feet, with of course much bone. The new Palmer mines report cannel. The Wilkeson field is of especial importance from its yield of coke. There are three large mines, the Carbon Hill of the Central Pacific R. R., the Tacoma and the South Prairie. Four beds 3 1/2 to 10 ft. are mined at the first; eight or ten, 3 to 14 ft.are known at the second but only one at 6 ft. is exploited, and one, at 4 ft. yielding a gas coal is worked at the last. All these coals are in great demand. The bed in Thurston Co. is 5 ft.and is not now mined. On the east side of the Cascades the oldest opening is at Roslyn near the Yakima river. A 4 ft.seam of bituminous character is mined and extensively used on the Nor. Pac. R. R. Two others are known. Further north in the Wenatchee river valley, through which passes the

Great Northern R.R. two seams, 3 ft. and 8 ft. are reported. Still further north in Okanogan Co. semianthracite is recorded on Swisp creek, a branch of the Methow River.

The chief shipping points by water for Washington coals are Seattle and Tacoma. California alone in 1893 took over half a million tons.

	H_2O	V. H.	F. C.	Ash.	S.
1. Bellingham Bay	8.39	33.26	45.69	12.66	
2. Skagit River	1.52	18.68	70.24	9.59	0.952
3. do. coke	0.30	3.8	86.38	8.6	0.62
4. Newcastle	4.18	43.79	40.20	11.85	
5. Franklin	4.01	40.07	51.82	4.10	
6. Carbon Hill	1.80	42.27	52.11	3.82	
7. Wilkeson Field	2.00		84.00	14.	
8. Roslyn	3.10	39.70	52.65	4.55	tr

1, 4, 5, 6. M.R.1886.369. 2. M.R.1891.334. 3. M.R.1893.453.
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OREGON. There is only one field at present opened up in Oregon although coal has been reported in about two-thirds the counties in the state. This is at Coos Bay in the southwestern portion. It has now one active mine, the Newport, that ships upwards of 40-60,000 tons yearly, almost all to San Francisco. The section is coal-2 ft.,Mining slate, 4 in. coal 1 ft.6 in. mining slate 4 in., coal 1 ft. making a 4 ft.6 in. seam. It dips 15 degrees S.W. There are various other outcrops and abandoned mines on Coos Bay, for the coal is thought to cover several hundreds of square miles.Other promising locations are at Yaquina Bay;in the Nehalem Valley 25 miles northwest of Portland; and in the John Day Valley in central Oregon where three seams of 14 ft., 7 ft. and 11 ft. are reported, the first being coking. Lack of transportation prevents their development The paper of Mr. Norton, below, gives the fullest account. So far as known all the Oregon coals are Eocene or, as it is locally called Tejon.

	H_2O	V. H.	F. C.	Ash	S.
1. Coos Bay Upper Bench	15.45	41.55	34.95	8.05	2.53
2. " " Lower "	17.27	44.15	32.40	6.18	1.37

1 and 2 are quoted from Norton as below. His paper gives analyses of all the other notable exposures, and additional ones will be found in M. R. 1886. 295.

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R. Henry Norton. Notes on Coal Mining in Oregon.-M.E. XIX. 23.

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CALIFORNIA. There are but one or two coal fields as yet developed of notable importance in this state and the general impression for some years past has been that the oldest of these is approaching exhaustion. It is the Monte Diablo field in Contra Costa county, nearly due east of San Francisco. There are two principal seams, the Clark, 20 in.to 4 1/2 ft. and the Black Diamond- 3 ft.to 4 1/2 ft. The coal is a lignite, rather high in sulphur, and inferior to the imported coals. From 50000 to 75000 tons are annually produced; less in late years. Its age, like that of all the California lignite so far as determined, is Tejon (Eocene). A lignite area of secondary productiveness lies in Amador County, next south of Contra Costa, and best known near the town of Ione. As mined the seam runs 5, 6 or even 15 and 24 ft. in thickness. It is a light lignite and is produced by several quite large workings. A considerable production of local importance has also been reached near Coalinga,Fresno Co. The seams run 4 ft.at one mine,two ft.at another. Innumerable other localities are recorded throughout the state, and some have been worked in a small way.

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		H_2O	V. H.	F. C.	Ash
1.	Monte Diablo Clark	11.64	45.67	34.55	8.19
1a	" " Black Diamond	13.01	42.15	34.23	10.6
2.	Ione	13.25	49.00	27.25	10.50
3.	Fresno County	11.25	48.50	31.40	8.85

1 and 1a. By S. F. Peckham Vol. 11. Appendix Geol.Surv.California.
2.By W.D.Johnson 11th Ann.Rep.State Min.147.- 3.do do p. 218.

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Mineral Resources. Contains an Ann.Review,with more or less of local details-The same is true of the Rep'ts.of the Calif.State Mineralogist
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THE GREAT BASIN. The desert region of the Great Basin as a whole is almost lacking in coal. Certain outlying prospects in California are perhaps to be considered in this great topographical division, but Nevada is destitute of these fuels; none are reported as yet in a reliable way from southern Idaho, and in the portions of Arizona outside the Colorado Plateau no fuel resources of this nature have been opened up. In Utah, in the drainage systems which discharge into the Great Salt Lake valley, there are two important productive areas, of which one in the upper waters of the Weber River is the oldest coal-mining district of the territory and is closely related to the neighboring Green River basin of Wyoming, the other lies in Central Utah in the San Pete Valley. The mines of the former, are in the gulches near the town of Coalville, 7 miles south of the Union Pacific Rail Road and 30-40 miles west of the Wyoming line. A number of openings have been made from time to time but today the Wahsatch mine is the chief producer. The seam is 11 ft. but the coal is tender and almost half is lost in slack. The market is chiefly found at Park City, some also going to Salt Lake. The coal is in the strata of the Montana group. The yield is rather more than 50,000 tons yearly.

The San Pete Valley mines are near the town of Wales and have fallen off greatly in late years in production, being but 2000-2500 tons at present. The seam is 5 ft.; the coal cokes and is of fair quality and its age is Eocene (Wahsatch). In southwestern Utah are outcrops of coal of no great statistical moment as yet but of some local importance. They had a mild boom in connection with the excitement over the iron ores of this region ten or fifteen years ago. Near Cedar City the seam is 6 ft. near Kanaraville it is 14 ft. It is feebly when at all coking. The coals occur in the Colorado Group of the Cretaceous. A very thin seam, less than two feet of Laramie coal is reported near New Harmony in southern Utah-

	H_2O	V. H.	F. C.	Ash.	S.
1. Grass Cr. near Coalville	9.00	41.58	46.03	3.37	2.06
2. Wales, San Pete County	6.86	42.34	45.11	5.60	
3. Cedar City	3.50	43.67	43.10	9.73	
4. Kanaraville	8.17	38.55	47.27	6.00	2.45
5. New Harmony	2.27	13.73	73.25	10.75	4.26

1. M. R. 1892. 518. 2. Average of three benches. M. S. Hanaur. M.R. 1892. 517. 3. G. W. Maynard. M.E. XIV. 412. 4. E. Daggett. M.R. 1882. p.81. Many more analyses in this reference. 5. M.R. 1892. 520.

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The other coals of Utah and the ones that really contribute its very important product are taken up under the area of the Colorado Plateau and Rocky Mountains-because they belong in it and are closely connected geologically with the Colorado and Wyoming fields. Additional papers are later cited.

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THE ROCKY MOUNTAINS, COLORADO PLATEAU AND GREAT PLAINS.

ALBERTA AND ASSINIBOIA, CANADA. A very extended and important area of lignite and coal is found in the prairie and mountainous region north of North Dakota and Montana. It begins in the watershed of Lake Winnipeg along the Souris river, north of Dakota and extends with breaks west to the Rocky Mountains and north to the tributaries of the Mackenzie. In the eastern outcrops away from the regions of mountain upheaval and disturbance the coal is a lignite, analogous to the lignites south of the line but as the outlying foothills are approached it changes to good bituminous and even, well up in the ranges to anthracite. The best exposures are along the Bow and Belly rivers and the coal field usually goes by this name. It has been pronounced by G.M.Dawson, a competant and conservative observer, the most extensive and best field in Canada. The Canadian Pacific railway has been the active agent in its development, requiring itself, large amounts of fuel and supplying an important local market east to Manitoba and west to the coast. The large bituminous mine are at Lethbridge on a branch of the main line 110 miles from Dunmore. Lethbridge was called Coal Banks in the earlier reports and the mines are sometimes called the Galt Mines. The seam runs a little over 5 ft. Its stratigraphical position is at the base of the Pierre formation, which horizon is the chief coal producer of the region. Other seams occur below in the Kootanie and in the so-called Belly river series and above in the Laramie. The anthracite now extensively mined is obtained in the Cascade valley, near the station called Anthracite. There are several seams reaching in instances 4 to 5 ft. The horizon is the Kootanie.

	H_2O.	V. H.	F. C.	Ash.	Ratio.
1. Lethbridge- - - -	6.50	38.04	47.91	7.55	1.26
2. Cascade Valley- -	1.04	9.15	87.18	2.63	9.53

1. G. C. Hoffman- Trans.Roy.Soc.Can. VII. 50-51. Anals.38.
2. Idem. 54-55 Anals. 66.1889

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" Canadian Naturalist VII.No.5.1874. A.J.S.III.8.142. in Central B.A.
Coal and Lignite of the North West. Geol.Can. 1876-77. 119. Several analyses by Hoffman. C.G.S. 1885 M 1.
" On the Lignite Tertiary Formation from the Souris River to the 108th
" Meridian. C.G.S. 1879-80 12A. Analyses by Hoffman 8H.
" App.1. On Tertiary Lignite Formation from Souris Riv.to 108th Merdian. Appendix II. follows the above Rep.Prog. A. 12-53 1879-80.
" Prelim.Rep.on Geol.of the Bow and Belly Riv.Region N.W.Tertiary with special ref.to the Coal Dep.Rep.Prog.Can.Geol.Surv.1880-82 pp.B1-23.
" Coals and Lignite s on the Bow and Belly Rivers . C.G.S. 1882-83-84 p.127 C. 1881-82-83.B 1.Rec. See also R.G.McConnell. 1885. 76C
" Notes on the Coals and Lignites of the Canadian Northwest. Reprint 21 pp. Montreal 1884.
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W. H. Merritt. The Cascade Anthracitic Coal Fields of Rocky Mtns.Canada. Q.J.G.S.XLII.560- Notes on Some Coals in Western Can. M.E.Oct.1889.

MONTANA. There is a very wide distribution of coal fields in Montana but of these, three furnish over 99 % of the product and one nearly 60 %. As in Canada, to the north, there are lignites underlying the plains to the east of the mountains, and as these lines of upheaval and igneous activity are approached the lignites change to coals, which in a few instances are coking. All the coals are Cretaceous or early Tertiary but they are quite varied in their geological position. The most productive field, the Great Falls is earlier than the Dacota, and is correlated by J. S. Newberry, with the Kootanie of the Canadian geologists, but the others are mostly of Laramie or post-Laramie (Fort Union) age. The little-explored fields of the Flathead river region are not sharply determined although the strata are said by Weed to contain Tertiary fossils.

GREAT FALLS FIELD. The coal is found in Cascade Co. near the Great Falls of the Missouri which give the field its name. As the Missouri leaves the Little Belt Mountains and begins its course over the plains, it and its immediate tributaries have cut through the coal bearing formation exposing the one large seam that is the basis of mining. The coal has been long known and was utilized at Fort Benton many years ago. It is chiefly mined on Sand Coulee creek 12 miles from Great Falls and in close connection with the Great Northern railway. The seam has a dip of 4 degrees and lies in an open, rolling country, with some abandoned, drift-filled water courses that have seriously effected the quality of the underlying coal and that gave it a bad reputation in earlier prospecting. The seam shows the following section according to Weed. Coal 23-28"; parting 3/4"; coal 10"; parting 1"; coal 24"; parting 6-8"; coal 28"; floor. At present the lowest parting and the underlying bench are left in the floor of the mine but as the coal is coking and of good quality it may be ripped up later. The middle seam is somewhat dirty and high in ash, but the upper two are good clean coals. The mine is large, admirably equipped with the latest machinery and the output in 1893, was about a half million tons.

The same coal is attacked on Belt creek and other tributaries of the Missouri in a small way. The coal tertiary really begins in the Judith field far to the eastward and sweeps around to the north even to the national boundary, but the Sand Coulee district is as yet the only serious producer .

BOZEMAN FIELD. This field lies in southern central Montana along the line of the Northern Pacific Railroad. It and the related Cinnabar field produce the coke now made in the state. It begins on the east, a few miles west of Livingstone and extends a mile or two west of Timberline a stretch of about 15 miles, but the area is not yet very fully propected The principal points of attack are at Timberline Gallatin County, where a steam coal is produced, and at Cokedale, Park Co. on a spur from the main line near Livingstone up Coke Creek. Several seams are known in the Bozeman field, of which three are of good quality and thickness. At Cokedale 4-7 ft. of clear coal is obtained, which however has a high dip, 43-50 degrees.

CINNABAR FIELD, PARK COUNTY. lies on the northern boundary of the Yellowstone Park with exposures both without and within the Park. The former in the great block of Electric Peak alone are worked. The Horr Coal Co. obtains an excellent coking coal from three workable seams, each 3-6 ft. The Cinnabar field was earlier called the Gardner.

ROCKY FORK FIELD is the most eastern in the southern part of the state. It lies in Park County, 43 miles by rail south of the Northern PacificR.R

The extent of the field is but little known, but the amount of coal is enormous. At Red Cloud where the Rocky Fork Coal Co. has its mine, 19 seams are identified, of which 11 show over 6 ft. of coal, with a total of about 95 ft. Some seams are better for domestic coals, others for metallurgical work. The production is only second to that of the Sand Coulee mines. The geological position is later than the Laramie.
OTHER FIELDS. are known in the Flathead river region in the northwest corner, which are not yet producers though certain to be in the future. Some thousands of tons of lignite are annually obtained near Havre in Choteau Co. and near Glendive in Dawson Co. The Judith basin east of Great Falls and the Bull Mountain north of Billings are important reserves. Indeed the advance of exploration has shown Montana to be one of the richest coal states in the Union.

	H O	V. H.	F. C.	Ash.	S.
1.Sand Coulee.	3.98	33.15	57.05	5.83	
2.Timberline.	2.16	20.98	70.16	6.70	0.35
3.Cokedale.					
4.Cinnabar. Horr-	2.81	36.89	53.63	6.67	
5.Rocky Fork No.4	8.11	43.29	46.56	2.04	

1.W.H.Weed E&M.J.-May 21'91 p.543. 2.M.R. 1886. p.286.
3. 4.F.A.Gooch.quoted in M.R.1886-286. 5.W.H.Weed. E & M.J. May 14.'91 p.521.

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W. M. Davis. Relation of the Coal of Montana to the Older Rocks. Tenth Census. XV.697.
G. H. Eldredge. Montana Coal Fields. Tenth Census XV.739.
F. A. Gooch. Analyses of Montana Coals. Tenth Census XV.780.
J. H. Jones. Montana Coal. 11th Census Mineral Industries 389- 8 seams in Gallatin County- 1 only 4 ft. coal worked.
Mineral Resources. U. S. Geol. Survey- All the Volumes-both under coal and coke.
O. C. Mortson. M. R. 1888.289- Analyses of Sand Coulee Coal.
J. S. Newberry. The Great Falls Coal Field,Montana. S.of M.Q. VIII.327 A.J.S. iii XLI.191. Mar.1891.
A. C. Peale. Near Fort Ellis & Bozeman. Ann.Rep.Hayden's Survey 1872.p. 113- 3 Analyses.
R. Pumpelly. Bituminous Coals and Lignites of the Northwest-Tenth Census XV.691- 2 maps.
W. H. Weed. Coal Fields of Montana- School of Mines Quarterly.Jan.1891 p.123.
" The Cinnabar and Bozeman Coal Fields- G.S.A.II.349.1891. Rec.
" Two Montana Coal Fields.-G.S.A.III.301-330.1892. Rec.
" Coal Fields of Montana. E.& M.Jour.-May 14.p.520.May 21.p.542. 1892. Mar.4.p.197. 1893.- Rec.
" The Laramie and the overlying Livingston Formation in Montana- Bull. 104. U. S. G. S. 1894. Contains many valuable data on the Bozeman Field.

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NORTH AND SOUTH DAKOTA. The lignites of the plains extend from Montana eastward into North Dakota and are mined to a considerable extent near the Northern Pacific R. R. in Morton, Stark and Ward Counties. They are

light lignites and only of local use. The geological age is Laramie. Further north are other exposures along the Mouse (called Souris in Canada) river, no doubt geologically connected with the Souris field of Assiniboia. Coal has also been reported in South Dakota around the Black Hills.

	H O	V. H.	F. C.	Ash.	S.
Bly Mine, N. D. -	13.09	39.81	35.58	11.52	1.07

From M.R.1886.251. where several other analyses are given.

LITERATURE.

J. A. Allen. Metamorphic Products from the Burning Coal Beds of the Lignitic Tertiary of Dakota and Montana- Boston Soc. N.H. Jan.1874. A.J.S. III. 8.141.
G. H. Eldredge. Laramie coal on Mouse river. M.R.1886.250. Rec.
B. Willis. Lignites of the Great Sioux Reservation. Bulletin 21.U.S.G.S.

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WYOMING is one of the richest of the states possessing coal and has long been a very heavy producer being of the western states second only to Colorado. Increasing exploration has shown coal in almost every quarter, but the heaviest producers are in order- Sweetwater Co. which, chiefly from the mines near Rock Springs, shipped in 1893 a little over 50 % the total. Carbon Co. which, from mines at Carbon and Hanna, produced about 15 %; Western Co. in which the mines at Cambria are among the latest opened but yielded 12 %; Unita Co.-whose mines at Almy yielded nearly as much. Converse and Sheriden Counties also are quite large, while the rest are scattering.

Westen County. In the southeastern flanks of the Black Hills, important and excellent seams occur in the Dakota formation, just above the Jurassic. At Cambria, where they are heavily mined for the Burlington and Missouri R. R. the seam runs about 7 ft. with some partings. It is a good coking coal and of great importance to the mining interests of the Black Hills. In Sheriden and the other counties further west, other exposures are known and are of prospective importance.

Converse County, has mines near Glen Rock, Douglass and Fort Fetterman. Some 50-60,000 tons are annually produced for local use and for the Fremont, Elkhorn & Mo.Valley R. R. The coal is a high grade lignite and the seams are at least three in number and from 5-9 ft.

Carbon County contains the oldest mines. They have been one of the chief sources of fuel for the Union Pacific R. R. since its construction in 1868. The first openings at Carbon Station are now pretty well worked out. There are several seams but the one worked was 7 ft. The heaviest shipments are now from the Hanna openings about 20 miles off the main line. In one slope there are 21 ft. of coal of which 17 are worked, and in another the entire seam at 31 ft. is taken out. The Dana mines once thought promising are now abandoned. The Carbon Co. coals are Laramie. From Carbon Co., westward across the state there is an almost continuous line of mines, but either because their operators have been crowded out by the management of the U. P. R. R. or because the coals are of too light a grade to compete with better fuels they are only worked at one or two important points.

Sweetwater County has the largest mines of the state at or near Rock Springs. The product is one of the standard domestic fuels of the West.

There are seven seams known of which the lower five from 4-12 ft. and of low dip are worked. Other smaller openings are situated at Black Buttes, Point of Rocks and elsewhere. These coals as well as those in Unita Co. lie in the Green River Basin one of the notable geological districts of the west.

Unita County. The largest workings are at Red Canon and Almy, north of Evanston and very near the Utah line. All the workings are on one seam which varies from 12-27 ft. with a dip from 6-13 degrees. The mines are gaseous and the waste has to be removed on account of its tendency to take fire spontaneously, some of the openings having been ruined by this cause. The workings are either managed by the Union Pacific R. R. or by the Central Pacific R. R. under the name of the Rocky Mountain Coal and Iron Co. Further north openings were earlier made in the Twin Creek district and on Hams Fork, along the Oregon Short Line R. R. but they have been abandoned. Seams up to 40 ft. are reported.

Reference should be made to the prominent part played by these coal strata along the Union Pacific R. R. in the great discussion that raged fifteen to thirty years ago regarding the geological age of the measures, whether Cretaceous or Tertiary. Well nigh innumerable papers were written by Newberry, Lesquereux, Marsh, and others, reviews of which will be found in the citations mentioned below under Ward and White. They are now generally regarded as belonging at the top of the Cretaceous.

	H O	V. H.	F. C.	Ash
1. Cambria, Weston Co.	6.72	39.38	44.25	9.65
2. Glenrock, Converse Co.	13.82	33.03	47.75	5.40
3. Carbon, Carbon Co.	7.42	35.43	48.30	8.85
4. Hanna, " "	8.72	44.37	38.70	8.21
5. Rock Springs, Sweetwater Co.	6.37	35.18	54.85	3.60
6. Almy, Unita Co.	7.37	34.88	48.75	9.00

All the analyses are by W. C. Knight and with many more will be found on p.159 of the valuable paper cited below.

LITERATURE.

H. M. Bannister. Rep't of a Geological Reconnoissance along the U.P.R.R. Haydens Rep. 1872 p.519. Good Sections

H. M. Chance. Resources of the Black Hills and the Big Horn Country, Wyo. M.E.Sept.1890.

S. F. Emmons. Green River Basin-40th Parallel Survey. II.191. 1877.

F. V. Hayden. Rep. for 1872.p.13. General Resumé of Wyo.& N.W. Especially the Lignitic.

G. C. Hewitt. Coal Fields of Wyoming- M.R.1893.p.412.

C. King. Green River Coal Basin-40th Paralel Survey III.451.

W. C. Knight. Coal in Wyo. Bull.14.State Expt.Station.Oct.'93.p.136. Analyses. Rec.

Mineral Resources. The volumes year by year give good reviews.

A. C. Peale. Rep.on the Geology of the Green River District. Haydens Survey. 1877.p.511.

L. T. Ricketts. Ann.Rep.Geologist of Wyo.1888-1889. Cheyenne 1890.

L. F. Ward. On the General Geological Relations of the coal. see 6th Ann Rep.Dir.U.S.G.S.405-559 and C.A.White Bull.82.U.S.G.S.

C. A. White. Geology and Physiography of a portion of Northwestern Colo. and adjacent Parts of Utah and Wyo. 9th Ann.Rep.Dir. U.S.G.S.683-710

UTAH. The coals of Utah which lie in the Great Basin have been earlier mentioned. They are the least important and least productive. The most productive field and the one which now furnishes over 85 % of the total lies in Emery Co. in the drainage system of the Green River, near the headwaters of the north fork of the Price. It is on the eastern slope of the Wasatch range and finds its outlet to Salt Lake by the Rio Grande and Western R. R. The large Winter Quarters mine of the Pleasant Valley Coal Co. is on a seam 11 ft. thick near Scofield. The Union Pacific Coal Co's mine is on a seam 28 ft. much broken by faults but with no partings. The Utah Central mine, 6 miles south of Scofield has 15 ft. 6 in. of coal. The Pleasant Valley Co. also carries on operations upon a 10 ft. seam of coking coal at Castle Gate. These coals are all in the Laramie and no doubt are represented in territory in the eastern part of Utah not yet opened by railways.

	H_2O	V. H.	F. C.	Ash	S.
1. Winter Quarters Mine.	6.55	39.75	47.65	6.05	----
2. Union Pac. Co. Mine.	5.00	45.37	45.23	4.40	0.73
3. Castle Gate Coal.	1.68	44.29	48.65	5.38	0.47
4. " " Coke.	1.22	2.26	82.21	14.31	0.55

All these analyses are from R. Forrester's paper, M. R. 1892 - 515 - 517.

The literature is practically that earlier given under Utah.

COLORADO - is one of the largest coal producing states in the Union. It was sixth on the list in 1893 and the leader among those west of the Mississippi. All varieties of coal are commercially mined and all the coals are in the Laramie strata except a comparatively unimportant field belonging to the Dakota group in southwestern Colorado. In connection with statistics the coal fields are usually divided into the Northern, or those north of Denver, including also Routt Co. in the extreme northwest; the Central or those on the eastern watershed between the latitudes of Denver and Pueblo; the Southern or those south of Pueblo; and the Western or those west of the continental divide. It is of interest in a topographical way, to note their distribution into three groups, the eastern foothills, the parks, and the western slope. Most of the coal comes from the first of these; considerable from the South Park, and a large and increasing yield from the western fields. These three grand divisions may be subdivided on their structural, geological relations into minor basins or fields.

EASTERN FOOTHILLS. South Platte Field. The coal areas in the northern central portion of the state and in the drainage area of the South Platte river have been grouped by R. C. Hills as the South Platte Field. The main exposures lie somewhat east of those in Wyoming, but are in the continuation of the same Cretaceous strata around the flanks of the Rocky Mountains. Boulder is the principal producing county in this field and is the second of the state (663,220 tons in 1893). Weld Co. on the extreme north is of local importance and El Paso, Jefferson, Arapahoe and Douglass are of decreasing moment in the order named. In the 1000-1200 ft. of the Laramie there are as many as four workable seams in the southern portion, but only one at the northern end. Near the mountains they are much faulted and stand at high angles but flat-

ten out as these are left and may be available forty miles out in the prairie. Eruptive rocks are very subordinate. The coals are all lignites of high percentage in water, ranging from 13 to 23 %. The seams are of good thickness, reaching 13 ft. as a maximum. Marshall, Louisville, Lafayette and Erie are the chief centers in Boulder Co. and are the oldest coal-producing areas in the state. Platteville and Eaton further north, and Franceville, east of Colorado Springs on the south, are worthy of mention.

Canon City Field. This is a comparatively small area near Canon City, and not far from the entrance to the Royal Gorge. As many as sixteen seams are known but only the lowest is workable over most of the field, and at the most only two others locally. The workable seams range up to 5 ft. Williamsburg, Rockvale, Coal Creek, Chandler Creek and Brookside are the chief mining towns. There are no igneous intrusions and few faults, yet the coal has largely lost the lignitic character, is non-coking, and one of the standard domestic fuels of the state. In the neighborhood is the Florence oil field and the local geology will be again referred to under petroleum. It is notable that south of Canon City the coals become coking, but to the north, they lack this property. Fremont Co. was third in 1893 with 536,787 tons.

The Raton Field. This begins about 75 miles south of Canon City with the exposures near Walsenburg and extends with minor breaks through Huerfano and Las Animas counties into New Mexico. It is the most productive of all the fields and supplies about half the total of the state. The group of mines near Walsenburg, are located on three of the four known workable seams. The region is not far from the great eruptive center of the Spanish Peaks, and dikes are met both in these mines and in the next group seven miles south at Rouse. The coal, possibly from their influence begins to coke and by a very gradual transition passes to a very strongly coking coal near Trinidad. Twelve or fifteen miles south of Rouse, are the Victor and Berwind mines with a total of three good seams in several canons collectively known as the Road Canon district. The coals yield a good metallurgical coke. Fifteen miles or so still further south is the chief productive district of the state, in the vicinity of Trinidad. The structural geology is that of a great basin, which sinks from the flanks of the Sangre de Christo eastward and emerges again thirty miles out on the prairies. In the noble butte of Fisher's Peak, near Trinidad, 2000 ft. high with a cap of basalt, a superb section is afforded. Wheeler's Survey years ago recorded 32 seams, and now more than forty are known but only 4 or 5 are over 3 ft. The one most worked is the lowest or Trinidad, with 6-14 ft. The seams lie quite flat, but are much cut up by basaltic dikes that destroy the coal near them. The mining towns in the order of production are Sofris, Engleville, Gray Creek and Starkville. The chief town for coking is El Moro by which name the coke is usually known. The Raton field extends south into New Mexico.

THE PARKS. Both the South Park and the North Park contain coal but only the former has been worked as yet, the latter being too remote for development although some thick seams of lignitic coal are known. In the South Park, at Como, on the Union Pacific branch from Denver to Leadville, are mines on a seam 4½-9 ft. It is an excellent coking coal, but the seams dip at a high angle - 30 degrees and upward, are much faulted and cut up by igneous intrusions. The coal is often call-the coal as things are left and may be available forty miles out in the [illegible]. [illegible] coals are very subordinate. The coals are all lig- nites of high percentage in water, ranging from 18 to 32 %. The seams are of good thickness, reaching 12 ft. as a maximum. Marshall, Louis- ville, Lafayette and Erie are the chief centers in Boulder Co. and are the oldest coal-producing areas in the state. Platteville and other [illegible], and Frederick, east of [illegible] to the north, are worthy of mention.

Canon City Field. This is a [illegible] district [illegible] and not far from the entrance to the Royal Gorge. [illegible] seams are known but only the lowest is [illegible] over most of the field, and at the most only two [illegible] locally. The [illegible] range [illegible] to 8 ft. Williamsburg, Rockvale, Coal Creek, [illegible] and Brookside are the chief mining towns. There are no [illegible] and few faults, and the coal may [illegible] [illegible] In the [illegible] the Florence oil field [illegible] [illegible] of Canon City [illegible] [illegible]

The Raton Field. This begins about [illegible] miles south of Canon City [illegible]

[illegible]

ed the Lechner.

THE WESTERN SLOPE. It is in this portion of the state that the newer developments have been made, and both in the northwest and southwest the results already attained are very considerable. In the northwest there is a vast area in the country of the White and Yampa rivers that is as yet hardly touched. This region is in close geological relations with the Green river basin of Wyoming. The Yampa field lies along the river of the same name and its tributaries. There are two or three seams of which one reaches 17 ft. as a maximum. The intrusions of the Elkhead mountains have served to change the coal from lignite to semicoking and even anthracitic varieties. They await development.

R. C. Hills, whose valuable paper cited below has been chiefly followed in these notes, groups all the mining districts in the watershed of the Grand river, into the Grand River Field. This therefore takes in the exposures as far south as Crested Butte, and really extends unbroken westward to Pleasant Valley, Utah. It is the most extensive and diversified of the Colorado fields for it contains all varieties of coal of a superior quality. Along the mountains there have been great disturbances and intrusions and these have had a marked influence on the quality of the coal. On the north the most important mining has been done near New Castle where the anticline of the so-called "Great Hogback" is cut by the Grand river. Seven seams, with a total of 106 ft. of clear coal, a most extraordinary amount, are exposed. Of these one, the Wheeler is 46 ft.; another, the Allen, is 20 and a third the E-seam is 18. Somewhat the same section appears in neighboring gulches but with less coal. Several of these great seams are only clinkers and ashes on the outcrop having been burned by spontaneous combustion. One is still on fire. The quality is chiefly, non-coking, making the fuel good for steam and domestic use. The ridge of the Hogback extends to the southeast and is mined in Jerome Park on its eastern front. Both coking and domestic fuels are met, the change taking place within a space of 300 ft. South of Jerome Park lies Coal Basin in Pitkin Co. and one of the most interesting and important of western coal exposures. West of the Hogback fold a laccolite has heaved up the Cretaceous strata in a great dome whose middle portion has been eroded down to the soft shales of the Montana group, so that the Laramie beds with the five workable coal seams dip away on all sides from the amphitheatre. The coals are low in ash and high in fixed carbon, and are regarded as the best in the state. A railroad is now being built to tap them, but the country is an exceptionally rough one. Further south in Gunnison Co. are a number of scattered and but little developed districts that yield anthracite as well as bituminous, the former having been developed by the closer approximation of igneous rocks. Such are Ragged Mtn., Chair Mtn., Mount Gunnison and others. The seams on Anthracite creek in the Ruby district have recently been reached by railroads. The mines at Baldwin (semicoking coal) and at Crested Butte, where both anthracite and coking coal have been long produced mark the southern limit of the Grand River Field. The Crested Butte anthracite is the best known of the western anthracites, while the coke is of a superior quality. Igneous intrusions or as Hills suggests the hot waters from them have caused the change. There are two seams of 4-7 ft., and a reminder of Pennsylvania in an anthracite breaker of 300 tons daily capacity.

Southwest of Crested Butte and in the drainage basin of the Gunnison river, between its tributaries the Uncompahgre and the Cimanon, lies the Tongue Mesa district with seams of local importance.

La Plata Field. This lies in the southwest corner of the state and extends into New Mexico. The good coal occurs in the Laramie but there are poor and thin seams in the Dakota. The most important developments are near Durango, where four seams are known. The thickness as mined is seldom over 4 ft. although impure seams may reach 20 ft. and by a coming together of all four of the above, there is at Carbonaria the famous 100 ft. seam - but only workable in benches of 3-5 ft. Near Durango the coals coke and are very important in connection with the local smelting interests. In several other places mines have been opened and the field has additional prospective importance in connection with railways southwest across Arizona to southern California. A reconnoissance survey has already been made of the Grand Canon of the Colorado for a line.

		H_2O	V. H.	F. C.	Ash	S.	Sp.gr.
1.	Lafayette Boulder Co.	12.01	35.19	46.24	6.56	1.00	-----
2.	Canon City Field.	6.59	37.60	50.51	5.30	0.58	1.324
3.	Engleville Raton Field.	0.75	31.13	57.07	11.05	0.55	1.287
4.	" Coke.	See reference 4 below.					
5.	Como South Park.	7.18	38.72	49.40	4.70	0.53	1.305
6.	New Castle.	2.58	36.85	48.57	12.00	0.53	1.291
7.	Jerome Park Coal.	1.77	34.63	57.24	6.36	1.018	-----
8.	" " Coke.	See below.					
9.	Crested Butte Coal.	1.94	38.18	56.80	3.08	-----	-----
10.	" " Coke.	0.32	0.49	87.02	12.17	-----	-----
11.	" " Anthracite.	0.93	6.87	84.78	7.42	0.67	1.445
12.	Porter Mine, Durango.	1.14	33.76	56.62	6.25	0.49	1.278

1. By Regis Chauvenet, Ann. Rep. Col. State Sch. Mines, 1889, 71. From Simpson Mine, and rather lower in moisture than many.
2. R. C. Hills M. R. 1892, 362 (Coal Creek Mine).
3. Idem.
4. R. Sadtler gives as general average, H_2O under 0.5; V. H. under 1; F. C. 76.6 to 80.3; Ash 16.5 to 22.3 with average 18.7; Ann. Rep. Col. State Sch. Mines, 1889, 234.
5. R. C. Hills, M. R. 1892, 363.
6. " " " " " " 364. Grand Butte Mine, Wheeler seam.
7. G. C. Tilden, Ann. Rep. Col. State Sch. Mines, 1889, 166.
8. R. Sadtler average of 15 analyses, H_2O mostly less than 1; V. H. mostly less than 1; F. C. average 83.78; Ash average 14, Ann. Rep. Col. State Sch. mines, 1889, 236.
9. C. A. Gehrman, do. p. 191. 1
10. By R. Sadtler, given as general average, do. p. 235.
11. R. C. Hills, M. R. 1892, 364.
12. " " " " " " 363.

Note. A most complete series of analyses is given by R. C. Hills, in M. R. 1892, pp. 362-365. They are both elementary and proximate and include determinations of calorific power. Many others are given by W. B. Potter, by A. Lakes and assistants, and by J. S. Newberry, in cita-

Southeast of Grayson [illegible] and in the drainage basin of the [illegible], between its tributaries the [illegible] and the [illegible], lies the [illegible] district, with areas of [illegible] importance.

[illegible] Field. This lies in the southeast corner of the state [illegible] into New Mexico. The good coal occurs in the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

tions given below.

LITERATURE:

Coal Field of La Platte Co. Col. section across Co. E. & M. J. June 29, 1878, p. 441.
F. F. Chisholm. The Elk Head Anthracite Coal Field of Routt Co. Col. Proc. Col. Sci. Soc. II. Pt. II. p. 147.
Colorado Coal Deposits, E. & M. Jour. Oct. 16. 80. p. 253.
F. M. Endlich. Coal in Trinidad Region. Hayden's Survey, 1875, 192.
F. V. Hayden. Annual Rep. Hayden's Survey, 1869. A. J. S. March 1868. 40th Parallel Survey, III. 481. South Platte Field in 1870.
G. C. Hewett. The Northwestern Col. Coal Region, M. E. XVII. 375.
R. C. Hills. Remarks on the Occurrence of coal in the Carboniferous Formation at Aspen and Glenwood Springs Col. Proc. Col. Sci. Soc. II Pt. 1. p. 25.
R. C. Hills. Coal Fields of Col. M. R. 1892, 319. This is much the best paper published. Nearly the same is in Hall's History of Col., and further Amplifications are promised in the future Proc. Col. Scientific Society.
C. King. Green River Coal Basin (More or less About the Yampa Field.) 40th Parallel Survey, III. 451.
A. Lakes. Ann. Reports of Col. State School of Mines. Especially 1889, which is a quite complete description Rec. Amer. Geol. July 1891, 7.
E. J. Mallett. On Middle Park, Mineral Coal, A. J. S. III. 9, 146.
Mineral Resources of the U. S. All the Volumes 1882 - onward. The earlier series of Raymond's Reports or Min. Resources West of the Rocky Mtns. contains much of historical interest.
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A. C. Peale. Mentions lignites on Coal Creek, Anthracite Cr. Rock Cr. Many analyses, Hayden's Survey, 1874, p. 175.
W. B. Potter. The Character and Composition of the Lignites of Col. M. E. V. 365. Rec.
Reports of the State Inspector of Mines.
J. J. Stevenson. On Col. especially Trinidad Coal. Wheeler's Survey, III. p. 389.
" Notes on the Coal Field near Canon City, Proc. Amer. Phil. Soc. 1881, 505. A. J. S. iii. XXIII. 152.
P. H. Van Diest. Remarks on the Plication of the Coal Measures in Southeastern Col. & N. E. N. M. Proc. Col. Sci. Soc. III. p. 185.

NEW MEXICO. The territory is well supplied with coals and the fuels are of great importance to the transcontinental railway lines and to the local mining interests. The coals are Laramie so far as known, and are, on the north, closely related to those in Colorado. The most productive area is the Gallup field to the west near the Arizona line. The southerly extension of the Raton field of Colorado, follows as a close second. The coals near Santa Fe are third, and the rest much smaller, a marked falling off having recently taken place in several of the older fields.

THE EASTERN SLOPE. The Raton Field is in the northeastern county,

Colfax, It is the oldest important mining district although the coal at Santa Fe was in a small way dug, before its day. Thirty five coal seams are known but, so far as reported, only one is exploited in each of the large mines. The productive centers are Raton and Blossburg. Many promising exposures are still remote from railroads. The seams as worked vary from 3/2 to 9 ft. but they have not been correlated or well described geologically. The coal is an excellent steaming coal, and is chiefly produced in the interest of the Atchison, Topeka & Santa Fe R. R.

The Santa Fe Field, lies 150 miles south west and near Cerillos station on the Atchison system. The mines are often called the Los Cerillos. Seventeen seams are known of which four are 4'-5' thick, and workable, but in a region much disturbed by porphyry dikes. The coals are both coking and anthracite. New railway connections have recently given them a great impetus, so that the production is now about 120,000 tons yearly, of which about 10,000 tons are anthracite.

The Socorro Field lies a 100 miles further south, and a few miles east of San Antonio. The mining town is Carthage and the mines are called the San Pedro. A 6' seam of coking coal in a somewhat limited and badly faulted field was a strong producer both of coal and coke up to 1893, in which year it practically ceased.

Some small outcrops are known further south of which one mine at White Oaks in Lincoln Co. yields local supplies for the neighborhood but none others of moment occur on the eastern slope.

THE WESTERN SLOPE. Coal seams of some importance have been developed in Rio Arriba Co. in the northern central portion of the territory. They supply the Durango branch of the Denver & Rio Grande R. R., and are known as the Amargo and Monero mines. The field is an extension of the La Plata of Colorado.

The Gallup Field lies along the Atlantic and Pacific R. R. near the Arizona line. Eight seams, of which three are 4 ft. or over are known in about 1200 ft. of strata. No.s 2 and 8 are worked. The coals are semibituminous steam-coals and are extensively used by the railways and the inhabitants as far as the Pacific coast. They make considerable slack in mining and as mined suffer also from lack of good cover.

In the extreme northwestern county, San Juan, there is a great coal area, as yet hardly touched.

	H O	V. H.	F. C.	Ash	S.
1. Raton.	0.98	35.56	48.59	14.87	0.70
2. Los Cerillos, Anthrac.	2.90	3.18	88.71	5.21	----

1. Tenth Census, XV. 788,
2. M. R. 1882, 63.

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J. F. Blandy. Gallup Coal Fields . Gives a geological section E. & M. J. Mar. 12, 1892, 299.

John Leconte. Cretaceous anthracite near Santa Fe N. M. 1867. A. J. S. II. 45, 136. Notes its metam. by lava.

O. Loew. Coal from the Los Cerillos and Placer Mtns. N. M. Wheeler's Survey, Vol. III. p. 634.

R. W. Raymond. Remarks on the occurrence of anthracite in N. M. M. E.

II. 140.

Mineral Resources. 1882 & 1883-84. The others through 1893, statistical.

J. J. Stevenson. Geology of Galisteo Creek (Santa Fe Field). A. J. S. iii, XVIII. 471.

Arizona. The Gallup field extends into Arizona but is not yet developed. Other coals are known in the Deer Creek Field, Pinal Co., and at some future day the territory will no doubt be a producer.

LITERATURE:

The Deer Creek Coal Fields, Arizona. E. & M. Jour. Dec. 17, 81.p. 404.

Min. Resources. 1884, p. 18.

C. D. Walcott. Deer Creek Coal Field in Arizona. Senate Doc. No. 20, 48th Cong. 2nd Session. A. J. S. III. 29, 338.

Texas. There is a wide distribution of lignites and there are one or two places where fairly good post-carboniferous coals occur in this state. Very recently such (described as Cretacious by J. S. Newberry in Trans. N. Y. Acad. Sci. Feb. 12, 1883, p. 94) have been developed extensively in Presidio Co. The field is called the San Carlos and a seam of coking coal from 4-6½ ft. in two benches with a one foot parting has been opened. The mines are 26 miles south of the Southern Pacific R. R. and are planned to ship about 1000 tons daily when the rail connections are completed. For mention of coal still farther west, see paper by E. J. Schmitz cited below. At Eagle Pass there is an extension of the Mexican Laramie coals, which are mined in the Sabinas field but are not yet much developed in Texas. Further down the Rio Grande near Laredo, is the San Tomas mine, which produces a good coal, apparently an altered Eocene lignite. The seam is 2½ ft. Eocene lignites or brown coals are widespread elsewhere in Texas, so much so that the formation has been called the Eolignitic. They are only mined as yet in the region around San Antonio, but great attention to their utilization has been paid by the Texas geological survey, as the references cited below indicate. E. T. Dumble's reports are the fullest works of reference that we have in English on the subject.

Texas Carboniferous coals will be taken up a little farther on.

	H O	V. H.	F. C.	Ash	S.
1. San Carlos Coal.	0.97	36.76	54.00	7.81	0.32
2. San Tomas.	2.5	51.05	39.1	7.35	1.5
3. Lytle Lignite, Medina Co.	13.25	40.62	36.47	8.40	1.26

1. M. R. 1893, 385. Average of two benches.
2. R. A. F. Penrose. 1st Ann. Rep. Tex. Geol. Surv. 1889, 96.
3. E. T. Dumble. Rep. on Brown Coal and Lignite, 187.

LITERATURE:

E. T. Dumble. Brown Coals & Lignites of Texas. Tex. Geol. Survey, 1892. Rec. A small prelim. Rep. was issued in 1891, and in the introduction to the 3rd Ann. Rep. Tex. Geol. Survey.

R. T. Hill. Mineral Resources U. S. 1891, 1892 and 1893. Statistical Review. Rec.
W. Kennedy. Lignites of Houston Co. Texas. 3rd Ann. Rep. Tex. Geol. Surv. p.33.
Lignite in Guines, Brazos, and Robertson Co's. 4th Ann. do.
O. Lerch. Lignites and their utilization. 2nd Ann. Rep. Tex. Geol. Surv. p. 38.
R. A. F. Penrose. Lignites of eastern Texas. 1st Ann. Rep. Tex. Geol. Surv. 94, 1889. Rec.
E. J. Schmitz. Geology and Mineral Resources of the Rio Grande Region in Texas and Coahuila. M. E. Sept. 1884. On El Paso Co. & on Eagle Pass.
R. S. Writzel. The coal fields of Texas. E. & M. J. Aug. 23, 1890, p. 214, from the Ohio Institute Mining Engineers.
C. A. White. Age of Coal found in the region traversed by the Rio Grande. A. J. S. III. 33, 18.

MEXICO. But few coal areas have been developed in Mexico. The most important one is that which extends from Eagle Pass, Texas, south through Piedras Negras to the Rio Sabinas and contains the mines at the last named point. It is called the Sabinas field and lies in the state of Coahuila. There are four seams, with 5 ft. as a maximum thickness. The coal is bituminous, coking and varies from fair to very good.

There are other coals known near Zacualtipan, Hidalgo; west of Tuxpan, Vera Cruz; in Sonora - and several other states. The paper cited below from the U. S. Consular Reports gives a good resume of both Mexico and the Central and South American localities. On these latter one or two additional papers are cited.

LITERATURE:

W. H. Adams. Coals in Mexico, Santa Rosa Dist. M. E. 10, 270.
Coal and Coal Consumtion in Spanish America. A good review. Special Consular Reports U. S. Dept. of State. 1891. Rec.
Coal Fields of Mexico. E. & M. J. June 9, 94, p. 535.
Coal in Vera Cruz. Reports of U. S. Consuls, No. 142, July 1892, p. 528.
E. T. Cox. Anthracite in Sonora. A. J. S. III. 24, 399. A. A. A. S. 1882.
E. D. Cope. Coal near Zacualtipan, Hidalgo. Amer. Phil. Soc. Oct. 16, 1885, p. 146.
H. S. Mauross. Notes on Coal & Iron Ores in the State of Guerrero, Mex A. J. S. II. 39, 309.
de Horner. Coal near Guerrero, Mex. called Anthracite Les Mondes Mar. 23, 1865. A. J. S. II. 40, 124.
Santa Clara or Barranca Coal Mines of Sonora, Mex. E. & M. J. Apr. 30, 81.
E. J. Schmitz. On Sabinas Field. Geol. and Min. Resources of the Rio Grande Region in Texas and Coahuila. M. E. Sept. 1884. Rec.
E. G. Tuttle. The Sabinas Coalfields. E. & M. J. Oct. 27, 94, p. 390.

John Evans. Coals of Chiriqui, Colombia. Good account in Document sent to President by S. P. Chase Sec. Treasury April 22, 1862.

Seeman. Coal in Venezuela. Reader No. 74, May 28, 64. A. J. S. ii. XXXVIII. 289.

Coal in Brazil. Nov. 1, 1879. p. 321, E. & M. J.

TRIASSIC COALS. Coal seams are known in several of the long, narrow, estuary deposits of the Triassic rocks, along the Atlantic seaboard. They are thin on the north being seldon over an inch or two but in Pennsylvania -, near Arcola station, about 25 miles from Philadelphia, 26 inches of good anthracite have been recently opened (O. C. S. Carter, Jour. Franklin Inst. Aug. 1894. E. & M. Jour. Aug. 18, 94, p. 147). Nevertheless these little seams are of small account. The coal first assumes economic proportions in Virginia and North Carolina. In the former state it was the first coal mined in America, and was opened in 1701. During the last century it was the main American supply for the Atlantic Coast. There are three fields one, the Richmond, running from the James to the Appomatox rivers, and west of Richmond and Peters burg; the second the Dan river in northern central North Carolina, and the third, the Deep river in central North Carolina.

All these Triassic strata (some are doubtless also Jurassic) are grouped by I. C. Russell as the Newark System.

VIRGINIA. The Richmond Field is a basin 30 miles long, 4-10 broad, that rests directly on Archaean granite, so that the coal actually has a granite floor in some mines, and corresponds to its inequalities. There has been much faulting throughout the area and for this reason great irregularities are met. The seams, too, are lenticular, in a way, and no general section can be well compiled. They pinch and swell, and are not to be correlated on opposite sides of the basin. They may reach great thickness, over 25 feet having been recorded. Trap dikes, of the usual Triassic diabase often cut them and have baked the neighboring coal to a sort of natural coke, called carbonite. The workings also are inclined to be gaseous. The mines are chiefly located on the northeastern edge of the basin, and a few others are on the northwestern. The coal is of a good compact, bituminous grade in the better seams, though rather high in ash and sulphur as shown by the analysis below. Richmond and Petersburg are the chief markets and up to 30,000 tons yearly are produced. There is a small Triassic area - further west called the Farmville, with thin seams, not worked.

NORTH CAROLINA. The Dan River Field is not much developed and is not a producer. The coals are thin and cut up with shales.

The Deep River Field is of more importance and is today the scene of important operations at the Egypt Mines, in Chatham Co. The coal occurs 400-500 ft. below the surface, and in two benches, an upper of about 4 ft. separated by a bed of blockband from a lower of about 2'. The coal is said to be a good coking coal, but is high in sulphur. 15,000-20,000 tons have been annually produced of late.

	H_2O	V. H.	F. C.	Ash	S.	Sp.gr.
1. Richmond Field, Coal.	-----	29.43	58.11	10.90	1.232	1.436
2. " " Carbonite.	-----	12.50	79.93	6.55	0.26	-----
3. Egypt, N. C.	-----	32.7	60.7	5.3	1.3	-----

1 and 2. Quoted by I. C. Russell. Bull. 85. U. S. G. S. p. 37, No. 1 is an average of eleven analyses.
3. E. G. Tuttle. E. & M. Jour. Nov. 10, 1894.
Many others are cited in references below, on inspection of which it will be seen that the coals are extremely variable.

LITERATURE, VIRGINIA.

W. Clifford. On Richmond Basin. M. R. 1887, 365. Many analyses. See also Trans. Manchester Geol. Soc. XIX. 326 and 355, XX. 247. See also under F. H. Newell.
M. Coryell. Eastern Virginia Coal Fields. M. E. III. 228.
W. M. Fontaine. Notes on Mesozoic Strata, Va. A. J. S. iii. XVII. 25, 151, 229.
O. J. Heinrich. On Midlothian Colliery. M. E. I. 346, II. 241, III. 183, IV. 308, V. 148. Also a General Paper on Mesozoic formation of Va. M. E. VI. 227. Rec. On the Trap Dikes & Natural Coke. E. & M. J. Jan. 1875, p. 35.
C. Lyell. On the structure & probable age of the Coal Field of the James R. near Richmond. Q. J. G. S. Vol. 3, 261.
Mineral Resources. 1883, p. 82. Many analyses , 1888, p. 367. do. and a brief description.
R. W. Raymond. On Natural Coke. M. E. II. 446.
W. B. Rogers. On the Relations of the New Red Sandstone of the Conn. Valley to the Coal-bearing Rocks of Eastern Va. & N. C. A. J. S. II. 19, 123. Proc. Bost. Soc. N. H. 1854, p. 14.
I. C. Russell. The Newark System, Bulletin 85, U. S. Geol. Survey, pp. 36-40. Also a full resume and abstract of literature pp. 140-339. Rec.

Note. The literature is much too great to be all cited here, but reference may be had to Russell's paper which contains a complete bibliography with abstracts.

LITERATURE, NORTH CAROLINA.

H. M. Chance. Report on North Carolina Coal Fields to the Dept. of Agric. of N. C. Raleigh 1885. Rec.
P. M. Hale. Coal and Iron Counties of N. C. Raleigh, 1883.
W. R. Johnson. Coal Lands of Deep River Co. N. C. etc. Mining Magazine 1853, I. 352. Good account with analyses. Several other papers by same author cited under Russell.
Kerr & Genth. Geol. Rep. N. C. 1875.
H. B. C. Nitze. Notes on the Dan R. Coal Basin N. C. E. & M. Jour. Apr. 11, 1891, p. 448.
J. C. Russell. See under Virginia above.
E. G. Tuttle. The Deep River Coal field of N. C. E. & M. J. Nov. 18th 1894, p. 441. Rec.
C. Wilkes. Report on Exam. of Deep R. Dist., 35th U. S. Congress 2nd Session, Ex. Doc. 26, 1858.

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CHAPTER IV. CARBONIFEROUS COALS.

INTRODUCTION. The Carboniferous strata in America are broadly divided into the three series, which are from above downward, the Permian, the Carboniferous proper or Pennsylvanian, and the Lower Carboniferous or Mississippian. The first of these is of small economic importance, especially in the coal fields immediately east and west of the Mississippi river. The last named only contains coal in the eastern states. In all the fields the chief interest centers in the Pennsylvanian series, and the same is true of Europe. This shows, at times important local subdivisions, as later noted. The coals vary enormously, yet none can be properly described as lignite. In one place and another, apparently depending on the degree to which they have been acted on by metamorphic agencies such as burial under later sediments, upheaval, pressure, heat, etc, we have bituminous, semi-bituminous, and anthracite varieties, but the last named is practically limited to eastern Pennsylvania.

The productive areas in a broad way are usually described as five.

1. The Western Central Area, 98,500 square miles, in Ia., Mo., Kansas, Ark., Ind. Ty., and Texas.
2. The Eastern Central Area, 47,250 square miles, in Ind., Ill., and Western Ky.
3. The Michigan Area, 6,700 square miles, in the southern peninsula of Michigan.
4. The Appalachian Area, (Alleghany would be a more accurate name) 61,-510 square miles, in Penn., W. Va., O., eastern Ky., Md., Va., Tenn., Ga., and Ala.
5. The Acadian Area, 2,200 square miles, in Nova Scotia, and New Brunswick.

In addition there is a small and economically unimportant area in Rhode Island and Massachusetts, and coal is also reported in Newfoundland. While the figures of square miles are important as affording some indication of the relative areas, yet it is to be appreciated that not all of this territory is economically productive. The Appalachian area is much the most important both in quantity and quality, product in 1893, 53,967,543 tons anthracite, 81,207,168 bituminous; the Eastern Central is next, product 1893, 25,502,809 bituminous; the Western Central third, product 1893, 11,651,296; the Acadian fourth, product 1893, 2,556,085; and the Michigan area a bad fifth, product, 45,979 bituminous. For the sake of comparison it may be added, that the Rocky Mountain, Great Plains, and Great Basin Areas combined afforded in 1893, 93,578 tons anthracite, and 8,468,360 bituminous; the Pacific Coast, in the same year, 1,379,163 bituminous, exclusive of Vancouver which would nearly bring it up to 2,000,000. The Triassic area of Va. and N. C. furnished 36,878. The Appalachian area produces thus about 4/5ths the total, and Pennsylvania alone rather more than one half (49/92).

While the above grouping is useful as a geographical summary it is geologically somewhat open to criticism. Thus the Texas coal fields are distinct structurally from those to the north, being cut off according to R. G. Hill, by the Ouachita uplift, while on the other hand the Eastern and Western Central Areas are very closely related. They will be described from West to East and in a subordinate way from South to

North, so as to work up to anthracite.

TEXAS. The Carboniferous rocks in Texas occur in a long north and south line, broken in two by encroaching Cretaceous. The two coal fields lie in the drainage areas of the Brazos and Colorado rivers. The coals in the former are alone of importance at present. The seams as worked run 30 inches as a maximum and afford a rather high ash, sulphurous coal. Erath Co. was the most productive in 1893, yielding 243, 773 tons. The need of coal fuel on the railways of Texas, and the immense distances traversed by them away from productive districts, make even these thin seams of great importance.

LITERATURE:

C. A. Ashburner. Brazos Coal Field, Texas. M. E. IX. 495. E. & M. J. July 30, Aug. 6, 1881.

W. F. Cummins. The Southern Border of the Central Coal Field. Texas Geol. Surv. 1st Ann. Rep. p. 158. Carboniferous 28".

" Northwestern Texas. do. 2nd Ann. p. 436. Average of 2' 6" over 190 miles of outcrop. Carbonif. Coal.

N. F. Drake, & R. A. Thompson. Rep. on the Colorado Coal Field. Austin 1893, Tex. Geol. Surv.

Mineral Resources. 1888, 367. Rec.

R. S. Tarr. A Preliminary Report on the Coal Fields of the Colorado River. First Ann. Rep. Texas Geol. Survey, p. 212. 18"-30", Carb.

" Carboniferous Area of Central Texas. Amer. Geol. 1890, 145.

INDIAN TERRITORY. The coals occur in the western extension of the Arkansas field. The productive area is large; and situated as it is on the line of railways to the southwest it has proved extremely valuable and productive, having attained in 1893, 1,252,110 tons. Four seams are known ranging from 2/2 ft. (not now worked) to 6 ft. These are in order downward the Mayberry, the Secor (narrow), the McAlester and the Grady. Bryan, McAlester, Krebs, Atoka and Lehigh are the chief towns from east to southwest and all are in the Choctaw Nation in the southeastern part of the territory. The coals are semi-bituminous on the east and bituminous on the west. Chance places the Carboniferous section at 8,500-10,000 ft.

	H O	V. H.	F. C.	Ash.	S.
1. Mitchell Basin.	1.058	19.032	71.736	7.525	0.649
2. McAlester.	2.10	29.71	62.67	5.52	-----
3. Atoka.	4.61	39.16	45.74	10.49	0.37

1, H. M. Chance as below. 2 and 3, M. R. 1888, 261.

LITERATURE:

H. M. Chance. Coal Measures of the Ind. Ty. A. G. VI. 238. Geology of the Choctaw Coal Field. M. E. Feb. 1890.

Mineral Resources, especially 1888, 260.

ARKANSAS. The coal fields of Arkansas are in two or three counties in the western part of the state and in close geological connec-

tion with those just described. Sebastian Co. on the line with Indian Ty. yields the most, (448,901 tons in a total of 574,763 in 1893). The seams run 3-6 ft. and furnish an open-burning, non-coking steam coal of high, calorific power, and low in volatile hydrocarbons. Further east the coals become semibituminous, with very low volatile percentages, approaching in fact semi-anthracite by which name they are usually described. They extend to within 75 miles of Little Rock. Coal Hill in Johnson Co. is the chief mining center but in the older books the fuels are mostly described as Spadra coal.

The coals are at two geological horizons, of which the lower is certainly Pennsylvanian, but the upper shows strong Permian affinities although still classed by J. P. Smith as true Carboniferous. The strata have suffered considerable metamorphism as is shown by the coal.

	H O	V. H.	F. C.	Ash	S.	Ratio	Sp.gr.
1. Sebastian Co.	0.853	14.921	73.870	9.041	1.324	4.95	1.341
2. " "	0.928	15.55	77.54	4.84	1.143	4.99	1.293
3. Ouita Slope.	0.980	12.20	76.82	8.174	1.829	6.29	1.339
4. Coal Hill.	1.017	10.84	76.12	8.35	3.672	7.02	1.333

1. Hackett City Shaft 2. Huntington Slope. 3. Ouita Slope. Pope Co.
4. Coal Hill, Johnson Co. All the analyses are from Winslows report. Table of Analyses, p. 43, Ann. Rep. Geol. Surv. Ark. 1888, III.

LITERATURE:

J. C. Branner. Coalfields of Arkansas. M. R. 1892, 303. Rec.
A Final Report on Coal is in preparation (Feb. 1895).

F. W. Simonds. Geol. of Washington Co. Ann. Rep. Ark. Geol. Surv. 1888, IV. Mentions thin seams - up to 14".

J. P. Smith. Ark. Coal Measures in their relation to the Pacific Carboniferous Province. Jour. Geol. II. 187, 1894.

A. Winslow. Coal in Arkansas. M. R. 1888, 216.

" Preliminary Report on Ark. Coal Fields. Ann. Rep. Ark. Geol. Surv. 1888, Vol. III. Rec.

" Geotectonic & Physiographic Geology of Western Ark. G. S. A. II. 225.

KANSAS. A considerable gap intervenes in the areas north of the Arkansas fields, before the next productive region is met in southeast Kansas and southwest Missouri, and one passes across the line of the Ozark uplift to meet the productive measures. They occupy a strip about four counties deep on the east. The area is estimated at 17,000 square miles, and the production reached in 1892 a maximum of over 3,000,000 tons. Cherokee and Crawford, the two southeastern counties are the leaders, yielding 3/5 the total, while Leavenworth and Osage, to the north and west, afford most of the remainder - 22 seams are known but only 10 are over 1 ft. The Cherokee seam is the largest at 3-4 ft. but others elsewhere at 20 inches are mined by the long-wall system. The coal is a good bituminous grade. It cokes and is an important fuel for the prairie regions. The seams dip about 30-40 ft. per mile to the west, and are usually first mined by stripping and later by shallow shafts. Cannel coal is also produced.

		H_2O	V. H.	F. C.	Ash
1.	Cherokee.	1.94	36.77	52.45	8.84
2.	Fort Scott.	2.94	41.76	47.55	7.75
3.	Leavenworth.	2.69	39.21	47.41	10.69
4.	Osage.	6.76	44.59	40.86	10.79

All the analyses are by Blake and Bailey, and are quoted from a Report to the State Board of Agriculture in 1888, which is in part reprinted in M. R. 1888, 275.

LITERATURE:

E. H. S. Bailey. Composition of Kan. Coals. Kan. Acad. Sci. XI. 46.
Blake & Bailey. Rep. on Kansas Coals to State Board of Agriculture about 1888.
Braidwood. Coal Fields of Kansas. M. R. 1888, 269.
R. Hay. Geology and Mineral Resources of Kansas. 8th Biennial Rep. State Board of Agriculture 1893, p. 34.
L. E. Hicks. Proc. Amer. Adv. Sci. 1880, 217.
E. Haworth. Rep. of Kansas Acad. Sci. 1882, p. 7. On Coal Measures of Cherokee Co. Kansas.
B. F. Mudge. First Biennial Rep. State Board of Agriculture 1879.
O. St.John. Coal in Eastern Kansas. 3rd Rep. State Board of Agric. 575.

MISSOURI. The coal measures of Missouri occupy very nearly the northwestern half of the state. They lie on the northwest side of the Ozark uplift and have a gentle dip in this direction. The general character of the country is that of a rather flat plateau, through which the Missouri and the other rivers have corraded their channels, but only the Missouri has reached a base-level. The usual sedimentary strata make up the series, with a greater preponderance of mechanical deposits along the margins. The series with a total thickness of 1900 ft. has been usually divided into an Upper or Barren (1317 ft.), a Middle (324 ft.) and a Lower (250 ft.) with most of the coal in the last named. The results of the late work of both the Missouri and Iowa Surveys lead to the view that the seams are often of quite limited, individual extent and that correlation over a wide area is therefore impossible. They range from one inch to 5 ft., with an average as mined of about 3 ft. but even 18 in. are mined. All are bituminous and rather high in sulphur, both in pyrite and in films of gypsum. The most common floor is clay, and the roof, shale. The seams are best developed and chiefly mined around the border but Arthur Winslow, lately State Geologist, thinks that the deeper coals will probably be more regular in quality and distribution. Many interesting channel fillings alike of Carboniferous, Pre-Glacial and Glacial age, cut the coals as mined. The most productive county is Macon (688,479 tons in 1893), on the northeast, and the coal ranges 3-5 ft. The next is Bates on the southwest (409,819 in 1893), but in former years Bates was the leader. It contains the famous Rich Hill mines on a seam 4-5 ft. The other notable counties, Lafayette, Vernon, Ray, Randolph, Putnam, and Henry (all over 100,000 tons in 1893) are mostly distributed between the first named.

In addition to the coal seams in the regularly, stratified series there are other outlying pockets, beyond the connected Carboniferous area. They lie in cavities or sink holes in all the Palaeozoic strata down to the Cambrian, and may afford cross-sections up to 70 feet of coal. They are too limited however to be of other than local importance. A very large pocket in Cooper Co. has yielded considerable cannel.

A small tongue of the Eastern Central Field projects beneath St. Louis and contains one seam.

	H_2O	V. H.	F. C.	Ash	S.
1. Rich Hill.	2.54	42.62	41.14	13.70	4.51

1. M. R. 1888, 287.

LITERATURE:

J. L. Kleinschmidt. Asphaltlagerstatten u. Kohlenbildung. B. & H. Z. 1887, p. 46, p. 405.
W. J. Megee. On Macon Co. Mo. Trans. St. Louis Acad. Sci. V. 305.
R. Pumpelly. Iron Ores & Coal Fields of Mo. 1872. Reports on counties by various assistants.
P. Schweitzer. True Composition of Coal and the Methods of arriving at it, etc. Catalogue of the Univ. of the State of Mo. 1871, Appendix A. Discusses a coal from near Columbia, Boone Co.
G. C. Swallow. On the Coal Measures of Mo. From State Geologist's Rep. 1855, A. J. S. ii. XXVI. 113. Good Abstract.
A. Winslow. The Mo. Coal Measures and the Conditions of their Deposition. Bull. G. S. A. III. 109, 1891.
" Coal Measures of Mo. M. R. 1892, 429. Rec.
" Preliminary Report on Coal. Mo. Geol. Survey, 1891. A final report is promised.
" The Higginsville Sheet of the Mo. Geol. Surv. maps, an important part of Lafayette Co. The Bevier Sheet with descriptive letter press by C. H. Gordon, covers portions of Macon, Randolph and Chariton Co's. in an important coal district. C. R. Keyes succeeded Winslow as State Geol. 1894.

IOWA. The Missouri coal fields that extend all across the northern boundary of the state, contract as they enter Iowa both from east and west and terminate at an apex somewhat north of its central portion. A narrow, separate strip extends up the west boundary along the Missouri river. The most productive districts lie along the Des Moines river, which cuts the area of the coal measures. C. R. Keyes in the recently issued, and valuable report cited below divides the Pennsylvanian into two series, a lower mostly of mechanical, shore deposits, such as sandstones, shales and clays, and called the Des Moines stage, from the Des Moines river; and an upper, mostly of limestones, and called the Missouri stage, from the Missouri river. The coal lies chiefly in the strata of the Des Moines stage. As was remarked under Missouri the coal seams pinch and swell in a notable way, and do not extend in constant thickness over as great areas as in the East. They cannot therefore be so closely correlated. As many as 12 seams were cut near Des Moines in 200 ft. but all told there was but 13/2 ft. of coal, while two of these thin seams swelled to minable thickness only

one-third of a mile away. They are clearly the results of shifting swamp growth along a shore line. The usual thickness as mined is about 4-5 ft. but seams are known to locally attain even to 10 ft. They are slightly faulted and show other characteristic small disturbances such as old channels, heaves, rolls, etc, well illustrated by Keyes. The chief productive county is Mahaska (1,093,530 in 1893), then follow Polk (693,103), Appanoose (650,775), Monroe (648,300) and seven others all 250,000 or over. All except Appanoose are traversed by the Des Moines river or its immediate tributaries. A number of smaller producers lie off this line.

(Note. There is a difference of nearly a million tons of production in 1893 between the figures of Keyes Report (p. 525) and the Mineral Resources for 1893, p. 286. The figures of the former are here given, and if they are correct, Iowa still outranks Colorado, contrary to a statement made earlier, under Colorado.)

The coals are bituminous, non-coking, and inclined to be sulphurous. They contain considerable mineral charcoal, which often creates slack. Nevertheless they are valuable steam coals and have a large market west and north.

	H_2O	V. H.	F. C.	Ash	S.
1. Mahaska Co.	4.91	41.69	43.01	10.39	5.09
2. Polk Co.	7.04	40.06	43.17	9.72	4.25
3. Appanoose Co.	9.70	35.84	47.14	7.31	4.41
4. Monroe Co.	5.05	42.64	44.93	7.38	4.79

1. Carey Mine, Rose Hill. Keyes Rep. 507.
2. Gibson Mine, Des Moines. do. 508.
3. Whitebreast, No. 19. do. 504.
4. Smoky Hollow Mine. do. 507.

LITERATURE:

G. A. Davis. Coal Mining in Iowa E. & M. J. Sep. 8th, 94, p. 221.
C. R. Keyes. Stratigraphy of Ia. Coal measures. Bull. G. S. A. II. 282.
" Coal Fields of Ia. M. R. 1892, 398.
Coal Deposits of Ia. Ia. Geol. Survey, Vol. II. 1894. Rec.
" Coal Measures of Iowa. E. & M. J. March 24th, 94, p. 269; March 31st, p. 295; April 7th, p. 317.
G. A. White. Geol. Survey Iowa, Vol's. I. and II. 1870.

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THE EASTERN CENTRAL FIELD.

As already emphasized this area has no marked geological separation from the coalfields just west of the Mississippi. It is cut off from them largely by erosion and is closely related both in character of coal and kinds of fossils. In their Southwestern portion the coal measures lie to the east of the Ozark uplift, and in their eastern portion they are on the western side of the Cincinnati uplift which latter separates them from the Appalachian field. They form a large synclinal trough in the valley of the Green river Kentucky, but elsewhere have

such gentle dips, that they can hardly be described otherwise than as constituting a markedly level area.

ILLINOIS. Coal is found under about two-thirds of Illinois, and the state is second to Pennsylvania in production. All the central and southeastern portion of the state consists of Carboniferous strata, the others forming a comparatively narrow belt around them. The Pennsylvanian strata are 600-800 ft.thick on the north and increase to 1200-1400 on the south. The lower measures contain the best coal. Sixteen seams are recognized, numbered from below upward but No. XI. and following are too thin to be mined. On the north and west they are sulphurous and of not especially high grade, but on the southwest in the Big Muddy district of Jackson Co. the quality is excellent and on the borders of Indiana, it approximates that of the Indiana coals. The coals are not well adapted to making coke and the output of coke has decreased yearly until now it is of no great moment.

The most productive county is St. Clair just opposite St. Louis (2,133,870 tons in 1893). From this point northward toward Chicago is the series of counties that furnish the largest output - over five others in 1893 passing the million mark, viz. Macoupin, La Salle, Sangamon Grundy and Bureau. The coals are obtained by shafts 50-300 ft. deep, and sunk in the level prairie.

		H_2O	V. H.	F. C.	Ash
1.	Belleville, St. Clair Co.	5.5	39.5	49.6	5.4
2.	Peru, La Salle Co.	10.30	33.90	51.26	4.54
3.	Barclay, Sangamon Co.	10.80	27.32	44.78	17.10
4.	Carbondale, Jackson Co.	6.36	26.40	59.84	7.40
5.	Grape Cr., Vermilion Co.	9.74	28.34	51.32	10.60

1. Macfarlane, Coal Regions America, 425, 1873.
The remaining analyses are from M. R. 1888, 383. In each reference others will be found. Unfortunately the analysts did not report sulphur.

LITERATURE:

J. V. Z. Blaney. Analyses of Ill. Coal. Geol. Survey Vol. I. p. 275, 1866; Vol. III. p. 574, 1868.
F. B. Comstock. The Fossil Fuels of Ill. and their exploitation. E. & M. J. July 9, 87, p. 24.
" The Fossil Fuels of Ill. &c. E. & M. Jour. May 25, 89, 477.
J. Johnson. On the Wilmington Ill. Coal Field. M. E. III. 188.
L. Lesquereux. Coal Fields of Ill. Geol. Survey III. I. 208, 1866.
A. H. Worthen and others. County Geology. Geol. Surv. Ill. Vol. I. 1866, III. 1868, IV. 1870, V. 1873, VI. 1875.
A. H. Worthen. Fuel Resources of Ill. A. A. A. S. XVII.

INDIANA. The Illinois area runs unbroken across the Indiana line, so that the southwestern portion of the latter is supplied with coal. Fourteen seams are known, which are called by the letters A-N; but C. D and E. are nowhere thick enough to mine, and the chief attention is given to I. J. K. and L. The seams as mined range from 2'-6 to as much as

7'. The region around Brazil, in Clay Co. affords a peculiar coal known as "block coal", because it is broken by intersecting joints into cubical blocks, and where stripped looks like a coarse pavement. It is a non-coking, low ash, low sulphur coal and much prized for iron smelting, etc. It has been used raw in blast furnace practice. Seams I. and J. afford it and have a general thickness of 3' 6" to 4'. The coal lies in small basins, roughly speaking. Indiana coal mines and miners are usually classed as the block coal and the bituminous coal groups. Outside of Clay Co. the coal is mostly bituminous of good grade and much used for steaming purposes. Some cannel is also mined.

The most productive county is Clay (1,209,703 tons in 1893); then follow Park, Vigo, Daviess, Sullivan, Vermilion, Greene and Pike, from about a half a million down to about 200,000.

	H_2O	V. H.	F. C.	Ash	S.	Sp.gr.
1. Block Coal, Brazil.	8.50	32.50	56.50	2.50	1.43	1.285
2. Seam I. Park Co.	2.98	40.98	50.70	3.46	1.88	-----
3. Cannel. Seam I. Daviess Co.	3.00	51.00	40.00	6.00	----	-----
4. Seam L. Pike Co.	2.27	40.01	56.13	1.59	----	1.275

All these analyses are from M. R. 1887, 238. A great many are scattered through the reports of the Indiana Geological Survey.

LITERATURE:

E. T. Cox, John Collett, Maurice Thompson & S. S. Gorby as State Geologists have issued approximately annual reports since 1869. The last issued was the 18th in 1894. The first fourteen of these contain many geological descriptions of counties, & coal analyses - with some general papers (such as chiefly make up the later ones) which are noted below.

E. T. Cox. On the Western Coal Measures and Ind. Coal. A. A. A. S. XX. 236.

L. Lesquereux. Coal Fields of Ind. Geol. Surv. Ind. 1859-60, pub. 1862, 273-341. Also county geology.

Mineral Resources. 1887, 238.

KENTUCKY contains portions both of the Eastern Central Field and of the Appalachian. The latter is much the larger in square miles, but the former is a little the more productive. Between the two lies the southern extension of the Cincinnati Uplift over which the Subcarboniferous rocks run unbroken from one to the other. There are 4500 square miles in the western field and 11,180 in the eastern. The western alone concerns us at this point. Broadly speaking it is a large synclinal basin, through which the Green river flows, furnishing a navigable stream throughout the entire extent. Twelve workable coals are known in seams of good size. The coals are steaming coals and although great efforts have been made to produce a good coke in order to smelt the local limonites and carbonate ores, the one as yet made runs rather high in sulphur. The coals outcrop around the fringes of the basin and can be mined for many years above the water line. Hopkins Co. much the largest producer of the state (713,809 tons in 1893 in a total 3,007,119) lies in the western central portion, while Ohio, Muhlenberg, Union and Henderson are all over 100,000. In the northeastern portion is the

17. The region around Brazil, in Clay Co. affords a peculiar coal known as "block coal", because it is broken by intersecting joints into [illegible] blocks, and where stripped looks like a coarse pavement. It is a non-coking dry coal, low sulphur coal and much prized for [illegible] [illegible]. It has been used raw in blast furnace practice. Seams [illegible] [illegible] and have a general thickness of [illegible] to [illegible]. The coal [illegible] small basins, [illegible] [illegible]. Indiana coal mines [illegible] [illegible] [illegible] as the block coal and the [illegible] coal [illegible]. [illegible] Clay Co. the coal is [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

The most productive county is [illegible] [illegible] tons per [illegible], then [illegible], [illegible], [illegible], [illegible], [illegible], [illegible] and [illegible], [illegible] [illegible] a million [illegible] [illegible].

		H_2O	V.C.	F.C.	Ash	S.	B.T.U.
1.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All [illegible] analyses are from U. S. [illegible], [illegible]. A great many [illegible] are [illegible] in the reports of the Indiana Geological Survey.

LITERATURE:

[illegible] [illegible].

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

[illegible] [illegible] [illegible].

[illegible] [illegible].

Breckenridge cannel coal that will be again referred to under cannel.

		H_2O	V. H.	F. C.	Ash	S.
1.	Clifton, Hopkins Co.	----	33.32	47.45	16.02	3.21
2.	" " Washed.	----	35.24	52.53	10.31	1.92
3.	Mud R. Muhlenberg.	----	36.50	58.60	4.90	1.92

1. Bed L. Unwashed Coking. M. R. 1887, 262.
2. do. Washed.
3. M. R. 1887, 262. Many other analyses are given in this report.

LITERATURE OF WESTERN FIELD.

J. H. Allen. Western Ky. Coals & Cokes. M. E. XVI. 581.

W. B. Caldwell Jr. Coal and Iron Ores of Western Ky. Louisville Courier Journal, Mar. 9, 1878 & issued by Ky. Geol. Survey as pamphlet & in Bulletin No. 1.

Geological Survey Reports, all with details on Coal have been issued under D. D. Owen (4 vols. 1856-61), N. S. Shaler (1876-1880), J. R Procter (1880-). Recently the economic data somewhat scattered in Shaler's reports have been collected and reissued under Procter in individual volumes.

P. N. Moore. On Butler, Grayson, Edmonson, and Hart Co's. i.e. Nolin R. district. Geol. Surv. Ky. New Issue, D. Western Coal Field, 1-56.
 " Airdrie Furnace & Property Muhlenburg Co. do. 69-96.
 " Geology of Hancock Co. do. 97-129. Report on Coal Washing Part III. 2nd series VI. 251-290.
 " Geol. Eastern Border of Western Coal Field, Ky. Geol. Surv. 2nd series IV. part XI. 423-444.

C. J. Norwood. On a Part of the Breckenridge Cannel Coal Dist. Geol. Survey Ky. D. 195.
 " Reports of State Inspector of Mines.
 " Geol. of Ohio Co. Rep. D. Ky. Geol. Survey New Series, 131-191.
 " Rep. on region adjacent to Louisville, Paducah & S. W. R. R. Geol Survey Ky. New Series, I. 359.
 " Rep. on North & South Running Railways of Western Ky. Ky. Geol. Surv. 2nd series, IV. part VII. 285-338.

R. Peter. Many analyses of coals in Rep. A. parts I. II. and III. Ky. Geol. Surv. New Series.

J. R. Procter. Coal Fields of Ky. M. R. 1892, 415.

B. Silliman. Breckenridge Cannel. A. A. A. S. May 1884.

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MICHIGAN FIELD.

The isolated coal field of the southern peninsula would be included in a circle of 50 miles radius, nearly central in the peninsula. The series is about 300 ft. thick of soft sediments and contains but one irregular seam. It has a maximum thickness of 4 ft. and averages less than 3. It is mined in Jackson and Clinton Co's. but the yield is falling off, (45,979 tons in 1893). The coal is poor and sulphurous; the mines are wet and the country is largely covered with Glacial Drift.

	H_2O	V. H.	F. C.	Ash	S.
Jackson.	2.0	49.	45.	2.0	2.0

Quoted in M. R. 1886, 280, but undoubtedly above the average grade.

LITERATURE:

Mineral Resources. 1892, 422. Rec.
C. Rominger. Geol. Survey of Mich. III. 122-150.
C. E. Wright. In Mineral Statistics of Mich. 1881, p. 23.

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THE APPALACHIAN AREA.

Broadly speaking the coal fields lie in a series of synclinal valleys, from central Alabama to northern Pennsylvania. As a general thing the anticlines have been eroded and lost, but this is not always true of West Virginia, Ohio and western Pennsylvania, for in this section the coal seams often ride over the anticlines. The great preponderance of soft and yielding sediments in the geological section shown on the north has occasioned the formation of folds without faulting, while in the south, the relatively thin Devonian and Carboniferous, but thick and stiff Siluro-Cambrian limestones have brought about faulting. It is important to emphasize the pitching character of the synclinal troughs, such that they oftentimes run out into the air at the north, and pitch down deeper and deeper towards the south. The general development of the drainage systems is also a vital factor in the geology. Hard and heavy beds as well as faults and folds have been of great influence in directing streams, and saving the coal from destruction. The widespread presence of a resistant conglomerate just beneath the chief coal bearing series has been no small factor in this. Our knowledge of these relations has been greatly increased by the recent work of Willis, Hayes, Campbell and others of the U. S. Geological Survey. In Alabama, Georgia and Tennessee, more or less faulting accompanies the folds, but in Pennsylvania almost none. It is important also to emphasize the great thickness of the Carboniferous sediments in Pennsylvania, and their thinning both south and west. The states will be taken up in order from south to north.

ALABAMA. The coal territory of Alabama covers some 8660 square miles. It is separated into three distinct fields, which are in the order of size and importance the Warrior, 7230 sq. ms. of which 4955 are basin and 2275 plateau; the Cahaba, 435 sq. ms.; and the Coosa, 415 sq. ms. In addition there is a fourth outlying plateau area, the Lookout Mountain, 580 sq. ms. The Warrior lies to the west and is drained by a river of the same name. It is separated from the Cahaba by the intervening eroded, anticlinal valley in which Birmingham is situated. The Cahaba field then forms a long, narrow synclinal ridge, with a second eroded, anticlinal valley between it and the Coosa. The anticlinals are unsymmetrical being overthrown by a compression acting from the east, and thus the prevailing dip in the syncline is southeast, while the axis of the trough is near its southeast side. The northwest flank is long and of relatively low dip, whereas the southeast is steep and

[illegible]

[illegible] 1899, [illegible] shows the average [illegible]

Bibliography.

[illegible] 1904.
[illegible] Field [illegible]
[illegible] In Annual Statistics of [illegible] 1901, p. 41.

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THE APPALACHIAN AREA.

[illegible] the coal fields lie in a series of [illegible] northern Alabama to northern Pennsylvania. As a general [illegible] [illegible] Pennsylvania [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Geological Survey [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] the [illegible] fields, which are in the [illegible] [illegible] In addition there is a [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] short. Great faults have served to break up the regularity of the measures. The total thickness reaches 5000 ft. and over 50 coal seams have been identified, of which in the Warrior field as many as 9 or 10 are worked, although most of the coal is obtained from two. Of these the Pratt seam with a general average of 4'6" affords about half the state's output and the Newcastle about one-quarter. The large mines lie to the west and southwest of Birmingham, in Jefferson, Walker and Tuscaloosa Co's. They are mostly controlled by the Tenn. Coal and Iron Co. Approximately half the coal mined is coked for blast-furnace use. It yields a serviceable coke, not perhaps as good as that from the New River region of W. Va., or from Pine Mtn. Ky. or from Connelsville, Pa. but still as the results show, a very fair fuel.

The Cahaba field is chiefly attacked in Bibb Co. at its southern end at Montevallo, Gurnee and Blocton. Further north at Helena are other openings. The seams have different names in different regions but practically four furnish all the coal while seven in all have been opened up.

The Coosa Field is the least developed and explored of the three. Its output is at present not great.

	H_2O	V. H.	F. C.	Ash	S.
1. Pratt Seam, Warrior Field.	1.50	31.48	61.60	5.42	0.92
2. Coke do. do.	0.157	0.803	87.30	10.54	1.20
3. Newcastle Seam, do.	0.50	28.24	59.69	10.92	0.64
4. Blocton, Cahaba Field.	2.24	34.12	60.75	2.41	0.48

1. M. R. 1892, 572.
2. M'Creath & d'Invilliers. Southern Cokes and Iron Ores. M. E. Feb. 1887, Reprint p. 20.
3. E. J. Schmitz. Contrib. to Geol. Ala. M. E. June 1883, Repr. p. 21. O. Wuth Anal. About 70 analyses are given in this paper.
4. C. A. Ashburner. Development, etc. Ala. Coal-fields. M. E. May 1888, Repr. p. 11.

LITERATURE:

T. H. Aldrich. Coal Mining in Ala. Historical Sketch 1853 - 1875. Geol. Surv. Ala. 1875, p. 28.

C. A. Ashburner. The Development and Statistics of the Ala. Coal Fields for 1887, M. E. 17, 206.

W. M. Brewer. Coosa Coal Field. E. & M. J. July 1893, 7.

Campbell & Ruffner. Physical Survey in Ga. Ala. and Miss. along Ga. Pac. R. R. N. Y. 1883. Contains Geol. Section of Ala. coal fields

A. M. Gibson. Geol. of Murphrees Valley. Small mention of coal. Geol. Surv. Ala. 1893.

" Coal Measures of Blount Mtn. do. 1893. E. & M. J. May 26, 1894, 489.

" Coosa Coal Field. do. Not yet issued (Feb. 1895).

C. W. Hayes. Geol. N. E. Ala. (Lookout Mtn. Coal.) Geol. Surv. Ala. 1892.

" and M. R. Campbell. Geomorphology of Southern Appalachians. Nat'l. Geographic Magazine. May, 1894.

ments. Great faults have served to break up the regularity of the measures. The total thickness reaches 4000 ft. and over 30 coal seams have been identified, of which in the Warrior field as many as 8 or 10 are worked, although most of the coal is obtained from [illegible]. The Pratt seam with a general average of 4'6" affords about half the present output and the [illegible] about one-quarter. The large mines lie to the west and southwest of Birmingham, in Jefferson, Walker and Tuscaloosa Co's. They are mostly controlled by the Tenn. Coal and Iron Co. Approximately half the coal mined is coked for blast-furnace use. It yields a serviceable coke, not perhaps so good as that from the [illegible] of W. Va., or [illegible] or [illegible] Connellsville, Pa. but still as the results shown, a very good fuel.

The Cahaba field is closely attached to [illegible] on its southwest end at Tuscaloosa, [illegible] and [illegible]. [illegible] north of [illegible] are [illegible] quantity. The seams have different names on different [illegible] [illegible] [illegible] all the [illegible] seams [illegible] have been [illegible] up.

The [illegible] field is the least developed and explored of the [illegible] and is at present not great.

		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.	[illegible] seam, Warrior Field.	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.	[illegible] do. do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.	[illegible] seam, do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4.	[illegible] Field.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1. [illegible]
2. [illegible] Coke and Iron [illegible] 1907, [illegible]
3. [illegible] Coal [illegible] [illegible] [illegible]
4. [illegible] Development, etc. Ala. Coal-Fields [illegible] 1910, [illegible]

LITERATURE.

[illegible] Aldrich. Coal Fields in Ala. [illegible] 1876. [illegible] Ala. 1876, p. [illegible]
[illegible] The Development and Exploitation of the Ala. Coal Fields [illegible]
[illegible]
[illegible] along [illegible]
[illegible] Coal Fields
[illegible] Coal of [illegible] Small [illegible] Coal [illegible]
[illegible]
[illegible]
[illegible]
[illegible]

T. S. Hunt. Coal & Iron in Ala. M. E. 11, 256.
Also T. & M. J. Mar. 3-83 p. 273.
Ch. Lyell. Coal Field of Tuscaloosa Ala. A. J. S. II. 1, 371. Good section. See also II. 2, 228, on Fossil Plants. See also Q. J. G. S. II. 278.
H. McCalley. Rep. on Warrior Coal Field. Geol. Surv. Ala. 1886, 571 pp. Rec.
" and E. A. Smith. Coal Measures of the Plateau Region. do. 1891. Rec.
A. S. McCreath & E. V. d'Invilliers. Comparison of some Southern Cokes and Iron Ores. M. E. Feb. 1887.
J. B. Porter. The Iron Ores & Coals of Ala. Ga. & Tenn. M. E. XV. 170.
E. Ramsey. The Pratt Mines of the Tenn. Coal & Iron Co. M. E. XV. 170.
R. P. Rothwell. Ala. Coal & Iron. M. E. II. 144. Geol. Survey Ala. 1875, p. 46.
E. A. Schmitz. Contributions to the Geology of Ala. M. E. June 1883, Many analyses.
E. A. Smith. Warrior Coal Field. Geol. Surv. Ala. 1877-78, 4 county maps.
" Resources of Warrior Region. 2 maps. do. 1879-80.
" Agricultural Features of Ala. do. 1881-82.
" Coal Measures of Ala. M. R. 1892, 293. Rec. Best brief account.
" Large Geological Map of Ala. with explanatory chart. Ala. Geol. Surv. 1894. Rec.
J. Squire. Cahaba Coal Field. Geol. Surv. Ala. 1890. Rec.

GEORGIA. The Warrior field of Alabama extends in the ridge of Sand Mountain across the northwest corner of Georgia, and supplies two seams of bituminous coking coal, at the mines at Cole City, Dade Co. The upper or Dade Seam is 3'-4' on the average, and the lower, 12' below, called the Red Ash is about 4'. They have been the chief producers in the past and have shipped a high ash but low sulphur coke to Chattanooga. After an eroded anticlinal valley to the southeast the ridge of Lookout Mountain is met, being the extension of the same from Alabama. Large mines began to ship in 1893 from Round Mountain in this field and nearly doubled the usual output of the state.

	H_2O	V. H.	F. C.	Ash	S.
1. Dade Seam, Cole C'y.	----	27.15	61.69	10.59	0.58
2. Red Ash, "	----	28.64	66.55	4.41	1.04
3. Coke, Cole C'y.	0.54	1.09	75.94	21.78	0.67
4. Round Mtn.	----	16.03	79.10	4.81	0.36

1, 2 and 4. Geol. Survey of Ga. 1893, p. 258. #4 had also P. .007.
3. McCreath & d'Invilliers. M. E. Feb. 1887.

LITERATURE:

J. W. Spencer. Report of State Geologist of Ga. 1893, 247. Rec. Contains a geological map of northeastern Ga.

TENNESSEE. The coal measures of Tennessee lie in the Cumberland tableland to the west of the Tennessee river. The topography is marked

[illegible] Ala. [illegible] 1888.
[illegible] p. 373.

[illegible] of Carboniferous [illegible] XVII. [illegible]
[illegible]

[illegible] Coal [illegible] 1876.

[illegible] of the [illegible]

[illegible] 1877.

[illegible] of Ala. [illegible] 170.
[illegible] of the Tenn. [illegible] 170.
[illegible]

[illegible] to the [illegible] of Ala. [illegible]

[illegible] Coal Field. [illegible] Ala. [illegible]

[illegible] 1879-80.
[illegible] 1881-82.
[illegible] of Ala. [illegible] 1883 [illegible]
[illegible] of Ala. [illegible] Ala. [illegible]

[illegible] Coal [illegible] Ala. 1875. [illegible]

[illegible] Plateau of Alabama [illegible] Georgia [illegible]
[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	---	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]

[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

and characteristic. From south to north the tableland is roughly speaking 60 miles across, and terminates on the east in a steep rampart of cliffs. In its southern portion it is cut by the Sequalchio river valley into two parts and on the north it has one or two faulted outliers. In the valley of the Tennessee river the early palaeozoic strata stand at high dips but as the tableland is approached they flatten down almost to horizontality. The coal measures are classified in three series. At the base is a heavy limestone, above it are found from 60-400 ft. of sandstones and shales capped by a hard conglomerate locally called the Sewanee, but the whole series has been named the Lookout sandstone on the U. S. Geol. Survey sheets. This, the "First Series" contains from 1-4 coal seams, of varying thickness and resembling great flat lenses, and locally of importance. The conglomerate is the protecting cap which has really brought about the formation of the tableland. Upon it, toward the east rests as a higher plateau, the second series, frequently with steep escarpments and forming the so-called "back ridges". Topographically the two merge into each other more or less further east. The series is from 250-500 ft. thick and capped by a heavy sandstone. As many as four seams are known. The second or "Sewanee" is the principal source of Tennessee coal, and is found about 50-60 ft. above the conplomerate. It has a wide extent and is extensively coked. The third series is thicker than either of the others and reaches as much as 3000 ft. It has only been preserved in the northeastern part of the Cumberland tableland where heavy faulting has dropped the lower series out of sight. Twenty seams occur in it, of which eleven are workable. This region is on the whole the most productive of the state, and contains Anderson the leading county. Beyond its eastern front is a disconnected ridge of steeply dipping beds, like an advanced rampart and called Waldens Ridge. The same name is applied to the ridge between the Tennessee and the Sequalchio series. The coal field as a whole has been called the New River Field by W. R. Calton, but is not to be confused with the New River of West Virginia. On the extreme northern border and running into Kentucky is Jellico Mtn. with workable seams, several of the upper ones being in the third series.

The most productive mining regions are at the northeastern and southwestern portions of the area. The coals in general are bituminous, and coking, but the coke is not all that is desired for iron smelting and much interest is felt in the neighboring fields that afford cokes of higher grade. The bane of these southern coals is said to be fine, fissile shale interbedded with them.

	H_2O	V. H.	F. C.	Ash	S.
1. Coal Creek, Anderson Co.	----	34.20	58.80	6.93	0.79
2. Soddy, Hamilton Co.	----	28.90	56.89	14.21	----
3. Sewanee, Grundy Co.	----	27.81	61.52	10.67	1.22
4. Etna, Marion Co.	----	27.45	62.71	9.80	1.18
5. Average 3 Cokes.	0.42	1.10	82.04	14.54	1.9

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EASTERN KENTUCKY. The Tennessee coal fields extend northward into eastern Kentucky and expand in the area which spreads eastward into West Virginia and Virginia and northward into Ohio and Pennsylvania. In Kentucky the geosyncline with the Ohio fields on the west flank, the West Va.-Penn. fields on the east and the Ohio river in the trough, begins to be in evidence. As earlier stated the eastern Kentucky field has some 11,180 square miles, and is a rich fuel reserve which has not as yet been much mined. The leading counties are Whitley (Jellico Coals) Laurel and Knox in the southeast corner, and Boyd and Carter, in the Hanging Rock region along the Ohio river on the northeast. The territory in between largely remains for the future. In the southeastern counties along the Virginia line there are coking coals of exceptional excellence and thought to be a promising fuel supply both for the Tennessee and Alabama furnaces and for Chicago and vicinity. The principal seam, called the Elkhorn, is thought to correspond to the Imboden of Virginia. A great abundance of cannel coal has also been found in this Kentucky field as well, and of all varieties of coals eight or ten workable seams have been identified.

	H_2O	V. H.	F. C.	Ash	S.	Sp.gr.
1. Jellico Seam.	2.00	33.70	61.90	2.40	0.796	-----
2. Elkhorn Seam.	3.26	32.24	61.60	2.90	0.656	1.291
3. " Coke.	1.20	0.60	94.14	4.66	0.906	-----
4. Coal #6, Boyd Co.	2.70	36.70	52.60	8.00	1.711	1.315

1. Procter Mines, Whitley Co. Crandall on Whitley Co. as below p.29.
2. Holcomb's Coal, Ky. River. Crandall on Pound Gap as below p. 21.
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4. Horse Branch. Geol. Surv. Ky. Rep. C. p. 21.

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R. Peter. Analyses of Ky. Coals. Geol. Survey Ky. J. R. Procter Director. Rep. A. I. 1884. Various analyses. II. Many scattered anals. coals. Table on p. 292.
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VIRGINIA. Mention was made earlier of the Triassic coals of Virginia. In the southwest portion of the state there are three areas of Carboniferous coals, two of which are near the base of the strata belonging to this age. The more easterly lies in Pulaski, Wythe, and Montgomery counties, and furnishes the oldest coal mined anywhere in America. It comes in the Virginian equivalent of the Pocono or Vespertine sandstone of Pennsylvania, at the base of the Lower Carboniferous. The coals are in thick seams but being of high ash percentage are only mined for local use, especially in the zinc works and salt blocks. They lie in the section of the state known as Appalachia and have been formed by an easterly extension of the sediment-depositing waters of the Vespertine times, as has been shown by M. R. Campbell in a neat piece of geological work, and not by overthrust faulting as had been earlier supposed. The Altoona mines are the best known. The coal is semibituminous. The coal fields further west supply some of the best coal and coke of the East. The Norfolk and Western railway has given the northern or Flat Top field of Tazewell Co. an outlet and under the name of Pocahontas coal it is one of the chief fuels of transatlantic

steamers all along the coast. Seven coal seams are known of which the Pocahontas or No. 3, at 5 ft. and upward is most mined. The coals are low in volitile matter and are all contained in the Pottsville or Great Conglomerate series of Pennsylvania and are therefore lower than the coals further north. South of the Flat Top field is the Big Stone Gap field in Wise, Scott and Lee counties, but chiefly productive in the first named. This has been but recently opened, yet it is manifestly a most important one for the future. Both the Conglomerate measures and the Lower Productive of the Pennsylvania section are present and contain coals higher in volitile matter than those of the Flat Top field. Ten workable seams 3 ft. and over have been recorded, of which the Imboden is one of the best known. This field extends into Kentucky and the Flat Top field, it should be stated, runs into West Virginia and the latter is south of the New River field. This section of country is undoubtedly to be a great coke-producer in the future.

		H_2O	V. H.	F. C.	Ash	S.
1.	Altoona Mines.	0.24	9.46	49.35	39.83	1.12
2.	Tom's Creek.	1.23	11.65	73.01	13.56	0.55
3.	Pocahontas.	0.69	18.83	74.07	5.65	0.76
4.	" Coke.	0.20	0.49	92.58	6.05	0.68
5.	Looney Creek.	1.40	33.66	58.36	5.87	0.71
6.	Big Stone Gap Coke.	----	-----	92.23	5.69	0.75

1. A. S. McCreath. Mineral Wealth of Va. 131.
2. do. p. 130. The samples represent the extremes of the Pocono coals.
3. do. do. Average of 10 samples. p. 119.
4. do. New River - Cripple Creek Region. p. 153.
5. Big Stone Gap F'd. Imboden Seam. J. M. Hodge as cited below. Repr. ½. 13."
6. Idem.

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INTRODUCTORY REMARKS ON WEST VIRGINIA, PENNSYLVANIA AND OHIO.

The geological relations of these three are so closely connected, and are so important that a few introductory generalities are advisable. Together they make up a geosyncline whose trough is not far from the Ohio river. The highest measures form the surface along the axis of the trough but die out east and west from it, and are succeeded by the lower measures. In Ohio, on the west flank, the dip is very gentle; there is scarcely a minor anticline worthy the name, or a fault or any disturbance, but on the east flank, anticlines, gentle and broad at first are succeeded by more and more pronounced ones, until in central and eastern central Pennsylvania, their crests are all eroded down through the Carboniferous rocks, and the coal seams remain as isolated, synclinal basins on the tops of intervening ridges. Finally in the anthracite basins the synclinal remnants are sharply compressed. Stratigraphically there is the Sub, or Lower Carboniferous, now best called the Mississippian series, below; the Carboniferous or Pennsylvanian in the middle (with almost all the productive seams); and the Permian, of slight importance, above.

The Mississippian series is divided into,

(1) The Pocono or Vespertine sandstone, No. X of Rogers, the horizon of the outlying Virginia coals;
(2) The Mountain Limestone and the Mauch Chunk or Umbral red shale, No. XI of Rogers.

The Pennsylvanian series includes,

(3) The Pottsville, Great or Seral conglomerate or New River series, No. XII of Rogers;
(4) The Lower Productive Measures or Alleghany River series, No. XIII of Rogers;
(5) The Lower Barren Measures, No. XIV of Rogers;
(6) The Upper Productive Measures or Monongahela River series, No. XV of Rogers;
(7) The Upper Barren Measures, Dunkard Creek series, (Permo-carboniferous) No. XVI of Rogers.

I. C. White, to whom is due the naming of the several series after prominent streams that cut them, divides (5) into a lower portion, marine deposits, the Elk River series, and an upper of brackish water deposits. The remainder are then the same but are determined as freshwater deposits. The names in use among the mining fraternity are how-

over the Pottsville Conglomerate, the Lower Productive, Lower Barren, Upper Productive and Upper Barren series. But the special word "Productive" in this connection has had less significance since the coals of the horizon of the Pottsville Conglomerate have been opened in Virginia and West Virginia. The characters of the faunas and floras furnish the basis of White's groupings. The names of individual seams, as used in Pennsylvania have spread into the neighboring states wherever the correlation can be carried out. In the Lower Productive Measures, there are eight - the <u>Brookville</u>, the <u>Clarion</u>, the <u>Lower</u>, <u>Middle</u> and <u>Upper Kittanning</u>, the <u>Lower</u>, <u>Middle</u> and <u>Upper Freeport</u>. Rarely six are workable, but as a general rule, only one or two in a given district. The Lower Productive Measures are thickest in West Virginia, and thinnest in Ohio. The Freeport seams are the most sought. The Lower Barren Measures have a few extremely variable seams which are only locally of value. At the base of these Measures is an important datum-sandstone, called the Mahoning, and the Pittsburg coal seam marks their upper limit. The Upper Productive Measures contain six seams which are only met in the central portion of the area, and of which only four are productive over a wide extent. From below upward they are the Pittsburg, the Redstone, the Sewickley, the Uniontown, the Little Waynesburg and the Waynesburg. The first named supplies the Connellsville coke and is the most important single seam of all. The Upper Barren Measures have but one seam worthy of mention, the Washington. These seams have other local names in all three of the states, but when used in print even these local names are usually correlated with the ones above cited.

WEST VIRGINIA lies mostly on the eastern flank of the geosyncline. It is par excellence, the coal state of the Union; for 48 out of 56 counties contain coal, and at present 17 are active producers making the state the fourth on the list. The most productive section lies along the Kanawha river and its upper tributary the New. The coal is obtained from the seams of the Lower Productive and Conglomerate Measures and they furnish about one-half the state's total. Much of it goes down the Kanawha and Ohio in barges. The next district is the extension of the Flat Top field of Virginia at the same horizon as the New river mines. The third district lies along the headwaters of the Monongahela river in Marion and Harrison counties. The Upper Measures are the producers. Next follows the southerly extension of the Cumberland field of Maryland on the extreme northeast. The seams of both the Upper and Lower Productive Measures yield the coal. Marshall Co. in the "panhandle" is the only remaining one of notable individual prominence. The West Virginia coals are all bituminous and of exceptional purity, but within this broad group they furnish all varieties. The New River and Pocahontas coals are of increasing importance for coke, and many think this section destined to be the coke center of the future. The unopened territory furnishes a most important reserve.

The asphaltic coal or Grahamite is later discussed.

		H_2O	V. H.	F. C.	Ash	S.
1.	Great Kanawha Colliery.	1.14	59.89	34.61	4.36	0.81
2.	Quinnimont Mines.	0.76	18.65	79.29	1.11	0.23
3.	Fire Creek Mines.	0.40	22.40	72.25	4.95	0.508
4.	Flat Top Field.	0.698	73.41	18.76	6.39	0.75

over the Pottsville Conglomerate, the Lower Productive, Lower Barren, Upper Productive and Upper Barren series. [illegible] in this connection [illegible] significance [illegible] of the Pottsville Conglomerate [illegible] Virginia. [illegible] the [illegible] Lower Productive [illegible] [illegible] the Pittsburgh [illegible] Upper Productive [illegible] [illegible]

[illegible]

[illegible]

		H_2O	V. H.	F. C.	Ash	S.
5.	Coke Field.	0.182	0.72	92.25	6.29	0.56
6.	Marion Co.	-----	35.00	65.00	5.00	----
7.	Mineral Co.	0.82	20.18	79.82	3.95	0.71
8.	Tucker Co.	0.70	22.03	80.53	6.74	0.924

1. W. S. Edwards, Coals and Cokes in W. Va, p. 65. Lower Kittanning Seam.
2. do. p. 67, New River series.
3. New River Field, No. 2 seam. do. p. 67.
4. Average of 8 samples, No. 3 seam. do. p. 68.
5. do. p. 78
6. American Mine, Pittsburg seam. M. R. 1888, 389.
7. Virginia Mine, Top 10 feet. Idem.
8. Lower Kittanning Seam. Davis. J. D. Weeks as cited below.

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OHIO. Approximately the eastern third of Ohio is covered by Carboniferous strata and a goodly share contains workable coal. The state was for years second to Pennsylvania in output, but recently Illinois has outstripped it, leaving it third with a production of 13,253,645 short tons in 1893. The representative of the Pennsylvania Pottsville Conglomerate, outcrops on the western and northern border but is no longer a conglomerate. It consists of sandstones shales and coal seams. The overlying series are then crossed as one passes southeast to the Ohio river, so that the Upper Productive measures are of great importance. Broadly speaking the Carboniferous rocks lie on the east flank of the Cincinnati Uplift, and the coals were formed in coastal swamps as elevation progressed in Carboniferous time. The swamps moved eastward successively so that it is not probable that the lower coals underlie at depths, the area of the Upper. The dip southeastward is almost too slight to be locally detected and the Ohio field as Prof. Orton has lately shown, is perhaps the most regular and undisturbed of any one yet discovered. From 15-18 seams are known, some of which are scarcely represented in Pennsylvania, although on the whole the correlation is close, and in this important work the Ohio Survey has made great advances under Professor Orton. He gives the following series, in the Pottsville Conglomerate Measures from below upward, the Sharon, Quakertown, Wellston or Jackson Hill, Lower and Upper Mercer, and Tionesta seams, six in all: in the Lower Coal Measures, the Lower Clarion or Brookville, Upper Clarion, Lower and Middle Kittanning, Lower and Upper Freeport, six in all: in the Lower Barren Measures four thin ones, the Mahoning, Cambridge limestone, Patriot, and Crinoidal limestone. In the Upper Productive the Pittsburg or Pomeroy, and the Sewickley or Meig's Creek are the important ones and practically complete the list although the Waynesburgh seam and in the Upper Barren Measures the Washington seam are known. While ten seams are actual producers, the main reliance is on the Middle Kittanning, the Upper Freeport and the Pittsburg. In the matter of correlation with Pennsylvania seams, the latest reports are to be consulted.

The Ohio coal field is so generally mined that the specially productive portions do not stand out in such prominent relief as in some other states. The greatest yield comes from the Lower Productive Measures in Jackson, Hocking, Athens and Perry Co's. on the southwestern limits. The Hocking Valley coal is a standard fuel in Ohio and along the lakes. In the central eastern portion the Pittsburg seam is important in Jefferson and Belmont. In Meigs Co. along the Ohio river, it is called the Pomeroy. The Sharon seam that furnished the famous Brier Hill coal is now exhausted. Ohio coals have a general average of 4-4/2 ft. They range from 1.24-1.34 in specific gravity. They are not as a rule good coking coals and this industry is strongly on the wane.

		H_2O	V. H.	F. C.	Ash	S.	Sp. gr.
1.	Brier Hill Sharon Seam.	3.60	32.58	62.66	1.16	0.85	1.28
2.	Mid. Kittanning Hocking V'y.	5.98	36.48	52.41	5.13	1.00	----
3.	Upper Freeport Seam.	2.32	39.08	52.78	5.82	2.88	----
4.	Pittsburg Seam.	1.45	36.35	57.95	4.25	2.72	1.30
5.	" Pomeroy.	4.10	33.90	56.10	5.90	0.43	1.358

1. M. R. 1884, 60.
2. do. p. 62.
3. Salineville, Columbiana Co. Idem.
4. Jefferson Co. do. 63.
5. Pomeroy Coal, Meigs Co. do. 64.

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J. A. Ade. The Wellston Coal District, Ohio. E. & M. J. Feb. 10, 1894 p. 126.

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" Hocking Valley Coal Field. Salem 1874, 78 pp. 2 maps.
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I. C. White. The Stratigraphy of the Bituminous Coal Field in Pa. W. Va. and O. Bull. 65, U. S. G. S.

MARYLAND. The coal area of this state is small in square miles, but a powerful producer of the most famous of American steam and blacksmith coals. It is a narrow trough that extends north into Somerset Co. Pa. as the Wellersburgh basin and south into West Virginia as the Elk Garden and Upper Potomac fields referred to above. This basin lies geologically eastward of all those in Pennsylvania except the Broad Top and the anthracite synclines, and seems to correspond with the Northern field of the latter. The basin in Maryland is called the Cumberland or St. Georges. It is a narrow synclinal trough about 20 miles long, and rather sharply compressed. The dips are fairly steep. Although the seams of the Lower Productive measures are present, and of good, thickness, the Pittsburg seam is so large, accessible, and of such good quality, that it along is mined as yet. It is locally called the "14 foot" but on account of a bad roof, only a part of this is taken out and an enormous percentage is left in pillars. The average yield per acre is but 5000 tons, of the 15,000 or 16,000 present. The coal is semibituminous and as stated a standard steam coal.

	H_2O	V. H.	F. C.	Ash	S.	Ratio
1. St. Georges Field.	1.23	15.47	73.51	9.09	0.7	4.75
2. "	1.11	15.3	73.28	9.08	1.23	4.78
3. "	0.71	15.26	68.28	13.24	2.54	4.47

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PENNSYLVANIA. In passing into Pennsylvania the classic ground of Carboniferous geology in America is met. As the strata of central New York have furnished the standard for the Palaeozoic up to the Carboniferous, so the undulating anticlines and synclines of Pennsylvania have proved the standards of reference for all American coal areas of Carboniferous age. The variety, excellence and accessible situation of Pennsylvanian coals, have all combined to make this state produce more than half the entire output of the country. In 1893 about 54 millions short tons of anthracite and about 44 millions of bituminous were obtained.

Bituminous Basins. There are six bituminous basins with separating and in central Pennsylvania eroded anticlinals between. In addition to these and distinct from them there are the outlying Cumberland, Broad Top and the Anthracite basins further east. The separating anticlines enter Pennsylvania from the south with a strike of about N. 30 E

but they curve around to about N. 70 E. as they die out. They are gentle in the west but become more marked and bold to the eastward and are sharply compressed in the southern anthracite fields. The intervening troughs rise to the northward on account of their southerly pitch and finally run out in the air. Some small minor anticlines appear between the main folds. The Sixth basin lies to the northwest beyond the Brady's Bend anticlinal; the fifth is between this and the Saltzburg fold, that crosses the Ohio river just below Pittsburg; the fourth between the the Saltzburg and the Blairsville anticlines and contains the Pittsburg region; the third between the Blairsville and the Chestnut Ridge and contains on the south the Connelsville coke region and toward the north the Reynoldsville and Blossburg districts; the second lies between the Chestnut Ridge and the Laurel Hill anticlinals and finally disappears in the Barclay district of Bradford Co.; the first is contained between the Laurel Hill and the Alleghany mountain, and holds the coals of Cambria and eastern Clearfield Co's and runs out in the Loyalsock or Bernice basin to the northeast. Between these are some minor rolls which have proved of great importance, especially in the northwest in connection with natural gas. The Brady's Bend, Saltzburg and Blairsville fade out more or less on the north but the others extend much further. The names of the coal seams have already been given The Pittsburg seam is the chief one, as it yields the coke at Connellsville, and the famous gas coal of Westmoreland Co. It is a complex seam, made up of several benches, as follows:- roof coals, and overclay; breast-coal (the bench mined); parting; bearing-in coal; parting; brick coal; parting; bottom coal. These characters are preserved over very extended areas. The Upper Freeport seam and the Lower Kittanning seam follow next in importance. The Lower Freeport seam is fourth and the Waynesburg fifth; the Brookville and Upper Kittanning are next and the others are only of local value. It should be also stated that the seams of the Lower Productive Measures are often called by the letters A to E and that there are several seams in the Lower Barren Measures that are locally large enough to mine. The amount of volatile hydrocarbons decrease in the same basin as a general thing from southwest to northeast; and in different basins from west to east - a very important point, geologically, and one on which J. J. Stevenson has wisely laid great emphasis in lately discussing the origin of anthracite. The northeastern terminations of the larger bituminous basins, as well as the eastern outliers are semibituminous. A great deal of emphasis was formerly placed on their characters and distribution and the general classification of coals has been influenced by them. The Cumberland, Broad Top, Johnstown, Snowshoe, McIntyre, Barclay and Blossburg sub-basins yield such fuel, but by the sharp lines of classification on page 23, most of them are still bituminous though low in volatile matter. The Cumberland field has already been reviewed. It is of minor importance in Pennsylvania. The Broad Top basin is a separate outlier in Huntingdon, Bedford and Blair Co's. as much as forty miles east of the Alleghany mountain. There are about 80 square miles of coal measures divided into two main and several minor synclines. A few acres of the Pittsburg seam are caught by the heights but otherwise the Lower Productive yield the coals which have fuel ratios from 4-5;

		H_2O	V. H.	F. C.	Ash	S.	Ratic
1.	Washington Seam.	1.695	39.15	46.66	10.52	1.97	1.19
2.	Waynesburg "	1.175	35.61	49.73	11.21	2.28	1.39
3.	Sewickley "	1.06	34.80	53.54	8.16	2.43	1.54
4.	Redstone "	1.06	33.59	48.69	14.29	2.37	1.44
5.	Pittsburg " Greene Co.	0.90	38.39	52.65	6.12	1.94	1.37
6.	" " Fayette Co.	1.26	30.11	59.62	8.23	0.73	1.98
7.	Upper Freeport, Cambria Co.	0.88	24.63	68.33	4.93	1.23	2.77
8.	" " Lycoming Co.	1.17	17.12	73.68	7.18	0.84	4.30
9.	Lower " Clearfield Co.	1.24	24.45	67.04	5.94	1.32	2.74
10.	Kittanning Middle.	2.27	40.99	46.79	8.07	1.87	1.14
11.	" Lower.	0.395	16.14	72.94	8.04	2.43	4.51
12.	Clarion Seam, Tioga Co.	1.12	18.57	72.10	7.63	0.53	3.88
13.	Brookville Seam, Cambria Co.	1.47	17.93	75.51	4.52	0.57	4.21

1. Pa. Geol. Surv. Rep. M. M. p. 4.
2. do. p. 6, Anal. 154.
3. do. p. 9, Fayette Co.
4. do. p. 11.
5. M. M. 19.
6. M. M. 22, Frick & Co.
7. M. M. 45.
8. McIntyre. M. M. 47.
9. M. M. 57.
10. M. M. 63, Butler Co.
11. M. M. 67, Broad Top Field, Huntingdon Co.
12. M. M. 79, Morris Run.
13. M. M. 86, Conemaugh Station.

REMARKS. These analyses are selected to show the general range in composition. To be especially significant analyses should be grouped by coal seams, and those of each seam by basins. Inferences of value could then be drawn about the character of the individual seam in a single field and about its variation from field to field. But for that extended treatment there is no apace here although the advantages of the method may be emphasized.

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ANTHRACITE. Although the anthracite fields of Pennsylvania cover but 470 square miles, they afford over one-fourth the country's production and the value of this fourth exceeds that of all the pig iron produced. This is due to the hot and smokeless fire that anthracite affords, to its nearness to the great centers of population, and to the unusual thickness and number of seams. The total cross-section of coal increases greatly from West to northeast as one passes from the bituminous fields to the anthracite. Owing to irregularities and disturbances correlation of seams throughout the several anthracite fields, and even throughout a single one has not been very successful, much less can it be carried out between them and the bituminous fields further West. The Pottsville conglomerate is a trustworthy horizon, but the popular reference of the Monmouth seam to the Upper Freeport is less easily established. There are as many as 18 seams known, and 12-15 are

workable. The most famous of all is the Mammoth which may attain more than 100 ft. There are four main fields, and a fifth outlier. These are each more or less divided into minor basins, especially the two middle ones, by subordinate folds parallel with the main ones and by cross-folds. The four fields are all more or less closely folded synclines, and only the Northern is represented to the southwest in the bituminous basins. The names and areas of the fields are the <u>Southern</u> or <u>Schuylkill</u>, 140 sq. miles - a long narrow one, forking to the southwest and with a trend a little north of east; the <u>Western Middle</u>, 90 sq. miles, with a trend still more nearly east, and consisting of one large and two or three small outliers; the <u>Eastern Middle</u>, 40 sq. miles of about 12 more or less detached basins; the <u>Northern</u> or <u>Wyoming</u> field 200 sq. miles, practically in one long syncline, less crumpled than the others; and the <u>Loyalsock</u>, or <u>Bernice</u> or <u>Western Northern</u> with one principal and several minor basins, the latter but little developed. In the two middle fields the folding has been especially violent and has gone to the extreme of overthrown anticlines, and in the synclinal troughs to a doubling of the coal seam on itself. In the case of the Mammoth seam this has afforded a great thickness of coal. The basins have been often likened in shape to spoon-bowls or warped canoes. They have also been much protected by the upturned edges of the heavy Pottsville conglomerate (No. XII.) that underlies them. This forms a notable ridge, back from which, after an eroded valley in the Mauch Chunk shales, there is a second ridge of Pocono sandstone. The projecting conglomerate and the inner crumpled coal measures have led Macfarlane to liken them to a scroll in a conglomerate binding. Both Upper and Lower Productive Measures are present. As regards trade regions, the Western Middle and the Southern fields except the outlying Panther Creek basin, furnish what is called Schuylkill coal; the Panther Creek basin and the Eastern Middle field afford Lehigh coal, and the Northern field ships Wyoming coal. The volatile hydrocarbons run lowest in the Eastern Middle (ratio 25.53-30.35); they are somewhat greater in the Western Middle (ratio 19.87-24) and the main portions of the Southern (ratio 11.64-23.27); they are of medium amounts in the Northern (ratio 19.33-19.92) and reach the values of true bituminous in the western prongs of the Southern field (4.63-12.40). These ratios are taken from J. J. Stevenson's paper, G. S. A. V. 69. In the trade the coals are classified by general agreement, as follows, being ranged in the order of productiveness. 1. Free burning White Ash. 2. Hard White Ash. 3. Wyoming Red Ash. 4. Lehigh Red Ash. 5. Shamokin. 6. Lykens Valley Red Ash. 7. Schuylkill Red Ash. 8. Trevorton. 9. Lorberry Red Ash. 10. Bernice White Ash. The Hard White Ash commands the best prices, but the free-burning White Ash supplies about half the total (See C. A. Ashburner. M. E. Feb. 1886, cited below). The ordinary sizes as shipped are,

Broken or Grate,	thro' 4",	over 2.5"	Chestnut,	thro' 1.25",	over .75"
Egg,	" 2.5",	" 1.75"	Pea,	" .75",	" .50"
Stove,	" 1.75",	" 1.25"	Buckwheat,	" .50",	" .25"

Very coarse lumps are also separated as steamboat coal, and finer sizes, known as "rice" and "flaxseed" are now dressed out. The utilization of these latter and the saving of the huge quantities of coal in the "culm", whose unsightly banks have impressed every traveler, has

been a very serious matter in Pennsylvania, and state commissions have taken it up. The exhaustion of the seams themselves is also a very serious question. It is thought that only about 40 % of the total is obtained in mining. A. D. W. Smith of the Pa. Geol. Survey, estimated in 1892 the total original amount at 19,500,000,000 tons. Of this 2,255,-000,000 have been mined or left as unavailable pillars. At present rates of mining exhaustion will be reached in about 150 years. But of course the order of events will be after some years, a gradual increase in price, and diminution of output so that complete exhaustion will never be really attained. Nevertheless any great falling off of this incomparable household and steaming fuel, which goes all over the country east of the Rocky Mtns., will be a very serious loss. Others have figured on the same subject. P. W. Sheafer allowed them in 1879 a life of 186 years, and R. P. Rothwell in 1894, estimates 70-100 years.

Several explanations have been advanced for the origin of Anthracite, a good review of which will be found in Stevenson's paper cited below. There is no question but that the heat of neighboring igneous intrusions and perhaps attendant hot waters are able to alter bituminous coals to anthracite. Such is true in western Colorado as earlier set forth. Pennsylvania however has no igneous rocks near the anthracite. H. D. Rogers as early as 1843 connected the increased violence of the folds on the east, with the decrease in volatile hydrocarbons and referred the anthracite to metamorphism brought about by escaping steam and other vapors attendant on the elevation and crumpling. He was forced to assume a more or less cataclysmic upheaval; whereas Stevenson shows that the elevation has been so slow that the coal has adjusted itself without crushing and even the old lines of drainage have not been disturbed. J. P. Lesley in 1877, explained them as due to a heavier covering of Permian strata sufficing to raise the isogeotherms to the inferior tightness (i.e. less shales) of this load, in the east as compared with the west, and to its more fractured character, all of which favored the greater oxidation of the coal. Stevenson in 1877 and more fully in 1893, referred it to the difference in the character of the original plant deposit, as contrasted with the bituminous fields to the southwest and opposes the view that the Permian load was ever especially thick. He believes that the swamps began to spread from the eastern side of the interior Carboniferous sea, and advancing on deltas, their accumulation became greatly oxidized before they were buried By carefully tracing out relationships in fuel ratios he certainly makes out a strong case. There are undeniably many puzzling facts - on any other supposition, and perhaps even on this. For instance in the Loyalsock field there is a seam of anthracite above, & 80' lower a seam of bituminous coal. In the Vespertine coals of Virginia, the seams are near great faults and are crushed and slickensided yet they are bituminous. The Rhode Island coal which is next taken up is in a heavily metamorphosed region, and is a stage beyond the Pennsylvania coal, being more or less graphitic.

		H_2O	V. H.	F. C.	Ash	S.	Ratio	Sp.gr.
1.	Primrose Seam, S.F'd.	3.01	4.12	87.98	4.38	0.506	21.32	1.584
2.	Mammoth " " "	3.09	4.27	83.81	8.18	0.641	19.62	1.631
3.	Primrose W. M. F'd.	3.54	3.72	81.59	10.65	0.499	21.93	1.654
4.	Mammoth " "	3.16	3.72	81.14	11.08	0.899	21.83	1.657

		H₂O	V. H.	F. C.	Ash	S.	Ratio	Sp.gr.
5.	Buck Mtn. W. M. F'd.	3.04	3.95	82.66	9.89	0.462	20.93	1.667
6.	Seven Foot " "	3.41	3.98	80.87	11.23	0.512	20.32	1.651
7.	Wharton E. M. F'd.	3.71	3.08	86.40	6.22	0.585	28.07	1.620
8.	Mammoth " "	4.12	3.08	86.38	5.92	0.496	27.99	1.617
9.	" Northern F'd.	3.42	4.38	83.27	8.20	0.727	19.00	1.575
10.	B. Seam, Loyalsock.	1.29	8.10	83.34	6.23	1.03	10.29	-----
11.	Seam 60' below B.	4.13	15.27	67.36	12.71	0.523	4.41	-----
12.	Lykens Valley S. F'd.	2.27	8.83	78.83	9.39	0.676	8.91	-----

No's. 1-10 are cited by C. A. Ashburner, M. E. Feb. 1886, "Classification of Pa. Anthracites".
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Attention is called to the complete analyses earlier cited, p. 11, and to the relative amounts of hydrogen as compared with bituminous.

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RHODE ISLAND AND MASSACHUSETTS. On Narragansett Bay, R. I. from Newport to the north, Carboniferous strata from the shores extend even beyond the state line across Massachusetts to Worcester. They consist of conglomerates so metamorphosed as to be practically gneiss, of slates, which in bituminous and graphitic, of some limestone and of several coal seams. The country is buried in drift which conceals the geology. The coal was opened as early as 1808. At Portsmouth, a few miles northeast of Newport, and north of Providence toward Woonsocket it has been somewhat mined. The seams prove to be more or less irregular, from the crushing they have undergone, and the coal itself is graphitic and although the published analyses do not indicate a specially low percentage of volatile hydrocarbons it kindles with much greater difficulty than normal anthracite. Many granite intrusions are near and on Conanicut island Pirsson has shown them to be later than the Carboniferous. They may have contributed to the general metamorphism. The graphitic slates and bony coals have been ground and used for a facing to prevent iron castings adhering to the moulding sand. Many beautiful carboniferous plants and insects have been found in the measures but as fuel the prospect of their utilization is remote.

[illegible] Coal and Mining in the Southern [illegible] Fields [illegible]

[illegible] On the Flora of [illegible] Coal Field [illegible]

[illegible]

[illegible]

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(78a)

THE ACADIAN FIELD.

NOVA SCOTIA contains the important portion of this field, because the seams in central New Brunswick are small and but slightly mined. Nova Scotia has two distinct and separate areas; one on the neck of the peninsula is called the Pictou or the Joggins and lies in Pictou and Cumberland counties; the other, on the eastern side of Cape Breton island, in Cape Breton county is usually spoken of as the Sydney field. The great number of seams (over 80) in the Pictou field was earlier referred to (p. 21). Althoügh the great majority are insifnificant there are among them some of exceptional thickness. At the Albion Mines, Stellarton, the "Deep Seam" is worked at 22 ft. and the "Main Seam" is still thicker. At several other mines 10-12 ft. of coal are not uncommon. In general the dip is rather steep, 15 to 45 degrees, and the available territory is therefore restricted. There are three principal districts from west to east, the Westville, the Albion and the Vale. The coals yield consideral slack and all things considered the field is hardly as good as the Sydney.

The Sydney field is on the coast at the northeastern part of Cape Breton. It is the one that has been such a subject of interest along the New England coast from the recent purchases of the mines, by Boston capitalists. Ten or twelve workable seams 2 to 10 ft. have been identified; and four basins, the Sydney, Lingan, Glace Bay and Cow Bay are recognized. The coals dip seaward and where worked near the coast are followed out under the ocean. The dip is low and the quality good. Expectations are entertained of developing important markets along the Atlantic seaboard, the Gulf of St. Lawrence and in the West Indies.

At the Acadia Mines in the Pictou field a coal was mined before the advent of petroleum that gave a rich yield of oil on distillation. It was called Stellarite and is of some scientific interest (See J. W. Dawson, Acadian Geology, 339. Q. J. G. S. XXII. 95).

NEW BRUNSWICK. One or two small outliers of carboniferous strata in central New Brunswick contain thin seams that produce a few hundred tons annually but are of no great moment.

	H_2O	V. H.	F. C.	Ash	S.	Sp.gr.
1. Foord Pit, Pictou Field.	1.48	24.28	66.50	7.74	0.55	1.294
2. Deep Seam, " "	2.54	20.46	68.50	8.50	1.69	1.345
3. Acadia Seam, " "	2.10	32.27	57.57	7.55	0.506	1.32
4. Sydney Mine, Sydney "	---	32.74	61.54	5.72	3.37	------
5. International Mine, Syd. F'd.	---	34.09	62.92	2.99	2.26	------
6. Glace Bay, " "	---	28.62	68.14	3.24	2.29	------

1. H. How, analyst, cited in Geol. Surv. Can. 1867-69. Appendix on Pictou Coal field, p. 8. Sample from Main Seam.
2. do. do. p. 1.
3. do. p. 18.
4, 5 and 6. W. Routledge as cited below.

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" On the Coal Measures of South Joggins. Q. J. G. S. X. 1.
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C. B. Kingston. The International Colliery. Cape Breton. Trans. Can. Soc. Civ. Eng. V. 19, 1891.
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H. S. Poole. The Pictou Coal Field. M. E. XIV. 403. Rec.
W. Routledge. Sydney Coal Field, Cape Breton, N. S. M. E. XIV. p. 542. Rec.
C. Robb. Cape Breton. C. G. S. 1873-74, 171. Sydney Field. C. G. S. '72-'73, 239. Rec. '74-'75, 166-194.

Bailey & Matthew. C. G. S. 1872-73, 224.
R. W. Ells. C. G. S. 1880-81-82, 21. 1879-80, 6 D.

CANNEL COAL. Although cannel coal is essentially a variety of bituminous, it has nevertheless such distinct and characteristic properties of its own that it deserves special mention. It is sold as a separate brand and commands a much higher price than ordinary soft coals. The supply is not unlimited nor is the coal very widely distributed. Seams of cannel are especially prone to variations in quality and thickness and because of their frequent high percentage of ash their relations with bituminous shales are close. The percentage of hydrogen is also often high. The luster is dull, the specific gravity is low, and the coking powers as a rule are very inferior if not entirely lacking. Cannels more often occur as a subordinate bench in bituminous seams, than as an entire bed. Plant remains are at times recognizable, spores

have been detected in some with the microscope, and fish remains are notably abundant in a number of localities. Cannels were used as a source of "rock-oils", before the wells of petroleum began to yield their supplies, but they gave way before the latter. Of late years they have only served as a fuel for open grates and therefore as a high-priced luxury, and as gas enrichers. Our best known brands are obtained in Kentucky and West Virginia. The "Breckenridge" cannel of the former in Hancock Co. on the northeastern edge of the western coal field is a standard brand. Others are obtained in Carter and Johnson Co's. in the eastern field, from Campbell Co., Tenn. (Jellico cannel) and at Connelton, Kanawha Co., W. Va. Pennsylvania, Ohio, Indiana and Illinois have less prized varieties. Years ago Missouri afforded a curious coal from the region near the mouth of the Osage river, where it occurred in great pockets, and was called Osage cannel. Its specific gravity was at times even less than unity. A very famous little deposit in its scientific relations, was discovered at Linton, O., by Dr. J. S. Newberry - during the operations of the Ohio Geological Survey. Although but six inches thick and only a few acres in extent, it yielded 40 species of amphibians and 20 species of fish.

At the Acadia mines of the Pictow coal-field of Nova Scotia, the peculiar coal "stellarite" which was above referred to was formerly mined. It received its name because it coruscated with sparks like stars while burning and therefore is perhaps as near cannel coal in its relations as any other variety. It formed a layer 1'10" thick between, a thin bench of bituminous coal above, and a rich bituminous shale below.

The origin of cannel has been an interesting and puzzling question and an explanation of its peculiar richness in volatile products, gases, oils, tars etc, has been sought by many. Dr. Newberry in 1857, argued that the Ohio cannels were formed from thoroughly macerated plant tissue that had washed into still lagoons in the coal-forming swamp. Others have considered it to have resulted from varieties of vegetation rich in gums and resins. Some microscopic observations give ground for this view. Spore cases have appeared in many thin sections and as this form of vegetation is rich in nitrogen and hydrogen, special cannels have been referred to it. The abundance of fish and molluscous remains in some cannels, rich in oils, has suggested with great reason that the soft animal parts of these organisms have been important contributors. Inasmuch as the composition and properties vary, in different regions, all of these explanations may have applications. A very complete review of literature and localities is given by Zincken in the paper cited below.

	H_2O	V. H.	F. C.	Ash	S.	Sp.gr.
1. Breckenridge, Ky.	----	53.53	34.37	12.10	1.89	-----
2. Grayson, Carter Co., Ky.	----	63.5	31.7	4.8	1.32	-----
3. Whitehouse, Johnson Co. Ky.	----	36.48	54.72	8.80	0.956	-----
4. Connelton, W. Va.	----	39.82	52.78	7.40	1.162	-----
5. Jellico, Tenn.	----	49.85	35.03	15.12	0.74	-----
6. Osage, Mo.	1.67	41.83	51.16	5.34	0.4	-----
7. Lower Freeport, Jeff. Co. Pa.	0.51	30.49	46.19	22.23	0.576	-----
8. Stellarite, Nova Scotia.	0.23	66.56	25.23	8.21	-----	1.103
9. Boghead, Scotland.	----	63.53	11.60	24.87	-----	-----
10. Wigan.	----	39.64	57.66	2.70	-----	1.276

Have been detected in many [illegible], but they are notably abundant in a number of localities. [illegible] "rockhounds" [illegible] [illegible] [illegible] Kentucky and West Virginia. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] W. Va. [illegible] Geological Survey. [illegible]

[illegible]

The origin of [illegible] [illegible] [illegible]

[illegible]

		C.	H.	O.	N.	S.	Ash
11.	Spores of Lycopodium.	64.30	8.73	6.13	20.19	-----	-----
12.	Lancashire Cannel, Eng.	85.75	5.66	8.04		-----	-----
13.	Boghead, Scotland.	61.04	9.22	4.40	0.77	0.325	24.23
14.	Wigan.	80.07	5.53	8.08	2.12	1.50	2.70

1, 2, 3, and 4, are recalculated from G. Macfarlane. M. E. Feb. 1890.
5. M. R. 1887, 357.
6. J. Macfarlane, Coal Regions of America, p. 474.
7, 9, 11, 12, and 13, Zincken as below 1st citation.
8, 10, and 14, How, Mineralogy of Nova Scotia, p. 24.

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J. S. Newberry. Method of formation. A. J. S. ii. XXIII. 212. Geol. Ohio, II. 125.
C. F. Zincken. Die Cannelkohle, Oest. Zeitschr. f. Berg. u. Huettienwesen, 1887 (Series of papers with good bibliography). Rec. See also Berg. u. Huet. Zeitung, July 1, 1881.
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BITUMINOUS SHALES may be considered coals or especially cannel coals high in ash. There is no line of demarkation but as the ash reaches 30-40 %, the seam can hardly be called a coal seam, nor above 90 or 95 % ash is it very highly bituminous. Bituminous shales are black or brown and if rich in bituminous matters they may be tough and leathery. In this country there are some, which are low in carboniferous substance but which are of enormous extent, such as the Marcellus and Genesee shales in New York and the Huron shale of Ohio. No such rocks have been found of value in this country as yet, but they have been regarded as possible future sources of petroleum should the wells give out. P. Neymann obtained from 100 grams Huron shale, oil at the rate of 10.78 gallons per ton. The famous "Torbanite" of Scotland yields 116-125, "stellarite" of Nova Scotia, just referred to, 53, cannel coals, 32-88, asphaltic coals up to 100, Australian "Kerosene Shale" 80, so that the adaptation of the low-grade American shales is a remote contingency. The origin of the bituminous matter involves the same discussion as is given above under cannel.

		H_2O	V. H.	F. C.	Ash	Sp.gr.
1.	Cleveland Shale, O.	1.10	6.90	4.90	87.10	----
2.	Huron Shale, O.	0.86	8.36	6.18	84.60	----
3.	" " "	1.06	17.95		80.99	----
4.	Genesee Shale, N. Y.	0.85	8.35		90.80	----
5.	Shale with Stellarite.	----	30.65	10.88	58.47	----
6.	Torbanite, Scotland.	----	71.17	7.65	21.18	1.17

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H. M. Cadell. Oil Shales of Scottish Carboniferous System. Jour. Geology, II. 243.
T. S. Hunt. The Pyroschists, Chemical and Geological Essays.

J. S. Newberry. Origin of the Bituminous matter in Bituminous Shales. Ann. N. Y. Acad. Sci. II. No. 12, 1883.
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C. F. Zinkken. As cited under Cannel - above.

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SUMMARY OF THE STRATIGRAPHY OF COALS AND LIGNITES.

CENOZOIC - TERTIARY SYSTEM.

Only peat and incoherent lignite occur in strata later than the Miocene.

MIOCENE SERIES. ALASKA.

EOCENE SERIES. Tejon stage. OREGON, Coos Bay. CALIFORNIA, Monte Diablo.
Wahsatch stage. UTAH, San Pete.
Eolignitic stage. TEXAS, San Tomas and other lignites.
Fort Union or Livingstone stage (Many consider this Laramie). MONTANA, Rocky Fork Field.

MESOZOIC - CRETACEOUS SYSTEM.

LARAMIE SERIES. WASHINGTON, Puget Sound and Roslyn Fields. VANCOUVERS ISLAND, some ALBERTA lignites. MONTANA, Bozeman and Cinnabar Fields. NORTH and SOUTH DAKOTA, lignites. WYOMING, Southern Fields. UTAH, Weber River Field, Pleasant Valley Field, New Harmony Field. COLORADO, practically all the coal. NEW MEXICO, all the coal so far as known. TEXAS, San Carlos Field, Eagle Pass Field. MEXICO, Rio Sabinas Field.

MONTANA SERIES. "Pierre" stage. ALBERTA, Lethbridge coal.

COLORADO SERIES. UTAH, Kanaraville and Cedar City.

DAKOTA SERIES. COLORADO, Lower coals of La Plata Field. WYOMING, Weston Co. The coals have usually been referred to the Dakota Series, but lately discovered fossil plants may prove them Kootanie (Science, Feb. 1, 1895, p. 137).

KOOTANIE SERIES. ALBERTA, Cascade Valley Anthracite. MONTANA, Great Falls Field (Queen Charlottes Is. anthracite is described as Lower Cretaceous).

MESOZOIC - JURA-TRIAS OR NEWARK SYSTEM.

VIRGINIA, Richmond Field. NORTH CAROLINA, Deep and Dan River Fields.

PALAEOZOIC - CARBONIFEROUS SYSTEM.

PERMIAN SERIES. The Washington seam and some other thin ones in the Upper Barren Measures of Pennsylvania and adjoining states.

PENNSYLVANIAN SERIES. Coals of the Western and Eastern Central Fields; of Michigan; of Rhode Island; of Nova Scotia and nearly all of the Appalachian Field.

MISSISSIPPIAN SERIES. Verpertine coals of southwest Virginia.

NOTE. In the Cretaceous coals do not confuse the names of Dakota, Colorado, and Montana, used at the left for geological series, with the same employed in the purely geographical way. It is evident that the Laramie series of the Cretaceous in the West, and the Pennsylvanian series of the Carboniferous in the East, afford almost all the coal mined; but the Kootanie is of growing importance.

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BRIEF STATISTICS. The following statistics for 1893 (except 16a which is for 1892) are serviceable as they give an idea of the relative importance of the productive regions. They are arranged in order by states, territories, and provinces. Short tons (2,000 lbs.) are here used. It is well to remember that a long ton (the usual unit at the mines) is 2,240 lbs., and the metric ton (the European unit) is 2,204.6 lbs., or practically 1.1 short tons.

1.	Pennsylvania total,	98,038,267	14.	Tennessee, - - - - - -	1,902,258
	Anthracite,- -	53,967,543	15.	Washington,- - - - - -	1,264,877
	Bituminous,- -	44,070,724	16.	Ind. Territory,- - - -	1,252,110
2.	Illinois,- - - - -	19,949,564	(16a	Alberta & Brit. Col.)	1,106,393
3.	Ohio,- - - - - - -	13,253,646	17.	Montana, - - - - - - -	892,309
4.	West Virginia,----	10,708,578	18.	Virginia,- - - - - - -	820,339
5.	Alabama, - - - - -	5,136,935	19.	New Mexico,- - - - - -	665,094
6.	Colorado,- - - - -	4,102,389	20.	Arkansas,- - - - - - -	574,763
7.	Iowa,- - - - - - -	3,972,229	21.	Utah,- - - - - - - - -	413,205
8.	Indiana, - - - - -	3,791,851	22.	Georgia, - - - - - - -	372,780
9.	Maryland,- - - - -	3,716,041	23.	Texas, - - - - - - - -	302,206
10.	Kentucky,- - - - -	3,007,179	24.	California,- - - - - -	72,603
10a.	Nova Scotia, - - -	2,811,693	25.	North Dakota,- - - - -	49,630
11.	Missouri,- - - - -	2,897,442	26.	Michigan,- - - - - - -	45,979
12.	Kansas,- - - - - -	2,652,546	27.	Oregon,- - - - - - - -	41,683
13.	Wyoming, - - - - -	2,439,311	28.	North Carolina,- - - -	17,000
				Total, - - - - - - - - - - - - - - - - - -	182,352,774

CHIEF COAL PRODUCING COUNTRIES. SHORT TONS.

1.	Great Britain(1893)	184,044,890	8.	New South Wales (1892)	4,226,000
2.	United States(1893)	182,352,774	9.	Canada (1893)- - - - -	3,719,170
3.	Germany (1892) - -	103,851,090	10.	Japan (1893 -- - - - -	3,400,000
4.	France (1892)- - -	28,862,017	11.	Spain (1893) - - - - -	1,688,820
5.	Austria (1892) - -	28,037,678	12.	New Zealand (1892) - -	673,815
6.	Belgium (1892) - -	21,590,448	13.	Sweden (1892)- - - - -	421,155

7. Russia (1892) - - - 7,621,969 14. Italy (1892) - - - - - 326,340

These statistics are from the Mineral Resources U. S. 1893, pp. 200, & 202. Mineral Industry, 1893, metric tons being changed to short tons.

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CONCLUDING REMARKS. The great part played by coal in modern civilization is a favorite theme for more or less fervid rhetoric but the significance of the above statistics can only be appreciated by computing the equivalent footpounds of work according to modern thermodynamics. Jeules equivalent is 772 footpounds. A pound of bituminous coal represents 10,570,147 footpounds; a pound of anthracite 11,028,715, or say for a pound of coal in general 10,000,000 footpounds of work.

	Footpounds per day	Equivalent lbs. of coal
A man raising his own weight on stairs or ladder develops -	2,088,000	0.21
A man carrying weight up & returning unloaded -	399,600	0.04
A man pushing or pulling horizontally - - - - -	1,526,400	0.15
A man working a pump- - - - - - - - - - - - - -	1,188,000	0.12
A horse walking with a boat or cart - - - - - -	12,441,600	1.24
A horse cantering & trotting with a railway truck	6,444,000	0.64

The efficiency of a steam engine is 10 %. Statistics show that it takes from 17-26 men to mine 10,000 tons per year in different states. The larger states are below 20, but one may select 20 as a fair average. That is 500 tons per man, per year, or about two tons per working day. In other words a man produces per day 4,480 lbs. of coal, equal to 44,800,000,000 footpounds of work, of which an engine makes 10 % or 4,480,000,000 effective. In this way comparing the work of a man as given in the above table, with the available footpounds in the coal, we see that a man multiplies under present conditions his strength from 2,200 to 11,200 times, using round numbers and is equivalent to from a sixth to a third as many horses. No more emphatic commentary could be adduced on the importance of coal, and yet no mention is made of the additional comforts, of warmth, light and convenience in cooking, etc. afforded by it.

NOTE. Graphite is treated after asphalt, for it appears to be a metamorphosed product from petroleum or something similar, quite as often as from vegetable tissue.

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CHAPTER IV. THE PETROLEUM SERIES.

The general name of the Petroleum Series is meant to include a group of minerals of widely varying physical properties and of exceedingly complex chemical composition. They each consist of several molecules and no one formula can be conceived to express the composition in an individual case, any more than it can of a coal, yet it is possible from elementary as well as proximate analyses to gain an idea of the elements involved and of their relative amounts. The ordinary process of alteration through which these substances pass in Nature, is in gen-

eral one of oxidation and much the same may be said of them as was earlier stated of coal. To a certain degree they correspond to the "Evolved Products" of the table on p. 4, but as they have not all been derived from vegetable materials, but clearly in some important cases from animal remains, this expression as there used cannot be sweepingly applied. Petroleum is selected as a generic name for the series because it is the mineral which may be considered with good reason, to be the source of the others in almost all cases. There is excellent ground for believing that all are of organic origin.

The series includes a succession of minerals, from an extremely light gas, to a perfectly solid asphaltic coal, or even to graphite, and individuals may be selected so as to give an almost unbroken series from one extreme to the other. The gases are grouped under the general name, natural gas. The oils from light to heavy are called petroleum. The tarry minerals that are at least ropy and viscous at ordinary temperatures are known as maltha. Those that are solid at ordinary temperatures constitute asphalt, and those that are brittle and jet-like, and resemble glauce coal, are the asphaltic-coals. Graphite occurs in such relations at times as to be evidently derived from some one of the petroleum series. At Ticonderoga, N. Y. for example it is in a fissure vein with feldspar, calcite, pyroxene etc. Besides these there are so-called natural waxes or ozocerite and a number of fossil gums or resins.

	Percentages by Volume.								Percentage in C_nH_{n+2} by Weight	
Natural Gas.	C_nH_{n+2}	C O	C O	N.	H_2S	H.	O.	C_nH_{2n}	C.	H.
1. Sandstone Gas	90.64	----	0.30	9.06	----	----	tr	----	76.69	23.31
2. " "	97.70	----	0.20	2.02	----	----	tr	----	74.96	25.04
3. Shale "	90.05	----	0.41	9.54	----	----	tr	----	78.14	21.86
4. Limestone "	93.35	0.41	0.25	3.41	0.20	1.64	0.39	0.35	-----	-----
5. " "	94.16	0.55	0.29	2.80	0.18	1.42	0.30	0.30	-----	-----
	Percentage by Weight.									
Petroleums.	C.	H.	N.	S.	O.					
6. Sandstone Oil	85.2	13.359	0.54	----	-----	-----	-----		-----	-----
7. Shale "	86.934	11.819	1.109	----	-----	-----	-----		-----	-----
8. Limestone "	------	------	-----	----	-----	-----	-----		-----	-----
Maltha.										Sp.gr.
9. Ohio	84.2	13.1	-----	----	~~2.7~~	-----	-----		-----	0.887
Asphalt.										
10. Trinidad	85.89	11.06	-----	2.49	-----	-----	-----		-----	-----
Asphaltic Coals.						V. H.	F. C.		Ash	
11. Grahamite	------	------	-----	-----	-----	55.	42.		3.0	------
12. Albertite	87.25	9.62	1.75	----	-----	54.39	45.44		0.17	1.091
13. Uintaite	78.43	10.20	2.27	----	8.70	-----	-----		.40	1.058

	C.	H.	N.	S.	O.	V. H.	F. C.	Ash	Sp.gr.
Ozocerite.									
14. Utah	85.44	14.45	-----	----	-----	-----	-----	-----	------
Resins.									
15. Amber	78.94	10.22	-----	----	10.9-	-----	-----	-----	------

Note. C_NH_{2N+2} is the general formula for the "paraffines" or marsh gas series; C H for the olefines.

1, 2, and 3, by F. C. Phillips. Pa. Geol. Surv. Ann. Rep. 1886, 815. No. 1, Sheffield, Warren Co. Pa. No. 2, Murraysville, Westmoreland Co. Pa. No. 3, Fredonia, N. Y.
4 and 5, by C. C. Howard. Geol. Surv. Ohio, VI. 137. No. 4 is Findlay O. No. 5 Kokomo, Ind. Both from Trenton limestone.
6 and 7, Tenth Census. Vol. X. p. 53. No. 6 Cumberland, W. Va. No. 7 Hayward Co. Calif.
8.
9. St. Claire-Deville as quoted by Kretzsch Geol. d. Kohlenlager, 72.
10. H. C. Bowen for F. V. Green. M. E. Oct. 1888. Undetermined 0.56.
11. Quoted by Macfarlane. Coal Regions of America, 288.
12. Quoted in Geol. Surv. Can. 1867-69. Appendix to Rep. on Pictou Coal Field, p. 16.
13. J. M. Locke, M. E. July 1887. See also W. P. Blake, M. E. Feb.1890
14. Quoted by E. B. Gosling, S. of M. Q. XVI. 44, Nov. 1894.
15. Schrotter Pogg, Annalen LIX. 64. It varies, C. 73-79, H. 9-10.5, O. 10.5-17.3.

A brief comparison of the analyses shows that carbon and hydrogen are the principal elements involved in all. As compared with the ash-free, elementary analyses of coals on p. 12, the range in carbon is much the same. The oils and asphalts are richer in this element than common coals although inferior to anthracite, but in hydrogen they surpass all coals. The paraffine, marsh gas or methane series (C_NH_{2N+2}) is the principal one present. In natural gas the paraffines above butane (C_4H_{10}) are doubtless absent because they are liquids at ordinary temperatures. Much the most abundant one present is C H which has by weight C. 74.97, H. 25.03, values near No. 2. The higher paraffines increase in amount with the increase in the specific gravity of the minerals. The components of ozocerite for instance have, carbon multiples mostly between 20 and 30. The olefine series (C_NH_{2N}) is relatively more abundant in the liquids and solids, and is of small account in the gases. It is improbable that the nitrogen has been derived from admixtures of atmosphere, because of the small amount of oxygen in any form that accompanies it.

The above classification has been based on the physical properties of the minerals, whether gas, liquid or solid, and none are introduced in the condition of mixtures with foreign matter. In the group of asphalts there are some which saturate limestone or other rock and in this form have important applications. Influenced by considerations of the latter kind some writers (as for instance Malo - and F. V. Greene as later cited under asphalt) give these mixtures great prominence; but as Blake points out, in a scientific scheme of classification accident-

al mixtures had better be ignored (M. E. Feb. 1890). The chemical composition is so complex that it is not a good basis. In most of these minerals we are at a loss how to group the atoms. The most that can be done is to contrast the oxygenated hydrocarbons, such as uintahite and the resins, with the simple hydrocarbons such as gas, oil and ozocerite.

NATURAL GAS. Although known from the earliest historic period in the oriental countries, and frequently met in the drilling of brine and petroleum wells before 1880, natural gas has only been practically utilized on a large scale within the last ten or fifteen years. Its treatment cannot be taken up otherwise than in close connection with petroleum for the productive regions, broadly considered, are the same and where one is found the other may be expected with considerable certainty. Natural gas is colorless and of variable specific gravity. Calling air 1.00, Orton states (Ky. Geol. Survey Rep. on Petroleum etc. 1893, p. 106) that Pennsylvania gas (sandstone gas) ranges from .51-.54. Findlay, O. gas from the Trenton limestone has been determined at .57 and .60. Others of locality not stated have reached .87. Increase of CO_2 (Sp.gr. 1.5241), of N. (Sp.gr. .974), of CO (Sp.gr. .972) or HS (Sp.gr. 1.17) raises the density, while increase of CH_4 (Sp.gr. .559) and of H (Sp. gr. .069) keeps it low. The varieties with even the slight percentage of H_2S have a strong, offensive odor, but the sandstone gases that lack it have a not unpleasant smell. From the same geological sources, the composition is surprisingly uniform; to such an extent, indeed, that Analysis 1, above, answers quite well for the general run of sandstone gas and No. 4 for that from limestone.

PETROLEUM. Crude petroleum varies much in appearance. The lightest oils are straw-color; the usual run of Pennsylvania and New York oils are greenish, and the limestone oils of Ohio and elsewhere are dark brown or nearly black. Oils are compared on the basis of density and this is expressed in degrees of the Beaumé scale. It is well to bear in mind that our usual specific gravity of 1. or of water is 10° Beaumé; 25° B = .9032, 70° B = .7. The formula of reduction is $\frac{140}{sp.gr.} - 130$ = degrees Beaumé. Oils from Allegany Co. N. Y. run 38-41 B; McKean and Venango Co's. Pa. 46-48 B; Warren Co. Pa. 43 B; Lima, O. 36-38 B; Florence, Col. 30 B; Wyoming surface oils, 25 B. The general average of Russian is 32 B. The bearing of this is, that with lighter oils, there is a better yield of illuminants (38-60 B) which are the products chiefly sought. The chief hydrocarbons present are the members of the paraffine series, with perhaps some olefines. The most troublesome substance is sulphur, in the form of complex sulphurous hydrocarbons. Some oils have nitrogen, as in California where surface pools become filled with larvae. When Pennsylvania oils stand a dark sediment settles out, called "B. S." which decreases the yield of illuminants and lowers the price.

GEOLOGY OF PETROLEUM AND NATURAL GAS. These substances in small quantities are wide spread, and almost all sedimentary rocks have at least traces. Some years ago, Professor Wright of Yale, detected an appreciable amount of a bitumen in the pegmalitic quartz of Branchville Conn. famous for its inclusions of carbonic acid (A. J. S. Mar. 1881, 209). Prof. Wm. Libbey of Princeton recently (1893) obtained spectro-

scopic evidence of burning hydrocarbons in the flames which play on the lava of the Sandwich Island craters. A. J. S. May 1894, 371. Even a very small percentage of hydrocarbons in a thick rock stratum constitutes a total of vast amount. Orton states that .02 % in a 1,000 ft. of rock would supply, if available, a greater yield per acre or square mile, than the richest of our developed fields, & that this is an amount that rarely fails in the rocks of the Ohio valley.

It is to be emphasized at the outset that in our eastern American localities gas, oil and salt water always go together, but of course in all manner of relative amounts. In the earth they are arranged in the order of their densities, the lightest on top.

In the geological problem of origin there are two main questions, viz. whence has the material come, and how has it been concentrated? The first separates at once into the two; is it of inorganic or of organic derivation, and what chemical reactions have led to its formation? In America almost no one seriously doubts that our local deposits are derived from organic matter, which has been originally buried in or below the strata that now afford the oil or gas. Abroad other views have had some acceptance and even seem to have impressed at least one American geologist with their claims to serious attention (See G.F. Becker, The Cosmopolitan Magazine, Dec. 1894, 256). They will however be dismissed with the mere statement.

INORGANIC HYPOTHESES. Bertholet (1866) as the result of experiment, stated that the hydrobarbons of the petroleum series could be produced by the reaction at a high temperature of water carrying carbonic acid in solution, upon alkalies if such existed in a metallic state in the interior of the earth (Annales, Chem. et Phys. IX. 481). Mendelejeff (1877) attained similar results by the reaction of water and carbonic acid upon metallic iron and metallic carbides. These he then assumed to exist in the earth's interior (Revue Scientifique 1877, 409).

It may be merely stated that this existence of metallic alkalies of carbides of iron in the interior of the earth is a pure speculation, and the difficulty of conceiving that the products of the reactions would pass upward through the many thousands of feet of overlying strata, is too great for most minds.

ORGANIC THEORIES. Granted an organic source, the question arises as to whether it was vegetable or animal. It is quite certain that oils from shales and sandstones are of vegetable origin, but that those from limestones have been derived from animal remains. The absence of sulphur in the composition of the former, and the accumulation of the latter under circumstances unfavorable to plant life give good ground for this view. Some California oils from shales seem to have also had an animal origin.

Differences of opinion have prevailed as to the course and causes of the changes from organic tissue to oil and gas. T. S. Hunt (1863 and later) advanced the view that they were developed in the ordinary processes of decomposition, and that they were indigenous in or near the rocks in which they are found. J. S. Newberry (1859 and later) explained them as due to a spontaneous distillation at low temperatures. "Distillation" implies heat and the process thus differs from Hunt's [illegible] evidence of burning hydrocarbons in the fissures which play on the base of the Canadian inland [illegible]. A. [illegible] 1904, 311. Even a very small percentage of hydrocarbons in a thick rock stratum totals [illegible] a total of vast amount. Orton states that .02 % in a 1,000 ft. of rock would supply, if available, a greater yield per acre or square mile, than the richest of our developed fields, & that this is an amount that rarely fails in the rocks of the Ohio valley.

It is to be emphasized of the extent that in our eastern American localities gas, oil and salt water always go together, but of course in all manner of relative amounts. In the earth they are arranged in the order of their densities, the lightest on top.

In the theoretical problem of origin there are two main questions, viz, whence was the material made, and how has it been concentrated? The first expresses at once into the query is it of inorganic or of organic derivation, and what chemical reactions have led to its formation? In America almost no one seriously doubts that our local deposits are derived from organic matter, which has been originally buried in or below the strata that now contain the oil or gas. Abroad since [illegible] have had some advocates and even now in rare instances at least one American geologist still claims an inorganic origin ([illegible] Becker, The Cosmopolitan Magazine, Dec. [illegible]). These will however be [illegible] with the facts [illegible].

INORGANIC HYPOTHESES. Berthelot (1866) as the result of experiments, stated that the hydrocarbons of the petroleum series could be produced by the reaction at a high temperature of water carrying carbonic acid in solution, upon alkalies if such existed in a metallic state in the interior of the earth [illegible]. Mendelejeff (1877) obtained similar results by the reaction of water [illegible] metallic iron and carbides were used. [illegible] to exist in the earth's interior [illegible].

It may be merely stated that this existence of metallic alkalies [illegible] in the interior of the earth is a pure speculation, and the difficulty [illegible] that the products of the reactions would [illegible] the many thousands of feet of overlying strata [illegible] for such a [illegible].

ORGANIC THEORIES. Granted an organic source, the question arises, is it from [illegible] vegetable or animal. It is quite certain that [illegible] from plants and substances are of vegetable origin, but that there [illegible] have been derived from animal remains. The absence of [illegible] in the composition of the former, and the accumulation of the [illegible] through which [illegible] in plant life give [illegible] California oils from shales seem to have [illegible] and [illegible].

[illegible] of opinions have prevailed as to the fauna and [illegible] which [illegible] to oil and gas. [illegible] (1863) [illegible] that they were localized in the [illegible] of [illegible], and that they have [illegible] in the [illegible]. [illegible] (1888) and [illegible] [illegible]. [illegible] and [illegible] from [illegible].

[illegible]

who does now necessarily assume temperatures above the ordinary. S. F. Peckham following out Newberry's idea referred the heat to the folding and upheaval of the Appalachian mountain ranges in Pennsylvania.

The difficulty of detecting the presence of any notable increase above surface temperatures in the oil wells and the absence of any large upheaval in the Ohio fields have led to increasing faith in the reactions cited by Hunt, and for limestone oils there is little reason to question them. The general barrenness of the sandstones that carry oils, etc. in traces of organisms, has led most geologists to favor Newberry's idea of the source in lower lying bituminous shales, whence the hydrocarbons have ascended.

The concentration and storage of oil and gas depend upon cavities of some sort in the rocks which hold them. E. B. Andrews first gave definite expression to the view that there were subterranean cavernous fissures in which gas, oil and brine ranged themselves in the order of their specific gravities. It was considered a matter of chance whether the drill struck such a cavity, and according to the point penetrated the well would yield gas, oil or brine (A. J. S. ii. XXXII. 39, 1861). This idea has been practically abandoned.

It was early noted both in Ontario and West Virginia that the wells were ranged in anticlines, but no great importance was attached to the relations at the time. In 1885 the work of I. C. White in western Pennsylvania and in the years following the observations of Edw. Orton in northwestern Ohio, have developed what is known as the "anticlinal" theory of storage and one that has proved of great scientific and economic value. In Orton's expressive phrase, porosity and relief are necessary to concentration, the former to admit of accumulation, the latter to occasion it. Anticlinals in whose stratigraphy a tight shale is involved, and which overlies a porous sandstone, conglomerate, or dolomitized limestone furnish the most favorable places. Gas and oil gathering or ascending under the impervious shale, in the porous receptacle, from some bituminous source around or below, will force away the brine left in the rock from its original deposition in the sea, and accumulate under hydrostatic pressure, proportionate to the depth of the porous stratum below its outcrop. The gas will be at the crest, the oil beneath, the brine still lower. A well at the crest yields gas, on the flanks, oil, and further out brine. It must be remembered that anticlinals rise and fall along the strike of the axes, & that the heights are especially favorable. It is also true that not everywhere is the receptacle sufficiently porous, and nor is the cap of shale always tight, so that an anticline does not necessarily imply gas or oil. The anticlines or even monoclines are often quite slight and close leveling was necessary at the outset to prove them. In this and in the determination of the depth of the oil sand or gas rock the need of a universal datum was felt and now even for the interior the sea level is used - it having been widely established by railway surveys. Maps have even been constructed in Ohio showing the varying depths as referred to the sea-level, at which an oil or gas rock might be expected. They are thus a sort of negative topographical-geological map.

Although anticlines have been shown to be the determining cause of the location of oil and gas pools in almost all cases, yet geologists of weight and experience (J. P. Lesley, C. A. Ashburner and others) have disputed the necessary connection and have argued against the uni-

versal application of the idea. Local porosity would then be the only determining factor. Anticlines have undeniably proved in recent years a great aid to the prospector.

GENERAL LITERATURE:

Note. A very complete bibliography up to and including 1880 will be found in Peckham's report for the 10th Census, cited below. It is reproduced with additions bringing it down through 1886 in Part II. Annual Report for 1886, Penn. Geol. Surv. 830. In the citations here only works of special importance or of general application are given and these have been mostly issued since 1886. A short bibliography especially on the technology of oils closes the paper of H. C. Folger mentioned below.

________. Some Recent Speculations on the origin of Petroleum. Amer Geol. IV. 371.

E. B. Andrews. Petroleum in its Geological Relations. A. J. S. ii. XLII. 33.

" See also Rock Oil, its Geological Relations and Distribution. A. J. S. ii. XXXII. 85. First shows the cavity theory. See also A. J. S. ii. XXXVIII. 159.

W. J. Buck. Early Accounts of Petroleum in the U. S. Hist. Soc. Penn. Mar. 13, 1876. Mineral Pamph. Cornell Library, Vol. I.

Calif. State Min. Rep. 1887, 17-23.

J. F. Carll and F. C. Phillips. On the Oil and Gas Region, Penn. Ann. Rep. Penn. Geol. Surv. 1886.

J. D. Dana. System of Mineralogy. Chap. on Minerals of the Hydrocarbon gp.

J. F. Carll. Many valuable reports in 2nd Geol. Survey of Penn. lettered I. II. III. up thro' I5. A general discussion is in III. 270.

H. C. Folger Jr. Petroleum, its Production and Products. Industrial Statistics of Penn. in Annual Report of Secretary of Internal Affairs of Penn., 1892. Part III. p. B1 to B208. Rec. A very valuable paper.

C. H. Hitchcock. Petroleum in N. Amer. Geol. Mag. IV. 36, 1867. 1867, p. 623. Rec. Neues Jahrb. 1867, p.623.

Hanns Halfer. Petroleum & its contents. Reviewed in E. & M. Jour. Aug. 4, 1888, p. 81.

T. S. Hunt. Contributions to the Chem. & Geol. History of Bitumens and Pyroschists or Bituminous Shales. A. J. S. II. 33, 157. See also Chem. and Geol. Essays.

J. J. Jahn Zur Frage über die Bildung des Erdöls. Jahrbush d. K. K. Geol. Reichsaustatt, Vienna, 1892, p. 361. Shows the chemical possibility of a derivation from animal remains, and endeavors to prove that this is consistent with observed geological facts.

C. F. Maleery. On the Composition of certain Petroleum Oils and of refining Residues. Proc. Amer. Acad. Arts & Sciences, Vol. XXV. Dec. '90, p. 218.

Mendelieff Theory. Theory of the Formation of Petroleum. E. &. M. Jour. Dec. 22 '88, p. 525.

J. S. Newberry. Rock Oils of Ohio. Ohio Agricultural Rep. 1859.

J. S. Newberry. The First Oil Well. Harpers Mag. Oct. 1890.
F. Orton. Geol. Ohio, Vol. VI. Chap. II. p. 60. Rec.
" Petroleum, Natural Gas, etc. in Kentucky. Ky. Geol. Survey 1894. Good review of origin. Rec.
S. F. Peckham. 10th Census. Vol. X. p. 3. Rec.
" Abstract of Chap. V. in A. J. S. III. 28, 105. Called The Origin of Bitumens.
F. C. Phillips. Researches on the Chem. Prop. of Gases. Amer. Phil. Soc. XVII. Part III. Trans. 149, Origin of Nat. Gas & Petroleum, 225. Many anals. 224.
Riche and Roume. L'Industrie du pétrole aux Etats Unis, d'Amerique Annales des Mines, 1894, 67-130.
J. D. Weeks. Annual Reviews in Mineral Resources, U. S. Geol. Survey, 1893. Rec.
" Mineral Industries 11th Census, pp. 423-578. Rec.
I. C. White. Anticlinal Theory. Sci. June 26, 1885.
See also Ashburner. Sci. July 1885.
The Mannington Oil Field. Bull. Geol. Soc. Amer. III. 187, 1892. Contains a good resumé of the Anticlinal Theory.

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PETROLEUM.

GEOGRAPHICAL DISTRIBUTION AND STRATIGRAPHY

OF THE

CHIEF PRODUCING REGIONS.

The following table shows the relative importance of the several states in 1893, in barrels of 42 gallons. The figures are from the Mineral Resources for 1893, p. 463.

	1892	1893
Pennsylvania,	27,149,034	19,283,122
Ohio,	16,362,921	16,249,769
West Virginia,	3,810,086	8,445,412
Indiana,	698,068	2,335,293
New York,	1,273,343	1,031,391
Colorado,	824,000	592,390
California,	385,049	470,179
The others,	6,635	3,110
	50,509,136	48,412,666
Russia,		33,104,126
Canada,		798,406

It is difficult to secure correct figures of neighboring states because of the mixing of products in pipe lines. In the above, Pennsylvania, West Virginia and New York afford sandstone oils; Ohio, Indiana and Canada limestone oils; colorado and California shale oils.

The productive regions in a large way will be called fields. The fields will be subdivided into districts. Following the usage of J. D.

Weeks as established in the Volumes of the Mineral Resources, there are

1. Appalachian Field, including districts in southwestern New York, western Pennsylvania, West Virginia, eastern Ohio, eastern Kentucky and some prospects in Tennessee, Alabama and Georgia.
2. Lima-Indiana Field, in northwestern Ohio and eastern Indiana.
3. Enniskillen Field, Ontario.
4. Florence Field, Colorado.
5. Southern California Field.
6. Scattered and Minor Fields.

THE APPALACHIAN FIELD begins in New York and runs in several belts southwestward into West Virginia. The oils and associated gas are all obtained from sandstones of the upper Devonian (Chemung and Catskill) or of the Carboniferous as high as the Pottsville Conglomerate. Oftentimes close stratigraphical determinations are difficult to make on account of the similarity of the beds. There may be several productive horizons, in the same district, which themselves are but a few feet thick and which are invariably porous sandstones or conglomerates. Allegany Co. N. Y. is the extreme northerly one and derives its supply from Chemung strata. In Cattaraugus Co. next west the Bradford district begins and runs southwest into McKean Co. Pa. The Chemung strata yield the output. The productive beds are a dark brown or black sandstone, called "black sand" as distinguished from the lighter colored sands earlier tapped in Venango Co. Penn. Collectively all the above are often called the "Northeastern field" using "field" in a more restricted sense than it is employed above. The wells have a small average production, 2/2 barrels daily in Alleghany Co., 8 in the Bradford district, but are long lived and reliable. Southwest from the Bradford district but on the same general belt are a number of separated pools in Warren and Forest Co's. forming the "Middle Field". The horizon is still Chemung. Although the oils differ more or less among themselves they are generally called amber oils. The wells average 8 bbls. daily. Still further southwest lies the "Lower Field" chiefly in Venango, Clarion and Butler Co's. There are three sandstones called the 1st, 2nd and 3rd, within about 350 ft. They were the first ones tapped in 1859-60, and led to the great excitement of those years. Where all three are present the oil is found in the lowest. They belong to the Catskill strata. The wells were drilled in the valleys at first, but later on additional ones located on the hills, struck higher sands which were called "Mountain Sands", but they never produced much. The wells today average 7-21 bbls. each 24 hours. Near Franklin the yield is lubricating oil. Several outlying pools in Beaver and Laurance Co's from the Pottsville conglomerate and the Berea grit are also included in this Field. In Allegany Co. south of Pittsburg, and in Washington and Greene still further south are a number of other districts which make up the Southwestern Field. The best known is the McDonald of Allegany Co. which after an opening career of phenomenal production has dropped off.

WEST VIRGINIA contains a southern extension of this Southwestern Field in the Mannington district, which was located by I. C. White in accordance with the anticlinal theory as described in his interesting paper cited below. The oil is obtained in what is called the Big Injun

sand, a member of the Pocono. Further west and south from Marietta on the Ohio river are the two pools at Volcano and Burning Springs, known for many years and of which the former yields lubricating oil (31 B). The horizon is the Big Injun sand of the Pocono. More recently developed districts are the Turkey Foot in Hancock Co. in the extreme northerly end of the Panhandle, the Sistersville in Tyler Co. and the Eureka in Pleasant Co. both on the Ohio river. For the immense increase in the production of West Virginia these last are responsible.

Eastern Ohio contains two or three districts closely associated with those of West Virginia. The Macksburg district is an old one that lies just north of Marietta and for many years has produced oil from the Berea Grit of the Lower Carboniferous, along a monocline. The Sistersville and Eureka districts of West Virginia extend into Ohio and yield oil from the Pocono. In northeastern Ohio, the Mecca-Belden district has long afforded a lubricating oil from the Berea grit. The chief districts of Ohio lie outside the Appalachian Field and differ from it in geological relations so much as to demand special treatment.

LITERATURE OF NEW YORK:

C. A. Ashburner. Petr. & Nat. Gas in N. Y. State. M. E. 16, 906.
B. Silliman Sr. Notice of a fountain of Petroleum called the Oil Spring (near Cuba, Alleg. Co. N. Y.). Interesting. A. J. S. 23, 97.
H. Wrigley. The Amount of Oil in Pa. and N. Y. E. & M. Jour. June 17, 82, p. 315.

Note. But little has been written on the New York except as connected with Pa. A forthcoming report on the Mineral Resources of N. Y. prepared by F. J. H. Merrill for the State Commissioners of the Chicago Fair, 1893, will have a sketch and geological map. It is not yet issued (March 1895).

LITERATURE OF PENNSYLVANIA:

Note. Attention is called to the citations of a general character earlier given p.   especially Folger's. The literature of petroleum up to 1885 is chiefly the literature of Pennsylvania. Of current journals, The Amer. Manufacturer and Iron World, and Stowells Petroleum Reporter, both of Pittsburg, The Petroleum Age, of Bradford, and the Oil City Derrick may be cited.

__________. The Pa. Oil Regions, Their Geology & Hist. E. & M. Jour. Sept. 3, 1881, p. 150.
C. A. Ashburner. The Bradford Oil Dist. P^{a}. M. E. VII. 316.
" Oil-Sands of the Bradford or Northern Oil Dist. of Pa. compared with those of the Venango or Western Dist. Amer. Phil. Soc. Mar. 5, 1880.
The Product and Exhaustion of the Oil Regions of Pa. and N. Y. M. E. XIV. 419.
J. F. Carll on Oil & Gas. Ann. Rep. 2nd Pa. Surv. 1885.
Carll, Phillips & Lyman. Oil & Gas Region. do. 1886.

J. F. Carll. Reports numbered I.-I5 on local geology of oil regions of Pa. Pa. Geol. Survey. Rec.
J. P. Lesley. On the Allegany Riv. at Brady's Bend. Proc. Am. Phil. Soc. X. 266, 1866.
I. Sayles. Oil Regionsof Pa. A. J. S. ii. XXXIX. 100.
J. D. Weeks. Annual Review in Mineeal Resources, U. S. Rec.
" Mineral Industries. 11th Census. Rec.
H. E. Wrigley. Pa. 2nd Geol. Surv. Rep. J. Petroleum of Pa. Good introductory sketch. Rec.
" On the Present & Prospective Conditions of the Petroleum fields of Pa. E. & M. J. Aug. 2, 1879, p. 70.
" The Am't of Oil remaining in Pa. & N. Y. M. E. X. 354.

LITERATURE OF WEST VIRGINIA:

Note. Aside from the general papers of J. D. Weeks and S. F. Peckham mentioned above, p. little has been written on West Virginia Oil.

E. W. Evans. On the Oil-Producing Uplift of W. Va. A. J. S. II. 42, 334.
I. C. White. The Mannington Oil Field and the History of its Development. Bull. Geol. Soc. Amer. III. 187, 1892.

The Literature of Ohio will be found entire under the Lima-Indiana Field.

THE LIMA-INDIANA FIELD is one of the most interesting of recent discoveries. The first gas was tapped in November 1884, at Findlay and soon after oil was found at Lima in the Trenton limestone a new and unexpected horizon. These discoveries started drilling in many new quarters and pools of oil are now known in seven counties, four of which are strong producers. The field has been one of the chief demonstrations of the anticlinal theory, so much so that in accordance with it, the promising country is now quite accurately outlined. The northerly extension of the Cincinnati anticline is marked by several low rolls at whose crests, and about 1,100-1,300 ft. below the surface there is porous, dolomitized, Trenton limestone under tight Utica and Hudson River shales. The porous bed lies about 10 ft. below the top of the Trenton, and is from 3-10 ft. & never more than 15 ft. thick. Some gas lies above the oil, but it may be but slight. Below the oil is brine. In the gas districts the oil is subordinate. It appears from the above that the wells are shallow as compared with Pennsylvania. They also require less casing and are cheaper to inaugurate. The oil is heavier than the sandstone oils, dark in color, and contains about 0.5 % S. This at first was a drawback in refining but successful processes are now in operation so that it and its odor are removed. The Trenton lime stone oil today yields a greater part of the illuminating oils, than does any other one geological formation.

LITERATURE:

F. W. Minshall. History & Development of Macksburg Field. Geol. of Ohio, Vol. VI. p. 443.

J. S. Newberry. Rock Oils of Ohio. 1859.
E. Orton. Econ. Geol. Ohio. Geol. Surv y Vol. VI. Rec. 1888. Specially on Trenton oil.
" Preliminary Rep. on Oil & Gas in Ohio. 1887.
" First Annual Report of 3rd Geol. Survey of Ohio, 1890. Rec.
" The Trenton Limestone as a Source of Petrol. & Inflammable Gas in Ohio & Ind. 8th An. Rep. Dir. U. S. G. S. pp. 483-665. Rec.

Indiana. The Lima field runs across the line of Indiana and within the last two years, in the border counties of Blackford, Jay, Wells, Adams, and Grant very productive ground has been found. The geological relations are in all respects like those of the Lima field.

One or two wells near Terre Haute far to the west of this portion had a brief career of productiveness some time ago, but the yield proved transient.

LITERATURE:

Note. The oil developments of importance are too recent to have as yet much literature. Further citations appear later under Natural Gas in Indiana, to which attention is directed, especially as regards A. J. Phinney.

A. C. Benedict. Petroleum in Indiana. 17th Ann. Rep. State Geologist, 1891, pp. 306-326 (Before the great discoveries).
T. S. Hunt. On the Oil Wells of Terre Haute, Ind. A. J. S. III. 2, 369.

THE ENNISKILLEN FIELD lies in western Ontario, a few miles east of Port Huron. The oil is obtained from the Corniferous limestone 370-500 ft. from the surface, and about 65 ft. below its top. There are two districts, Petrolia and Oil Springs, of limited extent separated by a marked syncline. The oil is sulphurous, and heavy, 31-35 B. It was the first limestone oil developed in North America (1867) and suggested the explanations of T. S. Hunt on origin, which were earlier cited. The Enniskillen field is thought to be approaching exhaustion.

LITERATURE:

Note. Canadian Geological Survey Reports give annual reviews.

R. Bell. Petroleum Field of Ontario. Trans. Roy. Soc. of Can. Vol. V.
H. P. H. Brumell. On Natural Gas & Petroleum in Ontario prior to 1891. Geol. Surv. Can. 1890-91. Q. 5-91 & Bibliography. Rec. See also Rep. for 1888-89, 77 s.
" Geology of Nat. Gas & Petrol. in S. W. Ontario, and Notes on Petroleum in Gaspé. Bull. Geol. Soc. Amer. IV. 225-244.
T. S. Hunt. On the Geology of Southwestern Ontario. Describes petroleum in the article. A. J. S. ii. XLVI. 355. Many earlier papers by Dr. Hunt will be found cited in reference of Brumell's above.
A. Winchell. Note on the Geol. of Petroleum in Canada West. A. J. S. ii. XLI. 176.

NOTE. Some indications of oil elsewhere in Canada have been met; they are not yet shown to be serious but a few references are appended.

R. Bell. Petroleum in the Northwest Territories of British America - on the Athabasca and elsewhere. Proc. of the Can. Inst. new ser. 1, 225, 1882.
H. P. H. Brumell. On Natural Gas and Petroleum in Ontario prior to 1891. C. G. S. 1890-91, q. See also other citations under Brumell above.
R. G. McConnell. Oil in Athabasca. Geol. Surv. Can. 1890-91, 66 D.

THE FLORENCE, COLO. FIELD is of limited extent and lies on the easterly edge of the syncline which contains the coal of the Canon City coal field (p. 41). The oil is somewhat exceptional in its geological relations being in a great basin and not on an arch. It has accumulated, apparently from enclosing bituminous shales, in the more sandy layers of the formation, and is accompanied by variable amounts of gas, and practically no water, salt or fresh. The geological horizon is the Pierre, the upper member of the Montana group in the middle Cretaceous. The wells are from 1,000-2,000 ft. deep, and the oil is rather heavy, 31 b. The production appears to be falling off.

LITERATURE:

G. H. Eldridge. The Florence Oil Field. M. E. XX. 442, 1891. Rec.
F. M. Endlich. Section at Florence, Col. Haydens Survey 1873, p. 317.
M. S. Ihlseng. The Canon City Oil Field. Ann. Rep. Colo. State School of Mines, 1885, 75. Rec.
J. S. Newberry. The Oil Fields of Col. S. of M. Q. X. 97. E. & M. J. Dec. 15, 1888, p. 479.

THE SOUTHERN CALIFORNIA FIELD is is many respects exceptional and peculiar. The oil is heavy and as a general thing has an asphaltic base, not one of paraffine. It is found in highly inclined strata and is collected in thin sandstones in the midst of shales or in the shales themselves. The dip is often as high as 75 deg. and the productive districts are in narrow canons whose walls scarcely afford a perch for the drilling rig. Tunnels have been resorted to in not a few cases instead of wells, because the high dips make trouble in keeping the holes straight. The productive fields are in Los Angeles and Ventura Co's. The latter contains the Santa Paula district, 22 miles west of Newhall, the former the Pico and Puente districts. Productive wells have lately been drilled in the city of Los Angeles. The oils are heavy, 26-32 B, and do not yield as much illuminants as our eastern product, so that they are largely used for fuel in the crude state. The Geological age of the productive strata is considered Miocene Tertiary. There are other small districts in San Mateo Co. on the coast, and in Fresno Co. and Kern Co. in the central valley (the Sunset district) but their output is not serious. Kern Co. has afforded oil as low as 12 B.

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" Amer. Chem. IV. 6.
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W. L. Watts. Gas and Petroleum Yielding Formations of the central valley, Calif. State Mining Bureau, Bulletin 3, 1894.

Minor Oil Fields, which are as yet only prospects or of small production are known in many places. Favorable anticlines exist in Alabama and some small quantities have been obtained from the Trenton lime stone (M. R. 1893, 509, 1890, 363). In Dickson Co. Tenn. oil was discovered in small amounts in 1865 but no serious production was ever attained. In Barron Co. southern central Kentucky, there is a small field near Glasgow that yields a few thousand barrels. Other prospects exist in Pulaski and Russell Co's. further east. As early as 1829 a salt well at Burkesville in Cumberland Co. had a brief but phenomenal production of petroleum which flooded the Cumberland river with a stream of oil that caught fire 40 miles below the well (Orton, Petroleum Gas and Asphalt in Ky. p. 144). Orton reviews a long series of unsuccessful ventures. Illinois produces a lubricating oil in small amounts at Litchfield, Montgomery Co. On the western border of Missouri (Bates Co.) and in the neighboring part of Kansas (Miami Co.) small quantities of a heavy lubricating oil, 23.5 B have been obtained. In Wilson Co. southeastern Kansas more promising yields of oil and gas were obtained in 1894. Texas has furnished heavy oils in Bexar Co. Wyoming contains some rather promising country but as yet no very serious results have been attained. Of greater importance to the western coast is the new Peruvian oil field, which extends also northward into Equador. The wells center about Negritos and are 500 ft. and less in depth. The oil is of good grade, 38-39 B. and it is stated that it is to go to Pacific ports as a fuel. 350,000 bbls. were produced in 1890 (M. R. 1893, p. 516. C. Ochsenius Chemiker Zeitung 1891, XV. No. 102).

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NATURAL GAS.

GENERAL LITERATURE:

C. A. Ashburner. The Geology of Natural Gas. M. E. 14. 428.
" The Geological Distribution of Natural Gas in the U. S. M. E. 15, 505. E. & M. Jan. 15. 22. 87. 58. Prelim. Paper. E. & M. J. Nov. 6, '86 p. 332.
H. M. Chance. The Anticlinal Theory of Natural Gas. M. E. XV, 3.
General Review to 1887. Amer. Man. & Iron World. Supplement. Dec. 30, 1887. Papers by Ashburner, Carll, and Phinney, especially good fo for Indiana.
G. W. Goetz. Notes on Fuel Gas. M. E. Wash. Meeting Feb. 1890.

J. F. Kemp. On the precipitation of Metallic Sulphides by Natural Gas. E. & M. Jour. Dec. 13, 1890.
W. J. McGee. Rock-Gas and Related Bitumens. 11th Ann. Rep. Dir. U. S. G. S. 587, 1891.
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E. Orton. Admirable general Essays in Geol. of Ohio. Vol. VI.- Ann. Rep. for 1890, Ohio Geol. Survey. Petroleum, Gas and Asphalt in Ky. 1891. 8th Ann. Rep. Dir. U. S. G. S. p. 475. Rec.
" Origin of the Rock Pressure of Gas. Bull. Geol. Soc. Amer. I. 87. A. J. S. iii. XXXIX, 225. Rec.
I. C. White. States the Anticlinal Theory. Science June 26, 1885. A. J. S. iii. XXXI. 393. Bull. Geol. Soc. Amer. III. 187.

The generalities regarding the geology of natural gas have already been set forth. They are practically the same as those of petroleum and the productive regions are closely related. Gas however is found in many localities which show no serious amounts of oil.

The early oil-wells and the still earlier salt-wells often liberated great quantities of gas whose inflammability was known and which was in rare instances utilized. On the Kanawha river, W. Va. it was employed to evaporate brines at a very early date; at Fredonia, N. Y. it was used in the illumination of the town and elsewhere it was burned with an insufficient amount of air so as to deposit a fine grade of lamp-black. But vast quantities were allowed to run to waste and some timidity was felt about its explosive capabilities and the apparently uncontrollable pressure at which it emerged. It was first piped in Butler Co. Pa. in 1873, but not till 1878 was it extensively used in manufacturing, and not till 1882-83 was it taken to Pittsburg. Then the industry took great strides which was much accelerated by the wells of northwestern Ohio (1884), and later on others in Indiana. Natural gas is incomparably the best of natural fuels. Fifteen thousand feet of gas are about equal to one ton of coal. The search for it has been prosecuted in all parts of the country and in addition to being sources of gas, the wells have added enormously to our geological knowledge.

The value of the gas produced in the states that yielded over $100,000 in 1893 is as follows.

	1893		1893
Pennsylvania, - - - - -	$6,488,000.	New York, - - - - - - -	$210,000.
Indiana,- - - - - - - -	5,718,000.	West Virginia,- - - - -	123,000.
Ohio, - - - - - - - - -	1,510,000.	Other States, - - - - -	297,250.
	Total, - - - - - - - $14,346,250.		

Statistics show a steady decrease from the maximum of $22,629,875 in 1888, of which Pennsylvania contributed $19,282,375.

NEW YORK. Energetic search has been carried on in New York and has developed productive wells in the oil field of Alleghany Co. with the gas in the same geological relations as the oil. The gas is piped to Buffalo. Small amounts have been also met in the counties west, and in the region around Buffalo, and near Oswego, from various paleozoic horizons. Gas from wells in Ontario about 10 miles from Fort Erie has also been introduced in Buffalo.

[illegible]. On the genetic relation of [illegible] [illegible] [illegible]. [illegible] Sept. 15, [illegible].

[illegible] Asphalt and Related Bitumens. [illegible] 1901.

[illegible]. The [illegible] Annual Review.

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

Origin of the [illegible] [illegible] [illegible]

[illegible] the Anticlinal Theory. [illegible] [illegible]

The comparative [illegible] [illegible] [illegible] [illegible] They are practically [illegible] [illegible] productive regions are [illegible] [illegible] [illegible]

The [illegible]

The value of the [illegible] [illegible] [illegible] [illegible] [illegible] as follows:

Pennsylvania,	$ [illegible]	New York,	[illegible]
Indiana,	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	Total,	[illegible]	

[illegible] [illegible] [illegible] [illegible] Pennsylvania [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible]

LITERATURE:

C. A. Ashburner. Geol. of Buffalo as related to Nat. Gas. Expl. along the Niag. River. M. E. XVII. 398.
" Petroleum & Natural Gas in N. Y. State. M. E. XVI. 906.
" Natural Gas Explorations in the Eastern Ontario Pa. M. E. Oct. 1889.
H. S. Williams. Geology of Southwestern N. Y. Petroleum Age. June, 1887, p. 1642. Bradford, Pa.

PENNSYLVANIA. The Bradford and neighboring oil regions produce considerable for local use, The supply for Pittsburg, which is the greatest single market, is obtained from wells along the Alleghany river to the north of the city and from Washington Co. on the southwest. The Murrysville, Tarentum and Grapeville wells were famous in their day, and yielded gas at 500 lbs. pressure to the square inch. The gas is now chiefly sold for domestic use. The same strata furnish it, as yield the oil of the region.

LITERATURE:

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J. H. Cummins. Geology of the Natural Gas Fields about Pittsburg. E. & M. Jour. July 30, 92, p. 106.
J. P. Lesley. Pressure etc. of Rock Gas. Ann. Rep. 2nd Pa. Surv. 1885.

OHIO. The Ohio gas is mostly derived from the Trenton limestone in the Lima field, but other smaller supplies are obtained in the eastern portion of the state from the Berea Grit, and lately large yields have been tapped from the Clinton limestone north of Columbus, to which city it is piped. A small anticlinal has occasioned the storage. In the northwestern portion, along the Cincinnati arch, phenomenal wells have been drilled at Findlay, and towns further north. They reached their zenith in 1889 and have declined steadily to date. The gas is piped to the towns along lake Erie. The anticline runs to the north and has been tapped in Ontario as well be later noted.

LITERATURE:

E. Orton. Prelim. Rept. Columbus. 1887.
" Ann. Rep. State Geologist, 1890.
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" The recently discovered sources of Natural Gas and Petroleum in N. W. Ohio. A. A. A. S. Vol. 34, p. 202, 1885.
" The horizon of Petroleum and inflammable Gas in Ohio. A. A. A. S. Vol. 33, p. 397, 1884.
" Origin of the Rock Pressure of the N. G. of the Trenton Limestone of O. & Ind. A. J. S. iii. XXXIX. 225.
J. S. Newberry. On Ohio & other Gas Wells. A. J. S. iii. V. 225.

INDIANA has developed into a close rival of Pennsylvania. All its gas is obtained from the Trenton limestone in a westerly extension of the Ohio fields. It appears that the Cincinnati Arch forks and sends a branch into Indiana, and along the anticlines in the eastern central part of the state, the pools are found. The gas is piped to all surrounding towns and even to Chicago. The wells range somewhat under 1,000 feet. The gas is identical in composition with that obtained in Ohio.

LITERATURE:

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F. Leverett. Studies in the Indiana Natural Gas Field. Amer. Geol. IV. 6.

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A. J. Phinney. Nat. Gas in Indiana. Am. Manuf. and Iron World, Aug. 1887.

" Nat. Gas in Indiana. 11th Ann. Rep. Dir. U. S. G. S. 579.

ONTARIO, CAN. There are two important fields in this province. One in Welland Co. opposite Buffalo obtains supplies from the Medina and Clinton horizons, another in Essex Co. opposite Detroit taps the Clinton limestone.

LITERATURE:

C. A. Ashburner. Natural Gas Explorations in the Eastern Ontario Peninsula. M. E. Ottawa Meeting, Oct. '89. See also E. & M. J. Mar. 15, 1890, 313.

Mineral Resources. 1891, p. 443.

R. Bell and H. P. Brumell as cited under Petroleum in Ontario above. Annual reviews are given in Rep's Can. Geol. Surv.

OTHER DISTRICTS. Kentucky. A small gas field has been struck in Meade Co. on the Ohio river, 25-40 miles below Louisville, which takes its supply from a black Devonian shale at a small anticline (Orton, Petroleum Nat. Gas & Asphalt in Ky. p. 170). Considerable quantities are obtained in West Virginia in the oil fields. In Missouri, Iowa, Minnesota, Kansas, Utah, California, in fact in almost all the states some little gas has been obtained and some explorations have been made. Full reviews of these are given in the volume of the 11th Census on Mineral Industries, so far as they were developed in 1890. In addition the following references may be noted.

Colo. R. C. Hills. Notes on the Recent Discovery of Natural Gas in Pitkin Co. Colo. Proc. Colo. Sci. Soc. II. Pt. II. p. 106.

Ill. T. B. Comstock. Oil and Natural Gas in Ill. Eng. & Surveyors Assoc. of Ill. Jan. 26-28, 1887.

Iowa. C. R. Keyes. Nat. Gas & Oil in Ia. Ia. Acad. Sci. 1892, p. 15.

" F. M. Wilter. The Gas Wells near Letts, Iowa - in Drift. Ia. Acad Sci. I. part II. p. 68.

Minn. N. H. Winchell. Natural Gas in Minn. Bull. 5, Minn. Geol. Surv.

MALTHA. Tarry fluids are not uncommon in small amounts in limestones and bituminous sandstones. So-called "tar-springs" ooze from them, and the bituminous substance is also spoken of as liquid asphalt. Only in southern California are they of practical value, and while not a few localities are known in Santa Barbara and other counties, the chief developments are at the Lan Conchas mine on the ocean near Carpenteria. The maltha impregnates a clean Quaternary beach sand, which may reach 20 to 30 feet in thickness. A strongly bituminous shale underlies it and from this the maltha exudes. The crude sand contains about 20 % bitumen, but the refined reaches 95 %. The deposit is described in the 7th Ann. Rep. Calif. State Mineralogist, p. 89; the 12th do, p. 31 and in M. R. 1893 p. 630. It is employed in softening solid asphalt and as a coating against moisture. Brea is a name often applied to maltha or liguid asphalt.

ASPHALT. The loss of the more volatile constituents of some petroleums and certain polymeric changes not well understood, lead to the production of asphalt, a residue, solid at ordinary temperatures. More or less water, sand and clay are always mixed with it as it occurs in the natural state, and it may also impregnate limestone. Its great employment is for street-paving, and other uses such as coating reservoirs, cellars, and the like. For these purposes it has a wide and growing field. The increasing interest in good paving for city highways has opened an inexhaustible market for it. Asphalts differ much in their properties and not all have the necessary "bond" for an enduring street surface. They shade by imperceptible gradations into brittle, shining coal-like substances which are here specially treated as asphaltic coals. The latter have different uses of their own. The chemistry is however so complex, that elementary analyses throw little light upon the question, and whether important groups of definite and characteristic hydrocarbons are to be separated and recognized in the future, only the future will reveal.

GENERAL LITERATURE:

W. B. Blake. Uintaite, Albertite, Grahamite and Asphaltum. M. E. Feb. 1890. Rec.
G. C. Broadhead. Centennial Rep'ts and Awards G'p. I. p. 2. On Asphalt Bitumen, Petroleum &c.
F. V. Greene. Asphalt and its Uses. M. E. XVII. 355.
L. Malo. Guide Pratique pour la fabrication et l'application de l'asphalte at des bitumes. Paris, 1877.
P. Marcy. Les Bitumes. Lille, France, 1889. Rec.
S. F. Peckham. Notes on the Origin of Bitumens with exp'ts &c. Am. Phil. Soc. X. 445. Also Abs. A. J. S. II. 48, 131. Rec.
" Tenth Census. Vol. XV. Rept. on Petroleum & Bitumens in general.
" Petroleum in its relations to Asphaltic Pavement. A. J. S. Jan. 1894, p. 28.
S. P. Pratt. Geological Position of the Bitumen used in Asphalt Pavements. Q. J. G. S. II. 80, 1846.
H. Wurtz. A Theory of Asphalts. E. & M. Jour. July 27 '89 p. 73.

Within the United States only two or three regions are of notable

importance although from abroad large quantities are imported.

Kentucky. In Breckenridge and Grayson Co.s, southwest of Louisville, tar springs have been long known and to their associated sulphurous waters medicinal virtues have been attributed. In the same region sandstones outcrop which are saturated with asphalt and which have of late been employed for street paving in several Ohio cities, with favorable results according to Prof. Orton. (Ky. Geol. Survey, Petroleum, Gas and Asphalt rock. pp. 206-221.)

Texas. In Uvalde Co. southwestern Texas, a shell limestone is found which contains about 20 % of bitumen and is called litho-carbon. The asphaltic product is reported to have great elasticity and preparations have been made to utilize it. (See "Current Literature" Sept. 1891, p. 131. M. R. 1893, p. 637.)

Utah. A bituminous limestone has been quarried in the northern part of Emery Co. on the Rio Grande and Western R. R. and sold for street paving in the interior cities. (M. R. 1892, 702 - 1893, 636.) No mention is made at this point of gilsonite and uintaite but they are later referred to.

California is the chief source of asphalt within the limits of the United States. The same general region that has already been referred to under petroleum and maltha likewise yields both asphalt and asphaltic rock, which are the foundations of important and growing industries. At the mine called La Patera 12 miles west of Santa Barbara some hundreds of acres yield an asphalt, which has mingled with it about 40 % of quartz sand as an impurity. When softened with the maltha mentioned above and mixed with additional sand or limestone it is much prized for paving. Another important asphalt district lies in the great valley of California in Kern Co. at the town of Asphalto. A large vein that runs nearly 80 % pure bitumen has been opened up, but the freights are more expensive than for deposits on the sea-coast.

Asphaltic rock that is used without refining by merely warming up and rolling, is mined in very large quantities near Santa Cruz, in the county of the same name. The asphalt impregnates a sandstone. Other deposits are utilized in San Luis Obispo and in Monterey Co.s. Several asphaltic coals from California are mentioned later.

LITERATURE:

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Wm. Denton. On the asphalt beds near Los Angeles Cal. & its contained Fossils. B. Soc. N. H. XVIII. p. 185.
E. W. Hilgard. Min. Resources U. S. 1883-84, p. 938.
" Asphalt in Ventura Co. Calif. State Mineralogist 10th Ann. Rep. 1890, p. 763.
Wm. J. Irelan. Calif.Min. Rep. 1887, p. 50. Good general account.
E. W. Parker. On Calif. Asphalts. M. R. 1893, 629. Rec.
W. L. Watts. Gas and Petrol. Formations in Central Calif. Bull. 3. Cal. State Mining Bureau. 1894, p. 41. (On Kern Co.)

Trinidad. The island of Trinidad, lying just off the coast of Venezuela is the principal source of asphalt for the eastern coast of America. The so-called "pitch-lake" is regarded by some as the crater of an old mud-volcano. It is at all events a basin 114 acres in extent three miles from the sea and filled with asphalt to a depth reported to be 78 feet in the middle and 18 ft. at the sides. Blue clay lies beneath it, and in the hollows of the surface are pools of water. About 40 % of the crude material is pure bitumen, the remainder being water (16-17 %), vegetable remains (9-10 %) and fine sand and clay (34 %). Outside of the lake proper are ancient overflow deposits whose quality is regarded as inferior. All the productive territory is now under one control and all the asphalt is sold by this central management to other users. In refining, the crude material is heated at a low temperature to remove the water, and allow the sand in part to settle and the vegetable material to be skimmed off. The percentage of bitumen is raised to about 60. In paving this is thoroughly incorporated with 4-7 times as much fine sand and laid. The asphalt has also applications as a mortar, and as a non-conductor. The analysis of the pure bitumen is given on p. 86.

LITERATURE:

W. O. Crosby. Natural Bitumen and the Pitch Lake of Trinidad. Am. Nat. 13, 229.

M. Cumenge. Gisements de Charbon et de Bitume de la Trinidad. Annales des Mines. Jult 1882. Other deposits than the Pitch Lake are noted.

F. V. Greene. Asphalt and its Uses. M. E. XVII. 355. Rec.

N. S. Mauross. Notice of the Pitch Lake of Trinidad. A. J. S. II. 20, 153.

Pierce (U. S. Consul). Asphalt of Trinidad Consular Reports on Commerce Manufactures etc. #145 Oct. 92, p. 169. Rec.

C. Richardson. Description of present ownership and of Technology. M. R. 1893, 640. Rec.

Wall. Rept. on Trinidad Asphalt. Q. J. Geol. Soc. XVI. 467.

An asphalt is also obtained near Maturin in Venezuela which is called Bermuidez asphalt and runs higher in volatile oils than that of Trinidad. At Pedernales, an island in the delta of the Orinoco, are other deposits of great purity, and near Maracaibo, Merida, and Coro inexhaustible quantities are reported (M. R. 1893, 666). Cuba has afforded asphalts which have been used for paving without much success. The same is true of Mexico. Considerable bituminous limestone from the Val de Travers, Switzerland and from Seyssel, France, have been imported into this country. They contain 7-11 % bitumen and are powdered, heated, mixed with some residual petroleum and laid.

The general technology of all these asphaltic pavements is well discussed in the M. R. 1893, pp. 640-669.

ASPHALTIC COALS. This name although widely used is doubtless not the best collective one but will be employed here because it suggests the solid nature of the minerals and their analogy to glance-coal. They are a stage beyond asphalt as the term is used above. They have

served as gas-enrichers from an early date, and of later years as a basis of coach varnishes, etc. Before 1850 a true fissure vein was discovered at Hillsborough, N. B., which was filled with a shining coal-like substance called "Albert Coal" from the county in which it was situated and later Albertite. It was the subject of much difference of opinion for some years, because it appeared to be a coal and yet was in a fissure cutting Devonian strata. Finally it was generally recognized as having resulted from petroleum and as being essentially an asphalt. While the mine held out the product was much prized as a gas enricher. Analyses are given on p. 86. Ten years later a similar vein was met in Wood Co. West Virginia, which was described by J. P. Lesley in 1863, and subsequently another in Ritchie Co., whose substance was called "Grahamite" by Dr. H. Wurtz in 1869. The Wood Co. vein was 2/3 of a mile long and 4-5 ft. thick. Lesley recognized the true method of origin from petroleum. An asphaltic coal has since been found in Texas, that has been called Grahamite by Dumble, but the quantity is insignificant. (M. E. XXI. 601.) Of greater importance is the large vein on the Uinta Indian reservation in northeastern Utah, whose filling has been named Uintaite by W. P. Blake. The vein from 3-4 feet wide runs for two or three miles, and is near Fort Duchesne. The material has proved so valuable for varnishes and insulators that despite the necessity of hauling it 90 miles to the railway, over 3000 tons yearly are sold. In the trade it is called "Gilsonite". Another asphaltic mineral from the same region but of different properties has been named by Blake, "Wurtzilite". It resists ordinary solvents for the bitumens, is elastic and related to elaterite. Kimball has reported grahamite from Huosteca, in the State of Vera Cruz, Mexico. Specimens, closely resembling the original Albertite have been received at the Columbia School of Mines, from near Honda, U. S. of Columbia, and the material is said to occur in large quantities. These solid asphalts are likely to appear in almost any petroleum or bituminous district.

LITERATURE. NEW BRUNSWICK.

Note. Various opinions on the nature of Albertite, expressed by various geologists of eminence in the early history of the mineral, or in its later relations to tariff classifications have been expressed and printed and are on file in the library of the Geolog. Dept. Columbia College.

Bailey & Ells. On Albertite. Can. Geol. Survey. 1876-77, p. 234.
W. P. Blake. M. E. XVIII. 567, reviews Albertite with citations.
J. W. Dawson. On the Albert Mine, Hillsborough, N. B. Q. J. G. Soc. Vol. 9, p. 107, 1853. See also Acadian Geology.
H. Y. Hind. Prelim. Rept. on the Geology of New Brunswick. Chap.V.
C. H. Hitchcock. The Albert Coal or Albertite of N. B. A. J. S. ii. XXXIX. 267.
S. F. Peckham. On the Probable Origin of Albertite & allied Minerals. A. J. S. II. 48, 362. Many Ref. given.

WEST VIRGINIA.

Wm. M. Fontaine. Notes on the W. Va. Asphaltum Deposit. A. J. S. iii. VI. 409.

J. P. Lesley. On an Asphaltic Coal Vein in Western Va. Am. Phil. Soc. IX. 1863, 183.
H. Wurtz. On the Grahamite of W. Va. and the new Col. Resinoid. A. A. A. S. 1869. Vol. 18, p. 124.
" On Grahamite. A. J. S. ii. XLII. 420.
" Rep. to the Ritchie Mineral, Resin and Oil Co. 1865.

UTAH.

W. P. Blake. Uintahite. E. & M. J. Dec. 26, 1885. A. J. S. iii. XXXI. 231. M. E. XVIII. 570.
" Wurtzilite from the Uinta Mtns. M. E. Feb. 1890.
" Uintaite, Albertite, Grahamite and Asphaltum, etc. M. E. XVIII. 565.
E. W. Claypole. Gilsonite or Uintahite. Amer. Geol. IV. 387.
R. C. Hills. Description of an Asphalt-like Mineral from Asphalt, Wash. Utah. Proc. Col. Sci. Soc. II. Pt. I, p. 27.
J. M. Locke. Gilsonite or Uintahite a New Variety of Asphaltum from Uintah Mtns. Utah. M. E. XVI. 162.
J. S. Newberry. Grahamite in Col. S. of M. Q. VIII. 332.
R. W. Raymond. Note on a Specimen of Gilsonite from Uintah Co. Utah. M. E. XVII. 113.
G. H. Stone. Note on the Asphaltum of Utah and Colo. A. J. S. iii. XLII. 148. Rec.
Henry Wurtz. Wurtzilite or Wurtzite. E. & M. J. Dec. 6, 1890, 645. See also pp. 566, 685 same volume; and Jour. Franklin Inst. Jan. 11, 25, and Oct. 21, 1890.
" Uintahite a variety of Grahamite. E. & M. Jour. Aug. 10, 89, p. 114.

MEXICO.

J. P. Kimball. On the occurrence of Grahamite in the Huosteca Mex. & Notice of the Geology of that Region. A. J. S. iii. XII. 277.
" Report on a Deposit of Grahamite known as the Cristo Coal Mine, 1876.

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OZOCERITE is generally described as a natural paraffine, belonging chemically to the paraffine or marsh gas series and embracing such of its higher members, that in the formula, $C_n H_{2n+2}$, n would be 24 to 30. Others have believed that the olefine series ($C_n H_{2n}$) was also represented and that the ozocerite is a mixture. Dr. H. Wurtz regards ozocerite as belonging with the olefines. The elementary analyses both of the Galician (Austrian) product and that of the Utah mines indicate very nearly 85 % C and 14-15 % H. There is no doubt that ozocerite has been in all cases derived from petroleum either by the loss of its more volatile constituents or by a polymeric rearrangement of atoms, or both. The mineral occurs in regions of oil, and in cracks and cavities in sandstones and shales. There are but two productive districts the world over, one the older and larger is in the Austrian province, Galicia; the other whose development began in 1888, is near Pleasant Valley Junction, Utah. From 25-150 tons are annually afforded. The ozo-

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cerite answers nearly all the purposes of beeswax, and is in addition of great value as an insulator and for many other adaptations. Large amounts are also imported.

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W. L. Lay. General Occurrence in Europe and America. Trans. N. Y. Acad. Sci. Vol. II. 1882, p. 43.
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FOSSIL GUMS AND RESINS.

The oxygenated hydrocarbons in the form of amber, gum copal and others have some useful applications and are found in considerable quantities in some parts of the world. Though resinous substances are not uncommon in western coals, and, as interesting minerals, have been met with elsewhere they are, so far as known, of no practical importance in either of the Americas. Where found they occur usually as detached lumps in beach sands and have been derived from the gummy exhudations of extinct trees. They are useful as ornaments and as a base for varnish.

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GRAPHITE.

The final stage in the metamorphism of all carbonaceous minerals is graphite. It results alike from the coal series and the petroleum series, but as mined is perhaps more often derived from the latter. The graphitic slates and coal of Rhode Island were earlier referred to (p. 78). Graphitic schists occur in various other places throughout the regionally metamorphosed districts of New Brunswick, Pennsylvania, Michigan and Wyoming, but they are seldom pure enough to be valuable. It is also a result of contact metamorphism. The historic region for graphite in the United States is near Ticonderoga, N. Y. Many years ago veins were worked north of the town that afforded considerable quantities and made the locality known. They are fissure veins, that cut squarely across the laminations of the gneiss that forms the walls, are vertical and filled with pegmatitic matter, feldspar, quartz, pyroxene, apatite, calcite and graphite. They were long ago worked down to a depth, that made the mining too expensive. The present source of graphite is radically different. About five miles west of Lake George, in the town of Hague, a graphitic quartzite is found in a bed from 6-15 ft. thick, in garnetiferous gneiss. It strikes east and west, dips

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15°S. and is faulted so as to give two outcrops. Almost nothing else except quartz and graphite are in the rock. It affords 8-10 % of the latter and is mined, crushed in a California stamp battery, and washed, the light material being saved. Graphite also occurs in limestone in the eastern Aderondacks but is not utilized. Most of our better grades are imported from Ceylon, where it occurs in veins with precisely the same mineralogy as in the older Ticonderoga mines, as may be seen by referring to the papers by Sandberger and Walther cited below. There is little doubt that the graphite has been derived from some hydrocarbons of the nature of petroleum or asphalt. We produce 300-400 tons annually and import 10-14,000.

Graphite deposits that have received some attention also occur in the apatite district of Quebec and Ontario Canada, and a small mine was opened years ago in St. John, N. B.

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CHAPTER V. STRUCTURAL MATERIALS, INCLUDING BUILDING STONE, SLATE, LIMES AND CEMENTS.

INTRODUCTORY. Almost all the common and some of the uncommon

kinds of rock are used as building material and yet the reasons for such selection vary widely. We may say that the influences governing a choice are usually the following in this order of importance. 1, Cost. 2, Strength. 3, Durability. 4, Beauty. 5, Fashion. The cost depends on a variety of causes such as nearness of quarries, development of the quarry industry, the structure and texture of the stone, and the like. The first of these is a question of transportation and is influenced also by water or rail connections. The second involves the preparation of the stone. An old established industry though at a distance may afford cheaper material because it has dressing machinery, skilled laborers, and everything developed. Quarries are expensive enterprises to inaugurate as they require much dead work. Quincy, Mass. granite for instance has been taken to Minnesota with economy via the lakes and Duluth, although there are local granites between Duluth and Minneapolis. The structure and texture of the stone are incidents of quarrying and working. By the former we mean the larger physical structure, whether stratified or massive, whether supplied or not with convenient joints that facilitate the removal of goodly blocks and save dressing, whether splitting easily or not. By the latter we understand the adaptability to tool treatment and hand dressing and it especially concerns stone in its ornamental employment as in carving and polishing. A homogeneous texture is often of vital moment. The strength is an important factor in the choice of a stone for any structure but in small edifaces it does not signify as much. It is usually expressed in the number of pounds per square inch under which the stone crushes in a testing machine. Precautions are to be observed in this estimation as follows. The blocks should be fairly true cubes, though not necessarily an inch on an edge and the opposite faces must be parallel. To give an even pressure some medium is interposed between the faces of the machine and the blocks, such as plaster of paris, sheet lead, or book binders board. In the School of Mines testing the method is to polish the faces that come next the jaws of the crusher to parallelism within .005 of an inch and to crush with no medium interposed. Two inch cubes are now most commonly employed. A higher result is also gained with larger than with smaller cubes and the readings may be reduced according to Gillmore's formula ($y=p\sqrt{x}$ wherein y= pressure per square inch in block of desired size. x= length of edge of block required in terms of edge of block tested. p= crushing strength in pounds per square inch of block tested. Experience in the School of Mines does not corroborate this formula). The crushed block yields an approximation to two opposing paraboloids and a variety of side flakes. It makes some difference also whether the cubes are crushed across or along the bedding if there be one and the first direction should be sought. The general range is from the extreme minimum of 3-4000 lbs. per sq. inch for weak sandstones up to 15000-25000 and the extreme maximum of 34000 for granites. The last figures are from so called blue granite or elaeolite syenite of Fourche Mountain, Ark. The specific gravity is another point of value in this connection. It is usually expressed in pounds per cubic foot, or in cubic feet per ton. The first is of course obtained by multiplying the specific gravity by 62.5, the weight of a cubic foot of water. This ranges from an extreme minimum of 120 (sp. gr. about 1.92) for very loose sandstone, to 180 (sp. gr. about 2.9) for basic traps. Granites run generally 160-170. The higher values make of course some-

what heavier material to handle. The absorption of water is also an important point, for a high absorption is a bad thing in cold climates. It is expressed in the ratio of the weight of water absorbed to the weight of the dry block. It varies with the texture of the stone; porous sandstones are very high, reaching 1/10 or more, while compact crystalline rocks may be 1/300 or less. It is obtained by weighing dry and then soaking until an approximately constant weight results and determining the increment. Rounded pieces of 1-2 ounces are used, and are allowed to soak 24 hours. They are then dried quickly with filter paper and weighed. A second soaking for 24 hours follows and a new weighing. If the two results are approximately the same the last is taken for the calculation.

Durability is a very important point in expensive structures which are meant to last. Our climate is a trying one on stone and material that lasts indefinitely in a clear dry air and equable temperature, scales rapidly here, as has been the case with the obelisk. Frost is the greatest agent of disintegration and acts through the agency of water. Porous stone thus is objectionable. The expansion and contraction from quick and extreme changes in temperature are also important causes of internal strain. Many artificial tests have been mentioned as trials of these, such as soaking the specimen in a solution of some easily crystallizing salt (i.e. Na SO) and drying. Then spraying off the disintegrated material and weighing it. The specimen may be soaked and frozen and for this purpose in warm weather, cold storage warehouses may be used with advantage in cities where they are available. Experiments by L. McI. Luquer, to be published in the School of Mines Quarterly for 1895, indicate that the sulphate of soda test is a severe one, as compared with frozen water. The specimen may also be heated and chilled and watched. But the best test of all is experience and if an old building can be found, or a tombstone, or the outcrop of the quarry some useful data may be obtained. The process of decay or weathering will be described under each kind of rock. The atmosphere of cities is comparatively severe on stone. The sulphurous fumes from burning coal seem to have their effect in the long run especially on limestones. The growth of mosses and other vegetation also gives rise to organic acids which in damp corners cause injury. Several artificial preservatives have been designed as preventives but their mention is hardly appropriate here. Resistance to fire has become of increasing importance in modern times. The nearer a rock approximates pure quartz the more refractory it is. Granites fuse in severe conflagrations and limestones spall off or calcine. Sandstones in these respects are least fusible and of sandstones, those with siliceous cementing material.

Beauty in a stone is a great point in its favor and the item is seriously considered when limitations of expense do not prevent. The special features of individual kinds can be best mentioned in their particular treatment.

Fashion largely determines the choice of a stone. Years ago New York used white marble, while today the large buildings are prevailingly granite, or brick with stone trimmings. But evidence is not lacking that marble is again coming into favor.

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In the discussion of building stones, the general geological classification of rocks is followed. Accordingly the igneous rocks, including however the gneisses, are first taken up; and next the sedimentary and metamorphic in this order, the sandstones, clays and slates; the limestones, marbles and serpentines. As a general rule under each, the eastern or more fully developed states are first treated, and afterwards the western. Very full details of localities are given in Vol. X, of the 10th Census, in G. P. Merrill's valuable treatise entitled Stones for Building and Decoration (Wiley, 1891), and in the volume on Mineral Industry, 11th Census, article Stone by Wm. C. Day. There are very complete collections at the National Museum, Washington, D. C., and in the American Museum of Natural History, Central Park, N.Y.

Some idea of the amount and relative importance of the industries in the various kinds of stone may be gained from the 11th Census which related to 1889, and reported a total of $53,035,620 of stone. This is an enormous increase over 1879, which was less than $19,000,000. The recent hard times made the total for 1893, $33,885,573. The several stones ranked as in the table.

	1889.	1893.
Limestone.	$19,095,179	$13,947,223
Granite.	14,464,095	8,808,934
Sandstone.	10,816,057	5,195,151
Marble.	3,488,170	2,411,092
Slate.	3,482,513	2,523,173
Bluestone.	1,689,606	1,000,000
	$53,035,620	$33,885,573

Bluestone is a trade name for the flagstone used in New York and neighboring states. It really is a sandstone.

IGNEOUS. The Orthoclase Rocks and Gneisses. These occur as knobs, bosses and great intrusions or surface flows in all geological formations, but especially in the Archean. There has been however in the past a general tendency to regard granites and gneisses as Archean, although they may prove later. As regards building purposes, granites are much the most widely used. Gneiss, which in its commonest variety differs from granite, principally in the laminated or banded arrangement of its minerals, is placed in the same group because it is called granite in the trade. Gneiss seems often to have been formed from granite by the great pressure attendant on mountain upheaval.

Granites are thoroughly crystalline rocks, of a general even or uniform texture due to the constituent minerals being all of the same size. This is varied sometimes by the exceptionally large size of individual feldspars, or by the segregation of dark silicates in unusual proportions. The constituent minerals are feldspar, orthoclase and

[illegible] Eng. Soc. Proc. 1896. [illegible]
[illegible] Stone [illegible] of Massachusetts [illegible]
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[illegible] Stone. [illegible]
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In the discussion of building stones, the general geological classification of rocks is followed. Accordingly the igneous rocks, including granite, [illegible], are first taken up, and then the sedimentary and metamorphic in this order, the sandstones, [illegible], the limestones, marbles and serpentines. As a general rule [illegible] the amount of [illegible] developed [illegible] first [illegible] and [illegible] the [illegible]. [illegible] details of [illegible] are given in [illegible]. [illegible] Merrill's valuable treatise [illegible] Stones for Building and Decoration [illegible] and in the [illegible] on [illegible] Industry, [illegible] Stone [illegible]. There are [illegible] collections of [illegible] Museum, [illegible] D. C., and in the American Museum of Natural History, Central Park West, [illegible]

[illegible] of the [illegible] building stones [illegible]. This [illegible]. The [illegible]. The general [illegible] as in the table:

[illegible]	Tons	
[illegible]	[illegible]	Limestone
[illegible]	[illegible]	Granite
[illegible]	[illegible]	Sandstone
[illegible]	[illegible]	Marble
[illegible]	[illegible]	Slate
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	

[illegible] is a [illegible] for its [illegible] work [illegible] building [illegible].

Granite. [illegible] Rock [illegible] Granite [illegible] rocks [illegible], [illegible] in [illegible]. Granite [illegible] however [illegible] granite [illegible] quartz [illegible] the [illegible] granite [illegible] of the [illegible] granite [illegible].

Granite [illegible].

[illegible]

oligoclase and at times albite, quartz, and biotite, muscovite or hornblende. Of the last three, biotite is much the most common. It is often accompanied by muscovite. Hornblende may be practically without the other dark silicates but it is usually has biotite with it. In addition to theseca little pyroxene occasionally appears, small grains of magnetite are always present, and microscopic zircous, apatites and titanites are almost invariable. Pyrite is not unfortunitely not rare in small amounts, and is the constituent specially injurious. On chemical analysis granites are found to contain from about 65 % SiO_2 as a general minimum to about 75 % as a maximum, although both limits may be passed in exceptional instances. Alumina ranges from a maximum of about 17 % in those low in silica, to a minimum of 11 or 12 when the silica is high. The iron oxides are both present and from 1.5 % to less than 5%. Lime varies from less than one to about 6%. Magnesia seldom reaches 2%. The alkalies, potash and soda, range from 4 % to 8 %, sometimes one sometimes the other being in excess. Fresh granites afford less than 1) % water. There may be a few hundredths of one per cent of sulphur, and a few tenths of manganese. In judging of analyses, practically no sulphur, and other things being equal high silica, are advantages. Of the constituent minerals the feldspar is the most abundant and influential and on its color the color of the stone chiefly depends. It may be white, gray or red. Quartz exerts but slight influence, for it simply transmits the colors of the others. Biotite and hornblende tend to give the stone a darker shade but they are less potent than the feldspar except in very basic granites. When in undue aggregates they occasion unsightly blemishes. The quartz and feldspar take the best polish, mica is of small value for this and hornblende or pyroxine are apt to rub out because of easy cleavage. The texture varies from coarse to fine, but fine granites are apt to be more durable, although less beautiful. The greatest excellence is a homogeneous and uniform texture.

In the quarry granites are notable for the even rectangular joints or planes of weakness that traverse them and that facilitate the removal of the blocks. The stronger of the two vertical ones is called the rift, the weaker the cut off and the horizontal one the lift. The cause of these is not well understood but R. S. Tarr has found that microscopic cracks cross the component minerals in corresponding lines (A. J. S. Apr. 1891, p. 267). Granites also have a peculiar tendency to develop exfoliation on a grand scale and to come off in horizontal sheets. These are referred to expansion and contraction from the sun's heat. They afford the benches familiar in all quarries. Granites alter under the atmospheric agencies by the physical action of frost and by the chemical change of the component minerals. The feldspar, a silicate of potash and alumina, becomes fine scaly muscovite, or kaolin, the latter a hydrated silicate of alumina. They lose their crystalline character and change to earthy aggregates. The dark silicates alter to chlorite and their iron affords limonite. The rock tends to crumble away or scale off and in nature affords finally the grains of quartz sand for sandstones and the earthy materials of clays. The decay of the feldspar was called by Dolomieu the "maladie du granit", a much quoted phrase. Nevertheless granite as rocks go, is one of our most durable stones. It is also the strongest and has now the preference for large buildings.

The greater part of the granite is produced in the New England states and ten years ago the statement had even greater ~~force than~~ today. But the accompanying figures will be most suggestive.

	1889	1893		1889	1893
Massachusetts	$2,503,503	$1,631,204	New Jersey	$425,623	$373,147
Maine	2,225,839	1,274,954	Minnesota	356,782	270,296
California	1,329,018	531,322	Virginia	332,548	103,703
Connecticut	1,061,202	652,459	Colorado	314,673	77,182
Rhode Island	931,216	509,799	South Dakota	304,673	27,828
Georgia	752,481	476,387	Wisconsin	266,095	133,220
New Hampshire	727,531	442,424	New York	222,773	181,449
Pennsylvania	623,252	206,493	Delaware	211,194	215,964
Vermont	581,870	778,459	North Carolina	146,627	122,707
Missouri	500,642	388,803	Others	199,014	150,279
Maryland	447,489	260,855	Total	$14,464,095	8,808,934

Although we ordinarily think of granite chiefly as a building stone, yet the statement has been made that, the world over, the greater portion of that quarried, is broken up for paving blocks. In 1889 about one-third of the output of America was used in this way. The Quarries along the Atlantic Coast are first taken up.

New Brunswick and Nova Scotia. At St. George, Kings Co., north of St. John, a red granite is quarried which is usually called Bay of Fundy granite. It has been to a small degree imported into the United States, but is apparently but slightly worked today. Gray granite has also been obtained in minor amounts at Shelburne and elsewhere in Halifax Co.

G. F. Matthew. Granite at St. George, N. B. Geol. Survey Canada, 1876-77, 345.

Maine. Great intrusions of granite are found all along the seacoast of Maine, and on its numerous islands. The stone lies in such convenient situation for economical shipment to Atlantic ports that it has been extensively opened in many places. Red granite, is obtained at Jonesborough and Calais, far to the eastward, but the general run is gray or slightly pink. Blocks of enormous size are obtained. Merrill mentions one 300'x20'x6' to 10'. Many other Maine quarries furnish blocks as large. Dix Island granite was a famous one in its way but is now worked out. The Hallowell biotite-muscovite granite is especially adapted to monuments being of very homogeneous texture, Many other quarries far too numerous to mention line the sea coast. Paving stones are also an important portion of the quarry output. The refuse when sufficiently large is worked up into them.

G. P. Merrill. Stones for Building and Decoration contains the best account of Maine granite, p. 184.

New Hampshire, is popularly known as the "Granite State" from the large proportion of it that is formed by this rock. The best known quarries are near Concord and yield a light gray stone that splits with

great ease and regularity and is extremely homogeneous. It is a muscovite-biotite granite and is specially adapted to monuments but is also employed in building. There are many smaller openings elsewhere in the state and much gneiss is locally used.

G. W. Hawes. Geology of N. H. Vol. III. Mineralogy and Lithology.

Vermont. Granite occurs as intruded masses in Vermont which are thought by Hitchcock to be not earlier than the Upper Silurian. The largest workings are at Barre and are very extensive. The stone is remarkably homogeneous and is prized for monuments and decorative work. It is a biotite-granite. Excellent granite of a light gray color is obtained near Battleboro in the Black Mountain quarries. It breaks in rectangular blocks and has a fine color. Numerous other granite quarries are operated to a less degree and some in gneiss. Vermont is best known for its marble and slate.

Massachusetts. The quarry industry is important along the coast. Cape Ann contains many openings. The granites are hornblendic and are often called syenites especially at Quincy. The Gloucester and Rockport stone is gray to greenish, the Quincy is a bluish or greenish gray. The latter is rather coarsely crystalline and has a peculiar transparent effect when polished. One seems able to see several inches into it. It is the most used of any monumental stone. The quarries at Quincy and West Quincy yield more granite annually than any other equal American tract. Many other towns have quarries of minor importance. An epidote granite is quarried at Dedham - an exceptional mineralogical composition. A finely crystalline granite of a bluish gray color, and of exceptional strength is obtained at Chester in the central part of the state. Gneiss has more than local importance at Monson on the New London Northern R. R. It splits with wonderful facility. W. H. Niles mentions a block taken out in 1869, 354' x 11' x 4'. When free from its bed it expanded $1^1/2$" and could not have have been put back, showing a local strain in the rocks.

J. F. Kemp. Note on the Chester Granite. Trans. N. Y. Acad. Sci. XI. 126, 1892.
M. E. Wadsworth. Nots on the Petrography of Quincy and Rockport. Bost. Soc. Nat. Hist. XX. 309, 1878.
G. P. Morrill. Op. cit. p. 194.
N. S. Shaler. Geology of Cape Ann. Ninth Ann. Rep. Dir. U. S. G. S. p. 537.

Rhode Island. The principal quarry industry centers about Westerly. A remarkably homogeneous stone is afforded which in its best grades is only used for monuments and the like. It is a biotite-granite. The same rock outcrops at Niantic and not a few local quarries are opened in other sections.

Connecticut. Long Island Sound furnishes water transportation for many quarries along the coast. The stone afforded is also of an excellent character and in several places is quite largely taken out. Millstone Point near New London is the seat of a large industry. The rock

is a fine-grained, light gray stone. Local quarries in gneiss are numerous throughout the state. At Lyme, near the mouth of the Connecticut river, a beautiful red porphyritic granite was formerly quarried but its feldspar was so coarse that it flaked off on sharp edges. A red granite from Stony Creek just east of New Haven is considerably employed.

George Rich. The Granite Industry of New England. New England Magazine, Feb. 1892, p. 742.

New York. Some quarrying is done on the granites and gneisses of the Highlands along the Hudson River and many paving blocks are made. The rock is gray and appears to be a very good stone. The knobs of granite that constitute Mts. Adam and Eve near Warwick in Orange Co. have been developed to some extent in late years. Quarrying operations have also been instituted in the green plagioclase rocks of the Adirondacks near Keesville which although not properly coming under the orthoclase division yet pass as granite in the trade. They furnish a very beautiful stone that is of an apple green color, somewhat marred in large blocks by spots of dark silicates. Among the Thousand Islands are some exposures of granite which are extensively worked. Those on Grindstone Island are best known and afford a hornblende-granite with great amounts of red orthoclase, that give the stone a beautiful warm red color, when polished. The markets are in the West and Canada.

J. F. Kemp and Arthur Hallick. The Granite at Mts. Adam and Eve and its contact Phenomina. Annals N. Y. Acad. Sci. VII. 638, 1894.
J. C. Smock. Building Stone in the State of New York. Bull. Vol. No. 3, N. Y. State Museum, p. 25. Vol. II. No. 10. Rec.

New Jersey, Pennsylvania and Delaware although containing much gneiss produce it only for local use. Maryland has numerous openings in gneiss and one biotite-granite at Woodstock near Baltimore. It is much employed in the neighboring cities.

Virginia contains many exposures of granite some of which are quite extensively quarried. The productive regions are in Chesterfield and Dinwiddie Counties near Richmond. The stone is a biotite-granite of a gray color much resembling those of New England. The State War and Navy building in Washington is built of Virginia granite.

North Carolina, is rich in granites of many kinds but as yet they are only quarried for local use. G. P. Merrill in the work often referred to gives a number of localities. Much the same is true of South Carolina but the local demand for the stone has not prompted as yet extended developments.

Georgia. A very extensive granite industry has sprung up at Stone Mountain and Lithonia, 20 miles or so east of Atlanta. Great domelike knobs of bare granite and low, rounded bosses furnish inexhaustible supplies of a gray variety that splits with remarkable exactness into cubical blocks. its development has placed Georgia sixth on the list of producers.

Wisconsin and Minnesota. Archėan exposures of granite are prominent in the states around Lake Superior and in Wisconsin and Minnesota have been wrought. The available outcrops are however long distances from the lake shore. Montello, Wis., which is in the western central part of the state affords a hard pink granite. Vast areas are formed of granite and related rocks in Minnesota. The quarries as yet opened are at St. Cloud on the Mississippi above Minneapolis. Both gray and red granites are afforded.

T. C. Chamberlain. Geology of Wisconsin, Vol. I. p. 66.
Truesdell. Building Stone of Minn. Jour. Assoc. Eng. Soc. June 1885, p. 302.
N. H. Winchell. Comparative Strength of Minn. and New England granite. A. A. A. S. Minneapolis Meeting, 12th Ann. Rep. Minn. Geol. Surv. p. 14. Final Rep. do. Vol. I. p. 142.

Missouri. The granites and porphyries of southeastern Missouri are prolific sources of stone. They are mostly red in color although gray varieties occur. They are poor in dark silicates and are chiefly orthoclase and quartz. Very large quarries are in operation at Graniteville, Iron county and at Knob Lick, St. Francois Co. These granites are also of extreme value in the large cities neighboring to them for street paving. They are the only hard rocks within easy reach and are much used under heavy traffic. For the general geology of the region see pp. 59-61.

E. Haworth. On the general Petrogrophy of the Region. Amer. Geologist I, 280 & 363. Geol. Surv. Mo. Bull. 7, 1891. See also Iron Mtn. Atlas Sheet and accompanying description by Haworth and Nason, p. 19, 1894.

Arkansas. The syenites of Fourche Mts. near Little Rock are important sources of building stone. They are the strongest granite rock yet tested in America and are being extensively developed. They supply a gray and a blue of excellent character. The rocks are of late Cretaceous Age.

J. C. Branner. Stone, Oct. 1889.
J. F. Williams. Igneous Rocks of Arkansas. Ann. Rep. Ark. Geol. Surv. 1890. Vol. II. p. 39.

Outcrops of granite occur in Indian Ty. not yet utilized and in Texas. The latter have been quarried to some extent for state buildings in Austin. The granite is a gray biotite-granite. In Burnett Co. is a well known coarse red granite.

Granites are abundant in the Rocky mountains but have been only slightly utilized. A coarse gray biotite-granite from Little Cottonwood Canon has been given some fame by having been employed in the construction of the Mormon Temple at Salt Lake City. It is an excellent stone and can be obtained in great quantity from loose boulders before the ledge is touched. In the other states of the Cordillera region granites are known to occur in inexhaustible amounts but the building of large structures has not yet utilized them.

California is an exception. Quarries have been operated for many years at Rocklin and Penrhyn, Placer Co. along the line of the Central Pacific 23 miles east of Sacramento. At Penrhyn it is a hornblende biotite granite, at Rocklin a muscovite biotite granite. California imports from the east and Scotland great quantities as well.
A. W. Jackson. Building Stone of California. Rept.of the State Mineralogist for 1888, p.885.
J. J. Crawford. 12th Annual Rept. State Min. 1894 p.384.

Canada of course contains in its extended Archaean exposures vast resources of granite. These are utilized in a number of places. In the same region as the quarries on Grindstone Island, N.Y. are others in Canada affording red granites. A red hornblende granite well known along the Atlantic seaboard is the so-called Bay of Fundy granite from St. George, King's County, N.B., as has been earlier mentioned. It resembles the familiar Scotch granite from Peterhead Scotland that also enters our ports. A gray granite is imported from Aberdeen, Scotland.
On Scotch and English granites Harris, G.F. Granite and our Granite Industries. London, Crosby, Lockwood & Son, 1888. Also "Building Construction" in South Kensingston Educational Series. Pt.III Material, London, 1879.

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THE PLAGIOCLASE ROCKS.

These are much contrasted with granite because of their darker colors. They are also seldom provided with the convenient planes of weakness that facilitate the quarrying of granite in so marked degree. Their dark colors tend to give a very sombre tone to the buildings into which they enter. They are thus far less used although in instances where a dark color is desired for certain effects as in monuments they are employed. Diabase, diorite and norite constitute the varieties. The only important source of norite, Keeseville, N.Y. has already been mentioned. Diabase is chiefly produced at Addison, Me. and to a less degree at Vinalhaven and Tenants Harbor. It goes by the name of block granite and at Addison breaks well in the quarry, The Triassic diabases along the Atlantic seacoast are the other chief sources of these rocks but they are only worked in a very subordinate way. Their chief value lies in their adaptability to paving blocks and macadamizing material. For these purposes, especially the latter they serve admirably. A gneissoid gabbro is taken out in Delaware and is somewhat extensively shipped. A gabbro is somewhat extensively broken near Duluth and placed on the market as Duluth granite. Certain diorites on the Hudson River have likewise attracted some prospecting but except in the localities referred to, the dark rocks are only used for local rough work and paving.

THE SEDIMENTARY ROCKS.

These are treated under the following heads: Sandstones, Clays, and Slate, Limestones, including Marble; Serpentine. The metamorphic derivatives are thus placed with their originals.

So far as amount and value are concerned the limestones are the most prominent building stones of all the rocks. They are obtained almost entirely from the later Paleozoic or Mesozoic formations and are thus generally developed in different regions from the granites and crystalline rocks. The country over, fragmental rocks constitute the great bulk

of the sedimentary series, and sandstones form a large portion of them. Sandstones are often called freestones from the ease with which they submit to tool treatment. In extreme cases they are the weakest of rock materials under pressure, but in good grades are sufficiently strong for all ordinary uses. Some varieties are soft when quarried and may almost be sawn out, but on exposure they harden to durable rock. The quarry water is thus an important element in working. In cold climates quarry operations are suspended in winter as a frozen stone is almost unworkable. Sandstones in most cases consist of quartz grains but with these are often found grains of feldspar, mica and the common rock making minerals. Extremely feldspathic varieties are called arkose. The grains at times give some clue to the original rock mass that furnished them. The grains are in all cases held together by a cement which is either siliceous, calcareous or ferruginous. The first named is due to a secondary deposit of quartz and this often continues the crystallographic properties of the original grain. It forms the most durable cement and is the one to be preferred when available. A calcareous cement is due to a secondary deposit of calcite. It indicates its presence by effervescing with acids. It is the weakest and least durable cement. Ferruginous deposits also bind grains together in rarer instances and then give the stone a strong red or yellow color. In deep colored sandstones the iron oxide enters into the silica or calcite that furnishes the chief bond, though it may be little more than a coloring agent. Sandstones are white, bluish-gray, greenish, brown, red and buff, due to the absence or presence of iron, FeO causes blues; Fe_2O_3, browns, reds and buffs. Sandstones with much argillaceous matter break readily into thin but tough slabs and yield flagstones. The quarry districts are taken in order from east to west.

New England. There are few available sandstones in this section because the crystalline rocks so largely prevail. The pink Cambrian quartzite near Burlington, Vt. supplies considerable for local use. The Triassic estuary deposit however, that stretches from Long Island Sound up the Connecticut valley to the Vermont line has two important quarrying regions that ship stone all over the country. The product is the familiar brown stone of our Atlantic cities. Longmeadow, Mass. supplies a fine-grained and easily wrought stone of a deep red color that is much prized. It is of rather finer grade than the Portland stone. The latter comes from Connecticut on the river just opposite Middletown and is the basis of one of our largest quarry industries. The bedding is very heavy and it is stated that blocks 100'x 50'x 20' can be taken out. The quarries in instances are 150' deep. The stone in all the Triassic deposits is in large part feldspathic and formed by the erosion of the neighboring Archaean gneisses and schists. It is rather loosely textured stone and scales off under the action of frost, when set on edge as a veneer, the plan generally pursued in New York. Like all bedded rocks it only gives the best results when laid up in a wall as it occurred in the quarry, so that the pressure comes normal to the bedding planes. The decay of brown stone in New York has especially drawn attention to this weathering of stone.

New York is for the moment passed over in order to speak of the other quarries of Triassic stone in New Jersey and Pennsylvania. There are some small openings of the Trias near Nyack, N.Y. but the next important developments are met further south in the belt that begins at Haverstraw and runs across N. Y. and southeastern Pennsylvania. The of the sedimentary basins, and sometimes from a large number of them. Fragments are often quite different from the rock with which they are [illegible] treatment. In several cases they are the product of [illegible] materials under pressure, but in good grains are sufficient [illegible] all ordinary ones. These varieties are often much coarser [illegible] be seen [illegible] so far as they [illegible]. Quartz is also an important element in sandstone. In gold [illegible] operations are supported [illegible] in places on a [illegible]. Sandstones in most cases consist of quartz grains [illegible] ten found grains of feldspar, mica and [illegible] materials [illegible] grains [illegible] to all [illegible] together by a [illegible] cement [illegible] of [illegible]. The forms [illegible] of quartz and [illegible] the crystalline [illegible] grains. It forms the most durable [illegible] cement [illegible]. It [illegible] the [illegible] is the product and least [illegible] [illegible] in order to [illegible] and also give the stone a [illegible] or yellow colour. In some other [illegible] that the colour [illegible] the [illegible] than a coloring agent. [illegible] and [illegible] brown, red and [illegible] the [illegible] of [illegible] [illegible] and [illegible] the [illegible] in order from [illegible].

New England. [illegible] in this [illegible] [illegible] [illegible] [illegible]

[illegible]

quarries are very extensive at Belleville, a suburb of Newark and at Passaic. The stone varies somewhat in the different beds and the good material is separated by shaly layers, 20'-30' in all of available stone are obtained. Some quarrying is also done in New Jersey along the Delaware River, and then as the Triassic exposures cross into Pennsylvania very important industries are based on them. A series of openings are found near the river but the largest quarries are to the southwest, at Hummelstown, in Dauphin County, near Harrisburg. As much as 70 ft. of available stone are exposed in some. The rock is quarried at one point in Maryland and furnishes a very good grade. This is in Montgomery Co. at the mouth of Seneca Creek. Virginia contains openings in the same formation near Manassas and on other Triassic belts in North Carolina some stone is taken out.

New York. There are three important sandstones in New York, one the Potsdam, in the Cambrian; another, the Medina, at the base of the upper Silurian; and the third, the North River blue stone in the Devonian, chiefly Hamilton. The Potsdam is a very hard red quartzite and is obtained on the western or northwestern flanks of the Adirondacks. It breaks in the quarries by natural joints and bedding planes and requires little dressing, which is fortunate as it is extremely hard. It has long been regarded as the ideal of building stone in strength, durability and fire resisting quality. The Medina sandstone forms the south shore of Lake Ontario from Oswego to Lewiston. The best stone begins however at Holley, 20 miles west of Rochester and extends to Lockport but increases in hardness toward the west. The available rock varies somewhat in thickness at different points reaching as a maximum 30'. It is mostly a pleasing pink, but shades to white and has a moderate hardness. It is one of the most beautiful and admirable of building stones and as the quarries are generally between the N.Y.Central Railway and the Erie Canal, transportation facilities are good. Almost all of it goes west and strangely it is never seen in New York. All the refuse of the quarries is broken for paving stone.

The North River blue stone or flagstone comes mostly from the Hamilton series of the Devonian, although found as well in the Portage. The larger quarries are situated in Ulster and Sullivan Counties, but available stone is found further west and also in Pennsylvania. The stone is a very argillaceous sandstone and owes its thin bedding to the clayey material present in it. The good rock is in the midst of useless shales and is exposed by stripping. It lies very flat and is merely pried up. When thick it may be used for underpinning. Essentially the same rock is obtained in Wyoming Co., Penn. and known as Wyoming stone.

J. C. Smock. Building Stone in New York. Bull.3, State Museum, Albany 1888. Bulletin 10. 1890.

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PENNSYLVANIA. The principal stones of Pennsylvania are the Triassic brown stone already referred to and the blue stone just mentioned. Some local stone in the carboniferous system is good and at several places, as for instance Curwensville in Clearfield Co. is quarried and shipped to a distance.

OHIO is the only other state east of the Mississippi possessing sandstones worthy of mention in this connection, but its quarries are the most productive in the country. The Berea Grit of the Subcarboniferous is the principal formation and affords the stone of northern Ohio. It

outcrops as an old abandoned lake shore south of Lake Erie and presents very convenient exposures. The stone is light colored and quite soft. It has little cementing material and in its softest examples is worked into grindstones. Some 50' are available for one purpose or the other favorable exposures. Amherst, Berea, East Cleveland, Elyria and Independence are the chief centers. At times the stone is buff. In southeastern Ohio near Marietta another sandstone in the upper Carboniferous is much used.
E. Orton. Economic Geology of Ohio, Vol.V.

INDIANA. Much sandstone for local use is produced in Indiana from the base of the Coal Measures.
J. Collett. Twelfth Ann. Rept. State Geol. 1882.

WISCONSIN AND MICHIGAN. The red sandstones that form the shores of Lake Superior on the south side have lately proved important sources of a fine building stone. South of Bayfield in Wisconsin they are extensively wrought. Again on Keweenaw Point at the eastern entrance to the Portage Lake Ship Canal there are very large openings. Nine feet of solid stone occur amid shaley layers. The color is a warm red, at times mottled with white.
H. G. Rothwell. Sandstones of Lake Superior.

MINNESOTA. has much good sandstone. At Ford du Lac are excellent ones of a red color and in the southwest are purplish red quartzites which though hard give beautiful effects when polished.
N. H. Winchell. Final Rept. Vol.I.

COLORADO. has of late years been developing extensive quarries. They are mostly of red sandstone from the Trias beds which are so well exposed in the eastern foot-hills near Manitou. Further north in Larimer Co. the stone becomes cream colored. Other Triassic stone of a salmon color comes from Glencoe near Golden and is shipped even to Chicago. Light colored stone from the Cretaceous is obtained near Longmont in Boulder Co. and near Canon City. Excellent red Triassic stone is quarried along the Midland R.R., on Frying Pan Creek in the western mountains.

SOUTH DAKOTA furnishes a good grade of red quartzite from near Sioux Falls that is very hard and durable. The Edgmont Stone Company in the Black Hills region have a warm yellow sandstone of pleasing color.

CALIFORNIA has many beds of fine sandstones. They are beginning to be extensively developed and descriptions by A. W. Jackson will be found in the Report of the State Mineralogist for 1887 & 1888. The quarries of other states are not important enough to deserve further mention here, but much fuller details will be found in G. P. Merrill's "Stones for Building and Decoration"
Wiley. 1891

NEW BRUNSWICK. Considerable amounts of an olive green sandstone from the lower Carboniferous beds of Dorchester, N.B. are imported along the Atlantic seaboard and considerable also of red sandstone comes from Dumfriesshire, Scotland, being shipped from Carlisle.

CLAYS AND SLATES.

General papers. Local References follow under localities.

Brackett & Williams. Newtonite and Rectorite, two new minerals of the Kaolinite Group A.J.S., July, 1891.p.11.
W. H. Brewer. Suspension and Sedimentation of clays, A.J.S. iii, XXIX, 1.
G.H.Cook and J.C.Smock. Report on New Jersey Clay beds, 1878.
W.O.Crosby. Composition of the Till or Boulder Clay, Boston Soc.Nat.Hist. XXV, 115, 1890.
C.T.Davis. Bricks Tiles and Terra Cotta.
R.T.Hill. Clay Materials of the United States, M.R. 1892. p.712
Johnson & Blake. Kaolinite and Pholerite, A.J.S. ii, XLIII,1867, p.351.
G.A.Koenig. Supplement to the Encycl.Brittanica, Vol.II p.127.Article Clay. Rec.
R.B.Morrison. Brick Makers Manual.
E.Orton Sr. & E.Orton Jr. Clays and Clay Industries of Ohio.Geol.Surv.Ohio Vol. VII, 45-254, 1893. Rec.
H. Ries. Article on Clays. Mineral Industry, II, 165, 1894. Rec.
Forthcoming Report on the Clays of New York, 1895.

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Clays are of two general kinds as regards origin, sedimentary and residual. The latter as the name implies are the less soluble materials that remain behind in the weathering and removal in solution of the substances in rocks which are more easily attacked. Limestones afford them and they often mark as well the position of former granitic masses. Sedimentary clays are formed by the finest products of erosion which are the ones that remain in suspension until the transporting water becomes quite still. But in these fine sediments in order to bring about a true clay there must be a sufficient proportion of a hydrated silicate of alumina to give them plasticity. Excessive amounts of quartz and other minerals however fine lack this property and afford fine sands, gritty clays or mud all of which with increasing coarseness pass into shales, greywackes and sandstones.

The distinguishing physical feature then of a clay is plasticity and the cause of it is the mineral commonly called Kaolin. Microscopic investigations have shown that Kaolin crystallizes in exceedingly minute, rhombic, hexagonal or rounded scaly crystals, to which has usually and with some reason, been given the name Kaolinite, and their composition has been formulated as Al_2O_3, $2SiO_2$, $2H_2O$. corresponding to SiO_2 46.50, Al_2O_3 39.57 H_2O 13.93. In the paper by Brackett & Williams cited above will be found a discussion of the Kaolinite group and the discovery of two new members in a series of four possible silicates. There always has been some difficulty in making analyses of exceptionally pure clays fit the Kaolinite formula and it is probable that other hydrated silicates of alumina are present in not a few. In the process of analysis it is difficult to separate the amount of silica present as comminuted quartz from that combined with the alumina and in very fine clays the mechanical means of differential settlings is not applicable. In coarser, gritty clays much free quartz can in this way be washed out, but even in the finest slimes some will remain. In the investigation of boulder clay referred to above Crosby divided it into four products; one, gravel, which would not pass a 12 mesh sieve, two, sand, which would not pass a 30 mesh sieve, three, Rock-flour palpably gritty and mostly comminuted quartz , four, clay, not gritty (or nearly so) and losing at least 12%.

combined H_2O on ignition. The last two were separated from each other by repeated decantation. All clays contain some free quartz, although in New Jersey in instances the very fat clays have as low as 0.2%. Other rock making minerals are present mechanically involved such as mica, feldspar, iron oxides and curiously enough rutile (TiO_2) to an almost invariable amount of 1.% in New Jersey fire clay. Rutile has been long known as a constant ingredient of slates. More or less carbonaceous matter appears in clays in the form of lignite. Balls or concretions of pyrite are also common. Carbonate of lime is frequently so abundant in brick clay as to readily effervesce, and its concretions or clay-dogs are found in almost every brick yard.

Sedimentary clays are either soft beds that have never hardened and that thus belong to the more recent geological formations (many occur in the deposits of the Glacial period) or else they are the mellowed outcrops of clay beds which are perhaps of older formation and only hard under cover. In their chemical composition clays contain SiO_2, Al_2O_3, and H_2O in largest amount, and with these are variable but smaller quantities of iron oxides or sulphides, lime, magnesia, potash, soda and titanium oxide. Their presents affects the uses of the clay whether for common brick, pottery, drain tile, fire brick, etc. Where a high refactory property is needed the ideal brick approximates as much as possible pure Kaolinite which is even less fusible than quartz. But as such a fat clay shrinks and checks in firing it has to be tempered by the addition of quartz. Titanium oxide has no bad effect and by itself iron oxide is less deleterious than the others. Lime, magnesia, potash and soda tend to make fusible double silicates with the alumina or with one another and thus injure the refactory property. Many years ago Bischoff suggested the following formula as convenient for expressing the excellence of fire clays $\frac{Al_2O_3}{RO} \times \frac{Al_2O_3}{SiO_2}$ in which the several molecules indicate the percentages of them afforded by analysis. R stands for the other bases; thus the excellence of a clay varies directly as the square of the percentage in Al_2O_3 and inversely as the other bases and the silica. When values are supplied in this formula it is found that the most refactory clays give results as high as 14, while ordinary fire clays may be as low as 4 or even 1. The work of H. A. Wheeler on the fire clays of Missouri has shown that this expression does not always hold good and that it is incomplete. Bischoff's formula calls for high percentages of Al_2O_3 for the best refactory results, whereas Wheeler has found that clays high in SiO_2 exhibit fire resisting powers not at all inferior. Wheeler shows that the other oxides or "detrimentals" as he calls them, are the great agents in promoting the fusibility, and that the density and fineness of the clay are also important factors. The formula that he recommends for clays of about the same fineness and whose specific gravities do not differ more than 0.2 is Fusibility Factor or $F.F. = \frac{N}{D+D'}$ in which N represents the non-detrimentals, SiO_2, Al_2O_3, TiO_2, H_2O, CO_2, D represents the total of detrimentals, or the Fe_2O_3, FeO, CaO, MgO, K_2O, Na_2O, S and SO_2. D' is the alkalies alone, they being of especially bad influence. If there is great difference in grain and specific gravity, a constant has to be added to the denominator. Values of the latter are given in the original paper (Sec.E.M.Jour.Mar.10,1894.p. 224, and forthcoming report of Mo.Geol.Surv.on Clays.) Fire clays are the most valuable clays, and in connection with them chemical analysis is especially important. In the best clays the alkalies should be not over 1%; iron oxide may be as much or a trifle more, and of the rest still less; of all these, however, the less the better.

[illegible] The [illegible] were separated from each other by [illegible]. All clays contain some free quartz, although in [illegible] that very fine clays have as low as 0.5%. Only [illegible] minerals were [illegible] such as mica, feld-spar, [illegible] and curiously enough rutile (Fig. [illegible]) in an almost invari-able amount [illegible] in the larger [illegible] rutile has been long known as a constant ingredient of clays. More or less carbonaceous matter [illegible] in the form of lignite. Small [illegible] of pyrite are also common. [illegible] of lime is frequently so abundant in brick clay as to [illegible] and its [illegible] are found [illegible]

[illegible] clays are either soft [illegible] that they have never hardened and [illegible] to the more recent geological formations [illegible]

[illegible]

[illegible]

Common brick clays are the most impure but the published analyses are fewer than those of fire clay.

Clays weigh about 3000-3500 lbs. to the cu.yd. The specific gravity ranges from 1.75 to 2.45. It is higher in the quartzose varieties.

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BRICK CLAYS.

Clays adapted to brick making are accessible to nearly all our large cities. In the north they are commonly derived from the finer sediments that settled in the floods which followed the melting of the great ice sheet of the Glacial Period. They are impure clays and even in a common kiln often fuse. The clay is at times in thin beds separated by a little coat of sand that prevents them mellowing together and that marks the more troubled waters of the seasons of floods when the clays were deposited. Again the clay is in a solid mass not marked by much bedding. The clay is tempered with sand to give stiffness and is often submitted to heavy pressure in the moulds in order to obtain the even surface of pressed brick. The quality of the tempering sand is important. It should consist of quartz fragments but there are not a few regions of limestones and calcareous shales where quartz sands are unknown. In such tempering material or in the clay itself are often limestone fragments that calcine in the kiln and afford quicklime which may cause the bricks to spall off after being laid in the wall. The absorption of moisture and the consequent explosive slaking is the reason of it. Central New York suffers in this respect.

Ordinary brick clay is extremely variable in chemical composition. The SiO_2 ranges from below 40 to over 80%, and the Al_2O_3 10 to 20%. The amount of iron oxide in clays used for ordinary red brick averages 3-6%, but as a deeper color may increase the price per 1000 very materially, this is sometimes artificially increased. The effect of the iron is influenced also by the amount of lime present with which the iron forms a light colored silicate. Thus the cream colored Milwaukee bricks are made of a clay not especially low in Fe_2O_3 (2.83-3.84) but high in lime-(15.45-13.24). Lime usually ranges from less than 1% to 10 or more. If it is not left in the brick as lumps of quick lime it does no especial harm. Magnesia is rarely as much as 5% and the alkalies are generally not far from 5. A practical test of a clay is a safer indication of its value than is an analysis. In the kiln the green brick is brought up gradually to a sintered but not thoroughly vitrified condition. H. Ries states that a good brick should fulfil the following conditions. It should be fairly dense, of a good color, of parallel sides and sharp edges. To yield this a clay is required that will not check or irregularly shrink in firing. It should be compact and uniform in texture and give a clear, ringing sound when struck. This is largely a function of the moulding. It should not absorb over 10-15% of water; it should have a specific gravity of 2.or more, and a crushing strength of at least 3000 lbs. per square in.

Shales have been ground in a few localities and then moulded into bricks and baked. They have given very satisfactory results both for building purposes and as later noted for paving. The Devonian shales in southern New York have such applications. It is unnecessary to mention in detail the localities of brick clay. They are especially found in New York and New England in the deposits of the Champlain Epoch which are wonderfully developed in the valleys of the Hudson and Connecticut rivers. Near New York the brick yards are found along the Hudson River and in the

estuary of the Hackensack River west of the Palisade or Bergen Hill Rid- According to the recent report of H. Ries the geological section involving the clays is, 1. Drift. 2, Delta Deposits (i.e. from streams flowing into the Hudson Valley from east and west). 3, Estuary Deposits of fine stratified sand, and of blue and buff clays. They all date back to the close of the Glacial times and have been somewhat elevated since. The clays may be 100 ft.or more thick or may sink to a mere trace. They are found from Sing Sing to Albany with a break where the Highlands cross the river. The clays are quite calcareous and furnish rather more than a billion bricks yearly. They are dug from the banks and to a less degree dredged from the river bottom.

H. Ries. The Quarternary Deposits of the Hudson River Valley,etc.
Report of the N.Y.State Geologist, published 1892.
Trans. N.Y.Acad.Sci., XI, 33, 1891.
Forthcoming Bulletin of the N.Y.State Museum, 1895.
The article on Clay by Mr.Reis in Rothwell's Mineral Industry, Vol.II. p.165 is especially to be recommended.

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The terminal moraine crosses the Delaware River north of Trenton and runs thence northwesterly across Pennsylvania. The clays south of it are of earlier date than the Glacial times. A most important belt of them passes southwestwardly through New Jersey of Cretaceous Age and appears in the banks of the Delaware from Trenton to Philadelphia and thence south. Either these clays or the Glacial beds further north have been re-deposited to form the Quarternary brick clay of Philadelphia from which are made the excellent pressed bricks for which the locality is famous. The Cretaceous clays are however important further south near Baltimore, Washington and elsewhere. They are often red in natural color.

A. Heilprin. Chapter on Philadelphia Brick in Town Geology. 1885.
Repts.of 2nd.Penn.Geol.surv., especially C6.

Excellent bricks are made at Buffalo from Glacial clays. In Ohio the principal clays are softened outcrops of Carboniferous strata and are mentioned later under refractory clays, but common brick are also furnished. Indiana places great quantities of brick of more than local importance on the markets. They are obtained from regions southeast of Chicago and afford pressed brick of high grade. Milwaukee has given its name to a cream colored brick of interesting properties. While one might infer that the crude clay lacked iron such is not the case, but as earlier stated the iron that is present fuses with the lime and alkalies to a white double silicate.

Reports of the Bureau of Statistics of Indiana,1880, 81,82,83,etc.
E. T. Sweet. Milwaukee clays and bricks. A.J.S.,iii, XXIV, 154.
N. H. Winchell. Minn.Geol.Surv. Miscellaneous Publications, No.8, A.J.S. iii, XXIII, 64.

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VITRIFIED BRICK.

The notable increase of interest in good roads and paving has led to the development of the vitrified brick industry. This material is often available in regions remote from crystalline rocks or others hard enough for street traffic, and has grown greatly in late years. A clay or shale is needed that will vitrify without losing its shape, when the fire of the kiln is pushed beyond the sintering stage needed for building brick.

The cost is much less than asphalt or granite and the raw material is more widely spread. Near Syracuse,N.Y., Charleston W.Va. and in the West are many works. The analyses range much as in brick claybut not all of the latter clays give good vitrified brick.

C. P. Chase. Brick Pavement. 1891.

T. W. Gibson. Vitrified Brick for Street Pavements- Rep.of Bureau of Mines, Ontario,1893. S of M.Quarterly,Jan.1895. p.149.

E. Orton Jr. Geology of Ohio. VII. 129.

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FIRE-CLAY.

The general properties of fire-clay have already been outlined. It remains to speak of the principal sources of fire brick.

NEW JERSEY. The belt of Cretaceous deposits that cross New Jersey from Staten Island to Trenton, as the northern boundary, consist of a northern and underlying belt of clays and a southern overlying one of marls and greensands. The clays are lower Cretaceous and afford several varieties. In general the beds consist of fire-clay, potters clay, brick clay and lignite and are some 350' thick in all. Although they contain many land plants they are marine deposits as is shown by the molluscs. The beds strike northeast. The clays have many varieties, some being suited to stoneware, some to pipes, some for firebrick, some, which are pure white, for paper adulteration, and some, that are pure kaolin, are called feldspar. The fire brick has a very high reputation and in instances has stood better tests than any other. Analyses show that the fire clays approximate kaolin but have somewhat less than the theoretical percentage of silica. The other varieties run much higher. Woodbridge and Amboy contain the most extensive pits.

Sixth Annual Report Bureau of Labor and Statistics of New Jersey.

G. H. Cook and J. C. Smock. N.J.Geol.Surv. Report on Clays, 1878.

J. S. Newberry. On the Raritan Clays of N.J. A.A.A.S., 1869.

J. C. Smock. Mining Clay, Trans.Min.Eng.,III,p.211 Fire Clays and Plastic Clays of N.J., do. VI, 177, E.& M.J. Mar.16, 23,1878. Potters Clay, A.J.S. iii, II, 198.

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The other sources of fire clay are largely from the beds which underlie coal seams and are thus found in the Coal Measures. The principal states producing such are Pennsylvania, Maryland, Ohio and Missouri. In Pennsylvania excellent fire brick is made in Clearfield Co., at Woodland. The clay lies under the Brookville coal seam, or seam A, and just over the Pottsville Conglomerate. Others from under bed B, are burnt at Johnstown in Cambria Co. and still others near Pittsburg. Clay at Mt. Savage, Md. in the Cumberland coal basin also affords an excellent brick. Ohio is abundantly provided with fire clays in the area of the coal measures. At Mineral Point, Akron and many other places kilns are in operation. Cheltenham, a suburb of St. Louis is one of the best known of our clays. It is available for glass pots and for this few others are adapted. It is often associated with a thin coal seam.

Maryland. R. A. Cook. The manufacture of fire brick at Mount Savage,Md. M.E. Feb.1886.

Pennsylvania. See Reports H7 on Clearfield, p.167. HH on Cambria Co. p.145. MM p.270 on tests of various clays and other local reports.

Ohio. Vol. V, p.643, Ohio Geol.Surv. Vol. VII, 45-254 Rec.

Missouri. Geological Survey Bulletin.3,1890.

G. E. Ladd. On the clay, stone, etc. of St. Louis City and vicinity. Forthcoming report of H. A. Wheeler. See also E.& M.Jour.Mar.10.1894,224

Colorado affords important fire clays near Golden that furnish a brick of deservedly high reputation. The clays occur in the Dakota series and are made into muffles and various other refractory articles. Mining Industry, Denver, January 24th,1890 p.53.

APPENDIX. Bauxite, the natural oxide aluminium $Al_2O_3,3H_2O$, has been employed as a refractory material and is a valuable mineral for this purpose. It has however a more important application now as an ore of aluminium and as such has been described in the Volume on Ore Deposits.

Mention should also be made of the applications of clays to pottery and stoneware and of the important centers of these industries. Trenton N.J. has very large works which supply high grades of table ware as well as the commoner kinds. The local clays are used for this purpose and much feldspar is brought to the works from various points and furnishes the materials for fine porcelains. East Liverpool,Ohio on the Ohio River, just as it leaves Pennsylvania is a great center for common crockery. Natural gas is utilized to some extent in the baking. The clays come from below the Lower Kittanning coal. Much stoneware is made at Akron and at Roseville, Perry Co. Ordinary household earthenware is a common product everywhere throughout the country. Suitable clays are common. On Trenton clays, see New Jersey Report often quoted. For Ohio, Vol.V, of Geol. Survey, and Vol.VII,45. The last is an excellent paper.

Feldspar should be also mentioned as one of the substances entering the finer grades of table ware. The merchantable mineral comes from coarse veins or segregations that contain the same minerals as igneous granite, but it is doubtful if they have cooled from fusion. They seem rather to be vein fillings formed at extraordinary pressures and temperatures and are often spoken of as pegmatite . Where coarse enough to warrant the separation of the feldspar they are mined. The mineral is worth about $5. per ton at the potteries. Quarries exist in Maine at Edgecombe, Lincoln Co. and Brunswick, Cumberland Co.; in New York, at Crown Point, Bedford, Tarrytown and Fort Ann; in Connecticut, at South Glastonbury, Middletown and Branchville, in Pennsylvania, at Brandywine Summit; in Delaware, at several points in New Castle County. The total annual product varies from eight to fifteen thousand tons.
Mineral Resources of the U.S. and local Pennsylvania Geological Reports.

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QUARTZ. is also quarried for admixture with feldspar, and is obtained from veins from much the same character. An enormous one forms Lantern Hill, north of Mystic,Conn. and is largely dug. The vein is some hundreds of feet across and formed of comby quartz crystals. The part that is dug has been corroded by some obscure process, probably by magnesian solutions, to sucha degree that the crystals crumble between the fingers and the whole vein is dug out with pick and shovel. It is ground and sorted. In Missouri, curiously decomposed cherts give a product of pure silica called Tripoli that is utilized quite largely.

SLATES. Clay beds have at times formed important members in rock series that have suffered foldings and great regional metamorphism. They develop under these conditions a cleavage that is normal to the direction of pressure and that splits the beds into thin slabs at all angles to the original bedding. The bedding planes can often be followed in folds in the quarries and can even be seen in single slabs. Any contained fossils are much distorted. The slaty cleavage is due to the rearrangement of the particles of minerals in the clay so that their long axes instead of being parallel with the bedding are now perpendicular to the pressure.

The structure has been imitated artificially. In nature, only extremely homogeneous clays have produced good slates. Where for any reason the rock is more silicious or coarse it has failed of the cleavage and such layers preserved the crumpled folds with no cleavage. They are troubles in the quarry and are called curly slates. Another drawback is met in the quartz veinlets that especially favor slate districts. They spoil the cleavage. Pyrite too is a bad feature when present. All such imperfections cause enormous waste and all slate quarries give the visitor the impression of the vast quantity of material necessarily handled to provide the output. It may be from five to twenty five times. Many endeavors have been made to utilize this refuse. It has been ground for paint, and serves very well. It has also been ground and with clay baked into serviceable brick. Slates are used for roofing and of later years for all manner of applications such as marbleized mantels, billiard tables, wash tubs, steps in stairways etc. When too thick for roofing the slabs are easily dressed, planed, sawed and worked into other shapes. For roofing it is important to get slate from a sufficient depth in the quarry to avoid weathered outcrops. If not good it is apt to slough away to mud on exposure.

Slates are mostly drab or blue-black, but there are also red and green varieties. These colors appear at times in the same quarry. Under the microscope it is seen that fine kaolin makes up a good portion of the slide, but that quartz and feldspar are also present. Mica sometimes appears and rutile in excessively minute needles is common. As rocks, slate shade into phyllites and mica and hornblende schists. They are sold by the "square" which means the slate including overlaps, which is needed to cover one hundred square feet of roof.

NEW ENGLAND AND NEW YORK. Maine affords small quantities of slate from exposures not extensively developed. They are in Piscataquis Co. New Hampshire has some near Hanover. The most prominent district of New England lies along the juncture of Vermont and New York. There are slates of two ages. One belt is in the Georgia series of the Cumbrian and the other is the Hudson River Stage of the Lower Silurian. The former furnishes purplish or green slate, the latter red and green. The former is most productive and its product is adapted to all the applications of slates. The red variety however brings a higher price.

Engineering and Mining Journal, IX, 19, May 10th,1870.
Manufacturers and Builders, Circa 1870 p.83.
J. C. Smock. Bull.3 New York State Museum.
C. D. Walcott. The Taconic System of Emmons etc., A.J.S. March and April 1888, with a geological map.

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PENNSYLVANIA. Slates are of some importance at Newton, New Jersey, but in Pennsylvania they are a valuable material. There are two productive points, one is regarded as Huronian, is principally developed in York Co. and is known as the Peach Bottom Slate. The belt also extends into Maryland. It really is a very fissile, carbonaceous schist. It dips at a high angle and is valuable in a belt but a few yards across. The larger area is in the slates of Hudson River Age, in Lehigh and North ampton Counties. The belt is 7 to 12 miles wide and much folded. The anticlines and synclines often show in the quarries. The slates are dark blue or bluish black, and furnish our chief supplies.

Pennsylvania Geological Report (Survey) D3.
Engineering News January 31st,1885, p.67.

VIRGINIA. has some notable quarries in Bingham County.

GEORGIA. Slates are also commercially important in northwestern Georgia near the town of Rockmart, but they have not been systematically worked until recent years.

MICHIGAN. Excellent slate of Huronian age, occurs near L'Ause in the Upper Peninsula. It has not been utilized in recent years.

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LIMESTONES INCLUDING MARBLES.

Limestones occur in all geological formations although in the later ones they are not always firm enough for building stone. They are less abundant than sandstones but at times form enormous deposits. In the less altered forms they consist of fossil remains and comminuted calcareous materials which have hardened to a solid mass. More or less silica, alumina and magnesia are always present. The increase of these ingredients, especially the alumina marks a change to hydraulic limestones. Those high in magnesia without so much argillaceous material are called dolomites. Limestones are both thick and thin bedded and need to be in layers about a foot thick to be of much importance, although much thinner stone can be utilized if thicker is not available. They furnish a moderately strong stone as a general thing and in exceptional cases reach well up into the figures of granite. Limestoneswork readily when of an even texture and often take a fine polish. Their absorption is less than sandstone as a general thing but is higher than granite. The specific gravity may drop to 2.40 (150 lbs.to the cubic foot) but it rules 2.50 to 2.70 with an average for marble not far from that of granite.

Where limestones have been subjected to regional metamorphism from foldings and geological disturbances they become crystalline and are then called marbles. They admit of a high polish and often afford a stone of surpassing beauty. Whatever carbonaceous matter was in the original limestone becomes graphitic and affords the lines in veined marbles.Other substances as well as organic matter itself give all manner of colors, Some harder metamorphic minerals, such as tremolite are at times formed and furnish imperfections in the stone. Marble or limestone breccias with variously colored cements afford a strangely mottled stone.

The weathering action on limestones is chiefly in the nature of solution of calcium carbonate. Acid gases and plant growth affect them seriously. The carbonic acid in the atmosphere when dissolved in rain water exercises a solvent effect, and is their greatest enemy. Its effects are manifested by pitted surfaces. Clay seams in the stone and irregularities of texture sometimes appear on exposure. Atmospheric waters have also a profound effect on the stone before opened in quarries, and occasionally workings meet with fissures and imperfections that curtail the amount of available good material. Joints speedily become larger from circulating waters and may appear in the quarry face as unsightly cracks filled with red, residual clay. Limestones are not especially good fire resisters, for theycrack and calcine under great heat.

WESTERN NEW ENGLAND AND NEW YORK. The most important marble quarries of America are found along the Green Mountains, and are in various beds of limestone of Cambro-Silurian Age that have been metamorphosed by the upheaval of this great ridge at the close of the Lower Silurian Period. The most productive section begins in Dorset, Vt. on the south and extends through Wallingford, West Rutland, Proctor (formerly called Suth-

erland Falls) Pittsford, Brandon and Middlebury. It lies on the flank of the Green Mountains. The geological structure is very complicated and not well understood, but near the West Rutland quarries, Chazy fossils have been found, while further east at Pine Hill and again at Rutland J. E. Wolff announces Cambrian fossils. The section varies much and particular beds have particular excellences. There are blue, white, veined and other varieties. The thickest are at Dorset from which point they thin to the north but afford a better grade of stone. The marble is loosened by channeling machines and wedged off. No powder is employed. The workings are enormous and much ingenious machinery is utilized. Further north, above Burlington, red mottled marble is obtained called Winooski. It belongs in the "red sand rock", as the formation was called by the early Vermont Survey before its Cambrian Age was known. It outcrops on Mallet's Bay and at St. Albans and Swanton, but is a very siliceous variety and hard to work. Still further west on Isle la Motte, one of the islands in the northern part of Lake Champlain are quarries furnishing a marble of dark gray ground mass, which is variegated by lighter colored fossil shells distributed through it.

Brainerd & Seely. The Marble Border of Western New England, Proc. Middlebury Hist. Soc. Vol.I, Pt.II, 1885.
J. D. Dana. On the Age of the Marbles. A.J.S.,iii, XIII, 332-347,405-419
E. Hitchcock. Geology of Vermont, Vol. II.
G. H. Perkins. On Winooski Marble, Amer. Naturalist, Feb. 1881.
J. E. Wolff. On the Lower Cambrian Age of the Stockbridge Limestone. Geol. Soc. Amer. II, p.331.

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MASSACHUSETTS. The Taconic Range in Massachusetts contains beds of metamorphosed limestones analogous to those of Vermont. In earlier years quite extensive quarries were worked at Lee, Sheffield and other towns. The marble contained more or less tremolite and is less used than formerly. The same belt extends into northwest Connecticut and has been utilized, at Canaan.

NEW YORK. Marbles are obtained on the west shore of Lake Champlain, in the southeastern corner of Westchester County and in the western confines of the Adirondacks. The first named region furnishes a variety of marbles. The well known dove colored "Lepanto" with its mottlings of pink and white fossils is quarried near Plattsburgh and in the township of Chazy. Further south in the township of Moriah the limestones are strongly magnesian and contain much disseminated serpentine. They are thus white and green mottled and are known as Moriah marble, verd antique ophite or ophicalcite. G. P. Morrill has shown that the serpentine has resulted from decomposed pyroxene. This is a beautiful stone and resembles granite at a distance. A similar variety is obtained at Reegate and Cavendish, Vt. At Glens Falls, N.Y. black marble is quarried of great beauty. In Westchester County the same dolomite beds appear as in Connecticut. They afford fine quarries at Pleasantville and Tuckahoe as the coarsely crystalline stone gives a snowflake effect. They are not much worked at present. On the west of the Adirondacks in the town of Gouverneur, beautiful white and blue mottled marbles are obtained and extensively quarried. Limestones not marbles, strictly speaking are locally worked in many places. The Lower Silurian in Central New York north of Utica is prolific and in the unmetamorphosed portions around Lake Champlain. At Greenport, Columbia Co. the Lower Silurian limestones are

again largely quarried.

Higher in the geological series the Niagara and to a less ~~degree the~~ Clinton limestones are available from Lockport to Niagara. Lockport is best known for a crinoidal variety that takes a fine polish and is called marble, but best exposures by far are across the Niagara River at St. Davids in Canada, where unusually thick and homogeneous beds occur in the crest of the escarpment . The Lower Helderberg contains some limestones locally employed for building southwest of Albany but is better known as a source of cement rock. The rocks of the Corniferous Period afford two important beds, the Onondaga gray limestone and the Corniferous. The former is much used in the vicinity of Syracuse, the latter in the northern outskirts of Buffalo. Above this horizon the Tully limestone is the only one in New York but it has no development worth mention.

J. S. Newberry. Reports of Judges Centennial Exposition, Vol.III.

J. C. Smock. Building Stone of New York, Bull.3, N.Y.State Museum, March 1888, pp.94-134. Bull.10.

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PENNSYLVANIA. Marbles are afforded by the Lower Silurian limestones of Montgomery County, and from other exposures in southwestern Pennsylvania. In instances they are of great strength. A statuary grade is reported at Avondale.

MARYLAND derives limestone or marble from an isolated Lower Silurian exposure near Cockeysville and also produces the famous Calico or Potomac marble from Point of Rocks. The last is Triassic.

VIRGINIA is known to contain great stores of marbles in the metamorphosed Cambro-Silurian limestones of the Great Valley. They await extended development although now locally employed. The same will doubtless prove true for North Carolina.

TENNESSEE. One of the largest marble industries of the country is based on the Lower Silurian limestones of the Great Valley near Knoxville in eastern Tennessee. A variety of color is found,but the one for which the section is best known is mottled with pink and white. It is a very strong and heavy stone,(180 lbs.to the Cubic foot) and is much used for decorations. Tennessee has great outcrops of limestones in the Nashville Valley as well.

Safford. Geology of Tennessee.

GEORGIA. Much attention has been of late given to the marbles of Georgia. The northwestern part of the state has many exposures of varied hues and they have been extensively sold in the north.

FLORIDA. Large quantities of a soft, fragmental shell and coral rock, called coquina were earlier quarried in Florida, but of late years wooden houses have proved so much drier that its use has passed away.

OHIO. Limestones are of extended occurence in Ohio but have little ornamental value. They are used for rough work,and strata of Carboniferous, Devonian, Upper Silurian and Lower Silurian are utilized.

E. Orton. Ohio Geol. Survey, Vol.V.

INDIANA. Several Carboniferous and Upper Silurian limestones are locally used, but the most important industry of this nature in the state is based on a belt of oolitic limestone, of the St.Louis division of the Lower Carboniferous. This extends from Kentucky northward for about 100 miles through central Indiana and is extensively quarried from Bedford on the south nearly to Greencastle on the north. The stratum runs about 40 feet thick, and is attacked wherever small valleys or gulches have made it accessible without stripping . The stone is called"Indiana limestone"

or"Bedford stone" or "Oolitic stone". The stratum scarcely shows a bedding plane, and can be cut out in blocks or monoliths of any desired size. There are two varieties, a blue and a buff. They shade into each other, and some quarries have both. The buff appears to be a slightly weathered form of blue. The limestone is homogeneous to an exceptional degree; it cuts with great favility and is noted for its adaptability to tool treatment. The industry now amounts to several millions of dollars annually, and the stone is extensively shipped even to New York.

J. Collett. Ann. Report State Geol. Indiana, 1878, p.88. 1881-82 p.20
A. J. S. iii. XXIV. 298

M. Thompson. Report on Indiana Building Stone, 17th Report State Geol. Ind. 1891. pp.18-114. Rec.

The belt of oolitic stone runs into Kentucky and contains resouces which are regarded as promising but they are far less developed.

ILLINOIS. The state is rich in limestones and these are available except where buried in drift. The Carboniferous, Devonian and Silurian Systems are all represented. The most important source is the Niagara limestone of the Upper Silurian. It is quarried of a somewhat poor and very bituminous quality in Chicago but is opened on an extensive [illegible] scale at Lemont and Joliet. Twelve to forty feet of stone are exposed. Though not specially durable when exposed to frost it furnishes a vast amount yearly, being easily wrought. In the northwestern corner Lower Silurian stone is obtained and elsewhere Carboniferous.

D. D. Conover. Tenth Census, X, p.261.

MISSOURI. The limestones of Missouri are either Subcarboniferous or Cambro-Silurian. The former are much quarried in St. Louis (St. Louis stage) and in southwestern Missouri (Keokuk stage), the Cambro-Silurian to some extent in southeastern Missouri. The stone of St Louis is locally used and developments are extensive.

G. C. Broadhead. Building Trades Journal, July, 1888.

IOWA. is in large part formed of limestone and affords numerous local quarries. The stone is obtained from the Niagara and Subcarboniferous strata, but is not shipped away.

MINNESOTA. Lower Silurian limestones are important in many regions St. Paul and Minneapolis have quarries in a rather thin bedded stone, that even where thick, may show bedding planes on weathering. At Frontenac in Goodhue County, very large and solidblocks are afforded of a rather weak variety. At Kasota and Mendota in Le Sueur County buff and pink varieties of greater strength are obtained and at Mankato, Blue Earth County solid blue dolomite in heavy blocks is quarried. These latter localities are southwest from St. Paul.

N. H. Winchell. Geology of Minnesota, Final Report Vol. I also preliminary report on Building Stone, 1889.

NEBRASKA AND KANSAS. Have Carboniferous limestones of poor quality which are called from the small protozoan that forms them, Fusulina limestone. In the latter state are other quarries in the Permian and in the former some in the Cretaceous.

COLORADO contains some marbles on the western slopes of the continental divide along Yule Creek. They are remote from transportation but efforts have been lately made to give them rail connections.

Dr. Newberry has spoken very highly of the beauties of the stone. Others are opened on the eastern slope in northern Colorado and utilized to some extent. J. S. Newberry. SCHOOL of MINES QUARTERLY, X, 71.

CALIFORNIA has some notable occurences of marbles. The openings near the town of Keeler, in Inyo Co. seem the most beautiful and bid fair to furnish extensive amounts of superior grade. The colors vary from pure white to mottlings of other tints, and in instances are unique in pattern. Banded travertines akin to the so-called Mexico onyx are quarried in San Luis, Obispo Co.
See the Seventh, Eighth, Tenth and Twelfth Annual Reports of the California State Mineralogist, especially the last, p.390.

ARIZONA. Quarries of stalagmitic limestone of beautiful banded structure, like Mexican onyx, have been lately opened in Big Bug Creek, thirty miles from Prescott, Arizona. They have been already introduced to some extent.
J. F. Blandy.Big Bug Onyx Quarries,Arizona. E.& M.J.,Mar.26,1892, p.348.

MEXICO. From two localities in Mexico beautiful banded marbles, the so-called"Mexican Onyx", are shipped to the United States. The one first opened is in the state of Puebla; and is a continuation of an industry that throve under the Aztecs. The stone usually lies in detached boulders of varying size, buried in red clay. These are sawn up and where checks or defects appear they are artificially remedied. The price increases rapidly with the size of the slab. The so-called onyx also occurs as veins in a cherty rock. Needless to say, the "onyx" is calcite, and not the mineral properly called onyx, whose bandings are, however, closely imitated. More recently large deposits have also been opened in Lower California. They lie in the interior valley of the peninsula and near the 30th parallel of latitude. About 100 feet of alternating beds of travertine or"onyx"and calcareous conglomerate, fill a narrow ravine, which has been eroded in sandstone. The travertine is a hot spring deposit. Beautiful slabs and small pillars are obtained. The company is called the New Padrara Onyx Co.
On the Puebla Quarries. See Eng.& Mining Journal.Dec.26,1891. p.729.
On the New Padrara Quarries, See Emmons and Merrill,Geol.Sketch of Lower California, Bull.Geol.Soc.Amer. V. 489, and especially 508.

Foreign marbles especially colored varities are imported in considerable quantities. Various points in Italy, in Portugal, Spain, France and Northern Africa supply them. They have their special names, a list of which with descriptions will be found in the paper by J.S.Newberry, Reports and Awards, Centennial Exposition, Philadelphia. J.B.Lippincott, p.145. The same names have been adopted in instances by American dealers for local marbles.

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SERPENTINE.

The ophicalcite marbles which occur in the eastern Adirondacks were earlier referred to, p. 130. They are closely akin to serpentine and often contain lumps of this mineral of notable size. Serpentine supplies a beautiful ornamental stone when it can be had in sufficient purity. It takes a high polish and affords mottled greens and reds that have been prized from remote antiquity. The best grades are called precious serpentine. Specimens are obtained at Newburyport, Mass. and at Montville, N.J. The massive rock is used as an ordinary building stone in Philadelphia. Although outcrops are met near New York, the stone is not solid enough for building purposes.

CALIFORNIA has some notable occurrences of marbles. The deposits near the town of Colton, [illegible] Co., [illegible] in the [illegible] marble groups. [illegible] ... in the [illegible], [illegible] ... Dept. ... [illegible] ... the State [illegible], [illegible] the [illegible] ...

[illegible] ... Arizona. [illegible] ...

[illegible] ... Arizona ... [illegible] ... 1928, p. 446. [illegible] ... in the United States. [illegible] ... in a quarry near the [illegible] ... [illegible] ... which ... [illegible] ... the [illegible] ...

[illegible] ... Vol. ... 1921, p. 506. ... [illegible] ... Dept., No. ... [illegible] ... p. 400, and [illegible].

[illegible] ... France and Northern Africa ... [illegible] ... [illegible] ... 1921. [illegible] ...

G.P.Merrill. Ophicalite of Thurman, Warren Co., A.J.S. Mar.1889. p.189.
" Serpentinous Rocks of Essex Co., Proc.U.S.Nat'l.Museum,XII. 1890. 595.
" Montville do. do. 1888. 105.

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LIMES AND CEMENTS.

Limes and cements are classed by General Gillmore into four classes; 1..Fat Limes, 2..Meager Limes, 3..Hydraulic Limes, 4..Hydraulic Cement. They each depend upon the composition of the crude rock. If this is a nearly pure carbonate of lime, the fat limes are afforded. If the aluminous impurities reach 8 or 10 % hydraulic properties begin to be developed and at 18 to 20 % the product has to be ground to a fine powder before it will slake. The varying amounts of these ingredients determine the uses of the stone. In this country we have chiefly to do with Nos.1 and 4. The so-called impurities consist of carbonate of magnesium, carbonate and oxides of iron, clay, silicates, and sand. Of these the magnesium carbonate does not destroy the character of fat lime although present in very large amount. Its effect needs investigation and would furnish an interseting subject for a thesis, as authorities differ. Cements have received so much attention that common limes have had but little. It is thought by some that magnesia makes the lime set more slowly and such is the recorded experience with the lime obtained years ago in the upper parts of Manhattan Island. Iron does no especial harm in cements but in limes, particularly if used for interior plastering it destroys the whiteness. The argillaceous ingredients are present in fairly large quantities in all cement rocks.

LIMES. The following analyses of several limestones employed for quicklime will give an idea of the range in composition. It appears that they vary from nearly pure calcic carbomate to those high in magnesia. Oyster shells afford a very pure product that is greatly esteemed but the analysis shows that they have more magnesia than many natural stones.

	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	H_2O	Insol.
1. Glens Falls, N.Y.	96.46	0.64	1.70	1.20	
2. Hardistonville, N.J.	92.50	2.88	0.15	1.80	
3. Denieville, Arkansas.	98.43	0.95			0.28
4. See below.					
5. Tuckahoe, N.Y.	54.49	43.62			0.91
6. Springfield, Ohio.	54.13	44.37	0.56		0.65

1. By Prof. J.H.Appleton, for the company. 2. N.J.Geol.Surv.1868 p.404, contains also quartz and graphite, 1.70. 3. Geol.Surv.Ark. 1890 IV, 146. 4. Oyster Shells, CaO 44.4. MgO 1.3, Alkalies .4, CO_2 35.4, P_2O_5 .1, SO_2 .6, H_2O 14.5, Cl .4, Organic matter 3. Total 100.1 N.J. Geol.Surv.1868 p.405. 5. Quoted by Ark.Geol.Surv.1890.IV.211. 6. Niagara limestone, Geol.of Ohio.VI.716.

Separate statistics are not available wherewith to illustrate the relative importance of the states because the lime industry is classed in with those for cements, building stone and iron flux, but in a general way it may be said that in amounts in 1889 the more important states ranked in the following order: Pennsylvania, Maine, Ohio, New York, Wisconsin, Missouri, Indiana; all being over one million barrels. The value of

Maine's product is greatest. Lime is put up in barrels of 200 lbs. each.

Lime kilns are so common and lime is so generally produced throughout the country that particular regions hardly deserve mention. In the east the principal geological horizons are the Cambro-Silurian including the Trenton; the Niagara; the Lower Helderberg and the Carboniferous. In the Mississippi Valley the Subcarboniferous limestones are abundant and in the prairie states the Cretaceous. In Pennsylvania some thin beds in the Carboniferous are calcined for fertilizing material. The principal sources for New York City are Glens Falls, N.Y., where the Trenton limestone is very accessible; Rockland, Maine; and St. John, N.B. where Laurentian limestones furnish the supplies.

L.W.Bailey. Lime in New Brunswick, Mineral Industry, II. 451.

G.H.Cook. Limestones and Limes of N.J. N.J.Geol.Surv. 1868. p. 387.

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T.C.Hopkins. Report on Ark.Marbles,Geol.Surv.Ark.1890.IV.144. Describes technology. On Limes-Mineral Industry, II.443.1893.

Alex. M'Ava. On Limes and Cements. Proc.Phil.Soc. Glasgow, XXIII.24.

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E. Orton.Production of Lime in Ohio.Geol.Ohio.VI.703-711.Good general discussion. Rec.

CEMENTS. There are two kinds of cements which are important in this country, hydraulic or natural rock cement and Portland cement. The former is manufactured direct from an argillaceous limestone, while the latter is an artificial mixture, whose proportions are determined by analysis. In addition to these their are hydraulic limes, referred to above under lime, and pozzuolana a name used for artificial mixtures of ground, blast furnace slag and slacked lime. The name pozzuolana was originally applied to a leucitic tufa from Pozzuoli near Naples, and for a similar rock from the Rhine Valley the name trass has been used. All these substances owe their hydraulicity to the formation during the process of burning of basic silicates and aluminates of lime or of lime and magnesia which, together with some calcic hydrate, crystallize gradually when exposed to water, and afford the necessary bond of cement. Some powdered rocks and slags possess this property without calcination. Natural rock cement sets more quickly but is less strong than Portland. The latter continues to harden even for a term of years.

NATURAL ROCK CEMENTS are manufactured at numerous points but of these only the most important are selected. Much the largest is the district around Rondout, Ulster Co. generally called the Rosendale district by which name the cement is also known. Its production is nearly three million barrels annually. Next to this is the region near Louisville,Ky. with from one-half to two-thirds as much. Next follows a belt from Syracuse to Buffalo, N.Y. with somewhat over one million barrels, then the Lehigh Valley,Penn., Milwaukee,Wis., Utica and Lasalle,Ills. and Cumberland,Md. The others are very much less important. The general composition of rock and cement is shown by the annexed table.

	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	H_2O,etc.
1. Rosendale, N. Y.	45.91	26.14	15.37	11.38		1.20
2. Louisville, Ky.	50.43	18.67	22.58	2.93		5.39
3. Akron, N. Y.	35.60	19.26	33.80	4.84		6.82
4. Coplay, Penn.	67.14	2.90	18.34	7.49		3.94
5. Milwaukee, Wis.	45.54	32.46	17.56	1.41	3.03	
6. Utica, Ills.	42.25	31.98	21.12	1.12		3.53
7. Cumberland, Md	41.80	8.60	24.74	16.74	6.30	6.18

[illegible] is greatest. Lime is [illegible] [illegible] [illegible] lime, which
Lime which are at present and lime is so generally produced through-
out the country that particular regions hardly deserve mention. In the
east the principal producing sections are the Eastern [illegible] including
the [illegible], the Niagara, the Lower Mississippi and the [illegible]. In
the Mississippi Valley the [illegible] [illegible] are [illegible] and
in the [illegible] states the [illegible]. In Pennsylvania [illegible] both of
the [illegible] are utilized for fertilizing material. The principal
[illegible] for New York City are Glens Falls, N.Y., where the [illegible] lime-
stone is very accessible; Rockland, Maine, and St. John, N.B., where
[illegible]. Louisiana furnishes the supplies.

[illegible] Lime in the [illegible], Mineral Industry, [illegible]
[illegible] Limestones and Limes of U.S., [illegible] p. [illegible]
[illegible], Limes, Hydraulic Cements and Mortars, [illegible], [illegible]
[illegible] Report on the [illegible] [illegible] Materials
[illegible] On Lime, Mineral Industry, [illegible]
[illegible] On Lime and Cement, [illegible]
[illegible] [illegible] in all the [illegible]. More than [illegible]
[illegible] of [illegible] limestones [illegible] p. [illegible]
[illegible] of lime in [illegible] [illegible] general
[illegible]

Cements. There are two kinds of cements which are important in this country, hydraulic or natural rock cement and Portland cement. The former is manufactured direct from an argillaceous limestone, while the latter is an artificial mixture, whose proportions are determined by analyses. In addition to these, there are hydraulic limes, referred to above under lime, and pozzuolanas, a term used for artificial mixtures of granulated furnace slag and slacked lime. The name pozzuolana was originally applied to a volcanic rock from Pozzuoli, near Naples, and for a similar rock [illegible] the name trass has been used. All [illegible] [illegible] of [illegible] silicates and aluminates of lime in [illegible], together with some [illegible], [illegible] in water, and afford the necessary bond of cement. [illegible] The latter [illegible].

[illegible] Portland cement [illegible] [illegible] [illegible] [illegible] [illegible].

	SiO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rosendale, N. Y.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Milwaukee, Wis.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Nos. 1. 4. 5. and 6. from paper by W.A.Smith, Mineral Industry I. 49. No.2. Geol.Surv.Ky. A Chem.Anals.Pt.2. p.134. No.3. Gillmore, Limes, Mortars etc. p.125 6.18 % of last column is given as alkaline chlorides. No.7. Geol.of Ohio. VI. 673.

	Ca O.	MgO.	SiO_2.	Al_2O_3, Fe_2O_3.	H_2Oetc.
1. Rosendale Cement	37.60	16.65	22.75	16.70	6.30
2. Louisville "	41.80	16.29	24.40	6.20	11.41
3. Akron "	56.75		32.22	10.91	
4. Coplay "	69.18	1.98	18.18	9.78	.88
5. Utica, Ills. "	33.67	20.98	35.43	9.92	

Nos. 1. 4. and 5. from paper by W.A.Smith, Mineral Industry, I. 50. No.2. Geol.Ohio. VI.674. No.3. Cement Rock and gypsum Deposits in Buffalo. M.E. Oct.1888.

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A brief study of the first table of analyses brings out the great variability in the composition of the crude rock. Lime and silica seem to be the chief essentials, because as in No.4. magnesia may fall very low and as in No.6. Al_2O_3 may almost disappear. The second table shows nearly as much variability but it is more significant as it represents the finished product. The figures indicate that MgO is the only one not a real essential. This inference is corroborated by experience with Portland cements in which not over 1 % MgO is allowed in the usual specifications.

E.C.Clarke. Experiments with Rosendale and Portland Cements. Trans.Amer Soc.Civ.Eng. April 1885. See also June 21 and Nov.1885 .for official tests.
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P.Giron. Methods of Burning. Proc.Engineers Club of Phila. X. July 1893.
E.Kinchling. On Cement Mortars. Appendix Ann.Report Exec.Board of City of Rochester, 1887.
M.Le Chatelier. Procédésd'Enaé des Maténaux hydrauliques. Ann. des Mines 1893. 252. Good review 100 pp. Translated in M.E.Aug'93
N.W.Lord. Natural and Artificial Cement. Geol. Ohio. VI. 671.
S.B.Newberry. Mineral Resources. 1893. p.618. Mineral Industry 1893p.84 Scientific American Supplement April 21, 1894.
Wm.Allen Smith. On Cements, Mineral Industry, I. 49. 1892.

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NEW YORK. The New York hydraulic limestones are almost all derived from the Waterline beds which are now placed at the top of the Salina. In the Rosendale region these occur just above the Climton quartzite and form two beds, from 7 to 25 feet thick and separated by a few feet of sandstone. The workings are now, in almost all cases underground, and the beds dip at all angles up to the vertical. For illustrations of stratigraphical disturbances the region is noted as one of the best in the East. Folds and unconformities are both admirably exposed. Rosendale, Binnewater, Lawrenceville and Rondout are the chief centers.

From Syracuse west to Buffalo are not a few additional quarries, which are based on the "Waterline" stratum, the transition member between the Salina and in this case the corniferous. The bed mined near Buffalo is 5 to 8 feet thick, and the product goes by the name of Akron cement. Mushrooms are grown in the abandoned tunnels and the same is true of Utica, Ills. The cement rock enters Ohio and is operated to some extent, but the state is more important as a producer of Portland.

T.N.Dale. Geol.Cement Quarries. A.J.S.iii. XVI. 293. 1879.
W.M.Davis. On the Geology near Rondout. see A.J.S.iii.XXVI.1883. 389. Bull. Mus. Comp. Zool. VII. 311.
Lindsley. Geol.of Cement Quarries. Poughkeepsie Soc.Nat.Science.II.44-48.
F.L.Nason. Econ.Geol. Ulster Co. Rep.of State Geol. N.Y. 1893. p.375. See also N.H.Darton Geol. Ulster Co. Idem. 291.
J.Pohlman. Cement Rock and Gypsum Deposits near Buffalo, M.E.Oct.1888. On the cultivation of Mushrooms-see paper by W.Y.Warren, same reference.

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KENTUCKY. The second area in productiveness lies near Louisville, by which name the cement is known. It is derived from beds, near the Falls of the Ohio.
See Kentucky Geol. Survey, New Series, IV. 404.

PENNSYLVANIA. Contains a very important district in Lehigh Valley. The chief developments are near Coplay and the rock is obtained from open cuts in limestone of the Trenton.
See Pennsylvania Geol. Survey DD. 59.

WISCONSIN. The quarries of cement rock are in the city of Milwaukee and are based on beds belonging to the Hamilton Period of the Devonian Age. The cement has a high reputation.
See Geol.of Wisconsin II. 395.

ILLINOIS. Near Utica and Lasalle are exposures referred to the Calciferous of the Lower Silurian. Six or eight feet of good rock afford the crude stone which yields an annual output of over half a million barrels.
See H.S.Freeman. Hydraulic Cement Works of the Utica Cement Co. Lasalle, Ills. M.E. XIII, 172.

Although small quantities of hydraulic cement have been made in not a few other states, yet the only one deserving special mention is Maryland, where at Cumberland in Allegany Co. about a quarter of a million tons are annually obtained.

PORTLAND CEMENT receives its name from the English town associated with its manufacture. It is made from an artificial mixture of clay or marl and some form of carbonate of lime. Chalk is most prized for this, but shell marls and limestones have also been employed. Anything with magnesia is however carefully avoided. The materials are usually dried, ground together, moistened, moulded into bricks and calcined to clinker. The clinker is then ground up to cement, A process has been started in this country to mix wet and then calcine and grind once for all, but it has not yet been established on a commercial basis. There is an attractive market for the local product for as yet this is scarcely more than 10 % of the imports. The composition runs quite uniformly as the annexed tables show and it is vigorously under the control of the chemist in charge of the works. Abroad the industry has grown enormously in late years, especially in Germany.

	CaO	MgO	SiO_2	Al_2O_3, Fe_2O_3	H_2O, etc.
1. English	60.0	1.00	25.00	12.00	2.00
2. German	59.98	0.36	24.90	11.22	3.52
3. Coplay, Penn.	62.79	1.72	20.64	6.93 5.41	2.51
4. Egypt, Penn.	60.13		22.90	12.10	4.87
5. Near Syracuse, N.Y.	63.00	.97	22.10	6.84 2.10	4.99

All these are taken from W. A. Smith's paper in the Mineral Industry I. 52. In No.4. the MgO is included in the last figure given- 4.87.

The Lehigh Valley, Penn. is as yet the most productive district. The raw stone employed for hydraulic cement as cited above is dressed up to Portland grade with pure limestone. Near Syracuse, N.Y. and in Ohio, shell marls and clay are used. The industry will no doubt grow in the next few years. For papers on the manufacture, see citations above under General Literature, especially S. B. Newberry, also H. Reid, Science and Art of Manufacture of Portland Cement, etc. E.& F.N.Spon-1877. Supplements of Scientific American, Nos. 64, 84, 231, 350, 386, which are cited by J. C. Branner in a brief paper in Geol.Ark. 1888. II. 291.

GYPSUM.

Gypsum is used both as plaster of paris (when calcined) and as fertilizer (when ground raw, i.e. land-plaster). It is $CaSO_4 \cdot 2H_2O$ in its composition, but alumina, oxides of iron and silica sometimes contaminate it. The dark earth varieties are ground for land-plaster, and the white, pure material furnishes the cement. Clear crystalline plates called selenite occur in all the quarries in minor amount and almost always some native sulphur derived by the alteration of gypsum coats the cracks. Pure massive gypsum is alabaster and is easily recognizable, but the impure varieties closely resemble limestone. In the kilns or rather pots the water is driven off and the resulting anhydrous sulphate has the strong avidity to reabsorb it and set, that gives the mineral its value, but the temperature of dehydration must not be raised above 250F. else the plaster will not set. Gypsum deposits are often in series of strata that contain rock salt and that have been formed by the drying away of isolated bodies of water, but it also seems to be formed by the alteration of limestone. The gypsum beds of central New York have been referred by Vanuxem to the action of sulphurous springs on limestone. This is however hardly demonstrated finally.

In the United States the most productive region is in the vicinity of Grand Rapids, Mich. Strata of Subcarboniferous Age supply the raw stone from an area of 8 or 10 square miles. The gypsum lies from 2'-70' below the surface and in two beds, an upper of 8' and a lower of 12' with 1' of shale between. The lower bed is worked. It is creamy pink and gray in colors and affords both land-plaster and stucco. Next in productiveness is a belt in New York State, extending from the mouth of Cayuga Lake eastward. It is dark in color and is all ground for land-plaster. The beds belong in the Salina for although referred to the Lower Helderberg by S. G. Williams, it was because a roll or low fold was overlooked by him (A.A.A.S., Vol.33, p.402, 1884).

Iowa ranks third in total product. Fort Dodge is the headquarters of the industry and the quarries are situated along the Des Moines River in Webster County. The gypsum is of an age later than the Subcarboniferous, but it is thought by C. A. White to be older than the Cretaceous and probably early Mesozoic.

The plaster industry in Kansas is one of great and growing importance. The gypsum is principally produced in Marshall, Saline, Dickinson Sedgwick and Barbour counties which extend across the state in a slightly northeast line near the middle. All the product is calcined for plaster of Paris. Kansas now ranks fourth in the total output.

The deposits in southwestern Virginia along the Holston River come fifth. The gypsum occurs in the same region with extensive beds of salt, and is thought by C. R. Boyd to lie along one or several great fault fissures in Carboniferous and Silurian strata. It is all employed as a

fertilizer.

The gypsum district of Ohio centers about Sandusky, but the quarries are at the town of Gypsum, ten miles west. The mineral is in strata of the Lower Helderberg. The bed worked is 7 feet thick and lies about 24 feet below the surface. The mineral is worked up into both stucco and land-plaster, about 40 % being applied to the former purpose and 60 % to the latter. The rock is of excellent grade and purity, but this district is overshadowed by the output of the Grand Rapids region.

Utah has become in the last few years an important source of the mineral, it being found there in Juab, Beaver, San Pete and Iron counties. Considerable plaster of Paris is also produced at Colorado City, near Colorado Springs, Colo.; and another region deserving mention is Santa Barbara County, Cal. Small amounts are quarried from South Dakota and Wyoming and the relative importance is shown by the following table of production:

Production of Gypsum in 1893.

	(Short) Tons.	Value.		Tons.	Value.
Iowa............	21,447	$ 55,538.	New York............	36,126	$65,392.
Kansas..........	43,631	181,599.	South Dakota.........	5,150	12,550.
Michigan........	124,590	303,921.	Virginia............	7,014	24,359.

Large quantities of gypsum are annually imported into the cities of the Atlantic seaboard from Nova Scotia. The mineral is derived from the Windsor and Cheverie districts on the Bay of Mines. Its geological age is Lower Carboniferous. The best of it is ground at New York City and Newburgh, N.Y., for terra alba, a cheap white pigment.

CANADA. R.Brown. On the Gypsiferous Strata of Cape Dauphin, Cape Breton
" Journal Geol. Vol.II. p.257, 1847.
A.Gesner. On the Gypsum of N.S. Q.J.G.Soc. Vol.V.p.129. 1849.
T.S.Hunt. Note sur les Sources Acides et les Gypses du haut Canada. Comptes Rendus, June 25.1855.
" On the Formation of Gypsums & Dolomite, Q.J.G.S.16.152.
" On some Reactions of the Salts of Lime and Magnesia and on the Formation of Gypsums and Magnesia Rocks. A.J.S. II. 28. 170 also 365.
J.B.Tyrrell. Gypsum Deposits in Northern Manitoba, Can.Rec.Sci.III. 353. April 1889. See also July 1889.
IOWA. C.R.Keyes. Gypsum in Iowa. Monthly Review Iowa Weather and Crop Service, IV. No.3. pp.2-4.1893. Also Proc.Iowa Acad. Sci. I. pt.iii, 19-22.1893.
C.A.White. Gypsum in Iowa. Geol.of Iowa. II. 293.
MICHIGAN. C.E.Wright. Gypsum in Michigan. Rep.of Commissioner of Mineral Statistics for Michigan, 1881 pp.3-20. See also C.Rominger, Geol. Mich. III. 100.
NEW YORK. W.C.Clarke. Gypsum Industry, N.Y. Bull.N.Y.State Museum III. April '93. 70.
T. S. Hunt. On the Acid Springs and the Gypsum Deposits of the Onondaga Salt G'p. A.J.S. II. 7. 175.
L. Vanuxem. Gypsum in New York. Geol.of Third District, p.98.
S.G.Williams. Geological Relations of the Gypsum Deposits in Cayuga County, N.Y. A.J.S. III. 30. 212. See also A.A.A.S. XXXIII. 402. 1884.
OHIO. E. Orton. Gypsum or Land-plaster in Ohio. Geol.Ohio VI. 696. Compare also Newberry do. II. 155. See also M.R. 1887. 696-where Orton's paper is reprinted.

CHAPTER VI. WATER AND SALINES.

Any good treatise on geology will furnish the generalities about the circulation and storage of water. Dana's Manual, and Geikie's Textbook are especially to be recommended, and numerous instructive analyses will be found in Justus Roth's Allgemeine und Chemische Geologie, Vol I. As a brief summary it may be said that water is the universal solvent. As it percolates everywhere throughout the rocks and soil, it gathers mineral matter in solution and its action is much intensified by the CO_2 which it holds in solution. The chief elements affected are calcium, magnesium, iron, potassium, sodium and silicon. Organic matter is also found but is rather of sanitary than geologic importance. The common salts in solution are carbonate, sulphates and chlorides. Limestones including the magnesian varieties and calcareous shales furnish hard water, granites, slates, quartz sandstones and crystalline rocks in general furnish the purest. Lakes with no outlets, as the Great Salt Lake and others of the Great Basin, become strong brines. Some marine sandstones that still hold sea water afford brines or at least alkaline well water. For large supplies, rivers are found to be on the whole the purest. In the analyses below the general range of various waters is indicated and a series is set forth from rain water, oceanic water, etc., to rock salt, the final residue.-

Rain	Delaware River: In 10,000 parts water		Ocean Average		Great Salt Lake	Syracuse Brines	Saginaw: Mich Brines	Rock Salt: Warsaw N.Y.
CO_2 1.77	$CaCO_3$	0.223	H_2O	96.5	85.006	83.574	78.680	1.5
N. 0.6447	$MgCO_3$	0.152	NaCl	2.665	11.862	15.531	17.510	96.498
O. 0.3376	K_2SO_4	0.032	$MgCl_2$	0.315	1.490	0.144	1.068	0.298
25 c.c.	Na_2SO_4	- - -	$MgSO_4$	0.216	0.932	- - -	- - -	- - -
dissolved	K_2CO_3	0.029	$CaSO_4$	0.175	0.085	0.577	0.098	1.464
gases per	Na_2CO_3	- - -	K Cl	0.140	0.086	0.012	- - -	- - -
litre.	NaCl	0.018	NaBr	0.035	- - -	- - -	- - -	- - -
	K Cl	0.002	K_2SO_4	- - -	0.536	- - -	- - -	- - -
	SiO_2	0.085	$CaCl_2$	- - -	- - -	0.153	2.643	0.136
	Fe_2O_3	0.005	$MgBr_2$	- - -	- - -	0.002	- - -	Insol.
			$FeCO_3$	- - -	- - -	0.004	- - -	0.104

A comparison of the above analyses brings out the fact that the carbomates, sulphates and chlorides of the alkalies or alkaline earths are much the commonest and most abundant of the dissolved mineral salts and of these in the end the sodium chloride becomes the chief. In this connection G. K. Gilbert brought up an interesting point at the Boston Meeting of the Geological Society of America, Dec. 1893, and which he has under investigation. It is that analyses of rocks indicate sodium and potassium in the earth's crust in practically equal amounts, (respectively 2.28 and 2.23 according to F. W. Clarke, Bull. 78, U.S.G.S. 34.) yet in alkaline deposits, brines etc., the sodium is in great excess. A possible explanation will be given in his final paper when published.

Water in all parts of the world has a quite constant and definate level at which it stands below the surface and affords wells. This was referred to earlier in speaking of the alteration of mineral veins, p.22. Water also circulates along cracks and fissures and where there is sufficient head it is forced out at the surface, in the form of springs. Joints afford the commonest water courses. Porous strata, such as open sandstones which lie between impervious layers, also supply the necessary conditions and are fruitful sources for artesian wells. Artesian wells are artificial springs and are of great importance in many portions of the country. The several conditions of success are best illustrated in the paper by T.C.Chamberlin,referred to below. These wells are of more importance in the regions of feeble rainfall such as the prairies than in the east although they are often economical as avoiding water rates. In thickly settled districts, if they draw their supplies from the immediate neighborhood,the water is only fit for steam or some such use. (New York) The necessary conditions for flowing artesian wells are a porous stratum with a higher outcrop to serve as conduit and reservoir, an impervious cap and floor on each side of the porous stratum, and no lower natural outlet. Synclinal basins afford these. In drilling cases have occurred where a flow has been obtained but on deepening the well it has been lost This is due to making connections with a lower lying porous stratum with an outcrop below the mouth of the well. In such cases the well is plugged below the first poeous stratum. If the head is insufficient pumping is necessary. Artesian wells have attracted great attention in the prairie states and official commissions have been appointed in several to investigate the subject. They are of especial importance where the rainfall is slight and have been regarded as possible sources for irrigating supplies. In general the latter expextation has failed of fulfillment because of the insufficient amount and of the salines in solution. The continual deposit of these destroys fertility as has been found in India where the waters were comparatively pure (Medlicott and Blanford, Manuel of the Geology of India, pp.413-415).

The referencesgiven below will afford access to the literature of those localities in the several states, where investigations have been carried on. Along the coastal plain much attention has been given to the subject and the geology is now fairly well outlined in its relations to artesian wells. They have proved successful in a great number of localities and being long distances from any marked elevations have been extremely serviceable for water supply. The principal drawback in connection with all artesian wells is the occasional sulphurous or alkaline water afforded by them. Pyrite and much organic matter in the horizon of supply, and old brines contained in former marine deposits are the main causes of contamination. The wells of the coastal plain draw their supplies from various beds of gravel and sand from the Cretaceous upward. In the sparsely watered areas of the prairie states and of the Great Basin, artesian wells have likewise been of the greatest importance. Minnesota has obtained considerable from the Drift, and from sandstones in the Lower Silurian and Cambrian. Many of the prairie states tap the Dakota sandstone which outcrops around the Black Hills and Rocky Mountains and seems to draw its supplies often from a surprisingly remote outcrop. It unfortunately too often yields a weak brine or water too saline for general use. The water may emerge under sufficient head to operate an inverted turbine. Kansas has wells in the sandstones of the

Dakota,Trias and Carboniferous. In Colorado, wells near Denver obtain extraordinarily pure water from Laramie sandstones. The general structure of the foothills is favorable to wells. In Texas great efforts have been put forth and the states has been carefully studied in these relations. The hopes that artesian wells would supply water for irrigation have seldom been realized, because the amount has proved insufficient or the dissolved salts have in the long run been deposited by evaporation to such an extent as to destroy fertility.

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PENNSYLVANIA.	O.C.S.Carter.	Artesian Wells. Jour.Franklin Inst. CXXXVI.230. (Good short account of Phila. neighborhood).
TEXAS.	R.T.Hill.	Occurence of Artesian and other Underground Waters in Texas, N. M.& Indian Territory. Artesian and underflow investigations of the Dept.of Agriculture, Washington, 1892.
	J.A.Singley.	Artesian Wells of the Gulf Coastal Slope-.Geol. Surv.Texas, Fourth Ann.Rep.1892. p.87.
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VIRGINIA.	N.H.Darton.	Artesian Well prospects in Eastern Virginia,Maryland and Delaware. M.E.Feb.1894.
WYOMING.	J.D.Conley.	Artesian Wells of Southern Wyoming. Bull.20 Wyoming Exp. Station, Oct. 1894.

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MINERAL SPRINGS. are abundant in many quarters and are often of importance as medicinal agents. In these latter applications they furnish an important contribution to the annual amount of mineral resources. Of late they have attracted not a little attention and have been esteemed of sufficient importance to deserve formal descriptions at the hands of our geological surveys. In their geological relations they are not essentially different from ordinary springs, but when they come up in regions of great geological disturbance or of dying igneous activity, they are often highly heated. The dissolved mineral matter consists chiefly of alkaline salts such as carbonates, sulphates, chlorides and the like, with at times alkaline sulphides, sulphuretted hydrogen, and even compounds of iron and the other but less common materials. Silica is likewise frequently present and carbonic acid gas gives to many an agreeable taste. In their scientific relations mineral springs have a close connection with the origin of the ore and gangue minerals and in this connection they have been quite carefully studied.

The best known regions of springs in the east are Saratoga, N. Y. and the mountains of West Virginia and Virginia. Great resorts have grown up around each. In the central part of the country, the smaller localities are very numerous and in Missouri and Arkansas the state surveys have issued special reports on the subject. The Yellowstone Park is the greatest of our localities for hot springs and their unique and explosive variety, the geysers, give them peculiar claims to scientific interest. In Colorado, Idaho Springs, Manitou and Glenwood are well known resorts, while in New Mexico, Las Vegas attracks visitors even from the East. In Nevada the famous Steamboat Springs have been important aids in the interpretation of ore deposits, and in California, Sulphur Bank has been of even greater significance.

In summary it may be added that Prof. Paul Schweitzer has published in the reference given below the following classification of mineral waters:-

1. Muriatic Waters, containing chiefly sodium chloride, with it are calcium and magnesium chlorides and calcium and magnesium sulphate, one or several.
2. Alkaline Waters, containing sodium carbonate or magnesium carbonate.
3. Sulphatic Waters, containing one or more sulphates as their main constituents.
4. Chalybeate Waters, containing ferrouscarbonate and usually other carbonates and sulphates.
5. Sulphur Waters.

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Paul Schweitzer. The Mineral Springs of Missouri. Mo.Geol.Surv.III.1892.

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COMMON SALT.

The chief sources of salt (NaCl) are ocean waters, salt lakes, subterranean brines, and beds of rock salt. The first named is such a weak solution that it has but slight use in this country. There are works in the bay of San Francisco, which have advantages during the rainless season of the Pacific Coast, but elsrwhere more economical supplies are obtained from other sources. At Turcs Island in the West Indies the industry is still kept up and an occasional cargo reaches the United States. Salt Lakes are of importance in the region of the Great Basin, and their dried bottoms or the salty strands left by their oscillations afford the mineral. Subterranean brines are obtained by artesian wells. They are either old and more or less concentrated sea-water left entombed in marine sediments, or else are formed by the natural leaching of beds of rock salt and saline shales. The subterranean brines are the chief source of American supplies, and they are often imitated artifically by admitting clear water to beds of rock salt and pumping it up again as a rich brine. Rock salt itself is of chief commercial importance in central New York, Western Ontario and Louisiana. The salt in the ocean has been with little doubt derived from the wash of the land and almost all large deposits of rock salt have themselves been deposited from more or less isolated bodies of the ocean. It was formerly customary to explain them as derived from bays or sounds which had been entirely cut off from the parent body and which had been then evaporated. Oscillations of the coast and repetitions of the process were regarded as the cause of successive beds when accompanied in the long run by a general submergence. The development of deposits of vast thickness, and of fairly pure rock salt has made this simple explanation seem unlikely. At Petite Anse,La., over 1000 ft. have been penetrated and in Prussia as much as 4000 ft. As it would require about thirty to forty times this depth of sea-water to provide the

amount of salt, isolated embayments seem open to objections. Prof.Carl Ochsenius suggested however some years ago an explanation that seems to fit the case much better. He conceives of a bar of sand or some such obstruction off the mouth of an estuary. Provided that the estiary is not subject to excessive inflow of fresh water from land drainage, it would evaporate and be kept full by inflow from the ocean over the bar. The more concentrated brines would sink and the inflow itself from standing on the shallows of the obstruction would also be exposed to concentration. In time the lower portions of the waters in the estuary would reach the stage of the precipitation of gypsum or anhydrite and later on of rock salt. Each influx of fresh brine would yield a small layer of gypsum or anhydrite and in the end a thick bed, chiefly rock salt would result, limited only by the original depth of the estuary, or by this and the progressive submergence of the coast and the continuance of favorable conditions. The residue of mother liquors would contain the most soluble salts which if precipitated, would yield a final upper layer containing the magnesium and potassium compounds, etc. This layer is seldom preserved for the Stassfurth district is almost the only large example. In this country it has not yet been met. American deposits yield little else than salt and gypsum. All through the series of precipitated beds, layers of argillaceous sediment are to be expected, from the periodic floods of inflowing streams or dust blown by winds. There are also possibilities of some variations in the chemical relations of the layers, as is set forth in some detail by Ochsenius in the second citation given below. This explanation, usually called the"Bar theory" is worthy of much confidence, and has illustrations now in progress.

Posepny in the citation below has advocated the accumulation of salt in the desert regions of our western states from having been blown in as fine dust from the sea. As is well known, breaking waves dash spray in the air and leave finely divided salt in suspension, but that this ever gives rise to deposits of any size is extremely doubtful.

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F.E.Engelhardt. General Paper. E.& M.Jour. Jan.2.1892. p.46. Rec.

C.A.Gaessman. Contributions to the Chem. of Common Salt, with particular reference to our home resources. A.J.S. II. 49. 78. Rec.

T.S.Hunt. On the Extraction of Salts from Sea-Water. A.J.S.II.25.361.

C.Ochsenius. Die Bildung der Steinsalzlager Halle. 1877.

" Bedentung des orographischen Elementes "Barre" in Hinsicht auf Bildungen und Veränderungen von Lagerstatten und Gesteine Zeitsche. f. prakt. Geologie. May.1893. 189.June.217. The paper cites earlier ones.

F.Posepny. Zur Genesis der Salzablagerungen, besonders Jener im Nord-Amerikanischen Westen. Sitz.d.k. Akad. d. Wiss. Vienna.LXXVI. July 1877.

N.S.Shaler. Note on the Value of Saliferous Deposits on evidences of former Climatal Conditions. B.S.N.H. 24 580.

Toula. Salzgebirge und Meer. Vienna. 1891.

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Production in 1893, in Barrels of 280 lbs.

1. New York- - - -	5.662 074	7. West Virginia- - -	210.736
2. Michigan- - - -	3.057 898	8. Louisiana- - - - -	191.430
3. Kansas- - - - -	1.277.180	9. Texas- - - - - - -	126.[illegible]
4. Ohio- - - - - -	543.963	10. Utah - - - - - - -	108.570
5. California- - -	292.858	11. Illinois - - - - -	59.161
6. Pennsylvania- -	280.343	12. Nevada - - - - - -	6.559

Total 11.816.772---value $4.054.668.

Statistics from the Mineral Resources-1893. 721.

Brines were early developed by the pioneer settlers of the eastern states because as they left the coast salt became one of the prime necessaries of life. Records of the brines at Syracuse date back to 1646, and when developed in fairly large degree, over 150 years later, the wells were acquired by the state lest so indispensable a substance should fall into the hands of a monopoly. Natural salt springs or "salt licks" are not uncommon in the Appalachians, and the earliest wells drilled for brine led to the discovery of oil and gas-(see p.99.). The statistics indicate the relative importance of the producers. Of these, New York Kansas and Louisiana have great beds of commercially developed rock salt, and with these should be mentioned Ontario, but the others are largely dependent upon brines.

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- - - - - - - - - - -	Salt Deposits of N. Y. E.& M.Jour. Feb.1889. 133.
- - - - - - - - - - -	N.Y.State Assembly Documents 1883.Vol.III.No.35-p.17. Vol.V. NO.34. Also all the Annual Reports of the Commissioner of the Onondaga Reservation to the Legislature.
I.P.Bishop.	5th Rep't. of State Geologist, N.Y.1885-p.13. Rec.
F.E.Engelhardt.	Report to the Sup't.Onondaga Salt Reservation. Syracuse. Jan.12th,1891. Rec.
Joshua Forman.	Remarks upon the Salt Formation ofSalina N.Y. and other places. A.J.S. I. 19. 141.
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"	Rep't.on the Manufacture of Solar Salt from them- do. December, 1863.
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F.J.H.Merrill.	Salt and Gypsum Industries of N.Y. Bull. N.Y.State Mus III No.11 April 1893. Rec.
J.S.Newberry	Rock Salt Deposits of the Salina Group in Western New York. Trans.N.Y.Acad.Sci.1889-90. Vol.IX p.59.
"	Salt Deposits of N.Y. Geol.Position &c. N.Y.Acad. Sci. 1884.-85 p.54. E.& M. April 11.18[illegible] .
C.S.Prosser.	The Thickness of the Devonian and Silurian Rocks of Western Central New York- Amer. Geol. VI. 199.

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NEW YORK. The salt of New York is all obtained from the beds of the Salina Series. It exists in these as rock salt in vast amounts which have only lately been opened up. The beds of the Salina, like the associated strata have a southerly dip of about 25 to 40 feet to the mile.

Their outcrop nearly follows the direct line of the New York Central R.R from Syracuse to Buffalo, but of course is only shown by shales from which the rock salt has been leached. From 25 to 30 miles south of this the wells have struck rock salt. The greatest thickness yet found is at Ithaca where some 252 feet were cut in 8 beds, the uppermost 2244 feet from the surface and the lowest 2672 ft. Some 20 miles north a salt works is now in operation at Aurora and 75 miles west in the Genesee and Wyoming valleys some extensive mining by shafts as well as pumping from wells is in operation at Warsaw, Piffard and other towns. One of the most interesting developments is in the town of Tully some 20 miles or so south of Syracuse. The Solvay Co., of Syracuse have sunk about 20 wells from 1000 to 1500 ft. deep. They bring into these fresh water from Crooked Lake with a fall of 300 ft. It sinks in the wells, rises of its own pressure as saturated brine and flows to the works in Syracuse some 500 ft. lower than the top of the wells. The brines controlled by the state are obtained from bore holes which are sunk 300 to 400 ft. in gravel. The gravel is in the filling of an abandoned river channel, a relic of the post-glacial drainage of the Great Lakes out through the Mohawk and the Hudson and as it cuts the outcrops of the Onondaga Salt Series (i.e. The Salina) it is filled with the brine which percolates from them. This brine is weaker than those from the rock salt wells and as a result the state has offered its reservation for sale.

MICHIGAN. Rock salt in the Salina strata has been found on both sides of the Lower Peninsula at depths ranging from 1600-2200 ft., but the great source of brine is the Napoleon Sandstone of the Lower Carboniferous. It is a taxonomic equivalent of the Berea Grit of Ohio which i later mentioned. The most productive region is around East Saginaw on Saginaw Bay, an arm of Lake Huron. The brines of Bay City are referred to the Coal Measures. The success of the industry is due to the cheap fuels which the lumber mills furnish in waste slabs, sawdust, etc. Up to recent years the output of Michigan salt has been much in excess of any other state, but the developments of New York rock salt has now placed it far in the lead. As noted later under Bromine some Michigan brines contain notable quantities.

- - - - - - -Geol.Surv.of Mich. III. 1873-76 App. B. p.171.
- - - - - - -Mineral Statistics of Mich. Annual Volumes after 1882.
A.Winchell. On the Saliferous Rocks and Salt Springs of Mich. A.J.S. II 34. 307. Also Geological Studies. Chapter on Salt.

ONTARIO. In close geological relation with those of Michigan are the deposits of this province. Great beds of rock salt have been shown to exist in the Salina strata under the town of Goderich which is opposite and south of Saginaw Bay on Lake Huron, 136 ft. of salt were found in six beds, beginning at 1028 and ending at 1400. The salt is developed to a considerable extent for the Canadian market.

John Gibson On the Salt Deposits of W. Ontario. A.J.S. III. 5. 362.
C.A.Goessman. Salt Resources of Goderich, Ont. Syracuse, N.Y. Jan.16.1868.
O.J.Heinrich. The Manhattan Salt Mine. Goderich, Can. M.E. VI. 125.
T.S.Hunt. Rep. on Goderich Salt Region. Geol.Surv.Can. 1870.
" Goderich Salt Region. Can.Geol.Surv. 1876-77 p.193.
" The Goderich Salt District Ontario. M.E. V. 538. See also Geol.Surv.Can. 1867. 69.
J.L.Smith. History and Statistics of Canadian Salt. Can.Geol.Surv. 1874-75. p.267.

OHIO. The Ohio brines like the oil, gas, and building stone of the eastern portion of the state are derived from the Berea Grit of the Sub-carboniferous. The wells are situated in the eastern central portion and usually in the neighborhood of coal with which they are evaporated. Meigs, Tuscarawas, Columbiana, Guernsey and Morgan counties contain the plants. The brines are not specially strong or pure and are severely crowded by the Michigan and New York wells. Some are productive of bromine.

W.J.Root. The Manufacture of Salt and Bromine. Geol.Surv.Ohio. Vol.VI653

ILLINOIS. Brines are obtained from Lower Carboniferous strata in several counties and are utilized to a small extent. They were formerly of greater relative importance. Local descriptions, now rather antiquated, will be found in the chapters of the state geological reports on county geology.

PENNSYLVANIA AND WEST VIRGINIA. are in close geographical and geological associations with Ohio. In the former the brines are utilized in the western portion and in much the same district that supplies oil and gas. The lower oil sands are the chief productive horizons. In West Virginia the plants are mostly located along the Kanawha River and in Mason Co. on the OhioFrom both these states supplies of bromine have been obtained

Edw.Stieren. Observations on the Saltwaters of the Alleghany and Keskeminstas Valleys. A.J.S. II. 34. 46.

The Mountain State-Pamphlet on the Resources of West Virginia. Distributed at Chicago, 1893. p.73.

VIRGINIA. Beds of salt are known along the Holston River in the southwest corner of the state. There is some uncertainty about their geological relations. C.R.Boyd thinks they lie along some great fault fissures in Carboniferous and Silurian strata. Lesley speaks of them as Tertiary. The same region was mentioned under Gypsum, p.138. The output is not great.

C.R.Boyd. Resources of Southwest Virginia.

C.B.Hayden. On the Rock Salt and Salines of the Holston A.J.S.I.XLIV.173

H.D.Rogers. Report on the Salt and Gypsum of the Preston Salt Valley and Holston River, Va. Boston 1854. A.J.S. II. XVIII. 273.

KANSAS. The greatest recent growth of the salt industry is in Kansas. From 75 to 250 ft. of rock salt have been found at depths from 450 to 1000 ft. and in the following counties, Ellsworth, Reno, Rice, Kingman and Barton, shafts are in operation in the first (town of Kanopolis) the second (Lyons) and the fourth (Kingman). The salt lies near the contact of the Permian and Triassic. Mr. Hay gives a good section in the American Geologist, V. 65. The counties form a north and south belt in southern central Kansas.

E.H.S.Bailey. On the Newly Discovered Salt Beds in Ellsworth Co. Kansas. Kansas Academy of Science, XI. 8.

R.Hay. Salt; its discovery and manufacture in Kansas. 6th Bien.Rep. Kan.State Board of Agriculture. Amer.Geol. IV. 309.

" Notes on a Kansas Salt Mine. Amer. Geol. V. 65.

" Geol.of Kan.Salt. Separate reprint 1891.See also M.R.1888 607.

LOUISIANA. The well known rock salt bed on the island of Petite Anse, near New Iberia, is one of the largest deposits in the United States. It is on the shores of the Gulf and lies in greatest part below tide. Drillings show it to be over 1000 ft. thick. It is capable of an

enormous output but up to the introduction of recent improvements it caked after grinding and hence labored at a disadvantage Its geological age has been variously called Cretaceous, Tertiary and Quaternary. Recently (April 1895) other deposits no less extensive have been reported on a neighboring island, and brines are not infrequent further north in Louisiana.

H.C.Bolton. Notes on the Salt Deposits of Petite Anse, La. Trans. N.Y. Acad. Sci. VII. p. 122.

C.A.Goessman. On the Rock Salt Deposits of Petite Anse, La. Amer. Bureau of Mines.-also A.J.S. II. XLIII. 284.

E.W.Hilgard. On the Geol. of the Miss. Delta and the Salt Deposits of Petite Anse.-A.A.A.S. 17th Meeting. Published in Abstract in A.J.S. II. XLVII. 77. See also M.R. 1889. 554.

Jos.Leidy. Notice of some Mammalian Remains from the Salt Mine of Petite Anse.La. Trans.WagnerFreeInst.of Sci.Phila.Vol.II.33-40

R.Owen. On the Deposit of Rock Salt at New Iberia,La. Trans.St.Louis Acad.Sci. II. 250. A.J.S. II. XLII. 120.

R.A.Pomeroy. The Petite Anse Salt Mine. M.E. XVII. 107.

Petite Anse Mine. E. & M. Jour. Oct.6.1888. p.280.

Vermillion Rock Salt Mine at Petite Anse, La. A.J.S. II. 36. 308.

TEXAS. Both brines and rock salt are known in Texas and are utilized extensively. Beds 140 ft. thick are cut at Colorado,Mitchell Co., on the Texas Pacific R. R. in the northwestern portion of the state and the brines obtained from there are pumped up by windmills. The salt is 1000 ft. down. The geological age is Permian. Various salines occur elsewhere and are locally important.

W.F.Cummins. Salt in Northwestern Texas. 2nd Ann.Rep.Tex.Geol.Surv. 444. Other volumes of the survey contain occasional local mention.

UTAH. Much salt is obtained around the shores of the Great Salt Lake. In dry seasons and with falling lake level it is precipitated on the beaches as a natural mineral, but in the commercial production shallow ponds are walled off on the beach, and are filled with the lake water by pumps. Solar evaporation ensues and at the close of the dry season the crop is gathered. On account of the variability of the weather, especially toward the close of the season there is some uncertainty connected with the business. Nephi, Juab Co., and Salina, Sevier Co., both south of the lake afford beds of rock salt that are the basis of quarries Mineral Resources. 1888. 605.

CALIFORNIA. The chief portion of California's very considerable output is obtained from sea-water on the shores of San Francisco bay. Ponds of fifty acres or more are cut off by dikes and filled about once a month at high tide. As the brine concentrates it is pumped by windmills into interior ponds and finally the salt is obtained and the bitterns are run off. It is used as domestic salt and for the chlorination process in the gold region. Salt is also obtained in the outlying portion of the Great Basin that reaches into southern California. The district lies below sea level and was flooded a few years ago by the Colorado River. Salton is a productive point and further south at Daggett in the Mojave desert rock salt is obtained for Arizona metallurgical works.

Mineral Resources. 1885. 480.

VIII Annual Report California State Mineralogist 30,1888. XII. 1894.408.

In Nevada from the salines of the Great Basin region small amounts are obtained, which fluctuate with the prosperity of the silver mines.

On San Domingo, in the West Indies good beds of rock salt are known, and along the west coast of South America there is an abundance in many places, aside from oceanic brines.

J.H.Gibbon. A visit to the Salt Works of Zipaquera near Bogota, New Grenada. A.J.S. XXXII. 89.

Robt.Peele Jr. A Peruvian Salt Mine- S.of M.Quarterly. Apr.1894. 219.

F.Ruschhauft. On the Salt Mines of San Domingo. Alxedgeo.Q.J.G.S.XXV.256

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Reference should also be made to the Europian salt deposits. In England the industry is an old and important one especially in Cheshire, east of Liverpool. Until recently great quantities have been imported into the United States. The brines are chiefly Triassic. On the continent are the most famous deposits of rock salt in the world. The deep well at Sperenberg near Berlin pierced some 1300 meters, nearly all of rock salt of the Permian (Dyas). The similar beds at Strassfurth are 330 meters and contain in their upper portions the potassium and other salts earlier mentioned in connection with the "Bar theory" of Ochsenius. At Salzburg, in the Tyrolese Alps, are great beds, of much historic interest and often visited by tourists. They belong to the Keuper of the Trias. At Wieliczka, in Poland, Tertiary rock salt is reported at over 1400 meters. In Algiers and many other points in Africa, and likewise in the far East other rich deposits are not lacking.

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B R O M I N E.

The manufacture of bromine is auxiliary to the salt industry and is carried on where the mother liquors contain this element in sufficient quantity. In Ohio and at Syracuse, N. Y. the brines and bitterns or pickle have the following composition:-

	Canal Dover-O.		Pomeroy-O.		Syracuse,N.Y.	
	Brine	Bittern	Brine	Bittern	Brine	Pickle
Water	89.545	55.360	90.472	69.000	83.5747	73.3488
Solids	10.455	9.528	9.528	31.000	16.4253	16.6512
		Composition of Solids.				
NaCl	71.645	30.128	79.273	7.603	15.5317	25.7339
MgBr	.271	.592	.097	.429	.0024	.0039
NaI	.013	.024	.012	.037	- - - -	- - - -

The two Ohio analyses are from the Geol.Surv.of Ohio, Vol.VI. pp.662,663. It is to be noted that the last three values in each column are percentages of the total solids and not of the original brine. The analyses from Syracuse are from Bull. N.Y.State Museum. III.No.11.p.41. and the last percentages refer to the original brine. For a rough comparison with the corresponding values under Ohio, they should be multiplied by 6. Even with this increase, Ohio brines will be seen to be much richer in bromine. According to the Mineral Industry, Vol.II. p.78, the following is the production for 1893-in pounds.

	Ohio.	Penn.	W. Va.	Mich.	Total.
1893----	113.575.5	111.403.5	80.852	42.568	348.399

The price ranges from 25-35 cents.

At Pomeroy and Canal Dover, Ohio, Midland,Mich., and in Pennsylvania and West Virginia salt districts mentioned above, the bromine is a byproduct in the salt industry. Details of the methods of manufacture will

be found in the paper cited below by W. J. Root. No attempt seems to have been made as yet to produce iodine in this country.
W.J.Root.The m'f't'r.of Salt and Bromine in Ohio. Geol.of O.VI.653. Rec. Statistical and descriptive papers also appear in the volumes of the Mineral Resources and the Mineral Industry.

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SODIUM CARBONATE OR SODA.

There are two places in the west where carbonate of soda is produced from natural sources, but in addition to these, it is known in many other localities in the arid region of the Great Basin. At RAGTOWN,NEV. there are two ponds, which together are rather less than 300 acres. One of these is filled with water and the other is dry. Both were regarded by the geologists of the 40th Parallel Survey as spring basins, but Russell has since shown that they are old craters. They probably received their supplies of sodium salts from the leaching of the soda-lime feldspars of the igneous rocks. Analyses of the waters of these and of two other lakes of present or prospective importance are appended.

	Ragtown.	Owens Lake	Albert Lake.
Specific Gravity	1.0995	1.045	1.03117
The Solids Contained.			
SiO_2	.24	.13	.59
$MgCO_3$	.73	.36	- - - -
KCl	3.73	3.44	2.62
NaCl	55.44	34.60	54.58
Na_2SO_4	14.86	18.45	2.68
$Na_2B_4O_7$	.31	.39	- - - -
Na_2CO_3	13.08	34.33	27.09
$NaHCO_3$	11.61	8.20	12.44
$(Al_2Fe_2)O_3$	- - -	.005	- - - -
$CaCO_3$	- - -	.09	- - - -

Ragtown- by Chatard, Bull.60, U.S.Geol.Surv. p.49 spec.grav.at 19.8° C
Owens Lake- do. do. 53, do. spec.grav. at 15.5° C.
Albert Lake- do. do. 55, do. spec.grav. at 19.8° C.

It appears that all have common salt in largest amount, followed by the two forms of carbonate, by the sulphate and various subordinate salts. Of these the sulphate is the most objectionable in the processes of crystallization. At Ragtown, in the Big Lake, the brines are impounded,evaporated by solar heat, and transferred from vat to vat as the concentration increases until the final crop of crystals is harvested, after which the mother liquors are run back into the lake. Essentially the same process is followed on a much larger scale at Lake Owens. At Little Lake, Ragtown, the solid deposit left by previous natural evaporation is redissolved in pure water and evaporated by solar heat, through the summer. As cold weather sets in, the chilling of the solution causes a crop of crystals, called "winter soda" to deposit. Their composition is $Na_2CO_3.10H_2O$ as against the so-called "summer soda" of Big Lake, which has a composition of $Na_2CO_3,NaHCO_3.2H_2O$, or of the mineral urao. The economic points of manufacture are fully set forth by Dr. Chatard in the reference given. The product of the Ragtown works has reached 750 tons yearly, but Chatard thinks it could be doubled.
T.M.Chatard.Natural Soda. Bull.60, U.S.Geol.Surv. 1888. p.27.
C.King. 40th Parallel Survey,Vol.I. p.510.See also A.Hague. II.746.
I.C.Russell.Geol.Hist.of Lake Lahontan. Monograph XI. U.S.G.S. p.73

OWENS LAKE, CALIFORNIA lies in Inyo County in the southeast portion. surrounding region belongs to the Great Basin and region, but the lake itself is 17 miles long, 9 miles broad and has a maximum depth of 51 ft. It is without an outlet and is supplied by the Owens River and various smaller streams. The surrounding country is volcanic and hot springs are not lacking. Beyond question the leaching of the soda-lime feldspars in the volcanic rocks has been the source of the soda, shown by the analysis given above. Extensive works are situated on the lake and the annual product of soda may reach beyond 200 tons. Oscar Loew of Wheelers Survey estimated that the lake contained 22,000,000 tons sodium carbonate and it is the largest source of supply yet discovered in this country. The process of manufacture is well described by Foster in the reference cited.

T.M.Chatard. Natural Soda. Bull.60, U.S.G.S. 57.
E.L.N.Foster. Production of Carbonate of Soda from the Alkali Waters of Owens Lake. Colo.Sci.Soc. III. 245.
W.A.Goodyear. On Owens Lake VIII Ann.Rep.Calif.State Min. 227. See View of Works in XII do. p. 410.
O.Loew. Wheelers Survey Report for 1876. 130 and 189.
I.C.Russell. Geol.of Owens Lake-8th Ann.Rep.Director U.S.G.S. 294.

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ALBERT LAKE, OREGON lies in the southeastern part of the state and within the area of the Great Basin. It lies in one of the troughs formed by a series of step-faults in a lava sheet. Russell's map shows it to be about 15 miles long by four broad at its widest part. It averages ten feet in depth. Analyses of samples having a specific gravity of 1.03117 at 19.6 degreesC indicated about 4 % of solids, of which nearly 40 % were the mono and bicarbonate of soda, with low sodium sulphate. The lake is as yet too remote from railways to be of commercial value.

In the desert region of the Great Basin in Nevada, Oregon and California are numbers of solid saline deposits, usually varying mixtures of the same alkaline salts that are given in the analyses above. Lists of the localities with analyses will be found in Chatard's paper pp.55-56. The carbonate and hydrate are manufactured from sulphate beds in Wyoming as stated under the next topic.

H.T.Biddle. On Albert Lake. A.J.S. iii. XXXV. 475.
I.C.Russell. On Albert Lake. Fourth Annual Report U. S. G. S. 435.

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VENEZUELA. In the province of Maracaibo, forty-eight miles from Merida is a small lake as described by Faxar (quoted by Chatard). It is 600-700 feet long and about 350 broad, not over 9 or 10 feet deep. In warm weather urao $Na_2CO_3,NaHCO_3+2H_2O$ crystallizes on its bottom and is brought up by divers. The supply is 25-40 tons a year. Although alkaline deposits are frequent along the west coast of South America they are chiefly of importance for nitrates under which head they will be mentioned.

T.M.Chatard. Bulletin 60. U. S. G. S. p. 40.
P.Faxar. Ann. de Chimie. ser.II. Vol.II. 432. Pogg. ANN. VII. 101.

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The natural carbonate is obtained abroad at Szegedin, Hungary, in Egypt, and in Armenia a brief sketch of which with bibliography will be found in Chatard's paper.

SODIUM SULPHATE.

This compound has been often mentioned above as an associate of the carbonate both in the solid deposits and in natural solutions. It is of chief practical importance in Wyoming, in which state it forms important deposits in several counties. The ones earliest developed are in Albany County and the most inportant lie southwest and west of Laramie. They are called the Union, Pacific and are connected with Laramie by rail. The so-called soda-lakes are dry in summer but have a thin sheet of water in winter. The chief compound present is the sulphate, and the process employed to utilize it was calcination with coal and subsequent leaching of the carbonate according to the familiar soda ash process. Some technical difficulty ensued, said to be the removal of the water of crystallization and the works are now idle. Caustic soda was at one time made, but the chief product has been used in glass manufacture. Carbon County and Natrona County also have lakes.

W.C.Knight. Bull.14. Wyo.Agric. Expt.Station Oct.1893. p.179.
L.D.Ricketts.Ann. Rep. Geol.of Wyoming. 1888-1889. Cheyenne 1890.
See also Minèral Resources-Annual volumes,especially 1885 550. - - - - - - - - - - - - - - - - - -

SODIUM NITRATE, (and Potassium Nitrate.)

Sodium nitrate is the chief natural product, potassium nitrate being far less abundant. The former is called nitratine in strict mineralogical nomenclature, the latter niter. The word saltpeter is most correctly applied to the potassium salt; while in distinction, the sodium nitrate is called Chili saltpeter. The process of nitrification in nature is somewhat obscure but it has been shown that nitrates form on exposed crags and thence pass into the general drainage in very small quantities. Where, however, guano or other nitrogenous organic matter is in association with alkaline deposits, and in dry climates, the largest amounts are produced. The excrements of bats and of other animals in caves lead to a similar reaction in the cave dirt. Cave deposits have been a minor source of the mineral in several places in this country, of which the Mammoth Cave is chief. Nitrates also form in surface soils exposed to decaying organic matter.

In the alkaline deserts of the west, saltpeter is not entirely lacking, although it does not yet appear demonstrated that the deposits are workable. The mineral is known at Forty-mile Desert, Humboldt Co., Nev., but has not yet been developed. Small amounts have been shipped from the Calico District of San Bernardino Co., California. Discoveries have also been reported from Springville, Utah Co., Utah, and near Milford in Beaver Co., Utah, and in Southern New Mexico.

The principal source of sodium nitrate today is that portion of Chili lying inland from Iquique, along the northern coast near the Peruvian line. The region is practically rainless and is hot. East of the range that forms the rampart of the coast, is an elevated valley forming the desert of Atacama which lies between the coast range and the Andes proper. On the western slopes of this valley are enormous deposits of sodium nitrate. The crude material is called caliche and contains about 25 % of the nitrate, mixed with common salt, sodium sulphate, water and insoluble materials. Great beds of guano also occur and it seems probable that the reaction of nitrogenous products from these on the usual sodium salines have produced the nitrate. Chili exports nearly a million

tons yearly, of which rather more than 10 % is brought to the United States.

Chilian Nitrates. E. & M. Jour. Aug.25th 1888. June 22nd,1889.

The Nitrate Deposit and Trade of Chili. E. & M. Jour Aug.9.1890.164. after a recent report by Consul Gen. Walker.

S.Child. The Nitrate Deposit of Tarapaca. Harpers Weekly Sep.13.1890. Illus. Rec.

W.C.Day. Articles on Potassium Salts and Sodium Salts in M. R. 1887. 644-657. See also M. R. 1882. 597. 599.

B.F.Gray. On Nitrification. Smithsonian Contributions. 1851.

Kraut. On Chili Zeitsche. d. d. Geol. Ges. XVIII, 130. 1866.

W.Kroll. Studie der Salpeterwueste und ihrer Industrie. Mitth. aus dem Naturwissen. Verein f. New Vorpommern und Ruegen in Greifswald. 1892.38. Good paper. May be found in Library N. Y. Acad. Sciences.

Noellner. On Chili. Jour. f. prak. Chemie. CII. 459. 1867.

C.Ochsenius. Die Bildung des Kalisalpeters aus Mutterlaugensalzen. Zeit. f. prak. Geol. Feb.1893. 60.

A.Pissis. Nitrate and Guano Deposits in the desert of Atacama. London. 1878.

A.H.Worthen. Saltpeter Caves. Jackson Co. Ills. Geol. ILLS. III. 80.

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B O R A X.

This useful product is obtained in the Great Basin region, as are the previously mentioned salines, and is of an importance that increases yearly. Its earliest source in America was native borax or tinkal $Na_2O.2B_2O_3 + 10H_2O$ with B_2O_3.36.65 %. It occurs withother alkaline salts in saline marshes which will be shortly mentioned. With it are tufts of acicular crystals of ulexite or "cotton-ball borax", a calcium sodium borate, $NaCaB_5O_9 + 5H_2O$, with B_2O_3 49.7 %. This is less easy to treat. More recently very extensive deposits of calcium borate, have been developed in the Calico district of San Bernardino Co. California, and in late years they have yielded the greater part of the borax. They appear to be old lake or marsh deposits that have been tilted up at high angles by folding so that they are now mined by underground workings like any vein. When well crystallized the mineral has been called colemanite, but in the massive form priceite. It needs subsequent treatment to change it to the sodium borate of commerce. Pandermite from Asia Minor is a closely related calcium borate. Stassfurtite produced in small amounts at the Stassfurt salt mines is a magnesian borate.

The borax marshes, the former sole source of the mineral are situated in Esmeralda Co., Nev., south of the Ragtown lakes referred to on p. 151., and in San Bernardino and Inyo Counties California. There are four in Nevada, called Seels, Columbus, Fish Lake and Rhodes. All are confined in valleys whose drainage evaporates instead of running off. The surface is sometimes coated with a boracic efflorescence that works up by cappilary attraction and after removal it renews the supply in the course of three or four years. Ulexite, priceite and tinkal are all met, and with them more or less dust, gypsum, halite, soda, sodium sulphate etc. Under the surface there is standing water as shown by artesian wells. The region contains many volcanic eruptions and probably hot springs stimulated by these, supplied the borax to the original lakes. There is

an additional marsh at Salt Wells, Churchill Co., Nev. In Inyo Co. Cal. there are three, the Saline Valley, the Armargosa, and the Furnace Creek; in San Bernardino Co. there is one, the State Range or Searles. Some years ago some borax was obtained at Little Borax Lake, near Clear Lake, 80 miles north of San Francisco. Boracic salts are shown by analysis in the large lakes, such as Owens (see p.151) and, to a less degree, Mono. Large isolated masses of priceite have been dug from the soil at Chetco, Curry Co. Oregon, and some notable amounts have been shipped to San Francisco. Northern Chili also contains deposits of calcium borates, at two points, Maricunga and Ascutan. They are elevated and remote but considerable ulexite is shipped to Germany. Smaller amounts are also exported from Argentina. The other foreign sources are the deposits of pandermite at Suzurlu, Asia Minor, the Tuscan hot springs, which afford sassolite, H_3BO_3, and Thibet, whence small quantities are shipped over the Homalayas on the backs of sheep.

In California and Nevada the Pacific Coast Borax Co. is much the largest operator. Recent production is shown by the following table from the Mineral Industry. 1893. p.76. Amounts are given in pounds.

	California.	Nevada.
1889	1,939,650	5,333,482
1892	11,050,495	1,487,701
1893	7,499,562	1,199,438

California-Nevada. Chemical News-1886. 54. 1891. Feb.13. Analyses Chemiker Zeitung Repertorium 1886. 35. Annales des Mines. 1885-No.6. Mineral Resources. 1882.p.566. Re Oil Paint and Drug Reporter, Mar.1891. 10, 25 Anals.

For History of American Borax see E. & M.Journal Sept.20th,1892.

H.DeGroot. On San Bernardino Co. Report of Calif.State Mineralogist1890

E.L.Fleming. Chemical News, Feb.13.1891.

W.A.Goodyear.Borax in Lake Co. Calif. Rept.of Cal.State Mineralogist 1890

H.G.Hanks. Third Ann.Rept.Cal.State Mineralogist 1883 partII.Good-Rec.

Hoke. Journal of the Soc.Chem.Industry. 1889. 854.

J.F.Kemp. The Mineral Industry 1892. 43. General Review.

W.H.Storms. On the deep mining of Priceite. 11th Ann.Rep.Cal.State Min. 345. 1892.

J.D.Whitney. On B. in C. Geol.of Cal. I.96. A.J.S. II. 41. 255.

C.G.Yale. Mineral Resources 1889-1890 p.494. Rec.

Chili.

Darapsky. Die Borax industrie in Chili. Chemiker Zeitung. 1887.No.40 see also 1885. 9.1305 1886. 10. 57.

Italy.

E.Bechi. On the Boracic Acid Compounds of thr Tuscan Lagoons- B. & N Z'g. Oct.18th,1854. A.J.S. ii. XIX. 119.

J.Bowring. The Boracic Acid Lagoons of Tuscany. A.J.S. I. XXXVII. 270.

The Lagoons of Tuscany. A.J.S. II. 9. 431. from the Bull.Soc.Geol. de France. Dec. 1848. 147. See also W.P.Jarvis and M.Rice in 3. California Min.Rep. 1883. p. 68 &70.

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CRYOLITE.

This mineral is an important source of sodium compounds and should

be mentioned in this connection. Its composition is $3NaF.AlF_3$, that is a double fluoride of sodium and aluminium. At only one locality does it occur in commercial quantities. This is Ivigtuk on the Arksut Fjord, latitude 61° 13', west coast of Greenland, near the southern end. It forms a vast bed or vein 80 feet thick in gneiss and dips at 45° . The present quarry is 600 x 200' and over 100' deep. Siderite galena, blende and a few rarer minerals are the sole admixture. It is shipped to Philadelphia, and thence to the Pennsylvania Salt Co. at Natrona, near Pittsburgh where it is turned into sal-soda, bicarbonate, caustic soda, alum and aluminium As a rare mineral cryolite is also known at Miask in the Urals and at Pikes Peak Colo.

G.Hagermann. On some minerals associated with cryolite, in Greenland. Amer.Jour.Science ii. XLII/ 93.
C.Hart. On the Cryolite Deposit-Jour.Anal.& Applied Chem. Oct.1892
Kryolite Pamphlet issued by the Penn.Salt M'f'g.Co. Natrona Pa.1893.
C.J.Lukens. Cryolite, Where found, Nature uses. The Manufacturer and Builder p.80.(Full reference not at hand. 1880-90)
J.W.Taylor. Cryolite of Evigtok. Quar.Jour.Geol.Soc: XII. 140.

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A L U M.

When clays or shales contain pyrite, it decomposes and affords sulphuric acid, which in turn reacts on the aluminous silicates present, and yields the double sulphates of alumina and some alkaline element, that we call alum. These "alum-shales" are not as yet of commercial importance in this country, but abroad have been leached to obtain the mineral. Our sole commercial sources are at present bauxite and cryolite and the treat ment involves the formation and solution of aluminum sulphate with sulphuric acid, after which an alkaline sulphate is added and the resulting double sulphate is crystallized out. Deposits of native alum have been reported at a great many localities, especially in the west but no one has ever been commercially operated. As an interesting mineral, natural alum is very common at the points where sulphurous springs emerge from shales, and the frequent association of shales or clays with pyrite in nature could not but lead to its frequent formation. For lists of localities, see

Mineral Resources. 1883-84. 949. 1886. 681. and the
Mineral Industry 1893. 5.
W.P.Blake. Alunogen and Bauxite of New Mexico. M.E.Oct. 1894.

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CHAPTER VII. SOILS, FERTILIZERS, and MINERAL PAINTS.

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All soils are produced by the decomposition of rocks, sedimentary, metamorphic or igneous, but the first two must ultimately be referred to the last, unless, as in the cases of calcareous rocks and a few siliceous

infusorians, their substance has been abstracted from the ocean, where it may have been in solution since the condensation of the water. The metamorphic rocks are either alterred igneous or altered sedimentary varieties, so that we are logically led back to the igneous for the original material, and are forced to find in their minerals the sources of all the others. These minerals are comparatively few when only the essential ones are considered. Quartz, the feldspars, the micas, the amphiboles, the pyroxenes, Olivine, lencite, nepheline and magnetite make up the list These decay under atmospheric agents and pass into hydrated silicates, carbonates and hydrous oxides, all but quartz which is practically inert and only breaks up mechanically. It thus forms the major portion of the fragmental rocks. Add to these products the limestones, including dolomites and the principal rocks producing soils are before us. There are great differences in them and hence resulting soils differ. Pure quartz sand has little fertility and needs calcareous and aluminous additions. Fairly pure aluminous silicates like clay are so tough and cold that they need sands and calcareous materials. Further, chemical elements which are taken by plants and removed in the harvesting have to be restored in order to keep land in good condition. Such elements are chiefly nitrogen phorphorus and potash and one of the great services of modern chemistry has been the light it has thrown on these points. We know that growing buds and young shoots in the spring contain phosphorus and nitrogen in comparatively large amount but later these elements disappear from the leaves and collect in the seed and are harvested. Other mineral matter gives stiffness to stalks and remains in the ash after calcination. Thus wood ashes afford potash or lye and are valuable fertilizers.

At the same time some decaying organic matter is also necessary for the best results of plant growth, for its organic acids aid in an important way in making mineral matters soluble. And it is also to be born in mind that the physical nature of the soil as a retainer of moisture or a quick drainer is a factor not to be overlooked, but it is the aim at this point to emphasize the mineral matters so as to bring out the part played by mineral fertilizers.

It has been the aim of modern agricultural chemistry to supply to the soil, either the necessary ingredients which were originally lacking, or those that have been exhausted by plant growth. As an illustration of the former the addition of lime breaks up the toughness and intractability of clays, and ten percent will sometimes change their character. The same is true of soils from many shales and sandstones so that their seams of limestone, such as occur in the coal measures of Pennsylvania, have considerable agricultural importance. Gypsum answers a similar purpose. In the second case the plantsremove mineral salts and these have to be artificially returned. Tobacco, for instance, with its excessive amount of ash, is an exhausting crop for potash and soon destroys the land unless fertilizers replace the missing elements. The so-called "old fields" of Virginia, exhausted by earlier methods of tobacco culture are familiar examples of induced barrenness.

In connection with soils attention should also be directed to their relations to the underlying rock. In that portion of the country south of the terminal moraine, the superficial deposits are chiefly made up of the alteration products of the underlying rock, The soils are indigenous and the float material give a clew to the geology of the solid strata. The varying character of these strata largely determines the diversity of

soils. Thus the Siluro-Cambrian limestones have made the Great Valley the garden of the eastern states, but the Devonian and Carboniferous sandstones and shales, to the west of it are far inferior in fertility. In indigenous soils we distinguish three layers, bed rock, subsoil and vegitable mound. The second consists largely of fragments of the first; the third of small comminuted derivitives of the second together with decaying vegitation. Above the line of the terminal moraine we have to consider not alone the decomposed country rock, but also sands, clays and gravels that may have had their home in localities far to the north. Under these superficial materials the bed rock is smooth and clean as it was scraped by the ice. Such deposits of foreign origin afford transported soils. Wind-blown sands and dirt are important in many regions, and volcanic ashes or lappilli may spread to great distances.

These brief introductory remarks are intended to lead up to the following topics of "Fertilizers". The search for mineral fertilizers has developed some important industries, to which as a form of natural resources of no minor magnitude attention will next be given.

Books on agriculture, or agricultural chemistry and the reports of the recently established experiment stations make up a fairly prolific literature. The following two citations afford good general accounts.

N.H.Shaler. The Origin and Nature of Soils. Twelfth Annual Report Dir. U. S. Geol. Survey.

S.G.Williams. Applied Geology. Chapter VI. 101. Gives bibliography.

FERTILIZERS.

GYPSUM GREENSANDS. The use of gypsum in this connection has been referred to on pp. 138-139 where the literature is cited. The employment of Cretaceous greensands and marls in New Jersey is also important. Their general geological relations were outlined in speaking of the underlying clays p.126. The marls are later Cretaceous and cover a large area in South Central New Jersey. They afford a valuable material and are also prolific in fossils. The name greensand has been given on account of the presence of glauconite, a green hydrated silicate of iron and potassium. Greensands also contain some phosphoric acid and a large amount of shell remains. It has been shown, especially by the naturalists of the Challenger expedition that greensand forms on the sea bottom at no great distance from the coast and in those places where foraminiferal remains exist together with feldspathic sediments from off shore drainage. The foraminifera become filled with silt and reactions probably from the presence of sulphur and iron, result, which lead to the formation of the glauconite, the potash being derived from neighboring feldspar. Greensands are known of all geological ages, and to them have been even refered the great iron ore deposits of the Mesabi range, but they are only dug for fertilizers in New Jersey.

J.W.Bailey. On the Origin of Greensand and its Formation in the Ocean of the present epoch. A.J.S. II. 22. 280-296. Proc.Boston Soc. Nat. Hist. V. 364.

W.B.Clark. Origin and Classification of the Greensands of New Jersey. Jour.of Geol.II. 161. 1894. Rec. Preliminary Report on the Cretaceous and Tertiary Formations of New Jersey. Report of State Geol. for 1892. 169. Both these papers give valuable bibliography.

G.H.Cook. Geology of New Jersey. 1868. p. 261.

De la Beche. Phosphates of Lime & Greensand and Marl. Geol.Soc.Lond. Proc. May 1849 p.lxxxii. A.J.S. II. 8. 422.
S.P.Sharpless. On Some Rocks and Other Dredgings from the Gulf Stream. A.J.S. III. 1. 168.
R.P.Whitfield. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of N.J. U.S.Geol.Surv. Monograph IX.

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PHOSPHATES. Phosphate of calcium in one form or another is the basis of commercial phosphates. It is obtained as the crystalline mineral apatite which contains also calcium chloride or fluoride; as nodules and concretionary or massive forms which seem often to have replaced limestone which also contain fluorine; and as the more or less recent excrements of birds in the form of guano. Fossil excrements or coprolites are ~~also~~ of value abroad. The crude material is subjected to some preparatory treatment to make the phosphates soluble in water, and in this sulphuric acid is so important an agent that the vitriol industry is closely linked with that of the phosphates. Certain standards of richness are established in the different productive regions which must be attained to make the crude rock soluble. The richness is usually stated on the basis of tribasic calcic phosphate, $Ca_3P_2O_8$, also called bone phosphates, of which P_2O_5 forms 45.80 %. Hence where P_2O_5 is expressed by analysis, the corresponding tribasic phosphate is in round numbers a little less than ~~five~~ two and one fifth times its amount. No crude rock under 50 % tribasic phosphate is merchantable. Canadian apatite has been usually shipped at 80 % of this compound. At the same time certain other ingredients should be as low as possible. Insoluble materials of which silica is chief should be washed out and reduced in amount, for they are simply inert. Alumina and ferric oxide are objectionable because after the formation of the fertilizer itself they tend to change a portion of the phosphoric acid to an insoluble form, or to "revert" it, as it is called. Calcic carbonate is bad because it neutralizes to no purpose the vitriol used in the manufacture. Crude rock and fertilizers in bulk are now sold on the basis of analysis, so that other deleterious ingredients being sufficiently low, so much per unit of P_2O_5 is paid. South Carolina and Florida phosphates have ranged from $3.50 to $5. per ton in the last few years at the mines, which is not over half the price that prevailed a few years earlier.

Phosphate of Lime. E.& M.Jour.June 8 1878. p.393.
W.H.Adams. List of Commercial Phosphates. M.E.Oct.1889.
T.M.Chatard. Phosphate Chemistry as it concerns the Mines.M.E.Feb1892
W.B.M.Davidson. Notes on the Geological Origin of Phosphates of Lime in the United States and Canada. M.E.Feb.1892.
C.C.Hoyer Millar.Phosphates. Relates to Canada,S.C.& Fla.-Sci.Pub.Co.N.Y.
C.G.Memminger. General Article. Mineral Industry. 1893. 551.
Mineral Statistics of the United States. All the Volumes.
R.F.Penrose. The Nature and Origin of Deposits of Phosphates of Lime. Contains a full Bibliography p.129 Bull.46.U.S.G.S. Rec.
W.B.Phillips. A list of Minerals containing at least 1 % Phosphoric Acid. M.E.Feb.1892.
J.Stewart. Laurentian low-grade Phosphate Ores. M.E.Feb.1892.
F.Wyatt. Phosphates of America. N. Y. 1891. Rec.

APATITE. Workable deposits of apatite are practically limited to the Archaean rocks, and to the older formations among these. On this side of the ocean they occur in the Laurentian heights of Ontario and Quebec. They occupy a section which includes the counties of Leeds, Lanark, Frontenac, Addington and Renfrew in Ontario, just north of Kingston and west of the Ottawa River, and which extends across the river into Ottawa Co. Quebec. The apatite is prevailing green and red and irregular although individual crystals of great size and perfection also occur especially in crystalline calcite. It is generally associated with pyroxene rock, called by Hunt pyroxenite, but which Harrington has shown to be quite variable and to contain considerable quartz and orthoclase as well. Adams and Lawson have likewise identified scapolite-bearing amphibolites and diorites in a few localities and have thus recognized in Canada, rocks which are related to the characteristic associate of apatite in Norway, where these scapolite rocks are called "Geflecter Gabbro' and "Apatitbringer". Feldspathic rock and crystalline calcite also occur in close connection with the apatite of Canada. The apatite is found in veins or what may be described as veins, that are often irregular and pockety but that in several instances run several miles across the country. The commonest gangue minerals are pyroxene and calcite. Hornblende titanite, mica, zircon and others are met often in crystals of extraordinary size and perfection. The aptite is mixed in with the gangue in more or less intimate relations. It was cobbed out to a high grade product, 80 % tribasic calcic phosphate, and in this purity was shipped abroad while the industry flourished. Great quantities of low grade rock were cast aside, and no method of preparation has yet been devised for utilizing it although the problem is an inviting one. The specific gravities of all the minerals in the mixture are so close that wet mechanical separation is impracticable. But in recent years the development of the Florida phosphates has ruined the industry and the mines are no longer operated.

The origin of these bodies is very obscure. T.S.Hunt regarded them as veins, analogous to vein granites or pegmatites. He opposed the idea that they were necessarily connected with organic life and his attitude was abundantly justified, for even in igneous rocks of all ages, apatite as a microscopic accessory is the most wide-spread of all the rock making minerals except perhaps magnetite. Those geologists who are predisposed to find in the Laurentian the traces of life, have cited apatite as one of the strong forms of evidence. Sir J. William Dawson is the most prominent upholder of these views, but the thesis is a difficult one and the geological occurrence and associations give but slight encouragement. In Norway the similar apatite enrichments have been viewed as segregations from an igneous magma, and connected thus with intrusions of basic plutonic rock. Such was the view of Brogger and Reusch cited below, and the same has received support more recently from J. H. L. Vogt.

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F.D.Adams. On the Occurence of the Norwegian Apatit-bringer in Can with a few notes on the microscopic characters of some Laurentian amphibolites. Geol.Mag.Vol.I. p.518.

F.D.Adams & A.C.Lawson. On some Canadian Rocks containing Scapolite with a few Notes on Some Rocks associated with the Apatite Deposits. Canadian Record of Science p.185. Circu.1890 containing a good bibliography.

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NEW YORK. In 1838 Dr. E. Emmons, while engaged in the early work of the New York State Survey, discovered a variety of apatite near Crown Point, that he called eupyrchroite from its phosphorescence. Some unsuccessful attempts were made to mine it. It is in a crushed zone along a fault that is chiefly filled with chloritic decomposition products of gneiss. In the same region the magnetites that are excessively rich in apatite and that are called "red ores" were also early mined and subjected to magnetic treatment for the apatite, but all the operations passed in time into iron mines.

Some attention has been directed to low grade magnetite rich in phosphorus, in connection with magnetic concentration. The by-products of the separators are unfortunately so rich in hornblende, pyroxene and quartz as to be of small value in this connection. There is slight promise of success.

W.P.Blake. Contribution to the early History of the Industry of phosphate of Lime in the United States. M.E.Feb.1892.

E.Emmons. On Eupyrchroite- 2nd Ann.Rep.N.Y.Surv. p. 1838. Final Report on 2nd District 1842.286. see also Beck's Report on Mineralogy of N.Y. 1842-240 and J.F.Kemp Rep.of N.Y.State Geol. 1893. 459.

C.T.Jackson. On Eupyrchroite of Crown Point, N.Y.- A.J.S.II.12.73. also N.Y.Rept. on Mineralogy p.240. Description and analysis of Phosphorite from Crown Point, N.Y. Proc.Bos.Soc.Nat.His.Vol.III.p.47.1856.see also p.264

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AMORPHOUS or NON-CRYSTALLINE PHOSPHATES. These are produced in the United States in largest amount along the sea-coast of South Carolina and on the western shores or at no great distance inland in Florida. Minor deposits are known in North Carolina, Georgia, Alabama and Tennessee. The South Carolina phosphates have been worked since 1867, but those of Florida are of much more recent development. The Tennessee discoveries are still more recent. In addition there are guano and phosphate rock deposits on several of the West Indies and on the islands of the Pacific.

SOUTH CAROLINA. The phosphates are distributed over an area about 60 miles long, and extending back 20 miles from the coast. Some mines are near the ocean while in other places the phosphatic stratum is near the surface at a considerable distance inland. Beaufort on the southwest and Charleston on the northeast, mark the limits in a general way. The coast is low, the surface being seldom more than 10-15 feet above tide, and it is cut by a network of estuaries and rivers characteristic of this section. The strata underlying the phosphates are Eocene, Tertiary and in 1848 were classified by Tuomey which grouping is accepted by W.B.Clark in 1891, into 1. Buhrstone, 2. Santee Beds, 3. Ashley and Cooper Beds, (Bull.83. U.S.G.S. pp.51. 81.). They are all sands, clays, marls, shell beds, etc. the buhrstone itself that gives a name to the lowest stratum, being insignificant. Many fossils such as vertrebrae, teeth etc., are scattered through them. The Ashley Beds are the highest of the series and upon these after an intervening bed of sand and clay, of no great thickness, rests the phosphate deposit itself. This has been usually called Eocene, and has been thought to have been formed by the wash of earlier Eocene beds,recent determinations by Dall,lead to the conclusion

that it is Upper Miocene (Amer.Jour.Sci.Oct.1894.p.301). The bed includes many fossil teeth, bones etc., phosphatic nodules and concretions buried in sand and clay. The bed varies from a few inches to two and a half feet, with a general average under one foot. About a dozen different varieties of nodules are recognized, the variations being due to color, luster, hardness and the nature of the foreign materials such as shells, sand etc., cemented by the phosphate. The yield per acre varies from 400 to 1200 tons. On the land the bed is dug by systematic trenching and the nodules are then washed thoroughly and calcined. Eight or nine feet of stripping are about the maximum of profitable working. The nodules are also dredged from the river bottoms by large dredging machines of various kinds. The industry has suffered in recent years from the competition of the Florida phosphates and the works experienced great damage from the hurricane and floods of August 1893. Nevertheless the production in 1893, of 502,564 tons was in excess of that of Florida by over 60,000 tons. Prices have fallen also to such a point that profits are much lower than in former years.

The origin of these deposits has been a puzzling problem. There seems to be little doubt that the phosphoric acid was derived from excrements and decaying animal matter deposited along a shore line. It may then have replaced carbonate of lime in nodules of marl or limestone, or formed concretions of lime phosphate, or in instances, as urged by N.S.Shaler, have collected in the bottoms of swamps. However originating, they were afterwards concentrated into the bed and river bottoms where now met.

The North Carolina beds are of much less importance and supply less than 7000 tons yearly. They are in part like those of South Carolina, but near Castle Hayne where the chief mining is done, they form conglomerate nearly six feet thick, of rolled nodules, bones and other pebbles.

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NORTH CAROLINA.

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W.B.Phillips. North Carolina Phosphates. Wilmington N. C. 1883.

A.Winslow. Phosphate Deposits of North Carolina.

E.Raleigh. E. & M. Jour. March 21st, 1885. 193.

FLORIDA. The development of phosphates in Florida began in 1888 and 1889, and has since grown to such proportions that the state begins to rival South Carolina. The productive territory lies along the western side of the peninsula, in a general belt from 20 to 50 miles from the Gulf of Mexico, and from the Caloosahatchie River on the south to the Appalachicola on the north west. Other deposits in the nature of river gravels are met near the mouths of the Alafia, the Manatee and the Peace rivers. Florida is a low geanticline, that heaves up Eocene porous and friable limestones in the central part of the peninsula, and has firmer Miocene beds of limestone on the western and southwestern flanks, and Pliocene clays, sands and tender limestones on the southern half. Recent sands are met on the surface of the uplands and in the beds of streams.

The phosphates are divided, according to Eldridge, to whose paper cited below the following notes are chiefly due, into "hard-rock" phosphate, "soft" phosphate, "land-pebble" or "matrix-rock" and "river-pebble". Hard-rock phosphate appears with both Eocene and Miocene limestones from which there is good reason for thinking it has been derived. It is a dense, firm, rock with occasional cavities, which are lined with a secondary incrustation of phosphate and which suggest the shape of fossils. The cavities may also contain still later phosphatic sediments. The rock-phosphate has also suffered by brecciation and by disintegration to a powdery material in the process of alteration. It now is mined as large boulders and fragments, buried up in finer sands and clays at moderate distances below the surface. The hard-rock phosphate is the richest of the varieties mined and yields an average according to Eldridge, of not far from 36.65 P_2O_5 or about 80 % tribasic phosphate. C.G.Memminger in the Mineral Industry 1893, p.532, gives as the average of several cargoes-phosphate of lime, 80.02, oxides of iron and alumina, 2.64. The hard-rock phosphates are obtained in the interior districts and are exploited by open cuts and stripping. The term soft-phosphate is applied to the loose phosphatic sands, clays etc., that occur with the hard-rock varieties. Soft phosphates are used on a small scale directly on the land without previous preparation, and Memminger states that they are variable in composition, with 39-70 % phosphate of lime and an average of 64. The oxides of iron and alumina are also variable, ranging from 2 to 15 %.

The land pebble phosphate is chiefly mined near Bartow, east of Tampa. The nodules are mostly white in color, and vary from an inch or two in diameter down to minute size. They are distributed through a bed of clayey material, from 6-20 feet thick, with an average of 10 feet, and an under stripping of from 3 to 10 feet. The phosphate forms 15-50 % of the bed as mined, with an average of 25 %, which means from 700-1000 lbs. clean, dry phosphate per cubic yard or about 6000 tons per acre. It ranges from 65-70 % tribasic phosphate, 2-4 % iron oxides and alumina, careful washing being necessary in order to keep the last named low. (These figures are from Memminger as cited below.) The pebbles are mined both by various methods of digging and by hydraulicking, and much care has been expended in developing economical and effective methods of washing. The river pebble phosphate is found under present streams, especially the Peace River, and in former channels near the present rivers, which may now be swamps and covered with timber. They are mined or dredged with centrifugal pumps, are washed, dried, and shipped. The dredges work up from the rivers into the land after the timber has been

cleared away. The pebbles average 60-62 % tribasic phosphate, and were the first form of deposit to be discovered and utilized.

The relative amounts of the several varieties produced in 1893, are the following according to the Mineral Resources 1893' Hard Rock, 215,685 tons, Soft Rock, 13,675, Land Pebble, 86,674, River Pebble, 122,820-making a total of 438,804 of a value $1,979,056. The figures given by the Mineral Industry vary somewhat from these.

The origin of these deposits is not always well understood, but it is most reasonable to believe that while the peninsula stood near the sea level, possibly in Eocene and again in Miocene times, great quantities of guano, dead fish, reptiles and other forms of decaying organic matter accumulatedin the shallows and led to the formation of crusts of calcic phosphate on the surfaces of limestone. In part it may have replaced limestone but it seems also to have formed independent crusts. The mechanical abrasion and redeposition or the concentration of these as residual deposits has given rise to the pebbles.

E.T.Cox. Floridite, a new variety of phosphate of lime. A.A.A.S. 1890. 260.

N.H.Darton Notes on the Geology of the Florida Phosphate Deposits. A.J.S. Feb. 1891. 102. Rec.

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G.H.Eldridge. Preliminary Sketch of the Phosphates of Florida. M.E. XXI-196.

A.R.Ledens. The Phosphate Beds of Florida. E. & M. Jour. Feb.8-1890 p. 175 & 220.

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ALABAMA. Much interest has been felt in the discovery of phosphate deposits in Alabama, but while marls and even some nodules have been met the latter are not as yet known in sufficient quantity to establish a mining industry. The marls are locally productive of very fertile soils.

E.A.Smith. Phosphates and Marls of Alabama. Bull.2. Ala.Geol.Sur.1892 Phosphates in Perry Co. Ala. A.J.S. June 1884. 492.

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TENNESSEE. In several counties of southern central Tennessee,workable beds of phosphates have recently been discovered, that bid fair to be the basis of a local industry. In Hickman, Lewis, Williamson and other neighboring ones, southwest of Nashville, a black, bedded phosphate rock occurs, immediately beneath a thin, black, Devonian shale, and resting on limestone of Trenton, Niagara or Helderberg Age, according to the locality. Though rarely thick enough to mine, yet it occasionally reaches 3 feet or over, and affords 60-70 % tribasic phosphate. In these

cases it will probably prove a valuable material for local fertilizer manufacturies. The age of the phosphate rock is Devonian. Above the black Devonian shale (called also the Chattanooga shale) lies a blue sub-carboniferous shale, named the Harpeth. In the lower part of the latter is a layer of phosphate nodules, of low grade, and of small promise at present. More recently than the above discoveries there have been found in Perry Co., just west of Hickman, beds of white phosphate, high in silica, and between 25 and 35 % tribasic phosphate, interstratified and mixed with Carboniferous chert. The phosphate appears to have replaced limestone. Along the slopes of the cliffs near the creeks, and at about the horizon of the Chattanooga shale, a surface deposit is also met which consists of a chert-breccia cemented by phosphate. The crude breccia yields about 40 % lime phosphate, but when cleaned of the chert, the analysis shows over 80 %. Its utilization seems feasible. It has been formed on the surface by the leaching of the neighboring phosphatic strata.

C.W.Hayes. The White Phosphates of Tennessee. M. E. March 1895.
T.C.Meadows & Tytle Brown. Phosphates of Tenn. M.E.Oct.1894. E.& M.Jour. Oct.20th, 1894. 365.
W.B.Phillips. Phosphate Rock of Tenn. E. & M. Jour. May 5.1894. 417. Mineral Industry, 1893, 537.
J.M.Safford. Phosphate Beds of Tenn. E. & M. Jour. Feb.24.1894. p.366.

Phosphatic nodules are occasionally met at other geological horizons and elsewhere in America, although none have attracted serious attention for economic purposes. W.D.Mathew has described some interesting ones from the Cambrian of New Brunswick and gives a good review of methods of origin. (On phosphate Nodules from the Cambrian of Southern New Brunswick, Trans. N. Y. Acad. Sci. XII. 108. 1893.)

GUANO. Superficial deposits of excrementa, chiefly of waterfowl are called guano. Penrose divides them into two classes- 1. Soluble, 2. Leached. Under the first head are to be placed those accumulations of recent time and in regions of such scanty rainfall that their soluble salts, such as ammoniacal and other alkaline compounds, have never been lost. They are or were especially abundant along the west coast of South America, in Peru and on the neighboring islands. Much nitrogen was also present, and through the excrements were bones and dead bodies of fish, birds and marine mammals. The beds have been chiefly exhausted as they were limited and as mining has been in operation for over fifty years. An analysis, quoted by Penrose (Bull.46 U.S.G.S. p. 121) from The Cultivator 1844, is as follows:

Water and Volatile Ammonia- - - - - - - - - - -	15.37
Organic Matter and Ammonical Salts- - - - - - -	51.44
Chloride and Sulphate of Soda - - - - - - - - -	5.50
In soluble Siliceous Matter - - - - - - - - - -	0.57
Phosphate of lime and phosphate of Magnesia - -	21.11
Carbonates of Lime and Magnesia - - - - - - - -	6.11
	100.

The leached guano is obtained on a number of the islands of the West Indies and presents some anomalies of composition. Where the island is formed of limestone a calcic phosphate is met. This may be in loose material, with occasional nodules or may form a hard crust upon the limestone below, from which it is blasted. Penrose cites Sombrero, Navassa, Turk, St. Martin, Aruba, Curacoa, Orchillas, Arenas, Roncador, Swan and Cat or Guanahani Islands, the Pedro and Morant Keys and the reefs of where it will probably prove a valuable material for lime, fertilizer manufacturers. The age of the phosphate rock is Devonian. Above the Black Devonian shale (called also the Chattanooga shale) lies a thin sub-carboniferous shale, named the Maury. In the lower part of the latter is a layer of phosphate nodules, of low grade, and of small promise at present. More recently than the above discoveries there have been found in Perry Co., just west of Linden, beds of white phosphate, both in situ, and between [illegible] phosphate, interstratified and mixed with [illegible] chert. The phosphate appears to have replaced limestone. Along the slopes of the hills near the streams, and at about the surface of the Chattanooga shale, a surface deposit is also met which consists of a [illegible] by phosphate. The brown phosphate [illegible] Tennessee. It was formed on the surface by the leaching of the neighboring phosphatic [illegible].

Hayes. The White Phosphates of Tennessee. [illegible]

Memminger & Lydia Brown. Phosphates of Tenn. [illegible]

Phillips. Phosphate Beds of Tenn. [illegible] Mineral Industry, [illegible]

Safford. Phosphate Beds of Tenn. [illegible]

Phosphatic nodules are occasionally met in older geological horizons [illegible] elsewhere in America, although none have attracted [illegible] attention for economic purposes. [illegible] has described some interesting [illegible] in the Cambrian of New Brunswick [illegible] (The phosphate Nodules from the Cambrian of Southern New Brunswick, Trans. N. Y. Acad. Sci. [illegible])

Slags. [illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

The [illegible]

[illegible]

Los Monges and Aves in the Gulf of Maracaibo. These extend almost entirely around the Caribbean Sea. The island of Redonda, in the eastern group of the West Indies, yields a phosphate of alumina and iron, known as redondite. It occurs as a cementing material in and around masses of basalt, and contains but little lime. The composition offers disadvantages from the presence of these two bases, on account of the tendency of the product to "revert". C.H.Hitchcock considers that the local geology does not admit of guano as a source of the phosphate, but rather that it is somehow linked with the volcanic origin igneous rock. This involves petrological difficulties.

Guano deposits were also formerly worked on a group of islands over a thousand miles due south of the Sandwich Islands. They were under the protection of the United States and were of coral formation. They are called America Islands on the maps, and formed a small archipelago, projecting to a limited height above the sea, and coated with superficial loose phosphates and underlying crusts. Notes upon them will be found in the citation from C. N. Shepard Jr.

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E.V.D'Invilliers.	Phosphate Deposits of the Island of Navassa. G.S.A. II p. 75.
J.D.Hague.	On Phosphatic Guano Islands of the Pacific Ocean. A.J.S. II. 34. 224.
C.H.Hitchcock.	The Redonda (Leeward Is.) Phosphate. G.S.A. II. 6. Treats of Guano & Phosphates, perhaps volcanic in origin
A.A.Julien.	Various Phosphates from the Key of Sombrero. A.J.S. ii. XL. 567.
Dr.S.Kneeland.	The Mineralized Phosphates & Guanos of the Equatorial Pacific Islands. Boston Soc. Nat. Hist. Vol.20. p.235.
R.A.F.Penrose.	The Nature and Origin of Deposits of Phosphate of Lime. Bull.46. U.S.G.S. on Guanos 117. Bibliography p.129.
T.L.Phipson.	The Phosphatic Rock from the Island of Sombrero,W.I.with observations on same by A.A.Julien-A.J.S.ii.XXXVI.424.
S.P.Sharpless.	Turks Island and the Guano Caves of the Caicos Islands. Proc.Bos.Nat.Hist.Soc. XXII. 242. 1882.
C.N.Shepard, Jr.	Foreign Phosphates, 1879.
C.N.Shepard, Sr.	Phosphate Minerals on the Islands of Mona, and Moneta. A.J.S.May.1882-see also C.N.Shepard Jr.-A.J.S.Jan.1878.

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PHOSPHATIC SLAGS. Phosphates for fertilizers have been also supplied by the slags from the basic, Bessemer converters. These are merely ground to a great fineness, 100 to 150 mesh, and spread on land without further treatment.

E.Jensch Zeitsch.	für Angewandte Chemie. June 1st, 1889.
W.H.Morris.	Basic Slags as Fertilizers. M. E. February 1892.
W.B.Phillips.	Phosphate Slag. M. E. May 1889.

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MINERAL PAINTS.

On Mineral Paints in general, consult the volumes of the Mineral Resources, The Mineral Industry, and the Engineering & Mining Journal, Jan. 2.1892.

Mineral paints may be divided into two classes, those produced from metallic minerals or ores and those from non-metallic or earthy minerals The former are chiefly the ores of iron, limonite (called also brown hematite and bog ore) red hematite, and the mixtures of limonite and clay known as ochres, but in which the ore gives the color. With these are also classified puddle cinder, white lead, red lead and zinc white. The non-metallic paints include barite, slate refuse, soapstone, graphite, ultra marine, etc.

LIMONITE AND OCHRE. The long succession of Siluro-Cambrian limonites on the New York and New England border and southward in the great valley has afforded suitable material for paint in a number of localities

Works were early established at Brandon, Vt. and still remain in somewhat desultory operation. The ore is dug and dried in small sheds much as are bricks, and is then ground. It affords in the crude state yellow or yellowish brown colors, but when roasted gives various shades of red and darker brown. Small developments have also been made near Hoosic Falls, N.Y. All these limonites are mixed with more or less ochreous clay that goes to waste when the ore is mined for iron. The locality most productive of paint from what may be called an iron ore is in the southern part of Carbon Co.Pa. A bed of a bluish rock that affords on analysis 29-35 % metallic iron and varying amounts of silica, alumina, lime and magnesia is found just over the Oriskany sandstone. The iron is probably present as a carbonate. The ore or rock is hand-picked to rid it of slate and is then roasted and ground. It affords a rich, dark reddish-brown pigment.

C.E.Hesse. The Paint Ore Mines at Lehigh Gap Pa. M.E. Oct. 1890.

F.A.Hill. Report on the Metallic Paint Ores along the Lehigh River. Annual Report Penn.Geol.Surv.1886.Part IV.p.1386-1408.

OCHRE. is a name distinctively applied to soft clay-like or powdery material not possessing that solidity of limonite proper, but being essentially a very impure iron ore. This occurs in many places and is of itself a valuable product in Pennsylvania, Georgia, Virginia & Maryland. The deposit at Bermuda Hundred, Va. affords an excellent grade and numerous others occur with the Siluro-Cambrian limonites referred to above. A large deposit of high grade has been reported by Dr.E.S.F.Arnold, of the N.Y.Acad.Sci., on the St.John's River, Fla.(Trans.XIII.22) but is not yet developed. Large amounts are also imported, especially from France, Italy and England. The tests of a good ochre are depth and strength of color afforded by the paint and the amount of oil required in grinding; the less oil, the more valuable the ochre, other things being equal. The oil is the most expensive ingredient. Umber is essentially an ochre of a brown color containing oxide of manganese, that gives it its peculiar tint. The best grades, and in fact nearly all the supply comes from Italy. Sienna is another variety of this ferruginous clay, with a different color.

RED HEMATITE. Within the last few years red hematite iron ore has been growing in favor as a pigment, and is now ground in large quantities in various parts of the country. The chief source of the mineral is the Clinton ore, or as it called in different sections, fossil ore, dyestone ore, oolitic ore, flaxseed ore, etc. This forms a series of beds in

shales of the Clinton stage of the Upper Silurian, and is a remarkably extended and persistent iron ore deposit. It outcrops in Wisconsin, Ohio New York and down the Appalachians to Alabama. It is utilized for paint at Clinton, N. Y. where ten to twenty tons are ground daily, and is employed in the same way in the South.

SLAG. Puddle slag and heating cinder have been recently utilized at Boonton, N. J. for paint. They afford what is practically an iron ore of about 50 % iron, and in convenient shape for utilization.

Axel Sahlin. The utilization of Puddle-and Reheating-Slags for Paint-stock. M. E. XX. 385.

BARITE. Barite (barytes), or heavy spar, is the natural sulphate of barium. It is a dense white mineral easily scratched with a knife and of extraordinarily high specific gravity, 4.5. Barite is a frequent gangue in mineral veins and is especially found in connection with galena and zinc blende. It also occurs alone as a vein-filling and in pockets in many limestone districts, so that these two forms of deposits are its chief commercial source. It reaches the market from two principal districts, the largest being in southwest Virginia and North Carolina, the other in eastern Missouri. Smaller amounts come also from Illinois. The mining is in general somewhat irregular and is carried on in Missouri, by farmers in off-times. The mineral is there known as "tiff". In earlier years a vein near Hopewell, N. J. was productive. (N.J.Geol.Surv.1868. p.225). The same is true of a vein in Triassic sandstone at Cheshire,Ct. which had coffer minerals with it and afforded wonderful barite crystals. Workable deposits have been announced from Mexico. (E. & M. Journal Sept. 27th, 1890. p. 357). Barytes of the best grade should be free from impurities, especially quartz and iron stains. The former injures the mills in grinding, as it is so much harder than the heavy spar, while the latter injures the color of the paint. In preparation the barytes is crushed to the size of buckshot and then boiled in sulphuric acid to remove the iron rust. It is then boiled in distilled water to remove the acid and iron salts, dried and ground. It is next sorted by"floating in water", as it is called. The coarser portion settles quickly while the finest which gives the best grade of pigment remains longest in suspension. It is finally dried by steam, barreled and shipped. The principal use is as a pigment. Its great specific gravity enables it to remain in suspension and through mixture when ground with white lead. As barytes is worth from 1 to 1 1/2 cents a pound and the value of white lead is 6 to 7 cents, it is a tempting adulterant. It can hardly be said to injure the pigment, the objection being that the purchaser pays for one thing and gets another. For some purposes it has its own decided advantages as a paint, in that sulphurous gases do not discolor it. Considerable amounts are imported from Germany. Crude barytes is worth about $5. per ton spot value.

SLATE. Within the last few years the refuse of slate quarries has been ground as paint, and even poor grades have been somewhat utilized for the same purpose. A quarry at Grafton, near Troy, N.Y., produces a considerable quantity. It makes a useful "filler" or first coat for other colors. Some thousands of tons are annually manufactured. Soapstone has been used in the same way.

GRAPHITE. Graphite has been finding some application as a pigment in recent years, and it is one of the most important uses to which this valuable substance can be put. It is ground with oil and is specially

employed for metallic surfaces. For this purpose inferior grades can be utilized which would be poorly adapted to lubricating or the manufacture of pencils, etc.

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CHAPTER VIII. MISCELLANEOUS MINERALS, viz.-

ABRASIVES, ASBESTUS, CARBONIC ACID, FLUORITE, GLOSS MATERIALS, LITHOGRAPHIC LIMESTONE, PRECIOUS STONES, TALC.

ABRASIVES are employed in the form of loose grits, of artificially consolidated grains, and as natural rock. The essential feature of them all is the presence of some mineral in angular grains, of size according to the grade of abrasion required. The mineral for most purposes should possess considerable hardness, quartz of the grade 7 being about as low as it is desirable to go, but for fine polishing and finishing especially of soft metallic surfaces, powders of hardness much below this find an extended field of usefulness. In the harder minerals, the absence of cleavage is desirable, so that the grains during wear, will crack in jagged fragments with sharp edges, and will not crush to a powder too readily.

SOFT ABRASIVE POWDERS. For this purpose diatomaceous or infusorial earth,tripoli,pumice dust,fine red hematite dust or jewellers rouge, and various artificial products such as zinc white,putty powder,etc.,find applications. Extensive deposits of infusorial earth occur in the Tertiary strata along the Atlantic seaboard in Maryland and Virginia. The famous bed near Richmond has been long known and has been utilized to a considerable extent and other diggings have been opened on Chesapeake Bay, at Dunkirk, and Popes Mills Calvert Co.,Md., which of recent years have furnished our chief supplies. A considerable ^(bed) was dug in former years at Drakesville, N.J. but was mostly employed as a dope for dynamite. Other deposits are known in Connecticut, which have been utilized; at Sing Sing N.Y., only of scientific interest, and in not a few lakes on the western side of the Adirondacks. In Storey Co. Nevada, near Virginia City, a variety has been mined for the so-called "electro-silicon", and in New Mexico, California and Oregon vast beds have been reported especially by J.S.Diller. Some special scientific interest attaches to the diatoms of post-glacial and preglacial lakes in the limits of the Drift.

M.Congell. Diatomaceous Sands of Richmond, Virginia. M. E. IV. 230
C.F.Cox. On Recently Discovered Deposits of Diatomaceous Earth in the Adirondacks. Trans. N. Y. Acad. Sci. XII. 219, XIII. 98.
Mineral Industry. 1892.
Mineral Resources. All the volumes.
B.W.Thomas. Diatomaceae of Minnesota Interglacial Peat, 20th Annual Report Minn. Geol. Survey, 290.

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TRIPOLI is a name sometimes applied to diatomaceous earth, but also used for powdery siliceous residues or "rotten stone" that are left by the decay of siliceous limestones and cherts. Such have been developed near Seneca, Newton Co., Missouri, and are very extensive. The material is employed for water-filters as well as for polishing powder.
E.O.Hovey. Study of the Cherts of Missouri. A. J. S. Nov.1894. 401.
Mineral Resources. 1892. 752.

PUMICE is produced in small quantities at Lake Merced, near San Francisco, California.

HARD ABRASIVES--CORUNDUM AND EMERY. Corundum is crystallized Al_2O_3 and is the mineral of hardness 9, in the common scale. The varieties with vitreous luster and light colors are called sapphire, the duller, more smoky colors still of vitreous luster, corundum, and the variety mixed with more or less magnetite, hematite, spinel, etc. and appearing like a powdered iron ore is called emery. These varieties are the common abrading agents when great hardness is required.

Corundum or emery is found in the United States at Chester, Mass., near Peekskill, N.Y., and in North Carolina and Georgia. At Chester it occurs as a bed or vein in gneiss near its contact with mica schist and is quite persistent for a considerable distance. Much talc especially in the pinched portions of the vein, and the usual minerals, margarite, corundophilite, diaspore, etc., are found associated with it. It was discovered about 1863, in propesting for iron ore,and led to the establishment of an industry which later spread to other portions of the country. The exact geological relations, as to whether it is a contact development along an igneous intrusion, need further elucidation. Near Peekskill, N. Y. small deposits of impure emery have been mined on a small scale. The material consists of hercynite, a green spinel, magnetite, garnet and corundum, and occurs along the contacts of the intrusive rocks of the Cortlandt series and the neighboring schists. Operations have recently ceased.

Beautiful crystals of red corundum have been obtained in Sussex Co. N. J. in the limestone belt containing the zinc ores at Franklin Furnace and Ogdensburg, but never in commercial amounts. In Chester Co. Pa., corundum was first discovered in this country, (1845). Large masses were found on the surface, but mining did not develop important quantities. The corundum is known over a stretch of five miles, and is said by T. D. Rand, to occur as loose crystals in a granite or syenitic rock. Corundum has also been met in Delaware and Virginia, but North Carolina and Georgia are the only states of economic importance. North Carolina is the chief producer and the mines are located in Macon and Jackson Cos. The mineral occurs in a variety of rocks, said by E. W. Parker to embrace gneiss, talc, chlorite and mica schists, massive anthophyllite, olivine and serpentinized rocks. It appears that some form of fresh or serpentinized peridotite or pyroxene is chiefly associated and the same is true of Georgia. The mines are found in both states along a crystalline belt, characterized by these intrusions. Large masses, sometimes several hundred pounds in weight and small crystals occur, mostly enclosed in hydrated micaceous minerals. Some of these micaceous minerals are eminently characteristic of emery or corundum mines in all parts of the world. In Georgia according to F. P. King, all the corundum deposits are in basic magnesian rocks, either peridotite or its close relatives. They form igneous intrusions in gneiss and schist. Hornblende-gnèiss always

forms one wall of the intrusion, and near this, in the peridotite the veins of corundum are invariably found. The associates are limesoda feldspar, quartz, hydrated micaceous minerals and hornblende, and octinolite in variable proportions. The chief counties are Rabun, Towns, Habersham and Union, but Rabun is as yet the only serious producer. Corundum has also been reported in Alabama, California and Colorado. Some prospecting has been attempted in the last named. Rather vigorous gravel washings have been in operation in the last ten years near Helena, Mont., where corundum pebbles of a good enough grade to furnish gems have been obtained. Some thousands of tons ofemery are annually imported, mostly from Asia Minor where it is found in crystalline limestone near contacts with mica schist.

The origin of the corundum in North Carolina and Georgia has been discussed by Julien and Chatard and that of other deposits of emery in the classic papers of Dr. J. Lawrence Smith. It appears that the chloritic minerals crystallized at the same time with the corundum, and that in the southern states ferro-magnesian solutions from the peridotites probably reacted on aluminous ones from the gneiss, and that heated alkaline waters as indicated by neighboring pegmatite veins in North Carolina may have had their influence. Alumina in some way crystallized out by itself. Caution is necessary in order to distinguish contemporaneous crystallizations associated with the corundum from alteration products from it. The late Dr. Geuth has described a considerable and very interesting series of the latter.

General Papers.	T.M.Chatard.	On Corundum. M.R. 1883-84. 714. See also under North Carolina below.
	F.A.Geuth.	See below under North Carolina.
	T.S.Hunt.	On Dr. Geuth's Researcher on Corundum and its associated Minerals. Bos.Soc.Nat.Hist. Vol.16 p.332. 1874.
	T.D.Paret.	Emery and Other Abrasives. Jour.Franklin Inst. CXXXVII. 353. 421. 1894. cited by King as below under Georgia.
	W.O.Rooper.	On the manufacture of Emery Wheels and Emery wheel Machinery. Iron Oct.24th, 1884.
	J.L.Smith.	On the Geology of Emery and Corundum. A.A.A.S. VI. 274. Essay in separate volume entitled "Original Researches" p.1. 1884. See also A.J.S.1850.354. Annales des Mines 1850 259. Vol.XVIII.
Asia Minor.	Jagnaux.	Analyses of Emery. Zeit.X. tab.X. 637.
	J.L.Smith.	Emery Formations of Asia Minor.A.J.S.VII. ii. 283. List of Minerals with A.J.S. ii.IX.289. Memoir on Emery Pt.I. Geol.& Min.of Emery from obs. made in Asia Minor A.J.S.ii.XI.53. ii. X. 354.
	W.E.Stevens.	Emery Mines of Asia Minor. E.& M.Jour.June 5 1886 p.410. M.R. 1885.429 from Consular Reports of approximately this date.
Colorado.	W.B.Smith.	Noted in Mineralogical Notes. 2. Proc.Colo. Sci.Soc. II. p.164. near Calumet,Colorado.
Georgia.	F.P.King.	Corundum Deposits of Ga. Bull.2. Geol.Survey Ga. 1894. Bibliography 116. Rec.

Massachusetts.	J.H.Adams.	Corundum at Pelham Mass. etc. A.J.S.ii.XLIX. 272.
	C.T.Jackson.	On the Discovery of Emery at Chester, Mass. A.J.S. ii. XXXIX. 87. Chem.Anals.of Minerals Associated with Emery of Chester Mass. Bost. Soc.Nat.His.Vol.10.p.321.1864-66 A.J S. ii. XLII. 107. Discovery of Emery in Chester Mass. Proc.Bos.Soc. N.H. Vol.10.p.84.1864-66.
	C.W.Shepard.	Corundum Associates at Chester Mass. A.J.S. ii. XL. 110 & 123.
	J.L.Smith.	On the Emery Mine of Chester Hampden Co.Mass. with remarks on the nature of Emery and its associate mineral. A.J.S. II. 42. 83.
New York.	J.P.Kimball.	On Aluminous Magnetic Iron Ore and its uses in iron metallurgy. Mar. 1874. Amer. Chemist
	G.H.Williams.	Norites of the Cortlandt Series on the Hudson Riv. near Peekskill N.Y. A.J.S.ii.XXXIII.191. 1887.
North Carolina.	T.M.Chatard.	The Gneiss Dunyte contacts of Corundum Hill N.C. in relation to the Corundum. U.S.G.S. Bull.No.42 p.45-63 Bibliography p.45. E. & M. Jour. July 21. 1888. 46. North Carolina Corundum. Min.Res.1883-84 p. 714. Rec.
	J.P.Cooke.	Corundum Regions of N.C.& Ga. A.J.S.iii.IX.48
	F.A.Geuth.	Corundum its Alterations and Asso. Minerals Proc. Am. Phil. Soc. Sept.19.1873 July 1874 & Aug.1882. A.J.S.iii. VI. 461. XXXIX. 47.
	"	& W.C.Kerr. Minerals of N.C. Raleigh 1885.28.
	C.W.Jencks.	Corundum and its Gems. E. & M. Jour.Nov.2.'78 p.311. Rec. See also A.J.S.iii. III. 301. Q.J.G.S. XXX. 303.
	A.A.Julien.	Dunyte Beds of N.C. Bos.Soc.N.H. XXII.141.'82
	W.C.Kerr.	Geol. N.C. 1875 Vol.I. Supplement 64.
	R.W.Raymond.	Corundum Mine Macon Co.N.C. M.E.7. 83.
	C.W.Shepard Sr.	On the Corundum Region of N.C. & Ga. with desc.&c. A.J.S. iii. IV. 109. 175.
	C.D.Smith.	Geol.of N.C. Vol.I. Appen.D.1875.Vol.II.42'81
	J.L.Smith.	Notes on the Corundum of N.C. Ga. & Mont. with a description of the Gem Variety of the Corundum from these localities. A.J.S.iii.VI. 180. Rec. See also several papers in second series A.J.S. as per index.
	J.C.Trautwine.	Corundum with Diaspore, Culsagee Mine. Jour. Franklin Inst. XCIV . 7. as cited by F.P.King
	J.Willcox.	Corundum in N.C. Proc.Phila.Acad.Nat.Sci. 1878. 225. cited by F.P.King.
Pennsylvania.	T.S.Seal.	Corundum in Chester County Penna. A.J.S. ii. XI. 267.
	B.Silliman.	Corundum at Unionville Penna. A.J.S. ii. VIII. 384.

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CARBORUNDUM the artificial compound of carbon and silicon, CSi, has attained considerable prominence as an abrasive which is still harder than corundum, and nearly as hard as the diamond. It has been recently discovered by E.G.Acheson, and is produced by passing a powerful electric current through a mixture of sand, powdered coke and salt.

E.G.Acheson. Carborundum- its History, Manufacture and Uses. Journal Franklin Institute, September 1893.

J.A.Matthews. Carborundum- its History, Physical Properties and Chemistry, S. of M. Quarterly, XVI. 73. Nov. 1894.

High carbon steel is also crushed and sold under the name of steel emery. It is a very serviceable abrasive, being tough as well as hard.

GARNET has in recent years been mined in considerable quantity in that portion of New York State lying west of Ticonderoga. It occurs in laminated pockets associated with hornblende and feldspar and in the southern Adirondacks. The variety mined is nearly 8 in hardness. Its cleavage planes and cracks afford very sharp angular grains, much superior to quartz for sandpaper and polishing powders for wood and leather.

F.C.Hooper. Garnet as an Abrasive. S.of M.Quarterly Jan.1895.XVI.124.

QUARTZ. is more largely produced for glass and pottery works than as an abrasive. It is afforded by veins either of the pure mineral or of pegmatite or coarse granitic mixtures. It has been quarried at Bedford, N.Y. and Mystic, Conn. Natural sands are too common for extended mention and will be again referred to under glass materials.

The SOLID ABRASIVES are buhrstones, grindstones and whetstones.

Buhrstones or millstones require a tough, hard, rough rock that will not wear smooth. A cellular structure is best adapted because the continual opening of new cavities keeps the surface rough. Granular yet firm sandstones have been used and the familiar term Millstone Grit for the Great Conglomerate of the Coal Measures suggests at once this employment. The Oneida Conglomerate is used also along Esopus Creek, N.Y. and is a well known stone. Another from Pennsylvania is called Cocalico, while still a third from North Carolina is the "North Carolina Grit". A weathered Silurian chert from Tennessee has been employed and also an Ohio stone from the Carboniferous. The cellular chert with fossils from the Tertiary of the Paris Basin is the typical buhrstone. It consists of a deposit of chalcedonic silica which has replaced fossiliferous limestone and whose cavities are due to the original presence of organic remains. A cellular basaltic lava from near Cologne on the Rhine is also employed, and even garnetiferous mica schist has been used in Norway. The grooving of millstones is a neat operation in stone cutting and requires great care, but stones are rapidly giving away before the new roller processes for grinding grain.

F.L.Nason. Millstones in Ulster County New York. Report of State Geologist New York, 1893. I. 393.

J.H.Safford. Judges Reports and Awards Group I. Centennial Exposition p. 176.

GRINDSTONES are manufactured from rather soft, gritty sandstones. The necessary qualities are the following. The stone should wear away with sufficient rapidity to preserve the roughness or "tooth" and should thus not glaze, and at the same time should not be so soft as to go too rapidly. The principal localities for the production of grindstones are in the neighborhood of Cleveland, and elsewhere in Ohio, and Grindstone

City, Huron Co. Mich. In the former, certain layers in the sandstone quarries mentioned on pp. 120. 121. are specially adapted to this purpose Independence, Berea, Amherst and Peninsula all supply suitable material from the Berea Grit of the Lower Carboniferous. Further south at Massillon, Marietta and Constitution, ledges in the Coal Measures proper are utilized. In Michigan the sandstone is obtained in the Marshall Group of the Lower Carbomiferous. Smaller amounts are taken out in South Dakota and California and in New Brunswick and Nova Scotia there are also quarries.

Michigan.	C.Rominger.	Geol. of Michigan III. 71.
	C.Wright & A.C.Lane.	Geol. of Michigan V. Part 2. 18.
Ohio.	E.Orton.	Geol. of Ohio V. 582.583.586.588.592.607.

The Mineral Resources have annual reviews. The reports of E.D.Ingall in the Geological Survey of Canada give statistics of Canada.

WHETSTONES when applied to rough use are made from sharp gritty sandstone, or from such a rock as mica schist that is set with crystals of some hard gritty mineral like quartz, garnet or rutile. Such schists are obtained in large quantity in the northern counties of New Hampshire (Grafton and Coos) at the towns of Piermont, Lisbon and Littleton. The stone is best known by the name Indian Pond. The stone is an argillitic mica schist containing minute garnets and rutile. (See Geology of N. H. Vol.III. Pt.4. p.222). Other quarries have been opened in Vermont, and to a less degree in Massachusetts. Up to 1893 the output was controlled by the Pike Manufacturing Company, but at present some independent concerns are also working, old contracts having expired. Scythe-stones are the chief grade made. Near Cortlandt, N. Y. on the shores of Labrador Lake, a fine grained, green argillaceous sandstone is quarried for whetstones and is known as Labrador stone. At Berea, Ohio , and Grindstone City, Michigan, scythe-stones of sandstone are manufactured. In Orange County Indiana, the Hindoostan stone is obtained and is a very fine grained sandstone. Near Pierce City, Missouri, a fine yellow sandstone, called Adamscobite grit is manufactured to some extent.

Fine whetstones are practically all obtained in Arkansas, and are made from the extremely close-grained siliceous rock known as novaculite. It appears to be a hardened siliceous ooze, throughout which are rhombohedral cavities left by the removal of minute calcite crystals. These occasion the grit. A variety with coarser cavities is called Onachita (or Washita), and a finer variety is called Arkansas. The individual grains are 0.01 min. and less in diameter, while the cavities reach about 8 times these dimensions. The novaculites form a series of beds or a great stratum about 500 feet thick, of geologic position in the Trenton. They extend as an east and west belt in western central Arkansas, and are largely quarried near Hot Springs. The stone is so broken with joints, shaly streaks, quartz veins and cavities that much waste is made in getting good materials. It is all shipped out of the state to be manufactured.

The authoritative American work on whetstones of all sorts is L. S. Griswold's Report on Whetstones and Novaculites, Ann.Rep.ark.Geol.Survey Vol.III. 1892. Both foreign and domestic stones are treated and copious citations of literature are afforded. Statistical papers appear year by year in the Mineral Resources. See also J.J.Sutton, "Washita and Arkansas Oilstones and Quarries" E. & M. Journal October 12th, 1889.

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ASBESTOS. Asbestos, in strict mineralogical definition is an anhydrous silicate, a variety of amphibole but the asbestos of commerce is chrysotile, a hydrated silicate of magnesia and small amounts of iron oxide, and a variety of serpentine. It always occurs in serpentine and forms veins in which the fibers lie transverse to the walls, f.

Asbestos of inferior quality is found in a number of localities in the United States, but these have never become important producers. Pelham, Mass., Staten Island, N.Y., various places in the southern states and in Colorado, Wyoming and California have at one time and another received attention. The American mineral is only adapted to grinding up for paints felts and cements. The chief source of the fibrous asbestos suitable for weaving, was formerly Italy, but since 1879 the Canadian Mines near Thetford and Black Lake, Province of Quebec, just north of Vermont have become heavy producers. The mineral occurs in veins in serpentine, with the fibers perpendicular to the walls. Four grades are made; No.1 has fibers one inch long and upward, No.2 has fibers under one inch but still good for weaving, No.3 has bits of gangue, etc., mixed with short fibers; and No.4 is the waste material good only for grinding. The American market is principally supplied with the Canadian asbestos. The price of asbestos has fallen off greatly in the last few years and curtailed operations in Canada materially.

History &c. E. & M. Jour. Nov. 5 1877 p. 328.
Zeitsch d. Vereines deutsch Ingenieuren-XXXVII 1893.1117-8

J.H.Adams Asbestos at Pelham Mass. A.J.S. ii. XLIX 271.

J.F.Donald. Notes on Asbestos and some asso. Minerals. Can.Rec.Sci.IV. 100.

R.W.Ells. Asbestos, Its History, Mose of Occurence and Uses. Ottawa Naturalists Club-Vol.IV. pp.201-225. Mar. 1891.
Asbestos in Quebec -Can. Report 1888-89 Vol.IV. p.139.

Jones. Asbestos, Its Properties and Occurrences , London. 1890.

L.A.Klein. The Canadian Asbestos Industry. The Canadian Mining and Mechanical Review July 1892. p.122. Rec. The best industrial sketch.

FLUORITE OR FLUOR SPAR. Fluor-spar (CaF_2) is a common vein-stone in ore deposits although not often utilized. It was an old time flux in led metallurgy and in this way received its name. Its principal use today is as a source of hydrofluoric acid which is a very valuable chemical reagent and is prepared in this country practically chemically pure. The one important source of the mineral is a district in Hardin Co., southeastern Illinois along the Ohio River. Galena veins occur in the neighboring part of Kentucky, but in Illinois the principal filling is fluorite with very subordinate galena and blende. The veins are in the St. Louis limestone near the top of the Lower Carboniferous. The chief vein worked is of large size and very persistent. It contains fluorite in thickness from 2'-12' with a clay selvage and at times a band of calcite next the wall. Comparatively few disseminations of galena and less blende and chalcopyrite are in the vein filling. The fluor is white or slightly iron stained and is mined, crushed jigged and ground. The mines are sometimes spoken of as near Shawneetown but this is some miles up the Ohio River. The nearest town is Rosiclaire.

G.J.Brush. Note on Illinois Fluorite. A.J.S.,ii.XIV.112.

S.F.Emmons. Fluor-spar Deposits of Southern Illinois. M.E. Feb.1892. XXI. 31. Complete Historical references are given.

A.H.Worthen. Economical Geology of Illinois. Vol. I. 1882. p.309.
See also Mineral Resources 1889-90 for applications.

GLASS SANDS. The chief raw materials for glass are SiO_2 and one or more metallic oxides. The former is supplied by very pure sands which have no staining impurities, the latter are soda, potash, lime and oxides of lead and zinc. Some other substances are added to correct existing impurities. Pure glass sands are the only ingredients mentioned here, and they are of importance because the various glasses contain from 50-80 per cent SiO_2. Glass sand should be white, angular and not too fine and should be nearly pure silica, with not over one or one and a half % of other materials. In the best grades marketed these are as low as 0.25 % and are little else than Al_2O_3. Iron is the element specially avoided. The color may not always be a sure test for some of the best English sand is slightly yellowish though very free from iron. Sandstones and even quartzites are ground up when available but the outcrop of such hard rock usually supplies mellowed and softer portions. The United States are richly endowed with suitable sands which leave little to be desired. The town of Chesire, near North Adams, in Berkshire County Massachusetts, between Pittsfield and North Adams furnishes a very high grade (SiO_2 99.78; Al_2O_3 0.22) from Siluro-Cambrian (Taconic) quartzite. Juniata County, Pa. has other deposits (SiO_2 98.84) in the Oriskany sandstone, that are extensively worked. Fayette County, further west, yields an excellent product (SiO_2 99.72) and Morgan County, W. Va. in the neighborhood of the Cumberland coal field, ships great quantities to Pittsburg. Ohio has some workable beds in the Coal Measures at Massillon. In Illinois the St. Peters sandstone southwest of Chicago supplies a very pure material that goes by the name of Fox River sand. South of St. Louis along the line of the Iron Mountain R. R. the taxonomic equivalent of the St.Peters sandstone, called the Saccharoidal Sandstone yields a famous glass sand at Crystal City (SiO_2 99.62). The Geological Survey of Arkansas has recently located other deposits in that state of which no developments have been made as yet, but which are of great promise.

The clay for glass pots deserves a word. In former years it came from abroad in large part, but the Americam sources are gradually supplying the demand. The Cheltenham clay near St. Louis, (p.126) is much prized and is brought to eastern glass works. The demands on glass pots are severe and only the best clays are equal to them. It is worthy of remark that instead of sands foreign glass makers have used felsites or other igneous rocks that lack iron but are high in alkalies with advantage. The economy lies in saving soda or potash.

Mineral Resources, Especially 1885. p.544
S.G.Williams. Applied Geology.

LITHOGRAPHIC LIMESTONE. Much attention has been given to the discovery of American sources of this valuable material. A limestone is required of very even and homogeneous texture, with no quartz, pyrite, specks, veinlets or imperfections. The Bavarian quarries at Solenhofen (Upper Jurassic) now produce but little of the best grade and their output of this is all absorbed abroad. Clay and Overton Counties Tennessee, have furnished a little and new enterprises are being pushed in Wyoming and Utah. There have also been some discoveries in Lawrence Co., southwestern Indiana; in Talladega Co., Ala.; 40 miles east of Prescott, in Yavapai Co., Arizona; in Searcy Co., Arkansas; near Thebes, Illinois; Jones and Van Buren Co's., Iowa; Hardin, Estell, Kenton, Clinton, Rowan

and Wayne Co's., Kentucky; near Saverton, Ralls Co., Missouri; Burnet Co. Texas; and Fincastle, Virginia. In Petersborough and Bruce Co's., Ontario, there are also openings. These localities are quoted from G.P.Merrill's paper cited below. Although so numerous very few have as yet supplied any serious amount. The Arizona seems good but its location is inaccessible. The Arkansas stone cost more to quarry than it was worth. Of the other American quarries only those in Tennessee appear to be of notable importance. Despite the interest in the subject the Eleventh Census reported but about 108 tons of value $1943. as the product of ten years 1880-1889. In Canada the industry appears to be more serious. Statistics for 1894 report $30,000 worth produced. From 70,000-100,000 dollars worth are annually imported into the United States. Of late years no local statistics have been gathered.

T.C.Hopkins. Lithographic limestone in Arkansas. Ann.Rep.Ark.Geol.Sur. 1890. IV. 76 and elsewhere as per index.

G.P.Merrill. In Mineral Industry. 1893. 453. Rec. See also Stone. III. 101. Published in Indianapolis.

Mineral Resources 1886. 690. Also other numbers.

E.W.Parker. Eleventh Census. Mineral Industries. 761.

MICA. This mineral is the basis of one of the minor industries of the country, and one that is of somewhat increasing importance in connection with electrical demands for insulators. Stove doors and similar applications that require a transparent substance, which is not effected by high temperatures; lubricants; wall papers, and a number of other adaptations take additional amounts. Both muscovite and phlogopite are employed, but chiefly the former. Biotite has little commercial value. Sheets of light color and devoid of imperfections and cross cleavages are the ones desired, and to obtain such of good size, a vast amount of waste is made. In addition to the remarkable cleavage that gives the mineral its value, mica has others that cut across the plates and cause the sheets to break. Muscovite occurs in great, coarsely crystalline veins or dikes of the same minerals that are characteristic of granite, viz., feldspar. and quartz. In addition they frequently have beryl, tourmaline, garnet, and some others which contain the rare earth. The mica is more or less irregular and pockety in its distribution. "Electrical" mica is now chiefly obtained in Canada and is an amber colored phlogopite. J.T.Donald states that it must be of very even thickness and that a piece .01 inch thick ought to bend to a cylinder of 3 inches diameter without cracking. The workings are in much the same district as those for apatite, viz., Perth and Renfrew Co's., Ontario, and Ottawa Co., Quebec. Phlogopite is quite invariably associated with limestone or pyroxenite.

In the United States, muscovite is obtained in Grafton Co., N. H. A belt nearly 50 miles long contains the veins, in gneiss, but in 1893, only those at Alexandria and Groton were operated. Earlier openings at Acworth, Sullivan Co. and at other places made this section a famous mineral region espevially for beryl. The industry is a very old one. In 1867 prehistoric mines of the aboriginees were reopened in western North Carolina and a considerable production was attained for about 20 years. The principal towns are Bakersville and Burnsville, but being 40 miles from rail, over rough mountain roads the conditions are hard ones. A little mica has been dug in Alabama, the Black Hills, New Mexico, southern Nevada and Labrador, and of recent years very considerable imports have been brought from India. In mining only about 4-5 % of the rough

mica, or at most 8-10 % is saved as the final product. The price increases greatly for large sizes.

J.F.Donald. Mineral Industry 1893. 473.
L.J.Childs. Eleventh Census Report on Mineral Industries. p.723.
C.H.Henderson. Mica and Mica Mines, Popular Science Monthly Sept.1892. E. & M. Journal January 7th, 1893.
W.C.Kerr. Mica Mines of N.C. M.E.VIII.457. E.& M.J.Mar.20.'81.211
H.B.C.Nitze. Ground Mica Industry in N.C. E.& M.J.Sep.24.'92.p.292.
- - - - - Note on Mica & Asbestos in N.Y. E.& M.J.Nov.24.'88.p.439
E.W.Parker. Mineral Resources 1893.744 See also other volumes of the Mineral Resources.
W.B.Phillips. Mica Mining in N.C. E.& M.Jour.April 21 1888.p.286.also in following: 306,322,382, June 2.,9.,16., 436. see also Mineral Resources 1887 and E.& M. Jour.Sep.26.1885.
N.S.Shaler. Mica Mines of New England. 10th Census, Vol.15. p.833.
W.A.Smith. Mineral Industry 1892. p.539.
- - - - - The Virginias; 1884, p.127. General short description.

MOULDING SAND. This useful variety is of value in several regions and is indispensible for foundries. A sand is required that has enough argillaceous matter mixed with it to make it take the shape of the pattern and hold it without baking or checking under impact and influence of the heated metal. At the same time the mixture must be very intimate, so that each grain of sand is coated. Coarse sands are used for heavy castings, fine for lighter work. The principal locality for moulding sands is in the vicinity of Albany, N.Y. Beds 6 inches to 5 ft. thick lie along the banks of the Hudson, under the surface soil and resting on heavy sands and gravel. According to Nason, to whose paper, these notes are chiefly due, 60,000-80,000 tons are annually shipped. F.L.Nason.Rep.N.Y. State Geologist, 1893. p.274.

PRECIOUS STONES. No industry connected with mining precious stones has proved a very serious one in North America. In South America however the now exhausted diamond fields of Brazil were formerly important and the emerald mines of Colombia are still quite largely operated. A number of minor localities are systematically worked in both continents to which brief reference will be made. A distinction is to be made between the precious stones or gems properly so-called, and mineral specimens which though obtained in notable quantities in not a few places, and sold for considerable sums are yet not treated. Only those that are serious contributors to national resources are here taken up.

- - - - - American Gems and Precious Stones. Am.Nat. 18.63.
- - - - - Gems & Precious Stones-E.& M.J. Nov.19.1887. p.365.
T.T.Bruve. Notes on Gems Garnet Hyacinth Emeralds or Hiddenites Zircons Sapphires etc.) Bos.Soc.Nat.Hist. XXIII. p.3.
A.C.Hamlin. The Gems of the United States. A.A.A.S. 1869.
G.F.Kunz. Gems & Precious Stones of North America. N.Y.1892. Annual Statistical Paper-Mineral Resources since 1882 but especially 1883-84. 1893. Also in 11th Census Mineral Industries-669. Precious stones gems etc.in Canada. Can. Geol.Surv.1887. Report on Mineral Statistics.
I.Lea. Further Notes on Miceos Crystals in some Gems. Phila. Academy Science 1869. 119.
Th.Taber. Practical Remarks on Gems. A. J. S. 38. 61.
H.T.Vulte. Precious Stones. School of Mines Quarterly II. 58.

rial, or at most ... is saved as the final product. The price in-
creases greatly in large sizes.

J.F.Kemp. Mineral Industry 1892, 478.
L.A.Phillips. Eleventh Census Report on Mineral Industries p.789.
J.G.Henderson. Mica and Mica Mines, Popular Science Monthly Sept.1888;
E. M. J. Journal January 7th, 1888.
Mica Mines of N.C. U.S.VIII.467. E.M.J.Mar.30.'01.311
F.L.Kerr. Ground Mica Industry in U.S. E.M.J.Sept.'08.p.509.
H.S.L.Kites. Note on Mica & Asbestos in U.S. E.M.J.Nov.24.'00.p.435
- - - - - Mineral Resources 1890. See also other volumes of the
L.W.Parker. Mineral Resources.
W.B.Phillips. Mica Mining in N.C. E.M.J.April 21 1888.p.286.also
in following: 306,324,348. June 2, p.16., 430. see also
Mineral Resources 1887 and E.M.J. Jan. 28.1888.
W.J.Sinclair. Mica Mines of New England. 10th Census Vol.15. p.835.
T.A.Smith. Mineral Industry 1892. p.335.
- - - - - The Virginias, 1884. p.187. General short description.

MOULDING SAND. This special variety is of value in several re-
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places, and sold for considerable sums are yet not treated. Only those
that are serious contributors to national resources are here taken up.
- - - - - American Gems and Precious Stones. Am.Nat. 18.23.
- - - - - Gems & Precious Stones. E.M.J. Nov.19.1887 p.380.
T.H.Brown. Notes on Gems Garnet Hypothesis. Emeralds of Middleville.
Lithium - Hiddenite etc.| Mem.Soc.Nat.Hist. XXIII. P.2.
A.C.Hamlin. The Gems of the United States. A.A.A.S. 1869.
G.F.Kunz. Gems & Precious Stones of North America. N.Y.1890.
Annual Statistical Paper Mineral Resources since 1882 but
especially 1883-84. 1887. Also in 11th Census Mineral
Industries 585. Precious stones gems etc.in Canada. Can.
Geol.Surv. 1887. Report on Mineral Statistics.
I.Lea. Further Notes on Inclusions Crystals in some Gems. Philad.
Academy Proceed. 1876. 112.
... Pressure. Practical Remarks on Gems. A.I.M.E. XX. 83.
W.E.Hidden. Precious gem crystals. School of Mines Quarterly. 11. 80.
(1890)

BERYL, EMERALD & HIDDENITE. A few clear beryls, or aquamarines are produced in North Carolina of sufficient excellence to warrant cutting. A most interesting and as it proved valuable find of a green lithia spodumene later called Hiddenite, was made by Mr.W.E.Hidden in 1880 at Stony Point, Alexander Co., N.C., where it was associated with emeralds. The crystals yielded a beautiful clear green gem, which has been much prized. Operations have fallen off in late years.

- - - - - Mining for Gems at Stony Point Alexander Co., N. C.
E. & M. Journal December 10th, p.391.

W.E.Hidden. On Emeralds, Hiddenite etc., in N.C. Trans.N.Y.Acad.Sci.
Jan.& Mar.1882. Vol.I. M.R.1882.500. A.J.S.iii.XXI. p.128.

G.F.Kunz. Emeralds from North Carolina, A. J. S. Feb. 1884, p.154.

DIAMONDS. The occurrence of diamonds as rare and interesting minerals has been noted in not a few places in the United States, but as yet they are of no commercial importance. Mr. Kunz in the statistical papers cited above, gives full reviews. In Brazil, though no longer flourishing, the industry is an old one.

Brazilian Diamonds and Carbons. E. & M. Jour. March 11.1882 p.132.

Diamond Mining in Prov. of Minas Geraes, Brazil. E.& M.J.Oct.6 '83 p.216

O.A.Derby. Geology of the Diamond, A.J.S. III. 23. 97. Geol.of the Diamantiferous Region of the Prov. of Parana, Brazil. Amer. Phil. Soc. May 16th, 1879. 251.

OPAL.has been discovered in notable quantities in andesitic or basaltic dikes near the Snake River, Idaho, in Owyhee Co. The quality is considered excellent. Other finds have been made near Moscow in the same state and companies have been organized in each instance. Opals are obtained in quantity in the state of Queretaro Mexico.

The Opal Mines of Queretaro, Mexico. E.& M.J. Sept.6.1886. p.170.

J.D.Dana.Precious Opal from near San Juan del Rio, Quaretaro, Mex.
A. J. S. III. 6. 466.

SAPPHIRE. Despite the abundant corundum of North Carolina and Georgia, almost none of gem excellence has been met. Waterworn crystals have been known for years however in the gravels of the Missouri River, near Helena, Montana, and of late they have been systematically washed, for gems. The gems prove of light colors, but of otherwise excellent qualities.

TOURMALINE has been mined for gems at Paris, Maine.

TURQUOISE is now the basis of our chief gem industry. It is obtained near Los Cerillos, and elsewhere in New Mexico. The mineral coat cracks in a decomposed volcanic rock, and yields a product whose value has reached $100,000. as the maximum for a year.

W.E.Hidden. Turquoise in New Mexico. A. J. S. Nov. 1893. 400.

On American gems in general, the papers and large work of Mr. Kunz will furnish all needed information.

SOAPSTONE AND TALC. Soapstone is a variety of serpentinous rock which is chiefly made up of fibrous or scaly crystals of talc. It has considerable utility as a material for wash-tubs, footwarmers, etc., as well as for slate pencils and for granding to powder. In the quarries the drawbacks are, the lack of homogeneity in the rock, especially as ocasioned by seams of quartz, bunches of pyrites, of hornblende, pyroxene, etc., which are harder than the stone itself and interfere with the preparation both by sawing and grinding. Soapstone is frequently met in the metamorphic belt of the Appalachians. The heaviest producer

is Pennsylvania from its southeastern portion, especially in the serpentine belt. New Hampshire follows second with a wide distribution especially in Hillsborough Co. New Jersey and Virginia are next and Vermont, Maryland and North Carolina also have small industries. Soapstones are in almost all cases, altered forms of amphiboles or pyroxenes, and probably in many instances were originally some form of basic igneous which has passed through an amphibolite stage.

Mineral Resources Annual Volumes, especially 1882-1893.
G.P.Merrill. Stones for Building and Decoration. p.45. Rec.

TALC, of great purity and in fairly sharp contrast to the usual serpentine, is the basis of an important industry in St. Lawrence Co., N. Y. in the neighborhood of Gouverneur, which is the central point. It forms beds of considerable size in crystalline limestone or marble belonging to the Oswegatchie series of the Archaean, as named by C. H. Smyth, Jr. The belt of marble is about eight miles long by a mile wide and extends through the towns of Edwards and Fowler. The talc is an alteration product of tremolite, and often contains considerable of this mineral. The ground product is chiefly used for weighting paper pulp in the manufacture of paper, for which purpose its fibrous charactter eminently fits it. It gives the paper also certain excellences so that it is not altogether an adulterant. Smaller amounts are used in hard forms of plaster for walls, and for various minor purposes.

A.Sahlin. The talc industry of the Gouverneur District, N. Y.
M. E. Oct. 1892. Mineral Industry, 1892. 435.
C.H.Smyth,Jr.Annual Report New York State Geologist, 1893. 511. Rec.
C.A.Waldo. Mineral Industry 1893. 603.
Annual Statistical Papers in the Mineral Resources.
See also E. & M. Journal May 25. 1889. 475.

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S U L P H U R.

SULPHUR as such is almost invariably obtained from deposits of the native mineral. The only other source is in the accumulated alkali waste of the soda manufactories, which is treated by the Chance process in England and on the continent.

Native sulphur resembles the artificial product in all respects. It is yellow, with an occasional brownish cast from contained bituminous matter. The presence of selenium also darkens the color. The hardness is 1.5 to 2.5; sp.gr. 2.07; the crystals are rather acute octahedra of the orthorhombric system, and are often extremely rich in faces. The common mineral is, however, massive, and the crystals only appear in cavities. The native mineral kindles readily in a flame, yielding the characteristic suffocating odors.

The geology of sulphur may be summed up under two rather simple types.

1. THE SOLFATARA TYPE--This is deposited directly from sulphurous gases, especially sulphuretted hydrogen (H_2S) and sulphur dioxide (SO_2) These two react on each other, most quickly in the presence of moisture, to produce water (H_2O) and sulphur (S). As is well known, H_2S is a powerful reducing agent. These gases enamate in regions of expiring or active volcanoes and form solfataras. The sulphur collects in cracks in the lava and in the tuffs, or in the kaolin and clay yielded by the corroding action of the acid fumes on the lavas. Gypsum, native alums,etc.,

is found [illegible] from its southeastern portion, especially in the serpentine belt. New Hampshire follows second with a wide distribution especially in Hillsborough Co. New Jersey and Virginia are next and Vermont, Maryland and North Carolina also have small industries. Soapstones are in almost all cases, altered forms of amphiboles or pyroxenes, and probably in many instances were originally some form of basic igneous which has passed thru to an amphibolite stage.

Mineral Resources Annual Volumes, especially [illegible].

Merrill: Stones for Building and Decoration. p.40. [illegible]

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Smyth: The talc industry of the Gouverneur District, N. Y.

[illegible] N. Y. Geol. [illegible] Mineral Industry. 1898. 688.

C.H.Smyth,Jr. Annual Report New York State Geologist. 1893. Vol. 1. 660.

[illegible] Mineral Industry 1898. [illegible]

Annual Statistical Report of the Mineral Resources.

[illegible] New York St. Mus. Bulletin 92, 1905. 470.

S U L P H U R

SULPHUR as used is almost invariably obtained from deposits of the native element. The only other source is in the accumulated slimes [illegible] of the soda manufacturers, which is treated by the Chance process in England and on the continent.

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The geology of sulphur may be summed up under two rather simple types.

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are frequent associates. Some vents, as Vesuvius, yield in much the same way deposits of ferric chloride, whose yellow color at first suggests sulphur and deceives the hasty observer. Occasionally some arsenic is found with this volcanic sulphur, in the associated minerals orpiment (As_2S_3) and realgar (AsS). Such was the case on the island of Vulcano, one of the Lipari group, off the coast of Italy, where for a time these minerals were gathered. The same association also occurs in the Yellowstone Park. Small traces of selenium and tellurium have been detected in an orange-yellow Japanese variety.

So far as can be learned, Japan and southern Utah are the only deposits of this character that are now of much actual importance.

II. THE GYPSUM TYPE--The second type results from the alteration of gypsum through the reducing action of bituminous matter, and hence always occurs in a series of sedimentary rocks, with marls, shales, and limestones prominently developed. The general reactions involved are apparent from the following: Gypsum is $CaSO_4$ $2H_2O$. The reducing action of bituminous matter destroys the sulphate and yields calcium sulphide, carbonic acid, water, and the like. The further changes may take place elsewhere in case the calcium sulphide wanders away in solution. The oxygen of the air, carbonic acid, and water react on this (according to Bischoff, at as low a temperature as 35° C.) so as to produce calcium carbonate, sulphuretted hydrogen, and a polysulphide of calcium. The polysulphide in its turn yields carbonate of calcium, native sulphur, and sulphuretted hydrogen. The original gypsum has, as a general thing, been deposited in the evaporation of isolated bodies of salt water, and it often has great beds of rock salt, as in Sicily, associated. It is a remarkable fact that such deposits of sulphur-bearing strata are very widespread in Europe and of uniform Tertiary (mostly Miocene) age. They are known in France, Spain, Sicily, northeastern Italy, Poland and Greece. In the Caucasus they are Jurassic. The beds in southwestern Louisiana are in the Quaternary belt. The reports from western Texas are as yet too meager to warrant an inference as to geological age.

As of mineralogical interest it should be also noted that sulphur results from the alteration of pyrites, marcasite, and related sulphides, although it is doubtless true that here, as in the last case, the presence of bituminous or organic matter is necessary. Masses of pyrite in limestone, as in the Calsiferous strata on Lake Champlain, may yield crusts of sulphur an inch or so thick, and the decay of the same in coal seams, frequently affords, flaky coats. Gypsum is a common companion in both cases. In the oxidized zone or iron hat of veins of sulphurets, crystals of sulphur are found, often very prolific in faces.

MEXICO. For many years (it is said even from the time of the invasion of Cortez) sulphur has been known to exist in the crater of Popocatepetl. This volcano, whose crater is still supplied with the sulphur-depositing solfataras, is one of the three or four highest peaks on the North American continent, reaching 17780 feet above tide and 10500 feet above the City of Mexico. The sulphur is obtained on the floor of the crater, some hundreds of feet below the summit, and is there deposited as a fine powder by burning jets of H_2S. It is scraped up by the men of a tribe of Indians who, accustomed from childhood to climbing the mountain, are able to stand the fatigue. When placed in bags the Indian packs it to the upper snow line, and then arranging himself and the bags on a mat, he slides swiftly to the lower edge of the snow, and thence

carries it to the retorts, where it is purified and sent to the City of Mexico. Obviously this source is not likely to yield large amounts.
M.Rahden: "Popocatepetl" , New York Evening Post, Nov.5th, 1892.

UNITED STATES. Although the United States forms the principal customer for the Sicilian product, its home sources are not as yet much developed. None the less the reports show that enormous bodies exist in Louisiana and in Texas, as yet undeveloped, and very rich deposits are opened in southern Utah, but too remote for the Eastern market. The Pacific Coast also imports from Japan.

ALASKA. For many years past it has been known that the volcanic islands off the coast of Alaska contains sulphur. Mr. Dall, in 1870, mentioned this mineral as being, next to coal and copper, the chief resource of the country. The largest deposit, so far as known, is on Kadiak Island, but others are recorded on Akutan, on an island southeast of Aklum, etc. They are all of the solfatara type, and are yet to be worked.
W.H.Dall Alaska and Its Resources, p.478, Boston. 1870.

CALIFORNIA. Twenty years ago sulphur was obtained at Sulphur Bank, on Clear Lake, some forty miles north of San Francisco. It occured in the white siliceous residue of a basalt flow, that had been decomposed by the uprising solfatara which deposited the sulphur. As development went deeper, however, the sulphur mine changed into a cinnaber mine, and as such had a brief career. Sulphur deposits were also for a time worked in Colusa County and a small refinery was erected. Sulphur also occurs in the San Joaquin Valley, Kern Co., cementing gravels, etc.
W.A.Goodyear. Rep.Cal.State Mineralogist, 1890. "Lake Co.,238; Colusa159
J.Leconte. "On Sulphur Bank" Amer.Jour.Sci., July,1882,23.
J.A.Phillips. "On Sulphur Bank" Philosoph.Mag., 1871, 401.

IDAHO. Sulphur has been reported near Swan Lake, and also four miles from Soda Springs, Oneida Co.

LOUISIANA. Probably the richest and geographically the most accessible of the American localities is in southwestern Louisiana, 230 miles west of New Orleans and 12 miles from Lake Charles. The first hole which revealed this sulphur was sunk in search of petroleum, of which the presence of oil and tarry matter on the surface were regarded, quite justly, as an indication. While more or less of these bituminous substances were revealed by the drill, the great bed of sulphur is the main object of interest. A number of holes have since been put down with the results recorded below, and they leave no doubt that there is a very large body which awaits exploitation. The first explorations were made by the Louisiana Petroleum and Coal Oil Co. It was succeeded by the Calcasieu Sulphur and Mining Co. The Louisiana Sulphur Mining Co., followed, and now the owners are the American Sulphur Co. The following i the record of the first well: Clay, quicksand and gravel-335 ft., Soft Rock-110, Sulphur bed(70-80 % sulphur)-108 ft., Gypsum and Sulphur-680, Total 1231 feet.

The difficulties in development lie in the quick sands and gravel, which are wet and soft, and in the soft rock which yields sulphurous waters under a head at the surface of about 15 ft. The sulphur beds themselves are, however, tight. A shaft on the Kind-Chaudron system was proposed some years ago, but has not yet been sunk. Beyond all question this is an exceptionally rich deposit, and it ought to have a future. As the sections show, it belongs to the gypsum type, and has plainly been formed by the alteration of the gypsum under the influence of the neigh-

boring bituminous matter. The geological horizon is the Quaternary.
A.Granet: Engineer's Report to the Louisiana Sulphur Company.
Preussner: Zeitschrift der deutsch. Geol. Gesellsch., 1888, XL., 194.

NEVADA. Sulphur has been reported from Humboldt House, and is described by Russell as filling the craters of one or two extinct hot spring along with gypsum,etc. Its quantity is small. The mineral is also mentioned from the Sweetwater Mountains, between Nevada and California, in latitude 38° 30′. The only important locality in Nevada is in the Rabbit Hole mines, on the eastern border of the Black Rock Desert. The sulphur charges a porous, rhyolitic tuff, and lines cavities in it to the depth at times of 5 or 6 feet. The impregnations lie along a great fault line, and are clearly of the solfatara type. The ore was treated with superheated steam and considerable quantities of sulphur were obtained in the past. Of late years the mines have not been worked. Very interesting sulphur crystals have been measured from them by E. S. Dana.

E.S.Dana: "On the crystals from Rabbit Hole Mines", Amer.Jour.Sci., (3), XXXIII.386; Zeit.f.Kryst.,XII.,460.

I.C.Russell.: "Sulphur Deposits of Utah and Nevada" Trans. N. Y. Acad. Sci., 1882.I.168; reprinted in the Eng. & Mining.Journal Jan.20th,1883 p.31. Mr. Russell's valuable monograph on Lake Lahoutan (U.S.Geol.Surv.,Mono.XI.) gives an excellent account of the geology of the region.

TEXAS. Mention of deposits of sulphur has been made by the Texas Geological Survey (Second Annual Report, lxxvi.) from Edwards Co., in the Llano Estacado, but as yet little of a definate character has been written. Northwestern Texas is known,however,to contain very extended deposits, although the definite description of the area has not yet been made public.

The Reports of the Texas Survey make but passing mention of sulphur.

UTAH. The largest producer of any American locality is in Beaver County, southwestern Utah, near the Millard County line. The mines are 26 miles east of Black Rock, a station on the Utah Central Railroad, 204 miles south of Salt Lake City. From Black Rock to the mines a wagon road traverses desert and lava sheets. An old outpost of the Mormons called Cove Creek Fort (also Ranch Fort) stands near the openings, and gives them their name-Cove Creek Mines. The fort is on the eastern limit of a plain, which is bounded on the west by Mineral Range, twelve miles away, and on the east by Sulphur Range, a southern prolongation of the Tushar Mountains, which themselves belong to the larger Wasatch. The region is one of expiring volcanic activity, and the deposits, though presenting some variations, all belong to the solfatara type. The name "cove" originated in the crescentic depression of the Sulphur Range, with the convexity eastward, within which the mines are situated. Between the horns of the cresent, and several miles northwest of the fort, is an extinct basaltic volcano 1000 feet high, with a cinder cone on its top. This is called the Cove Creek crater by Russell, but Mount Dickert by Vom Rath Subaerial gravels form the surface from the cone to the eastern hills, but at their base volcanic tuffs are developed.

Most of the mines are along the junction of the gravels and tufas. It is stated by Russell (from whom this description is chiefly taken) that there are three varieties. The first is the one now worked under the name of Cove Creek mines. It is an extinct solfatara at least 1800 by 1000 feet, and with sulphur rock as much as 30 feet thick. The sultaining bituminous matter. The geological horizon is the Cretaceous. A.Steiger in a report to the Dominion Sulphur Company. Grasselli [illegible] der Erdteil. Zeit. Kristallogr., 1908, XL, 194.

NEVADA. Sulphur has been reported from Humboldt House, and is described by Russell as filling the crevices of one of the ancient hot spring cones with gypsum, etc. The quantity is small. The mineral is also mentioned from the Rabbit Hole locality, between Nevada and California, in latitude 41°, 20'. The only important locality in Nevada is in the Rabbit Hole mines, on the western border of the Black Rock Desert. The sulphur occurs in a porous, rhyolitic tuff, and large portions of it to the depth of three or four or five feet. The deposits lie along a great fault line, and are clearly of the solfataric type. The ore was treated with superheated steam and considerable quantities of sulphur were obtained in the past. Of late years the mines have not been worked. Very interesting sulphur crystals have been measured from them by E. S. Dana.

E.S.Dana: "On the crystals from Rabbit Hole Mines", Amer.Jour.Sci., (3), XXXIII, 1887, [illegible].

I.C.Russell: "Sulphur Deposits of Utah and Nevada" Trans. N. Y. Acad. Sci., 1882, I, 168; reprinted in the Eng. & Mining Journal, Jan. 1883, p. 31. Mr. Russell's valuable monograph on Lake Lahontan (U.S.Geol.Surv.,Monograph XI) gives an excellent account of the geology of the region.

TEXAS. Mention of deposits of sulphur has been made by the Texas Geological Survey (Second Annual Report, 1891.) from El Paso Co., in the Llano Estacado, but as yet little of a definite character has been written. Northwestern Texas is known, however, to contain very extended deposits, although the definite description of the area has not yet been made public.

The Reports of the Texas Survey make but passing mention of sulphur.

UTAH. The largest producer of any American locality is in Beaver County, southwestern Utah, near the Nevada county line. The mines are 20 miles west of Black Rock, a station on the Utah Central Railroad, 200 miles south of Salt Lake City. From there back to the mines a wagon road stretches across and lava deserts. An old outpost of the Mormons called Cove Creek Fort (also Cove Fort) stands near the springs, and gives them their name—Cove Creek Mines. The fort is on the eastern limit of a plain, which is bounded on the west by Mineral Range, twelve miles away, and on the east by Sulphur Range, a southern prolongation of the Pahvant Mountains, which themselves belong to the larger Wasatch. The region is one of Tertiary volcanic activity, and the deposits, though presenting some variations, all belong to the solfataric type. The Cove Creek Fort is situated in the crateriform depression of the Sulphur Range, with the volcanic eastward, within which the mines are situated. Between the border of the crater, and several miles northeast of the fort, is an extinct basaltic volcano 1,000 feet high, with a cinder cone on its top. This is called the Cove Creek crater by Russell, but Mount Dickert by the Utah geological survey. From the surface from the crest to the eastern hills, rise their rhyolitic and volcanic tuffs are developed.

Most of the mines are along the junction of the gravels and tuffs is indicated by Russell (1883) when this description is chiefly taken. The mines have been worked. The first of the mines was worked under management of [illegible]. It is an extinct solfatara at 1,600 to 1,800 feet, and this sulphur rises as much as 30 feet above. The [illegible]-

[illegible]

phur richly impregnates sand, doubtless decomposed volcanic rock, lines cavities, and is associated with gypsum. After being mined out it is to some degrees reproduced by the fumes which constantly rise. The workings are noticeably hot. The second variety of deposit is an impregnation of tuff and of the alluvial deltas resting on it. The third variety is in fissures in trachyte (andesite of vom Rath) and in dark, carboniferous limestone, along a line of faulting. Much gypsum has resulted from the action of the fumes on the limestone. Shales also appear in the section. Various claims are located on these last two forms of deposits, but the really productive one is the first named, in connection with which there is a refinery worked on the steam principle, with condensers, grinders, etc. Up to 2000 tons yearly are produced. Vom Rath estimates the ore at 75 %, to extend over 500,000 square meters up to 3 meters thick.

Utah also contains another mine, the Barnes, near Frisco. Descriptions have not yet been published. It was productive in 1889, but in 1892 the entire Utah product came from the Cove Creek Mines.

A.F.Du Faur: "The Sulphur Deposits of Southern Utah" Trans. Amer Inst. Min. Eng.XVI.33 1887.
H.C Myers: "The Sulphur Industry of the West, Amer. Jour Pharmacy 1887 p.16.
G.vom Rath: Neues Jahrb. 1884 I.
I.C.Russell: "Sulphur Deposits of Utah and Nevada Trans. N.Y.Acad. Sci. 1882, I. 168.

The Mineral Resources, published by the Geological Survey, contains frequent mention of the mines.

WYOMING. Native sulphur has been reported from several places in this State, all quite remote. Thirty miles south of Evanston, on Salt Creek, is one, while another is in the western central part of Uinta Co. The Wind River Mountains are likewise said to contain sulphur. Mr. W.H. Weed of the United States Geological Survey has reported sulphur from a number of the smaller vents and fumaroles of the Yellowstone Park. Some interesting crystals were yielded, but the deposits do not appear to be of practical importance. Orpiment and realgar were found in similar relations.

W.C.Knight: "Resources of Wyoming, in Bull. 14 of the State Experiment Station 1893p.197.
W.H.Weed and L.V.Pirsson "Occurrence of sulphur, orpiment and realgar in the Yellowstone National Park" Amer.Jour.Sci. Nov.'91 p.401.

WEST INDIES.-GUADELOUPE-Sulphur deposits have been mentioned from this island, and one or two tons have been exported to the United States. The sulphur occurs in an old crater along a great fissure,from which emerge fumes and hot waters, that yield alum and gypsum as well. The crater is five or six miles from Basse Terre, and about 4500 feet above tide. The amount does not appear to be either large or accessible.

Sainte Claire Deville: "Sur le Gisement de Soufre, etc., de la Guadeloupe," Bull. de la Soc. Geol. de France, 1847(2) IV. 428.

SABA. This island, a Dutch possession northwest of St. Christopher contains an extinct crater, with sulphur impregnations of the solfatara type. Attempts have been made to mine the sulphur, but the low grade of gypsums in which it occurs has discouraged the investment of capital.

N.S.Higgins: Extract from a report on the properties, Amer.Jour.Sci.(2) XLVIII. 278. 1868.
Molengraff: Geology & Crystallography, Zeitsch. f. Kryst.XIV.46.1887-88.

In general it may be said of sulphur deposits that they are apt to be irregular, and that, though very rich in places, quite extended test-pits or drill-holes are desirable before drawing too confident conclusions. In this country the principal employment of sulphur is in the sulphuric-acid industry, and especially in connection with the manufacture of fertilizers and in refining petroleum. We are also using for the manufacture of vitriol an increasing amount of pyrites, as elsewhere set forth in this volume. Sulphur is also used as an important ingredient of insecticides for vines and vegetables as a medicinal agent, and for various other purposes. In the aggregate, as will be seen from the statistics, we use an enormous quantity, and the market is a tempting one for local producers. For an account of sulphur deposits of the world together with bibliography and sketch of methods of treatment see
J.F.Kemp: Mineral Industry 1893, 585.

I N D E X.

I N D E X. (continued)

I N D E X. (continued)

Abbreviations.

A.A.A.S.--Proceedings of the American Association for the Advancement of Science.
A.G. or Amer.Geol.--American Geologist, Minneapolis, Minn.
A.J.S. or Amer.Jour.Sci.--American Journal of Science-also known as Silliman's Journal. Fifty half-yearly volumes make a series- The Journal is now (1895) in the last year of the third series In the references, the series is first given in small type, then the volume in capitals then the page in numerals.
Am.Phil.Soc.--American Philosophical Society, Philadelphia.
Ann. des Mines.--Annales des Mines, Paris, France.
Ann.Rep.--Annual Report.
Bost.Soc.N.H.--Proceedings Boston Society of Natural History.
B. und H.Z.--Berg-und Huettenmaennische Zeitung, Liepzig, Germany.
C.G.S.--Canadian Geological Survey.
E.& M.J.--Engineering and Mining Journal.
G.S.A.--Bulletin Geological Society of America.
J.G.--Journal of Geology.
M.E.--Transactions American Institute of Mining Engineers.
M.R.--Mineral Resources of the United States, Annual of the United States Geological Survey.
Min.Ind.--The Mineral Industry, Annual of the Engineering and Mining Journal. The Eleventh Census also issued a volume on the Mineral Industries.
Neues Jahrb.--Neues Jahrbuch fur Mineralogie. Geologie und Paleontologie, often called Leonhard's Jahrbuch,Stuttgart,Germany.
Q.J.G.S.--Quarterly Journal of the Geological Society of London.
U.S.G S.--United States Geological Survey. The Survey issues Annual Reports of the Director; Monographs; Bulletins, and the Mineral Resources.
Zeit.d.d.g.Ges.--Zeitschrift der deutschen geologischen Gesellschaft, Berlin, Germany.
Zeit.f.prak.Geol.--Zeitschrift fur praktische Geologie.Berlin,Germany.
Zeit.Kryst.or Xtal.--Zeitschrift fur Krystallographie. Leipsig,Germany.

---The other abbreviations are self explanatory---

ERRATA and ADDITIONS.

The errata are noted as follows--first number means page; second number, inches and decimals of an inch of mistake below top of top line. No attempt is made to note ordinary and self evident typographical errors, of which there are numbers.

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2, 7.5, After have, insert long. 3, 5.3, past, not pass. 3, 6.6, swamps, not salts. 5, 5.3, original, not origin. 5, 6.3, post, not past. 8, 2.2, strange, not change. 8, 8., exposes.

Abbreviations

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Am.Phil.Soc.--American Philosophical Society, Philadelphia.
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Zeit.d.d.g.Ges.--Zeitschrift der deutschen geologischen Gesellschaft, Berlin, Germany.
Zeit.f.prak.Geol.--Zeitschrift fur praktische Geologie Berlin, Germany.
Zeit.Kryst.or Min.--Zeitschrift fur Krystallographie, Leipzig, Germany.

--The other abbreviations are self explanatory--

[illegible] and [illegible]

The strata are noted as follows--first number [illegible] [illegible] [illegible] [illegible]

[illegible]

8, 8.7, Grand-Eury. 9, 4.2, Geologie. 9, 6., Ueber. 9, 6.3, Orton. 10, 2.1, Ueber. 11, 2.3, Kanara. 12, last line, last three numbers should read 4.839; 54.14; 0.60. 13, last word of page, gram. 16, 1. tr, not to. 17, 5.5, delide a. 18, Eastern States should precede Literature. 19, 1.5, led not lead. 19, 4.7, read divide it into. 19, 5.9, read, may be in the same situation. 19, 6.8, occasion. 21, 7.6, Belgian. 22, 0.7, Geosynclines. 22, 5., Augenkohle. 22, 6.2, Glanzkohle. 23, 0.1, in, not and. 27, 0.7, delide close. 28, 6.4, Prime. 29, 0.8, tram, not train. 29, 4.5, G.S.A.Bull.(not Ball.) V. 117, 1894 etc. belongs on the line above and is the reference of Dawson's paper. 29, 6.2, definitely. 31, . 4, Kittitas. 32, 2. After Field, insert Coke. 32, 3.2, read Bailey Willis. 33, 5.5, Vol. II. 41, 7.2, Sopris. 43, 0.2, Cimarron. 47, 7., Manross. 50, 8.6, R.T.Hill. 51, 0.3, Before Texas, insert THE WESTERN CENTRAL AREA 53, 3.5, after Kansas insert "The Stratigraphy of the Kansas Coal Measures. Kan.Univ.Quarterly, III, 171, 1895. A full report is about to be issued by the Kan.Geol.Surv.(June 1895). 55, 6.9, C.A.White. 55, 7.4, Field should be Area. 57, 5., delide which are noted below. 58, 7.5, Field should be Area. 62, 0.5, Sequatchie. 62, 5., Sequatchie. 62, 5.3, Colton. 65, 0.5, and 65, 1.6, volatile. 65, 8.4, Killebrew. 68, 0.2, after Coke, insert Flat Top. 74, 8.7, Mammoth not Monmouth. 78a, the duplication was not intentional. 79, 0.2, Area not Field. 81, 1.7, Cannelton. 81, 3.2, Pictou. 82, 1.7, 3rd not 1st. 82, 4.6, carbonaceous not carboniferous. 84, 1., Area not Fields. 84, 1.6, Vespertine. 85, 7 4, CHAPTER V. not IV. 86, 4.1, $C_n H_{2n+2}$, not $C_n H_{n+2}$. 87, 1.3, $C_n H_{2n}$, not C H. 89, 5.6, first word, or not of. 88 to 92, Reference should be made to the views of Carl Ochsenius on the origin of petroleum, and sulphur gas by the reactions taking place in the mother liquors of isolated and avaporating estuaries of brines, between the salines and any organic matter, especially of animal origin that might be present. See p.144 & 145, and reference there given. Also Zeit f.prak.Geol.May, 1893.197.and Geol. of Michigan, V. part II. p.XIX.

91, 6.4, Hanns Hoefer. 91, 7.5, Reichsenstalt. 91, 8., C.F. Maberry. 91, 8.5, Mendelejeff. 93, 3.7, output. 93, 7., Lawrence. 94, 6.3, p.91. 95, 2.8, p.91. 97, 3.5, B not b. 97, 4.2, Eldredge. 98, 0.3, Marcou. 99, insert at bottom of page, Gas has recently been discovered at Fulton, N.Y. 99, 4.8, were, not was. 99, 5., after 1894 insert, E.Haworth-Oil and Gas in Kansas, A.A.A.S.XLIII.229.1894. 101, at foot insert, Kansas. R.Hay, Trans.Kan.Acad.Sci.X.57.1885. Hist. E.Haworth.Oil and Gas in Kansas, A.A.A.S.XLIII.229.1894. 102, 1., Las not Lan. 104, 4.8, Manross. 104, 6.3, Bermudez. 105, 4.5, Huasteca 105, 5.8, delide the second various. 105, 6.1, and 6.3, delide "expressed and". 106, 5.5, Huasteca. 108, 0.8, Adirondacks. 108, 7.7 Kenntniss. 108, 7.9, seiner Begleiter. 108, 8.4, CHAPTER VI., not V 109, 6., $y = p \sqrt[3]{x}$. 110, 2.8, for agent read cause. 110, 4.3, and 4.4, for School of Mines Quarterly read Trans.Inst.Civil Engineers.1895 114, 4., instead of Kings Co. north of St.John, read Charlotte Co. 114, 4.8, after Halifax Co. add Nova Scotia. 114, 6.8, day, not way. 115, 2.1, Brattleboro. 115, 6.3, Notes. 115, 6.7, G.P.Merrill. 116, 4.3, Hollick. 117, 1.7, Chamberlin. 117, 4., delide last sentence. 118, 2.3, Charlotte, not Kings. 118, 8.5, delide later. 125, 3.1, presence, not presents. 125, 2.7, after recommended insert one still more complete will appear in Mineral Resources for 1894.

E R R A T A and A D D I T I O N S (continued)

127, 6.3, for second "from"read "of". 127, 6.6, for formed read "is made up". 130, 6.9, Merrill.

132, 8.1, By an oversight the notes on Arkansas Marble were omitted. The state has great resources as yet only slightly opened up. They promise to be of importance in the future. The report cited below, by Mr. T.C.Hopkins is the best work on the utilization of limestone and marble, available for American readers, and is not limited to Arkansas. T.C.Hopkins. Marbles and Other Limestones.Ann.Rep.Geol.Surv.of Ark. 1890, Vol.IV. Rec.

133, 4.7, and 5.1, Pedrara. 133, 5.4, insert, Aguilera and Barcena, Smithsonian Rep. 1886. part II, 482. M.Barcena Rocks known as Mexico Onyx. Phila.Acad Sci.Aug.29,1876.

133, add at foot of page, J.F.Kemp. Crystalline Limestones, Ophicalcites, etc. of the Eastern Adirondacks, G.S.A. VI. 241. 1895.
134, 0.1, Ophiolite. 136, 5., Kuichling. 136, 5.3, Procedes d'Essais des Materiaux. 136, 8.2, Waterline. 137, 5.5, barrels, not tons. 137, 7.5, rigorously.

140, 0.1, CHAPTER VII. not VI. 141, 0.5, delide p.22. 150, 1., delide Alxedgeo. 151, 3., and 5.5, Abert, not Albert. 151, 8.9, insert W.J.Mc Gee, A miniature extinct Volcano.A.A.A.S. XLIII.225.
152, 3.6, 6., and 6.2, Abert, not Albert.

156, 7.5, CHAPTER VIII, not VII. 158, 7., vegetable. 158,2.1, lapoli. 158, 7., referred. 158, 7.4, after Jersey, insert "and elsewhere in the coastal plain". 158, last line G.H.Cook. 161, 7.8, Torrance. 163, 5.2, insert W. de L. Benedict, Mining, Washing and Calcining Land Phosphate. E.& M. Journal Mar.26th,1892. Rec.
165, 4.1, A.R.Ledoux. 167, 6.8, and 7., C.U., not C.N.

170, 1.6, CHAPTER IX, not VIII. the title should read, Miscelaneous Minerals, viz. Abrasives; Asbestos; Fluorite; Glass Sands; Lithographic Limestones; Mica; Moulding Sands; Precious Stones; Soapstone and Talc; Sulphur.

172, 0.5, actinolite. 172, 3.8, 4.5 and 4.6, Genth. 172, 6.8, The reference should read Zeit. Xtal. X. 657. 173, 4.3, Genth.
176, 3.8, deutscher. 176, 6., lead. 178, 3.8, affected. 178, 5.7, earths. 179, 3.1, indespensable. 179, 5.6, on, not in. 179, 7., Bouve. 179, 8.3, Micros. 180, 5.6, coats. 180, 8.4, occasioned.
181, 5.2, character. 181, 8.3, emanate. 182, 5.5, A paragraph ought to have been inserted referring to the views of Ochsenius, regarding the formation of sulphur from the mother liquors of salt deposits formed by the "bar" or estuary process. (see p.145). He considers the alkaline sulphates left in the mother liquors to have been reduced by decaying organic matter and thus to have yielded sulphur in the original process of sedimentation. C.Ochsenius, Zeit.f.prak. Geol. June 1893, 223.

182, 6.1, Calciferous. 183, 3., occurred. 183, 3.5, cinnabar.
184, 3.5, Lahontan. 186, 1.3, delide "as elsewhere set forth in this volume". 186, 2.5, add at close , "from which the above notes are taken".

ERRATA AND ADDITIONS (continued)

187, 3.5, for second "Cretaceous" read [illegible]. 187, 4.1, for [illegible] read [illegible] [illegible], [illegible].

[illegible] 4.1, to be [illegible] and [illegible] of Arkansas [illegible] were [illegible] [illegible] yield and [illegible] we [illegible] only slightly [illegible] [illegible] to be of importance [illegible] [illegible]. The [illegible] [illegible] [illegible] [illegible] in the [illegible] of limestone and [illegible], available for [illegible], and is not [illegible] to Arkansas. [illegible] and other [illegible] [illegible] of Ark. [illegible] IV, [illegible].

[illegible] and [illegible] [illegible] 1850, [illegible] [illegible] of [illegible]. [illegible] 1879.

[illegible] Limestone, [illegible] of the [illegible] [illegible], [illegible] VI, [illegible] [illegible].

[illegible]

[illegible] 1856, 1857, [illegible] (after 1.4.8.8. [illegible]) [illegible]

[illegible]

[illegible] [illegible] [illegible] [illegible].

[illegible]

[illegible]

[illegible] of sulphur from the [illegible] [illegible] of [illegible] [illegible] ... [illegible] to have been [illegible] by [illegible] [illegible] [illegible] [illegible].

[illegible]

[illegible]

[illegible]