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OUTLINE INTRODUCTION

TO THE

MINERAL RESOURCES OF TENNESSEE

Compiled and Written

BY GEORGE H. ASHLEY

EXTRACT (A) FROM BULLETIN NO. 2, "PRELIMINARY PAPERS ON THE MINERAL RESOURCES OF TENNESSEE."

NASHVILLE
FOLK-KEELIN PRINTING COMPANY
1910

2—A

STATE OF TENNESSEE—STATE GEOLOGICAL SURVEY

GEORGE H. ASHLEY, State Geologist

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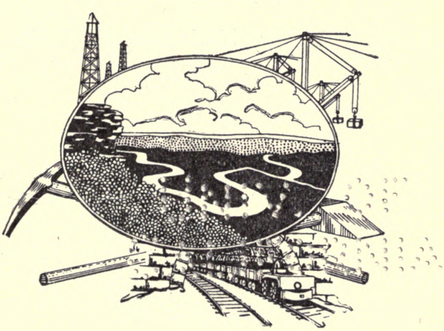

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FOLK-KEELIN PRINTING COMPANY

1910

STATE GEOLOGICAL COMMISSION

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Governor of Tennessee.

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Vice-Chancellor, University of the South.

GEORGE H. ASHLEY,
State Geologist.

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OUTLINE INTRODUCTION

—TO THE—

MINERAL RESOURCES OF TENNESSEE

BY GEORGE H. ASHLEY.

NOTE.—This pamphlet will ultimately form Part "A" of Bulletin No. 2—"Preliminary Papers on the Mineral Resources of Tennessee," in which it will be followed by brief, though more extended papers, on the more important resources of the State. The several parts of Bulletin No. 2 are published separately as "Circulars of Information," as listed on the inside cover.

Bulletin No. 2 is not intended as an original contribution to the knowledge of the State's mineral resources. It contains a succinct statement of such general facts about the State's mineral resources as have been *published,* supplemented by such additional facts as may have come to the notice of the survey in the few weeks since its establishment. It is issued to meet the urgent demand for "immediate information" on the State's mineral resources, pending the appearance of reports to be prepared as a result of the Survey's field work now in progress, or to be carried on in the future.

Part A of Bulletin No. 2 is for the reader who has only a general interest in the State's resources, and to meet immediate demands, as it is recognized that it is going to require many months to prepare all the following papers, brief as they are intended to be.

Part A contains:

I. Location, Size, etc., of Tennessee.
II. Surface Features of Tennessee.
III. The Rock Formations of Tennessee.
IV. The Geological History of Tennessee in Outline.
V. The Rock Structure of Tennessee.
VI. Alphabetical List of the Minerals of Tennessee, with a Brief Notice of Their Occurrence, etc.

No attempt is made in this paper to give the authority upon which statements are made. It is hardly necessary to say that reports of Safford and Killebrew and the U. S. Geological Survey folios and "Mineral Resources" have been largely drawn upon. In most cases there has been attempted a review of all the papers dealing with the several subjects. The fuller papers on the mineral resources, which will appear in later numbers of Bulletin No. 2, will in most cases give lists of the principal papers that have been published on each subject. The statistics of production in the State and the lists of producing mines, etc., are fully set forth in the annual reports of the State Mine Inspector, and need not be repeated here. Those reports can be obtained by addressing the State Mine Inspector, Nashville, Tenn.

LOCATION, SIZE, ETC., OF TENNESSEE.

Tennessee lies between latitude 35° 00' and 36° 30' north, and longitude 81°, 56' and 90° 28' west, with an extreme reach from east to west of 483 miles. It has a width along the parallel of 36°, 30' of 432 miles; its width along the parallel of 35° north is 336 miles; its greatest width from north to south is 115 miles, with an average of 109 miles. It has an area of 42,050 square miles, of which 300 are covered by water. It contains 96 counties, grouped into three principal divisions—East, Middle and West Tennessee—which are recognized in the Constitution in the election of judges and otherwise. In 1900 the population of the State was 2,200,616, of which 31 per cent. was colored. At this writing the census figures for 1910 are not available.

The State has four large, thriving cities—Memphis, Nashville (the capital), Chattanooga and Knoxville—and scores of smaller cities. Memphis claims to be the largest inland cotton market in the United States, if not in the world; Nashville, the largest hardwood market in the world, the largest publishing city in the United States outside of New York City, the largest educational center in the South, with 11,000 visiting students, etc.

There are at this time almost 4,000 miles of railroad track in the State. The Cumberland River is navigable for 518 miles, of which 315 are in Tennessee, the Tennessee River furnishes 320 miles of navigable river; the Mississippi 200 miles. Altogether there are about 1,200 miles of navigable streams in the State, thus insuring low freight rates to a large number of points.

Tennessee combines a southern position, with high average altitude, rendering the climate one of the most equable and delightful of any State in the Union—the winters are short and the summers long, but neither the winter cold, nor the summer heat is as great as in the Northern States. The average rainfall is about 52 inches, well distributed all through the year, with an average of 265 clear days in a year. The growing season, as measured by the number of days between frosts, is 189.

With her abundant and varied mineral resources, soils and climate, Tennessee, if cut off from communication with all other States, could continue to supply herself with all, or nearly all, of the needful materials to maintain her present or future civilization. Water-power and coal would supply her with power; her iron, lead, zinc, copper, gold, silver, aluminum and other mines would supply her with metals; her building stones, marbles, clays, cement materials and forests would supply her with building materials; most of the materials used in chemistry and the arts, she could secure from her own storehouse, if cut off from outside supplies; and with the exception of tropical fruits, she can raise any food raised anywhere in the United States.

SURFACE FEATURES OF TENNESSEE.

Though Tennessee lacks the attractive features of the seacoast and the rugged wildness of the mountains of some of the Western States, it is safe to say that no State in the Union excels it in general attractiveness of physiographic aspect. The eastern edge reaches the eastern crest of the continent, with an average elevation of 5,000 feet above sea-level, and the western edge borders on the Mississippi River, with an average elevation of about 225 feet above tide. Two great navigable rivers cross the State, one of them twice. There is a minimum of level ground, with the usual monotony of scenery, yet on the other hand the area of wild mountain lands of low economic value is very limited. To the east the great wilderness of the Appalachian mountains belong to North Carolina, and Tennessee has only the crest and the western slope, giving an abundance of mountain scenery, peaks and passes, river gorges and waterfalls, without its absorbing much of its territory. On the west the great swampy bottoms of the Mississippi lie almost entirely on the Arkansas side, while on the Tennessee side are some of the richest agricultural lands in the State, up on the bluff, where they are well drained.

The Alleghany Mountains, which in Kentucky render all of the eastern part of the State rough and rugged and of little value for agriculture, in Tennessee narrow down to the flat-topped Cumberland Plateau, and even the heart of that is occupied by the broad, fertile Sequatchie Valley.

Again, the great Central Basin of Tennessee, which is almost a continuous garden, is not flat, as are some of the States farther north, but gently rolling, rising into picturesque hills, or sinking into sloping valleys, through which run clear, rapid streams, and almost always the hills of the Highland Rim form a distant background resembling small mountains.

The State crosses a series of distinct physiographic types of topography which extend northeast and southwest in the eastern part of the State, and north and south in the western part of the State. These, from east to west, are the Unakas, or Great Smoky Mountain belt, the Valley of East Tennessee, the Cumberland Plateau, the eastern Highland Rim, the Central Basin, the western Highland Rim, the Western Valley of Tennessee River, the Plateau of West Tennessee, extending to the Mississippi River bottoms.

The Unakas.—This is the western flank and foothill region of the Unakas, or Great Smoky Mountains, an area of 2,000 square miles, with often rounded crests, suited for grazing, steep, timber-covered slopes and deep, gorge-like ravines opening out into enclosed valleys, a region of fine timber, great water-power and abundant grazing grounds. The crests of the mountains have an elevation of from 4,000 to 6,650 feet; the elevation at the foot of the mountains is about 1,000 feet. This region is the source of the copper, gold, silver, slate and granite of the State, and of great deposits of iron.

The Valley of East Tennessee.—This region has an average width of about 50 miles and an area of 9,200 square miles, with an elevation of about 1,000 feet above the sea. It is a region of long northeast-southwest limestone and shale valleys separated by narrow, saw-toothed ridges of sandstone or chert. The valleys, and often much of the slopes of the ridges, are at once beautiful, populous and fertile. The Great Valley is the seat of the State's marble industry and the source of barytes, zinc, red fossil iron ore, and many other economic products.

The Cumberland Plateau.—This is the coal region. It is a high table-land, capped with massive sandstones and underlain with coals, clays, shales and limestones. The elevation is about 2,000 feet above tide, with some mountains rising above the table-land to 3,000 or 4,000 feet above tide at the northeast. It has an area of over 5,000 square miles. It faces the Great Valley with a fairly even escarpment 1,000 feet high and generally precipitous. On the western side it forms a series of projecting headlands, enclosing rich coves. From either edge of the plateau wonderful views are to be had of the broad, rich valleys to the east and west.

The Highland Rim.—This is a high, broad shelf surrounding the "Central Basin." The edge facing the Basin has a cherty soil, back of which is a broad belt of rich limestone country. The inner rim supplies chert, and on the western side of the Basin the "blue" phosphate rock just underlies the chert. From the outer edge of the Rim will be supplied lithographic stone and building stone, fluorite, zinc and other metals. This division has an area of 9,300 square miles, with an elevation of 950 feet above sea-level.

The Central Basin.—The Central Basin with an area of 5,400 square miles lies about 400 feet below the Rim, or about 500 feet above tide. It is a limestone basin. Much of the limestone of the western side is rich in phosphate, and large quantities of commercial fertilizer are now being mined. It is not flat, but beautifully rolling, the hills rising 50 to 150 feet above the adjoining broad valleys. For the most part, hill and valley are equally rich. It is one of the few regions of the world combining great agricultural richness with beautiful scenery, clear, flowing streams and health conditions of the highest type, a region of wealth, culture and influence.

The Western Valley of the Tennessee River.—This is a narrow, irregular belt of low, swampy land, sparsely settled, with an area of 1,200 square miles. It is a region of great possibilities for the future when the river shall have been harnessed. Some of the side valley bottoms with their great richness are prophetic of what some day may be true of the whole valley.

The Plateau and Slope of West Tennessee.—This is a region of rolling upland, with light, fertile soil, sluggish streams with swampy bottoms, the uplands rising 200 to 400 feet above the stream bottoms. The reclamation of the stream bottoms has already begun. The region is well supplied with railroads. It is the most densely populated part of the State and is growing rich raising small fruits and vegetables for the early Northern market. As the stream bottoms are brought under cultivation this region will become one of the garden spots of the United States. The district gives promise of a great future industry in the manufacture of clay products. The area is about 8,850 square miles and the elevation 500 feet above tide.

The Mississippi River Bottoms.—Nearly 1,000 square miles of Mississippi River bottom exists in Tennessee, mostly awaiting reclamation to become what such river valleys all over the world become when properly reclaimed—the world's granaries. At present most of this area is covered with a dense vegetation, spotted with lakes and marshes, and underlain with a soil of imperishable fertility.

ROCK FORMATIONS OF TENNESSEE.

As is well known, the rocks of any region vary—some are sandstones, some shales, some limestones, granites, marls, etc. Originally most of these rocks were laid down in the ocean, either along the shore or farther out as great stretches of sand or mud, as vast coral reefs, as gravels, or as other material, or as mixtures of these. Later these beds were buried by other materials as the constant movement of the land carried the sea farther in, or forced it farther out, and in time each bed of similar material became deeply buried beneath later materials and it was hardened into shale or sandstone, or limestone, or some other rock. But the same conditions of shore or sea often recurred at any one point, so that the same kind of bed was laid down at many times in the history of one locality. Therefore, in referring to any single bed it is desirable that it have a name. It has become customary to give each bed a name from some place where it is especially prominent, and not likely to be confused with any other similar bed at that place. Thus, the Camden chert is named from Camden, in Benton County, where it is practically the only rock to be seen. The Murfreesboro limestone is named from Murfreesboro in the same way.

These layers of rock may have a thickness of from a few feet to several thousand feet, and an extent of from a few square miles to 100,000 square miles, or more. Thus, the Knox dolomite has a thickness of 4,000 feet, and probably underlies nearly all of Tennessee, though exposed only in East Tennessee and in the Wells Creek basin. It is found also all through the Appalachian Valley through Virginia, Maryland and Pennsylvania. The red Clinton iron ore can be traced from Lake Ontario to south of Birmingham in Alabama, and from East Tennessee to west of Nashville. It is not continuous, nor always in a single bed. When the layers of rock are thin and variable a number of them are grouped together and called a formation; as the Rome formation, or the Mingo formation, which contains shales, sandstones, clays and coal beds. The general term "formation" has been given to all of the named strata, or "formation" groups.

These formations are traced and mapped in two ways—by actual tracing from place to place, and through the study of the contained fossils. In the Western States where rain is scarce and vegetation scanty the rocks are commonly well exposed, and it is often possible to trace a given rock layer for hundreds of miles, but in Eastern United States where the vegetation is usually abundant this is seldom possible, and always difficult. Again, the dips, faults, or other structural features often carry the stratum being traced underground for a long distance, or have raised it above the present surface, so that it has been eroded, and under these conditions the direct tracing may not be possible. In almost all cases, therefore, where the tracing is carried any distance dependence must be placed on a study of the fossils.

The fossils are the remains of the animals and plants that lived at the time any rock was being laid down. A study of the rocks shows that there has been a steady change and advance in the plants and animals living in the sea at the time the various rocks were laid down. Hundreds of thousands of different forms have been recognized and described. Where two layers follow each other closely in time it is found there is a close resemblance between the animals or plants, but invariably it is found that some forms in the lower layer are lacking in the upper layer, and new forms have appeared in the upper layer, generally descended from the missing forms of the lower layer. In ascending through several layers it is soon found that all of the forms have changed. Again, in closely succeeding layers, it is often found that where the same species has persisted from one layer to the next that it shows some slight variation by which it is possible to recognize what particular bed a given specimen was taken from. To recognize these minute variations, however, requires an amount of study, training and experience that shuts out all but those who are willing to devote their whole time to it, and as a rule most of the paleontologists confine themselves to either the plants or animals of a single era. Notwithstanding this necessary specialization for the detailed work, the general geologists, or laymen, can quickly learn the common fossils of the larger rock groups, so as to readily distinguish them.

The practical value of the study and knowledge of the rock formations lies in the fact that a large part of the economic products of any region have certain definite relations to the rock formations. Thus, the bituminous coal of Tennessee is found only in rocks of Carboniferous age and the lignite in certain other rocks of Eocene age, the blue phosphate in close association with the Chattanooga black shale, or brown phosphates on the edges of the Trenton and Lorraine limestones or fossiliferous red iron ore in rocks of Clinton age; the bauxite of Tennessee is found associated with the Knox dolomite, as is most of the zinc ore. The Holston marble is found in a definite stratigraphic position, as are the lithographic limestones and the oölitic (Bedford) building limestones. The same is true also of the oil, gas, novaculite, chert, slate, cement rocks, and many other of the State's resources. If we wish to find deposits of any materials, a knowledge of the rock strata and where they occur serves as a guide in the search; or in finding a given formation we look for the possible occurrence of certain economic deposits.

Following are given first a list of the named formations of the State, arranged to show the correspondence in age; then a brief characterization of each, giving its thickness, the location of its outcrops, etc.

TABLE OF ROCK FORMATIONS IN TENNESSEE

F-Formation; S.S.-Sandstone; L.S.-Limestone; Sh.-Shale; Cgl.-Conglomerate; Sl.-Slate; Qtz.-Quarzite; Gr.-Group; Sd.-Sand; Cl.-Clay; Ch.-Chert.

Era.	Standard Section: System	Standard Section: Series and Groups	Safford, 1869	Western Tennessee	Eastern Tennessee
Cenozoic	Quaternary	Recent	Alluvium Eastern Gravel	Alluvium	Alluvium High level gravel
		Pleistocene	Bluff Gravel	Columbia: Milan loam Memphis loess sand	
Mesozoic	Tertiary	Pliocene Miocene Oligocene		Land	Land
		Eocene	Bluff lignite Orange sd. or Lagrange	Lagrange F.	Land
			Porter's Creek F.	Porter's Creek F.	Land
	Cretaceous	Upper	Ripley group	Ripley F.	Land
			Green sd.	Selma Cl.	
			Coffee sd.	Eutaw Sd.	
		Lower	Land	Land	
	Jurassic	Upper Middle Lower	Land	Land	Land
	Triassic	Upper Middle Lower	Land	Land	Land

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Era	System		Series and Groups	Safford 1869	Safford and Killebrew 1900	Cumberland Gap Ashley & Glenn 1904	Northern Appalachian Field Keith	Southern Appala-chian Field Hayes
Paleozoic	Carboniferous		Permian					
		Pennsyvanian	Monongehela			probably	land	
			Conemaugh					
			Allegheny			probably	eroded	
			Pottsville	Upper Coal Measures	Brushy Mt. Gr.	Bryson F. Hignite F. Catron F. Mingo F. Hance F.	And'rs'n S.S Scott Sh. Wartb'g S.S. Briceville Sh	Eroded
				The Conglomer-ate.	Emery S.S. Tracy City Gr Sewanee S.S. Bon Air Gr.	Lee F.: Naesa S.S. Member	Lee F.: Rock-castle Cgl. Bon Air Cgl.	Walden S.S. Lookout S.S.
		Mississippian	Chester	Mountain L.S	Mountain L.S.	Pennington Sh	Pen'gton Sh.	
			St. Louis	Siliceous Gr.: St. Louis	St. Louis L.S.			Bangor L.S.
			Keokuk	Siliceous Gr.: Lower or Protean Gr.	Tullahoma	Newman L.S.	Newman L.S	
			Burlington					
			Kinderhook				Waverly F.	Fort Payne Ch

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Era	System	Series and Groups		Safford 1869		S. & K. 1900	Western half of Tennessee			Eastern half of Tennessee
Paleozoic	Devonian			Blackshale		Maury Green Sh.		Maury Sh.		Grainger Sh.
						Black Sh.		Chattanooga Sh.		Chatta. Sh.
		Upper	Chemung			Hardin S.S.		Hardin S.S.		
			Portage			Swan Creek Phosphate		Swan Cr. Phosphate		
		Middle	Hamilton							
			Onondaga					Onondaga L.S.		Land
		Lower	Oriskany			Camden Ch.		Camden Ch.		
			Helderb'g	Lower Helderberg		Linden L.S.		Linden L.S.		
	Silurian	Cayuga	Monroe	Menison's Limestone	Sponge Bearing Bed	Clifton L.S.		Land		
			Salina							
		Niagara	Guelp					Decatur L.S.	Clifton Limestone	
							Brownsport	Lobelville F.		Sneedville L.S.
								Bob F.		
								Beech Riv. F.		
			Lockport		Variegated Bed			Dixon F.		Hancock L.S.
							Glenhook	Lego L.S.		
								Waldron Sh.		
			Rochester					Laurel S.S.		
							Maddox	Osgood		
		Clinton		Dystone Gr. White Mt. S,S.		Dystone Gr.		Clinton F.		Rockwood F.
		Medina		Clinch Mt. S.S.		Clinch Mt. S.S.		Land		Clinch S.S.
										Bays F.

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Era	System	Series and Groups		Safford 1869		S. & K. 1900		West half of Tennessee	East half of Tennessee	
Paleozoic	Ordovicin or Lower Siluran	Cincinnati	Richmond	Nashville	Upper	Nashville	Hudson or College Hill	Mannie Sh. Ferndale F. Arnheim (Warren) F.	Sevier Shale	Sevier Sh.
Paleozoic	Ordovicin or Lower Siluran	Cincinnati	Maysville Lorraine Eden Frankfort	Nashville		Nashville		Land Leipers F. Land	Sevier Shale	Tellico S.S.
Paleozoic	Ordovicin or Lower Siluran	Mohawk	Utica Trenton	Nashville	Middle	Nashville	Criptodonta & Stomatopora bed Dove & Ward L.S. Capital or Mt. Pleasant L.S.	Land Catheys L.S. Bigby L.S.	Sevier Shale	Athens Sh.
Paleozoic	Ordovicin or Lower Siluran	Mohawk		Nashville	orthis bed	Nashville	orthis bed	Hermitage L.S. Saltillo L.S.	Sevier Shale	
Paleozoic	Ordovicin or Lower Siluran	Mohawk	Black Rvr. Lowville	Nashville		Nashville		Land	Moccasin L.S.	
Paleozoic	Ordovicin or Lower Siluran	Chazy	Upper Stones River	Trenton or Lebanon	Center Glade Ridley Pierce Central	Stone's River	Center lst. Lebanon lst. Ridley lst. Pierce lst. Murfreesboro lst.	Carter L.S. Lebanon L.S. Ridley L.S. Pierce L.S. Murfreesboro L.S.	Holston marble Chickamauga L.S. Lenoir L.S. Knox Dolomite upper 2,000	

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Era	System	Series and Groups	Safford 1869	Valley of East Tennessee	Cranberry Folio (a) or Nantahale Folio (b)	Ocoee of Knoxville Folio
Paleozoic	Cambrian		Knox Dol'mite	Knox Dolomite		
		Saratoga	Knox Shale	Connasauga Sh: Nolichucky Sh. Honaker lst.: Maryville L.S, Rogersville, Rutledge L.S		
			Knox Sandstone	Watauga sh.: Rome form (Russel), Beaver L.S., Apison sh.		
		Arcadian	Chilhowee Sandstone and Ococe	Shady L.S. Hesse Qtz. Murray Sl. Nebo Qtz. Nichols Sh.	(a) Erwin Qtz. (a) Hampton Sh. (a) Unicoi F. (b) Tusquito Qtz. (b) Natahala Sh.	
				Cochran cgl.	(b) Great Smoky Clz	Clingman Cgl. Herzel Sl. Thunderbreed Clz.
		Georgia		Hiwassee Slate		Cades Cgl. Pigeon Sl.
				Snowbird F.	(a) Starrs Cgl. lent. (b) Sandsuck Sl.	Citico Cgl. Wilhite Sl.
Algonkian					(b) Metarhyo-lite (b) Lynnville metadiabase	
Archean					Beech granite Max Patch granite Cranberry granite	

CENEZOIC ERA, QUARTENARY SYSTEM, RECENT SERIES.

Alluvium.—Recent deposits along river and stream bottoms; all over the State, especially in West Tennessee. Rich agricultural lands; source of brick clays and locally of sand and gravel.

High-level gravels.—Gravel, reaches often 300 to 400 feet above streams in East Tennessee, and especially in the gaps of the Unakas. Gravels up to the size of a man's head and extending back from streams as much as three or four miles.

PLEISTOCENE (COLUMBIA).

Milan loam.—Yellow clay loam without laminar structure, containing fine sand; 0 to 15 feet thick, average 3 feet. Fine agricultural land. Plateau of West Tennessee.

Memphis loess.—Fine, siliceous,, calcareous earth, ashen to buff color, up to 100 feet thick. Vertical walls in cuttings stand for years. Uplands along the Mississippi River.

Sands (Lafayette).—Soft, loose, light-colored sand, with rounded pebbles; four to five feet thick, and up to 10 or 12 feet. West Tennessee.

MESOZOIC ERA, TERTIARY SYSTEM, EOCENE SERIES.

LaGrange formation.—Orange, red, yellow and white sands, and beds of gravel, often locally compacted or cemented, with lenses of plastic, siliceous clay. 200 feet thick. Yields clay for tile and brick; lignite; iron ore. West Tennessee.

Porter Creek formation.—Fine grained clay, gray when dry, or dark to black when wet, with some interbedded sands, or sandstones; some green sands and impure limestone. 200 to 300 feet thick, narrow outcrop across West Tennessee, west of Tennessee River.

CRETACEOUS SYSTEM (UPPER).

Ripley formation.—Colored sands and clays, 400 to 500 feet thick, containing some lignite. Some pottery clay. Makes belt 6 to 12 miles wide, west of Tennessee River, east of Porter Creek formation.

Selma clay.—Gray to green clay, with glauconite, fossil shells yielding lime; 100 to 375 feet thick. Outcrops only in the southeast part of West Tennessee.

Eutaw sand.—Variable sand, with some clay; 250 feet thick, southeast corner of West Tennessee.

PALEOZOIC ERA; CARBONIFEROUS SYSTEM; PENNSYLVANA SERIES. POTTSVILLE GROUP.

(Upper Pottsville, or "Brushy Mountain Coal Group.")

The first five formation names given below were used in the Cumberland Gap area for the upper Pottsville rocks. The next four were used for the same general group of rocks in the Briceville and Wartburg folios. These formations are confined to the northeast part of the Cumberland Plateau.

Bryson formation.—Sandstones interbedded with shales, coals and clays; 200 feet thick in Bryson Mountain.

Hignite formation.—Shales interbedded with sandstones, coals and clays; 440 to 550 feet thick. Several thick coal beds.

Catron Formation.—Shales and sandstones, interbedded with coals and clays. Numerous workable coal beds; 280 to 360 feet thick.

Mingo formation.—Shales and sandstones, interbedded with coals and clays; many workable beds. 950 feet.

Hance formation.—Mostly shale, with some interbedded sandstones, coals and clays; 600 feet thick. Several workable beds.

Anderson sandstone.—Sandstone interbedded with shale and coal beds; 1,000 feet thick.

Scott shale.—Shale, with some sandstones; thin coals; 500 to 600 feet thick.

Wartburg sandstone.—Interbedded sandstones, shales and coal beds; 500 to 600 feet thick.

Briceville shale.—Shale with thin sandstone and thick coal beds; 250 to 650 feet thick.

LOWER POTTSVILLE, OR LEE CONGLOMERATE.

Emory sandstone.—Massive sandstone, usually conglomeratic; 100 to 150 feet thick; under all of the east part of the Plateau region.

"Tracy City group."—Mostly sandstone, with interbedded shale, coals and clays; 500 to 600 feet thick.

Bon Air conglomerate, or Sewanee conglomerate.—Massive sandstone 40 to 100 feet in thickness, usually conglomeratic, forming the top of Lookout formation. Used in the Pikeville, Chattanooga, Kingston, Sewanee and McMinnville folios. Used as a building stone.

"Bon Air Group."—Mostly sandstone, with some shale, coals and clays; 0 to 600 feet thick.

MISSISSIPPIAN SERIES.

Pennington shale.—Calcareous shale, sandstone and thin limestones, showing often bright red in color; 160 to 1,000 feet thick along east and west escarpments of Plateau.

St. Louis limestone.—Gray and blue thin-bedded limestone, with chert nodules; 250 to 300 feet thick; outcrops around Highland Rim, back from the edge. Yields lithographic and oölitic limestone. Good agricultural land.

Tullahoma limestone.—In Middle Tennessee, mostly chert, with some limestone and siliceous shale; 200 feet to 1,200 feet thick. Makes inner edge of Highland Rim around Central Basin in Middle Tennessee, and makes chert ridges in East Tennessee.

Newman limestone.—Includes last two formations in northwest part of Valley of East Tennessee; 650 to 750 feet thick.

Waverly formation.—Used in the Standing Stone folio for the bottom 400 to 500 feet of the Carboniferous.

Bangor limestone.—Blue crinoidal limestone, with few lenses of sandstone and chert near the bottom. Includes the Pennington, St. Louis and upper part of the Tullahoma. In folios in southern part of East Tennessee. Thickness 800 to 850 feet.

Ft. Payne chert.—Chert, in the main; used in the southern part of East Tennessee for the lowest 150 to 200 feet of the Tullahoma.

DEVONIAN SYSTEM.

(In a recent paper Schuchert assigns the Chattanooga black shale to the Lower Carboniferous. Corelations used in the Columbia folio have been followed here.)

Maury shale.—Green, or greenish shale; a few inches to 4 or 5 feet thick, generally containg concretions of all sizes and shapes, with calcium phosphate; especially western Middle Tennessee.

Chattanooga shale.—Black bituminous shale; 0 to 450 feet thick; usually only a few feet in thickness, but very persistent, and found in all divisions of the State. Probably the source of much of the oil and gas of the State, sulphur waters, etc.

Hardin sandstone (*Swan Creek phosphate*).—A dark, fine-grained, bituminous sandstone in Hardin, Wayne and Perry counties; 12 to 15 feet thick. Becomes phosphatic farther north, locally losing all, or nearly all of its sand grains—the blue phosphate rock of commerce. Where phosphatic usually less than 4 feet thick. Northwest part of Middle Tennessee.

Camden chert.—Light to white chert, or novaculite; 60 feet thick. Benton and adjoining counties, and Wells Creek Basin. Novaculite very fossiliferous. Fine road material.

Linden limestone.—Blue thin-bedded limestone and interbedded shale. Very fossiliferous; 100 feet and less thick. North part of Western Valley of Tennessee.

SILURIAN SYSTEM.

Note.—The following formations down to Osgood have been differentiated only in part of the western valley of the Tennessee, notably in Decatur and Perry counties:

Decatur limestone.—Massive white, coarsely cyrstalline, crinoidal, magnesian, limestone; 70 feet thick. Found in Decatur county.

Lobelville formation.—In two zones; coral zone, 45 feet thick, yellow clays and thin argillaceous limestone, full of corals. Bryozoan zone, 31 feet thick. White to blue shale, or red to purple shale, or shaly limestone.

Bob formation.—Occurs in three zones. Conchidium zone, 15 feet thick; massive crinoidal, and argillaceous, limestone. Dictyonella zone, 30 feet thick; blue clay and shale. Uncinulus zone, 30 feet thick, gray massive limestone.

Beech River formation.—Blue to white shale, with limestone; 106 feet thick.

Dixon formation.—Red to purple shale, and shaly limestone; 44 feet thick.

Lego limestone.—Compact gray to white clay, or gray to white argillaceous to sub-crystalline limestone; 46 feet thick.

Waldron shale.—White indurated clay and argillaceous limestone; 4 feet thick.

Laurel limestone.—Massive pink, or reddish purple, clay and argillaceous limestone; 28 feet thick.

Osgood limestone.—Thin-bedded, reddish, argillaceous limestone; 14 feet thick.

Clifton limestone.—General name for the above formations of Niagara age, where undivided when traced farther east and north; 200 feet thick. Source of much building stone. In northwest part of Middle Tennessee.

Hancock limestone.—Massive blue limestone and bluish gray shaly limestone, 400 to 450 feet thick; in the north part of the Valley of East Tennessee.

Clinton formation; Rockwood formation.—Variegated, calcareous shales with thin fossiliferous limestone and thin, smooth sandstones; 100 to 300 feet thick. Contains valuable red Clinton iron ore, with a thickness of from a few inches to 8 feet; in ridges of East Tennessee and along the east foot of Cumberland Plateau, and in small thickness in Middle Tennessee.

Clinch sandstone.—Hard, gray sandstone in crests of mountains in East Tennessee; 200 to 500 feet thick.

Bays formation.—Red calcareous and argillaceous sandstone and limestone; 200 to 500 feet thick. East Tennessee.

ORDOVICIAN, OR LOWER SILURIAN SYSTEM.

Sevier shale.—Light blue sandy and calcareous shale, with beds of shaly limestone and argillaceous marble 1,000 to 1,500 feet thick. In East Tennessee.

Mannie shale.—Brown and blue shaly clay, in the western valley of Tennessee; 0 to 25 feet thick.

Ferndale formation.—Blue shale in upper half; coarse-grained, cross-bedded, light-colored phosphatic limestone, in lower half; 0 to 35 feet thick; in embayments in western Middle Tennessee.

Arnheim (Warren) formation.—Coarsely crystalline, phosphatic limestone, with abundant chert. Three feet thick. Western valley of Tennessee.

Tellico sandstone.—Bluish gray and gray calcareous sandstone and shale, 800 to 900 feet thick; in knobs of East Tennessee.

Leipers formation.—Knotty, earthy limestone to uniform granular limestone, the whole highly phosphatic; 0 to 100 feet thick.

Athens shale.—Light blue calcareous shale to black carbonaceous shale; 1,000 feet thick.

Catheys formation.—Fine-grained blue, earthy limestone at the top, shales and limestone in the middle, heavy-bedded subcrystalline limestones at the bottom, sometimes including phosphatic layers; 0 to 1,000 feet thick.

Bigby limestone.—Uniform, granular limestone, or laminated limestone, with thin beds of shale; 30 to 100 feet thick. Main source of "brown" phosphate.

Hermitage (Saltillo) limestone.—Even-bedded limestone alternating with thin layers of argillaceous, siliceous limestone, shale and siliceous, granular limestone; more or less phosphatic in upper part. Thickness, 40 to 70 feet.

The last three formations are recognized only in the western part of Middle Tennessee.

Moccasin limestone.—Red and gray, flaggy limestone and calcareous shale; 300 to 500 feet thick. Northern part of East Tennessee.

The following occur in rings about the Murfreesboro limestone, which has a circular outcrop at Murfreesboro:

Carters limestone.—Heavy bedded, fine grained, white to light blue limestone, with chert; 40 to 50 feet thick.

Lebanon limestone.—Thin-bedded, often shaly, fine grained, blue or dove colored limestone; thickness, 70 to 100 feet.

Ridley limestone.—Thick-bedded, light blue limestone; 95 feet thick.

Pierce limestone.—Thin-bedded, bluish, fossiliferous limestone; 27 feet thick.

Murfreesboro limestone.—Light blue, heavy-bedded limestone, often cherty; 70 feet thick.

All of the following formations are found only in East Tennessee, except small outcrops in the Wells Creek Basin, reaching down to the Knox dolomite:

Chickamauga limestone.—Blue and gray limestone, sometimes massive, sometimes shaly, and containing the Holston marble, and the Lenoir limestone at its base. Thickness 0 to 2,400 feet.

Holston marble.—Layers occurring in the Chickamauga limestone. Variegated marble, brown, red, gray and white. Thickness 0 to 300 feet.

Lenoir limestone.—A stratum of blue, shaly limestone at the base of the Chickamauga. Thickness 50 to 600 feet. Probable source of cement limestone.

Knox dolomite.—Only the upper part of the Knox dolomite is of Ordovician age, however, will be all described here: magnesian limestone, light and dark blue and white, with nodules of chert. A few thin standstone beds. Thickness 3,000 to 4,400 feet.

CAMBRIAN SYSTEM.

The Knox dolomite forms the upper part of this system in Tennessee.

Nolachucky shale.—Yellow, red and brown calcareous shale, with a few limestone beds; 400 to 750 feet thickness.

Maryville limestone.—Massive blue limestone; 500 to 750 feet thick.

Rogersville shale.—Bright green, clay shale, with limestone beds; 70 to 250 feet thick.

Rutledge limestone.—Massive blue limestone, with a few shale beds at the base; 200 to 500 feet thick.

Connasauga shale.—The name used for the last named four formations where not differentiated; 500 to 6,000 feet thick.

Honaker limestone.—The name used for the last three formations when not differentiated.

Rome formation.—Red, green, yellow and brown shales and sandy shales; in the lower part sandstones and shales of the same color. Also called the Russell formation; 1,600 to 2,600 feet thick.

Beaver limestone.—Massive, blue limestone; 300 feet thick.

Apison shale.—The upper 200 feet green, argillaceous shale, with 900 feet or more of bright red, green and brown, sandy shales below; 1,500 feet thick.

Watauga shale.—The name used for the formations, including the Rome and Apison, where not differentiated.

Shady Limestone.—Gray, bluish gray, mottled gray and white limestone, with masses of chert; about 1,000 feet thick.

Hesse, or Erwin quartzite.—Massive, white quartzite and sandstone; 700 to 800 feet thick.

Murray slate, or Hampton shale.—Bluish gray to gray, argillaceous, sandy shale and slate, with thin sandstone seams; 300 to 400 feet thick.

Nebo quartzite, or sandstone, Tusquito quartzite.—Massive, white quartzite and sandstone, coarse and fine, with a few layers of sandy shale, reddish sandstone; 20 to 900 feet thick.

Unicoi formation.—Massive white sandstone, feldspatic sandstone and quartzite, with interbedded shales and sandstones in the upper part. A thin bed of amygdaloid near the middle and conglomerate arkose and graywacke in the lower part; 1,500 to 2,500 feet thick.

Nicholas shale or Nantahala slate.—Bluish gray to gray, argillaceous and sandy shale, with thin sandstone layers; 400 to 700 feet thick.

Cochran conglomerate, or Great Smoky conglomerate.—Massive quartz conglomerate and quartzite. Light and dark gray, with dark slate, altered toward the south into coarse and fine graywacke quartzite, with beds of black schist, mica and ottrelite schist; 200 to 6,000 feet thick.

Clingman conglomerate, Hazel slate, Thunderhead conglomerate.—(Names used for metamorphosed portions of the Cochran conglomerate as a part of the "Ocoee," when their stratigraphic position was unknown.)

Hiwassee slate.—Blue, gray, black and banded slate, with a fine mica schist; includes layers of sandstone conglomerate and beds of calcareous sandstone; 500 to 1,500 feet in thickness.

Cade's conglomerate, Pigeon slate.—Ocoee names corresponding to the Hiwassee slate, the names having been used before the correlation was determined.

Snowbird formation.—It contains the Starrs conglomerate lintel.

Sandsuck shale.—The name used for the Hiwassee and Snowbird formations where not differentiated.

Citico conglomerate, Wilhite slate.—White slate formations. Names of the "Ocoee," used before their correlation had been determined.

In the Nantahala folio a metarhyolite and the Lynnville metadiabase are questionably assigned to Algonkian age. Below those are the granites to which the names Beech granite, Max Patch granite, and Cranberry granite have been given.

A BRIEF OUTLINE OF THE GEOLOGIC HISTORY OF TENNESSEE.

Our first knowledge of Tennessee comes in early Cambrian time, during which time, it has been recognized, some of the rocks of East Tennessee were laid down. That a vast extent of time existed before the Cambrian, and that during pre-Cambrian time Tennessee may have had as many interesting episodes as since that time is well recognized, but the records of those episodes have been erased and can not be followed today. In early Cambrian, or Georgian time the whole State appears to have been a land surface, except the extreme eastern edge and the Valley of East Tennessee. There, in a long strip of water, extending northeast and southwest, shales and sandstones were being laid down. In upper Arcadian time the north part of Middle Tennessee alone was out of water, and the rest of the State was receiving deposits, still largely shale and sandstone, though some limestone deposits were laid down in the eastern counties. In late Cambrian time all of the State was under water receiving the Knox dolomite, which shows in East Tennessee, and the Wells Creek Basin of Stuart and Houston counties. In Lower Ordovician time the State was still under water, with limestones being laid down and dolomite, as in the upper Knox dolomite. Similar conditions existed through middle Ordovician time, or Stones River time, the marble of East Tennessee being laid down at this time, and the limestones which now form the surface over the center of the basin in Middle Tennessee. In Lowville time a large dome lifted most of the Central Basin out of the water, and a thin strip in East Tennessee, but the rest of the State was still receiving deposits. With the beginning of the Trenton there was a subsidence, and most of the dome was submerged, the submergence continuing until in Middle Trenton the dome was entirely submerged. Vast quantities of almost microscopic shelled animals, whose shells were composed of lime phosphate instead of lime carbonate, resulted in the phosphate deposits of Western Middle Tennessee, while in the eastern counties the deposits were mostly shale, with some limestone.

Then came a general uplift in Utica time, and no deposits were laid down in the State. This land condition continued into Lorraine time, when subsidence allowed deposits over most of Tennessee, the Leipers formation in western, and the Tellico sandstone in eastern Tennessee, were laid down. The old dome about Murfreesboro was still apparent; its center not having been submerged.

In Richmond time the land conditions extended to the southeast by emergence, with deposition in East Tennessee, and west of the basin of the Central Basin. The emergence continued into the early part of the Silurian, or until all of the State was out of water, except a narrow strip in East Tennessee where the

Clinch sandstone and Bays formation were laid down, and west of the Tennesse River. In late Clinton time there was wide submergence over all except the Central Basin, and the deposition of the red fossil iron ore in East Tennessee and west of the Central Basin. In the middle Silurian the Central Basin and Eastern Tennessee were above tide, while deposits were being laid down in West Tennessee, the area of sea gradually narrowing until at the end of the Guelph time land conditions existed all over the State. The Silurian closed with a small incursion of the Bristol district.

At the beginning of Devonian there was a general incursion of the sea from the south in West Tennessee and the Chattanooga district with a fluctuating shore-line. These fluctuations continued, sometimes the State being entirely out of water, until the Chattanooga black shale was laid down over nearly the entire State.

During Mississippian time the State was generally under water, though for short periods, as during Forest Glen, uplifts raised most of the State above sea-level.

In early Pennsylvanian time the plateau region was an area of swamps, with many fluctuations bringing in deposits of shales, sandstones, and limestones, but alternated with the swampy conditions, which resulted in coal. The land must have been low, and probably near sea-level. Middle Tennessee remained above tide, and western Tennessee was probably receiving marine deposits.

In late Pennsylvanian time this State became a land area and remained so through most of the Mesozoic, or until well into the Cretaceous. This long land period, however, followed great structural changes in East Tennessee. All through the Cambrian, Ordovician, Silurian, Devonian and Carboniferous time vast deposits of rock were being laid down in East Tennessee. Though there were many slight uplifts with land conditions, on the whole the land had been sinking, and into the great basin thus formed sediments had been accumulating until they had a depth of many miles, and corresponding quantities of rock had been removed from adjoining parts of the earth's crust. Without going into detail, the final result was the need of readjustment of weights and strains over a large area of the earth's surface (for similar conditions had existed extensively). Without concerning ourselves with what may have taken place at a considerable depth, at the surface there was a gradual apparent giving away along the whole eastern part of the United States, the forces apparently acting from the southeast, the rocks being pushed to the northwest, folding, breaking, squeezing up into mountains, and at the east becoming crushed and metamorphosed. It should not be thought for a moment that this change took place suddenly. It is more than probable that had we been living at that time we should have had no more visible evidence of the enormous changes taking place than they have today in California and Japan, where it is evident that earth forces are engaged in some stupendous changes in the earth's surface. It should be remembered in this connection that close studies of the sea-level show that nearly everywhere on the face of the earth the land adjoining the sea is either slowly rising or sinking, and such forces as those which folded up the Appalachian Mountains are still active, and may be in active progress in many parts of the globe today. Again, it should not be supposed that because this great thickness of rocks was shoved into great folds, which if complete would extend many miles above the present surface, that mountains of such height ever existed in the eastern part of the State. Just as the mountain-making forces probably acted with great slowness over long ages, so at the same time the forces of erosion during those same ages were actively cutting down the mountains, though possibly not as fast as they were uplifted, but on the whole, during this long land period, covering most of the Mesozoic era, the surface of the rocks of this State appear to have been worn down more or less nearly to a gentle plain. The Unakas on the east edge of the State, and many of the higher mountains in the northeastern part of the plateau region, still projected above this gentle plain as hills or small mountains. Early in Cretaceous time there appears to have been seaward tilting of the land, allowing the Cretaceous sea to creep up over the land, resulting in extensive deposits along the Atlantic Coast, and in the southwest corner of the State. During Cretaceous time this movement continued, so that in Middle Cretaceous time all of West Tennessee was under water and receiving deposits. With many variations this condition continued through the Lower Tertiary or Eocene time, when again general land conditions ensued. In Pleistocene time West Tennessee appears to have been under water and deposits of sand and loam laid down. It was during this time that the northern part of the United States underwent a series of invasions by great ice-sheets, and the water from these ice-sheets brought large deposits along the Mississippi Valley; the final retreat of the ice ushered in the present conditions, which have changed little since then.

In addition to the movements which have influenced the position and character of the deposits, have been broad movements, recorded mainly in the physiography of the State—the uplifting of the Cumberland Plateau, the erosion of the Basin of Middle Tennessee, in the many changes in the courses of the Tennessee and other rivers. Space will not permit of going into details of these movements and changes here.

THE LAY OF THE ROCKS, OR STRUCTURE OF TENNESSEE.

In the eastern edge of the State, in the flanks and foothills of the Unakas, the rocks have been subjected to pressure, folding, and possibly heat, until they have lost all resemblance to their original condition, and appear as a great complex or mixture of granites, gneisses and metamorphosed slates, quartzites and conglomerates, of which it is hardly possible to more than map the area of surface exposure without attempting to determine the unknown extension of the rocks underground.

Coming out into the Great Valley the slates and quartzites change to shales and sandstones, and the great body of late Cambrian and post Cambrian limestones are found across the whole width of the Valley. These rocks have been closely folded in long, often straight, northeast-southwest folds, as though compressed from the southeast, just as when a bolt of cloth lying spread out on a counter is pushed from one end. The beds of rock have been pushed forward until they are found standing at high angles, or vertically, or frequently overturned. Close study has shown that often these folds have broken, and parts of the rocks have been shoved over the adjoining rocks, sometimes for miles.

The movement seems to have largely spent itself in the Valley, for on reaching the Plateau it is found that in a very short distance the rocks become horizontal and apparently unaffected by the folding. That they were affected by the titanic forces that produced the folding and yielded to them to a certain extent is shown by the existence of the sharp Sequatchie Valley fold well within the plateau region, extending two-thirds the way across the State, and by the Pine Mountain fault and other faults at the north where the strata have been forced forward several miles overriding the strata behind them.

In general, from the eastern front of the Plateau the strata have a gentle rise to the northwest until the Cincinnati-Nashville arch or anticline is reached, when they turn and descend gradually to the west. The axis of this arch passes near Murfreesboro. This arch has been further affected by another less pronounced articline extending from the northwest to the southeast across the State, crossing the axis of the first arch near Murfreesboro and the plateau region near Chattanooga. The effect has been to produce a sort of dome where the two axes cross near Murfreesboro, the lowest formation there being exposed in an oval and the successively higher formations appearing in oval rings around it. The Central Basin owes its existence to this domed structure, and not to its having been a lake basin, as has sometimes been suggested. The affect of the northwestern axis on the coal-bearing rocks is seen in the fact that while at the north edge of the State the base of the coal measures is 1,000 feet below sea-level, at the south end of the State the same base is 1,500 feet above sea-level. Though the general dips in all of the central plateau regions are very slight, there are many local rolls in the strata, and occasionally small faults. West of the Cincinnati-Nashville anticline the rocks are nearly flat, with a slight westward dip until they disappear under the Cretaceous rocks of West Tennessee. The working out of the structure west of Murfreesboro is complicated by the fact that this arch begins to date away back in Ordovician time, at which time the axis rose above sea-level, and the succeeding formations for the most part were deposited against the irregular flank of the exposed arch.

Thus the relation of the Palezoic rocks to the overlying Mesozoic has not been worked out. Whether deposits were laid down in a basin carved out of the earliest rocks, whether they were deposited in overlapping sheets on the sinking floor of the earlier rocks, or whether the earlier rocks were first beveled and then overlapped, has not been shown. The later rocks of Cretaceous and Eocene age have a gentle dip to the westward and the Mississippi River. The Quarternary beds are most prominent in West Tennessee, lying as a mantle over the irregular surface of the earlier beds.

ALPHABETICAL LIST OF THE MINERALS OF TENNESSEE, WITH A BRIEF NOTICE OF THEIR OCCURRENCE, USE, ETC.

Alum.—Alum is a white mineral, with a well-known taste. It is found in nature as a silky efflorescence or crust on the edge of the shales, especially where protected from the weather, as in rock-houses, where shales containing pyrite have weathered back under an overhanging ledge of sandstone. The alum is formed by the oxidation of the pyrite into sulphuric acid, which then combines with the alumina of the shale, and with some other element usually present in the shale, as potash, in the formation of common alum, or with iron, magnesia or soda to form other alums.

Alum occurs abundantly in the "rock-houses" of Tennessee, notably in Cannon, Coffee, DeKalb, Franklin, Giles, Jackson, Lincoln, Overton and Putnam counties. It is not known that any alum is obtained in this State on a commercial scale at present.

Barite, or Barytes.—Tennessee stands second among the States in the production of barytes, being exceeded only by Missouri. Barytes, often called heavy spar from its weight, is barium sulphate. It has the formula $BaSO_4$, or $BaO+SO_3$, (baryta) 65.7% sulphur trioxide 34.3%=100. It is a heavy mineral, commonly having a white color, but with a range to dark brown.

Its principal use is for the adulteration of white lead; the mixture Venice white lead contains one-half barytes, and Hamburg white contains two-thirds barytes, and Dutch white three-fourths barytes. It makes the paint very opaque and less acted upon by sulphuric vapors. It is also used for refining sugar, enameling iron, oil clothes, paper collars, rubber, lithophane, and as a general adulterant.

Barite usually occurs in more or less nearly vertical veins, usually not more than one foot wide running through the country rock. In Tennessee the country rock is commonly limestone. The ore is often the gangue rock of lead ores. It occurs in all of the limestone counties of the State, but is workable, or has been worked in only a few. It was known in Tennessee as early as 1840, when a large body of it was discovered by Col. R. C. Morris, in McMinn County, on the point of the ridge between Mouse

Creek and Hiwassee River. In 1873 over 1,000,000 pounds of barytes were shipped from Greene, Hamblen and Monroe counties. In 1907 shipments were being made from Loudon, McMinn and Monroe counties, to the extent of 20,861 tons, and with a value of $37,138, at an average price of $1.78 a ton. Monroe County furnishes the larger part of the supply. There is only one mill in the State for refining the product, located at Sweetwater. In Smith County a vertical vein one foot or more thick has been traced for several miles, which is associated with calcite, fluorite and zinc blend. It has been dug near the Trousdale Ferry-Lebanon Road. In addition to the counties mentioned, it has been mined in Bradley, Washington and Jefferson counties.

The barytes appears to have been deposited from water solutions. In at least most cases, it appears to have been associated with lines of faulting, though it is of distinctly later origin. Near Cleveland, for example, the barytes fill groups of fissures in the Knox dolomite, with much metasomatic replacement of the rock wall. At Sweetwater the fissures are often only partly filled.

Bauxite.—Bauxite is an aluminum iron hydrate. The well-known Georgia bauxite, to which the Tennessee ore is similar, contains about 60% alumina, Al_2O_3; 32% of water, H_2O; 5% of silica, SiO_2; 2½% of titanium dioxide, TiO_2; 1½% of iron oxide FeO_3. It is used in the manufacture of alum, aluminum alloys and compounds, and the metal aluminum. Bauxite has long been known in Georgia, where it occurs in the Knox dolomite in association with faults. It is also associated with kaolin and iron ore. The mineral usually occurs as small balls, or concretions, of reddish yellow color in a similarly-colored matrix. The balls may be as large as marbles, or up to 1½ inches in diameter, and down to the size of fish-roe (oölite) or smaller. The size of the balls forms the basis of classification into pebble ore, pisolitic ore, or oölitic ore. The vesicular ore is the matrix left at the surface by the dropping out of the concretions. When the ore is structureless, or hardly shows the concretionary structure, it is called amorphous ore.

While it is probable that bauxite ore may be found in many places in Tennessee when definite prospecting of the zones of faulting in the Knox dolomite is undertaken, up to the present only one deposit has been worked. This occurs on the southeast slope of Missionary Ridge, near Chattanooga. This is doubtless the northward extension of the better known fields of Georgia.

The National Bauxite Co. was mining ore in 1907 from two pits 250 yards apart. The ore varies from the pebble variety to what is known as "block" ore, having only a small number of concretions in it. The former has the usual light color, while the latter varies from light to dark olive gray ore. The ore is rich in alumina and low in both iron and silica.

Cement—Portland.—For the present purpose it is sufficient to state that the Portland Cement problem is to find sufficient quantities of pure non-magnesian limestone in close proximity to suitable beds of clay or shale, near a railroad, and preferably near a cheap supply of coal. The problem is almost, or quite as much, an economic one as a geologic. The problem does not seem to have been studied with care in this State, unless by private parties, who have published no report of their findings. Lacking analyses of both limestones and shales, the best that can be done is to point out where conditions would seem to be favorable.

In a general way, it would seem that the most favorable places would be found along the east front of the Cumberland Plateau, in the Sequatchie Valley, and on the west front of the Plateau. The plateau contains coal, which could be delivered direct to the plants. The coal measures contain many beds of shale, besides the clays under the coals. While the lower flanks of the mountains are largely composed of the Silurian and Carboniferous limestones. The Queen and Crescent Railway skirts the east front of the Plateau from Chattanooga to Harriman; the Nashville, Chattanooga & St. Louis Railroad runs up the greater part of the Sequatchie Valley and reaches many points along the western escarpment. The Tennessee Central Railroad crosses both faces of the plateau. Within 50 feet of the base of the coal measures the writer has found limestone resembling structurally the Bedford stone of Indiana, though not of quite as high grade. It should prove suitable for cement. Other limestones lower down the flanks of the escarpment would doubtless be found equally suitable. Cumberland Gap is typical of many points, having limestone, coal, clay and transportation all at hand.

The second place of promise would seem to be the limestone and marble quarries of both East and Middle Tennessee, where often large quantities of refuse rock is available, or is being produced. At such places the cost of the limestone is reduced to the minimum, and there is apt to be good railroad connection.

Among the limestones of the Great Valley would be mentioned first the Lenoir limestone, just overlying the Knox dolomite. The Lenoir corresponds in position with the "Trenton" limestone, extensively used for cement in the northern part of the Appalachian Valley. Locally, it is a marble, analysis of which shows as high as 99% of pure calcite. It is closely associated with the Athens shale, which could doubtless furnish the necessary clays for mixing. In places this limestone is several hundred feet thick. Of the other limestones, most of the Chickamauga is low in magnesia, as well as limestones in the Sevier shale.

In the Central Basin are a great variety of limestones, most of which are rather high in clay, but they are in the main non-magnesian, and in many places are pure enough for cement. The Trenton limestones in the counties bordering the Cumberland River are particularly promising. Unfortunately no analyses of the limestones exist, nor has the area been especially studied for its cement possibilities. At present there is only one cement plant in the State—the Dixie Portland Cement Co., operating at Richard City, Marion County. In 1908 they produced 272,731 barrels, valued at $295,913.00.

Cement—Natural.—Under the preceding heading the statement was made that many of the limestones of the State are argillaceous, or contain a considerable admixture of clay. In many cases analyses would doubtless show that the relative proportion of carbonate of lime and clay is such as would make a natural hydraulic cement. Such a limestone has been used for making natural cement in Harding County, near Clifton, and the cement made there appears to have been of good grade. Among the counties which it is believed will prove to show natural cement limestones may be mentioned: Harding, Wayne, White, Decatur, Warren, Montgomery, Knox and McMinn. In Knox County cement has been made of the brown, calcereous shales.

Chert.—Chert is the amorphous form of quarts, or silica. It is of interest in this connection because of its value in road building. The cherts of the State (including the variety called "novaculite") probably make by far the best materials for macadam roads in the State. It is so far superior to the limestone, which at present is mainly used, that some day its use will entirely supersede that of limestone wherever it can be obtained. It appears to wear much better than limestone, as it is much harder, packs better, does not become dusty in dry weather, nor muddy in wet weather. Where it outcrops or accumulates on top of the hills it often makes natural roads of the highest character. Where it slides down on to a road only in large pieces, or is placed on a road in that shape, without rolling or coverings, it naturally is hard on horses or tires. In Tennessee, chert occurs most abundantly in the lower part of the Knox dolomite, of Cambrian age, and in the Tullahoma formation of early Carboniferous age. (See under Novaculite for "Camden Chert"). The Knox dolomite is practically confined to the Valley of East Tennessee, where it covers large areas and is very abundant. In many cases the cherts of the lower part of the formation have been the cause of ridges, the chert being left when the limestone, or dolomite, dissolved and by its accumulating and protecting the underlying rocks formed the chert ridges. Such ridges are found all over East Tennessee, so that in most cases it would be but little more difficult to haul in the chert from the ridges and crush it in a rock-crusher for the roads in the valley than to use the limestone usually found in the valley itself.

The Tullahoma chert forms the edge of the basin of Middle Tennessee on all sides. In many places the formation appears to be solid chert for several hundred feet, the chert occurring in thin plates, continuous, though irregular, tending to break up into small pieces, or splinters. Often the formation weathers down in the hills to a depth of from 40 to 60 feet, when it can be dug out with a steam shovel, and when placed on the road this weathered chert makes an excellent top dressing, as is well seen at Centreville, Hickman County, and elsewhere. Large deposits of the material could readily be obtained for shipment wherever railroads climb or skirt the edge of the Highland Rim, as near Normandy, west of Nashville, on the Centreville Branch of the Nashville, Chattanooga and St. Louis Railroad, and on the Tennessee Central Railway east of Nashville.

Clay and Shale.—Tennessee, in 1908, stood twenty-fourth among the States in the production of clay products, having produced that year $1,129,174 worth of brick and tile, and $122,555 worth of pottery, a total of $1,251,728, as compared with $1,613,862 worth in 1907. The value of the clay mined and shipped is estimated at $77,680, most of that being ball, saggar and fire clay from Henry County. Brick clays are common throughout the State, as is evidenced by the fact that brick plants are maintained in about one-half of the counties of the State. Front brick are made in Blount, Davidson, Hamilton, Knox and Madison counties; ornamental brick in Davidson and Knox; fire brick in Hamilton, Knox, Madison and Putnam counties.

In East Tennessee the residual red clays of the Chickamauga limestone make good brick, and that as well as some of the Cambrian shales are extensively used for tile. The calcareous Athens shales yield a brick clay worked at Mayesville and Knoxville, as do also the Knox dolomite, the Connasauga shale, the upper part of the Rome formation and the shales of the Bangor and Chickamauga limestone formations. Fire brick is made at Cleveland from silicous residual clays of the Knox dolomite. The red and blue residual clays of the Bangor are worked in Warren, DeKalb, Grundy, White and Van Buren Counties.

In the coal field practically all of the coal beds are underlain by clays, some of which will doubtless prove suitable for the manufacture of fire brick. No flint clay has yet been reported in this State. The coal field also contains large quantities of shale, some of which will doubtless prove suitable for paving brick and other brick. This is as yet an entirely unexploited field and practically unexplored.

The great Central Basin of Tennessee is underlain almost entirely by limestones. These yield residual clays, and doubtless exploration will reveal many shales, or other bedded clay deposits of value. In the district between the Central Basin and the Tennessee River on the west numerous deposits of fire-clay have been found in Stewart and Houston counties. The clay is grayish white and was used for many years in making fire brick for the rolling mills.

West Tennessee is abundantly supplied with clays, and some day should be the seat of a great clay industry. The fact that some of the clays of Carroll and Henry counties have been shipped to Akron and East Liverpool, Ohio, and Louisville, Ky., is evidence of their good quality. The clay immediately below the LaFayette formation yields stoneware and fire-brick clay. Many of the quarries show from 25 to 35 feet of clay. Some of the "ball" clay of Henry County has the composition of almost pure kaolin. It will run from 60% to 75% of non-plastic material. Pottery is made in a number of the counties of West Tennessee, as well as drain tile. The industry, however, is as yet in its infancy.

Kaolin has been found in small quantities in Carter and Carroll counties, and probably will be found in other counties. In the past but little special attention has been given in the field to the study of clays of the State. It is believed that when a comprehensive study is made that this State will be shown to have an abundance of clays and shales suitable for all purposes.

Coal.—Tennessee ranks eleventh among the States in the production of coal. In 1907 this amounted to 6,810,243 short tons, and in 1908, 6,199,171 tons. The coal field has been estimated to have an area of 4,400 square miles. Mr. M. R. Campbell has estimated the original contents to be 25,665,000,000 short tons. The figures for production up to the close of 1908 show 90,503,772 tons taken from the ground, equivalent to an exhaustion of 135,000,000 tons, or one-half of one per cent. of the total. At the rate of exhaustion in 1908 the coal in this State, as estimated, would last 2,475 years. It may be noted, however, that the production has been increasing rapidly, as it has in other States. Taking the figures from 1850 to 1908 the production has more than doubled on the average of every ten years. From 1870 to 1900 the production increased more than three times every ten years. From 1900 to 1908 the production nearly doubled. If the production were to continue doubling every ten years, as it has in the last 70 years, the coal would be exhausted within 110 years from now.

The coal field of Tennessee is coincident with the Cumberland Plateau lying in a northeast and southwest direction across the State a little east of the center. The field has an average width of from 35 to 50 miles. It covers practically all of Morgan, Scott, Sequatchie and Bledsoe counties; the western part of Claiborne, Campbell, Anderson, Roane, Rhea and Hamilton counties; nearly all of Fentress, Van Buren and Grundy; and a part of the eastern side of Pickett, Overton, Putnam, White, Warren, Coffee and Franklin counties.

The coal-bearing rocks have a thickness of 4,000 feet at the north end of the State. To the south the whole body of rocks has been raised so that their base is about 1,500 feet above tide, and all the upper rocks have been carried away. At the north end of the State at least 50 beds of coal have been noted in Bryson Mountain, while at the south only the basal 6 or 8 remain.

Safford divided the coals into three groups, separated by widespread, massive sandstones. The lowest group he called the "Bon Air" group. This included the Bon Air, Nelson, Soddy, Lower Etna, the Castle Rock and Dade coals, worked mostly along the western edge of the basin.

The beds are all of irregular thickness, ranging from a knife-edge to 12 feet, or more, though they are seldom more than three feet over any large area. In most places not more than two of the beds are workable, and in many places all of the beds will be found to run thin. Rocks contained in this group are thin on the west side of the field, but reach a thickness of 600 to 700 feet on the east side of the field. Between this and the next overlying group is the massive Bon Air or Sewanee conglomerate, a heavy bed of sandstone 40 or 50 feet thick that makes conspicuous cliffs along the west edge of the Cumberland Plateau, or Sequatchie Valley and along the eastern face of the plateau escarpment.

The second group of coals, the "Tracy City" group of Safford, contains the Kelley, Richland or Whitwell bed, just on top of the Bon Air conglomerate; the Sewanee bed 40 to 50 feet higher; the Walker bed still higher and others above not now being worked. These coals, like those of the first group, are irregular in thickness, sometimes maintaining a thickness of five feet over quite an acreage, but usually not running over three feet, and they are too thin to work over large areas. In local basins, or "pots," they may thicken up to 7 or 8 feet, or even up to 18 feet. The rocks containing this group have a thickness of 500 to 700 feet along the eastern edge of the basin, but thin to a feather-edge on the western side of the field. Above this second group of coals is a second great sandstone, called the "Emory" sandstone, that makes a conspicuous bluff at the top of the eastern escarpment of the Cumberland Plateau from near Chattanooga at least as far north as Harriman.

The third group of coals, called by Safford "The Brushy Mountain Group," extends through rocks having a thickness of several thousand feet. Practically all of the coals being mined in the northeast part of the field belong to this group, the first two groups being below drainage in most of that area. In Bryson Mountain, Claiborne County, this group contains 50 beds with a total measured thickness of about 95 feet. Of these beds thirteen are over two feet thick, and seven were being worked in 1902-3 when examined by the writer. The beds being worked there showed an average thickness of from 4 to 6½ feet, with a range of from 3 1-3 to 9 2-3 feet. Most of them contain some partings, and that reduces the available coal by six inches to one foot. Such large numbers of coal are only found in some of the highest mountains—unreduced residuals projecting well above the level of the Cumberland Plateau. There remain, therefore, very small areas of the uppermost coals, and even the areas of the lower coals of the group have been much reduced by erosion. The upper coals are not only thicker, but much more regular than the coals of the lower groups. The coals of this group occur only in the northeast part of the field, having been eroded from the western and southern parts, being confined mainly to the area northeast of the Queen & Crescent Railroad above Harriman.

The coals of Tennessee are of the bituminous variety, and most of them will coke, yielding from 48 to 60 per cent. The coal of the Jellico field produces an indifferent coke, but it has a wide reputation as a very high-grade household coal. The coals of the lower groups, as a rule, are cleaner and harder than the higher coals.

Cobalt.—Traces of cobalt in the form of asbolite, or black cobalt oxide, have been found in Hickman County. The ore occurs in managanese oxide, or wad, as an earthy black to blue mass deposited in boggy places. Mr. Lucius Brown, State Chemist, states that none found has yet analyzed over 2% of cobalt, compared with South Carolina ores that yield 24% of cobalt oxide and Missouri ores that yield 40%. The cobalt bearing wad is found at a number of points near Centreville, in Hickman County. It attracted considerable attention about 1907, through the interest of Thomas Edison, who was then looking for a supply of cobalt in connection with his studies of secondary batteries. It is possible that other deposits of wad in the State may be cobalt bearing, and ore of value may yet be found.

Copper.—Tennessee stands sixth among the States in the production of copper, with a production in 1908 of 19,459,501 pounds, valued at $2,568,654. In 1907 the copper output, though smaller, was valued at $3,778,623. The production comes entirely from the region about Ducktown, in Polk County, in the extreme southeast corner of the State. Two companies produce all of the ore.

The ores occur in a belt two miles wide by four miles long, lying in a northeast-southwest direction. They occur in fissure veins from a few feet to one hundred and fifty feet wide, in metamorphoric schists. The veins are nearly parallel to the schistosity dipping about 50 degrees, S. 65 degrees to 70 degrees E., apparently in slip planes of fault fissures following the foliation. The ore, which is mainly an iron ore, contains very near 10% of copper ore, averaging about 3½% of metallic copper. The ore is chiefly pyrrhotite or magnetic pyrite, or iron sulphide, with which is inextricably mixed finely disseminated chalcopyrite, or copper pyrites. The latter, when pure, contains roundly one-third copper, one-third sulphur and one-third iron. The ore contains an average of about 31.4 pounds of copper per ton. In addition there occur small quantities of native copper, malachite, cuprite, chalcanthite and chalcocite. The latter is the black sulphide of copper, and was the common ore at first, until the workings reached below the belt of surface weathering. In the weathered belt at the surface the pyrrhotite has weathered into limonite, forming a great cap or "gossan," which has been used as a source of iron ore. The black ore near the surface was formerly thought to be the black oxide, but more recently shown by Mr. W. H. Weed to be the black sulphide. This ore is now exhausted. It had a thickness of from a few inches to eight feet or more. In addition to the copper, the mines also yield iron, as just stated. Gold, silver, and small amounts of lead and zinc ore are found.

Copper ore appears to have been known in Tennessee in 1843, but not actively mined until about 1850. In 1855 there was shipped 14,291 tons, worth, at that time, $1,000,000. After the exhaustion of the black surface ore, mining nearly ceased until 1889, when the Marietta and North Georgia Railroad entered the district and mining took a new lease of life. In 1899, the Tennessee Copper Company began the opening up of their mines, which is the beginning of the present development. In 1908 several of the mines were down to the depths of from 700 to 800 feet or more, and some of the levels have followed the vein three thousand feet or more and are still in ore. Recently an expensive plant has been installed at Ducktown to conserve the sulphur fumes formed in the reduction of the copper and convert them into sulphuric acid.

Copperas.—Copperas is iron sulphate. It occurs in nature through the action of the atmosphere on pyrite. It is found in many of the "rock-houses" of Tennessee, especially where the underlying shale is the Chattanooga black shale, which commonly contains pyrite. It only accumulates where it is sheltered from the weather.

Today practically all of the copperas of commerce is made artificially. At one time it was manufactured extensively in Ducktown from the refuse of the copper mines, but probably all of it is obtained now as a by-product in the manufacture of wire and sheet steel.

Dolomite.—The Knox dolomite of East Tennessee has been used very extensively for abutments of railroad bridges and similar structural work. It is readily cut and dressed, and due to its firm, fine structure, is capable of standing great weight. It splits readily along bedding plains six inches to three feet apart, and resists frost and heat well.

Epsom Salts.—The mineral epsomite is found at many points in the State associated with alum and copperas. It does not appear to have been made use of at all in a commercial way.

Fluorspar.—Fluorite, or, as it is commonly known, "Fluorspar," is calcium fluorite. In its purest form it is used in the manufacture of opalescent glass, enamels, agate ware, hydrofluoric acid and other compounds of fluorine. Slightly lower grades are used in the manufacture of open-hearth steel, to increase the fluidity of the slag. Still lower grades are used in foundry work. The use of hydrofluoric acid in etching glass is well known.

Tennessee has never been a large producer of fluorspar. From 1902 to 1906 small quantities were mined in Smith, Trousdale and Wilson counties. The ore is high-grade, and occurs in fissure veins intersecting limestones of Ordovician age. It is said that lumps of pure fluorspar weighing 1,500 pounds have been taken from these deposits. No igneous rocks have been reported as occurring in the neighborhood of these veins, as they do in Kentucky and Illinois. In some cases the fluorspar is associated with barite.

Gas.—(See under heading "Oil").

Glass Sand.—Sandstones and conglomerates of the coal field are often made up of white sand and pebbles. When quarried, crushed, separated and washed, they are suitable for the best grades of plate-glass. Some have been shipped to Indiana for use in the glass works of that State. Good sand is found at Coal Creek, in Anderson County, and glass has been made in Knoxville from sand obtained on the opposite side of the Holston River. Benton County furnishes saccaroidal sandstone of dazzling whiteness that should be suitable for the manufacture of glass.

Gold.—Gold has been found in Tennessee only along the eastern edge of the State in the Cambrian or pre-Cambrian rocks on the western flank of the Great Smoky Mountains. Placer gold has been found in the creeks a few miles east of Montvale Springs and back of Chilhowee Mountain in Blount County; in Polk County; and on Citico Creek, Cane Creek, the headwaters of the Tellico River and on Coker Creek, in Monroe County. The last locality has furnished nearly all of the gold found in the State, amounting to probably not over $200,000.

The Coker Creek (Coca or Coqua Creek of the old reports) deposits embrace a strip of country eight or nine miles long by two or three wide. Gold was first discovered here in 1831, followed by the usual "rush," during which the whole region was thoroughly prospected. The gravels at first yielded an average of $2 a day, but gradually decreased to a yield of about fifty cents a day. The largest piece reported found was worth about $20. Later a 6-inch vein of gold-bearing quartz was found on Whippoorwill Branch of Tellico River, and has been worked some. It is more than probable that some day, other, and probably richer, quartz veins will be found. In 1908 Monroe County yielded 21.61 ounces. In the same year 149.33 ounces were obtained from the copper ores of Ducktown, in Polk County, as a by-product.

Granite.—In Tennessee granite is confined to the western slope of the Great Smoky Mountains. At present no granite is being quarried for commercial shipment in the State. Portions of the Max Patch granite, marked by red feldspar, are very ornamental, as are the porphyritic masses in that granite. These beds are often heavy enough to yield large blocks of building stone, though much of the granite tends to be gneissoid. The Cranberry granite is lighter in color and fairly uniform in texture. It would be suitable for many purposes. Large blocks of granite were exhibited at the Centennial Exposition, Nashville, 1897. Granite is found in Johnson, Carter, Unicoi, Greene, Cocke, Sevier, Blount, Monroe and Polk counties.

Green Sand.—Associated with the Selma clays are often found beds of greenish sand. The color is due to the presence of glauconite. Analysis of this green sand usually shows it to contain a considerable percentage of lime, often an appreciable amount of phosphorus. Such a calcereous sand has been called a marl. It is of value as a fertilizer, depending on the amount of lime, phosphoric acid and potash present. It occurs in West Tennessee. Samples showed on analysis 50 per cent. of silica, 10 per cent. potash and phosphoric acid, 2 to 10 per cent. of lime carbonate.

Gypsum.—No workable deposits of gypsum have yet been found in Tennessee. It occurs in small quantities in many of the caves of the State, often making handsome cabinet specimens; sometimes as crystals, or transparent clevage plates; sometimes as rosettes, etc. Small, irregular masses of snowy gypsum are common in cavities in many of the limestones. In some cases these might be separated from the limestones in connection with the quarrying of the whole, but in no place that the writer has seen yet are they in a sufficient quantity or size to make them the subject of commercial exploiting.

Hydraulic Rock.—(See cement).

Iron.—Tennessee ranks eighth in the production of iron. In 1907 she produced 269,182 tons of hematite, 544,508 tons of brown ore, a total of 813,690 tons, with a value of $1,352,131. In 1908 the production was somewhat less, amounting to 226,038 tons of hematite and 409,305 tons of brown ore, a total of 635,343 tons, valued at $876,007. In the production of pig iron the State ranked seventh in 1907 with a production of 393,106 long tons, valued at $7,542,000. In 1908 the production was 290,826 tons, valued at $4,011,000.

It is impossible to estimate correctly the quantity of iron ore now available, or to be available in the future. Very roughly it has been estimated that Tennessee has about 500,000,000 tons of iron ore, of which 100,000,000 tons are now available, and the other 400,000,000 will became available under more favorable mining and market conditions.

The ore occurs in four belts: First—An eastern belt through Johnson, Sullivan, Carter, Washington, Unicoi, Greene, Cocke, Sevier, Blount, Monroe, McMinn and Polk counties, containing limonite, hematite and magnetite. The ores are usually in irregular masses of limited extent, associated with the older rocks and the metamorphosed rocks.

The limonite occurs in compact form, in shapeless masses, in the foothills, spurs, coves and valleys, mingled with clay and cherty masses. When pure it contains 59.52% of metallic iron. The hematite, anhydrous oxide of iron, is of the hard variety. It is found in massive layers in the valley of Stony Creek, in Carter County; in vein-like, nearly vertical masses in Sullivan County; in compast masses in Monroe and Cocke counties; in angular nodules on Cross Mountain; in nearly cubical masses in McMinn County, east of Athens; in Ordovician strata in Loudon County.

Magnetite, the black, magnetic oxide, containing 72% of iron when pure, occurs in many of the older rocks in the mountain spurs of Carter County, where they run down into Crab Orchard Valley.

Second—A belt along the east face of the Cumberland Table Lands and in the Sequatchie Valley. The ore in this case is mainly a red, fossiliferous oölitic hematite ore, known as "Clinton Ore." It has been mined extensively in Hamilton, Bradley, James, McMinn, Meigs, Rhea, Roane, Henderson, Campbell, Union, Grainger, Claiborne, Hancock, Marion, Sequatchie and Bledsoe counties. The ore occurs as a bedded deposit with much regularity, having a thickness of up to six feet. The leached ore at the surface yields about 56% of iron, though the hard, unweathered ore yields much less.

It has been estimated that the ore has an average thickness across the State of 20 inches. In many places there are several beds, though usually there is one bed of importance. This may vary from a few inches to two or three feet thick, occasionally swelling out to six feet. The Clinton ore is also found in many of the ridges east of the Plateau escarpment, though most of the mining has been done among the low foothills just at the foot of the escarpment. The ore should outcrop all along the east side of the Sequatchie Valley. It is hidden by faults on the west side of the Valley. Apparently the same ore was seen by the writer in west Davidson County 5 feet thick, and it is reported that it is extensively exposed west and north of Nashville.

The third belt is co-ordinate with the coal field, and the ores consist of "clay iron stone" nodules in the shales of the coal measure rocks.

The nodules, balls and flattened concretions usually carry 30% to 33% of metallic iron. They occur from the size of small pebbles to masses weighing a ton or more, disposed in layers interstratified with the shales. Much of this ore has been noted below the Wiley coal band in Anderson County and elsewhere. A layer of black band, or coaly carbonaceous iron ore, 6 to 12 inches thick, has been noted near Beersheba Springs, and some limonite is found scattered over the table-land.

The fourth belt is in western Tennessee, covering an area 50 miles wide, or 5,400 square miles. It lies in the counties of Lawrence, Wayne, Hardin, Lewis, Perry, Hickman, Humphreys, Dickson, Houston, Montgomery and Stewart east of the

Tennessee River, and Benton and Decatur counties on the west of the Tennessee River. The ores in this belt are liminite, with some hematite and turgite, and occur associated with the chert and clay from the decomposition of the St. Louis limestone. These deposits in places have a thickness of up to over one hundred feet. The ore makes up from one-half to one-fourth, or less of the mass.

These ores have never been adequately prospected, but sufficient work has been done to show large quantities of ore. The ore typically occurs as layers in intermingled chert and clay, or as "nests," or large, irregularly-shaped masses, or in lumps down to the size of a walnut, usually underlying an over-burden of clay, chert or gravel.

Iron making in Tennessee dates from 1790, when a bloomery was built at Embreeville. In 1856 there were 75 forges and bloomeries, 71 furnaces (using charcoal, and varying in capacity from 5 to 18 tons a day), and 4 rolling mills.

In 1908 there were 67 iron mines being worked by thirty-eight companies, with 17 furnaces in active operation, all but one of them using coke for fuel; seven furnaces were not running during that year.

Kaolin.—(See clay.)

Lead.—Lead ore has not yet been found abundantly in Tennessee, though most of the counties have reported some lead. It is frequently found in the Knox dolomite, associated with zinc, and probably most of the production has been from the zinc mines. Galena, or lead sulphide, is found in true veins in grains and lumps, in Union County, and disseminated in grains through the rocks of Bompass Cove in Washington County, and as irregular masses or benches in McMinn County. Veins are known in Monroe, Bradley and Jefferson counties, all of which have been worked. Many veins have been found and opened in the Central Basin, but none have proved profitable. Mines have been opened in Davidson County and in Williamson County, near Nolensville. Fine specimens have been found in Hickman, Henry and other counties.

Lead has been mined with zinc on Straight Creek, in Claiborne County, five miles southwest of New Tazewell. It is found in minable quantities in Blount County and in Bradley County, 20 to 30 miles east of Chattanooga. It has been mined for some years at Blue Springs, six miles south of Cleveland, and at the Cedar Ridge mine encouraging prospects are found.

The ores in Tennessee are the sulphide—galenite, or galena, occurring granular, or massive granular form, showing on analysis up to 74% of lead; and cerussite, or lead carbonate, a secondary form derived from the original galena, occurring only in narrow bands at the top of the undecayed limestone. In 1908 no lead was mined in Tennessee, though some lead had been mined for several years preceding, the amount varying from 15,000 pounds to over 200,000 pounds, the latter in 1906, when the output was valued at over $10,000.

Lignite.—Lignite is a form of coal in one of its earliest stages. It is brown or black, sometimes appearing compact like coal, sometimes like a mass of decayed vegetation. It is found extensively in the Eocene deposits of West Tennessee, the beds being interstratified with clay and sand, and varying from a few inches up to four or five feet in thickness. As a rule the beds do not seem to have much lateral extent. Recently (August 29, 1910) a 20-foot bed of lignite is reported to have been found near Cottage Grove, in Henry County. The papers of Sept. 5, 1910, report the discovery of "genuine coal" two miles southwest of Burleson, Tipton County. This is doubtless lignite, and indicates the close resemblance to bituminous coal. The beds have been found extensively in Obion, Dyer, Lauderdale, Tipton, Shelby and Johnson counties, along the escarpment of the Mississippi bottoms. Attempts to use the lignite of West Tennessee as fuel have not been successful in the past. New interest has recently been taken in the subject through the work of the National Bureau of Mines in showing the availability of lignite for power when converted into producer gas and used in the gas engines.

Limestone.—A majority of the rocks of this State are limestone. They are in every shade of color from gray to black, and in every variety from pure, heavy-bedded limestone to very impure laminated, shaly, or sandy limestones that soon crumble when exposed to the weather. They are put to a variety of uses, from building roads to lining fine buildings. Some are burned to lime. Twelve counties in the State in 1908 furnished 69,754 tons of lime, valued at $224,236. The lime was used in alkali works, in buildings, for fertilizer, for paper mills, sulphate and soda-pop mills, sugar mills, tanneries, etc. In 1908 the total output of limestone in Tennessee was 837,893 tons, valued at $500,677 (not including marble); of this value $8,103 was for rough building stones, $3,500 for dressed building stones, $315.00 for paving stone, $2,999 for curbing, $16,609 for rubble, $13,591 for rip-rap, $205,275 for crushed stone for road making, $63,634 for railroad ballast, $89,001 for concrete, $16,065 for flux, and $1,585 for miscellaneous uses.

The Clifton (Niagura) limestone has been extensively quarried for building stone, curbing, etc., at Goodlettsville, Newsom and elsewhere, though large quantities of Bowling Green (Ky.) stone are now being imported into the State, and many of the quarries are devoting their time to crushing the rocks for roads. It is hoped in time to find oölitic limestone of sufficiently high grade, and under favorable conditions for quarrying and marketing to supply the home market, and displace the Bowling Green stone.

Lithographic Stone.—The limestones of the Mississippian or Lower Carboniferous tend locally to have the compact structure necessary for lithographic work. Such stone has been found in Indiana, Kentucky and Tennessee. As a rule the difficulty has been to find stone sufficiently free from flaws over a large enough surface to be usable. In Tennessee some very good stone has been found near Algood, in Putnam County. The Dunbar Lithographic Stone Co. have taken out some, but little work has yet been done. While the stone gives some promise, it has not yet yielded large sized stones, such as the market demands. The stone occurs just under the base of the coal measures, and should be looked for all around the western edge of the Cumberland Plateau and up the Sequatchie Valley.

Manganese.—Manganese in the form of oxides occurs commercially in northeastern Tennessee. The principal deposits are in Shady Valley, Johnson County; near Unicoi, Unicoi County; near Newport and Del Rio, Cocke County. The ores occur in the lower part of the Shady Limestone, or at the contact of that formation with the Erwin Quartzite. They are found in variegated clays, and are generally associated with brown iron ores. The ore is in the form of hard nodules, or irregular masses, mainly of psilomelane, or in the form of irregular pockets of soft pyrolucite, or wad. The ore also occurs near Morristown, in Hamblen County, associated with the brown iron ore; near Sweetwater, Monroe County, in the red residual clays from the Knox dolomite. Small quantities are found in the Chilhowee Mountains, in Hickman County, and elsewhere. As a black stain on the rocks, manganese oxide occurs somewhat as does iron in staining rocks all over the State.

It has been mined some near Elizabethton, in Carter County, and in other counties of East Tennessee. No maganese was produced in the State in 1908. In 1907 100 long tons were produced, worth $1,500, or $15 a ton. The maximum production in Tennessee was, in 1894, 922 tons. The total production has been 2,475 tons.

Marble.—Marble is the name commonly applied to a crystalline limestone that will take a good polish, and be attractive when polished. The name is also applied to many other non-calcerous stones—serpentines, breccias, conglomerate, etc. Tennessee is abundantly supplied with marbles of many and high grades. In 1908, the State stood third among the States of the Union, with a production worth $761,222. The present commercial output of Tennessee comes almost entirely from one bed, the Holston marble, a bed in the Chickamauga limestone, and all from East Tennessee, and mostly from Knox County, though Blount County is also a large producer. The bulk of this stone is used for interior decoration, to which purpose it is highly suited.

The main marble stratum has a thickness of 300 to 400 feet, and up to 650 feet, though usually not over 50 feet is workable at any one point. The bed shares in the usually folded condition of the rocks of East Tennessee, sometimes pitching steeply and making a narrow outcrop, sometimes outcropping broadly with a low dip. In general it forms a narrow, irregular line of outcrop across Hawkins, Hancock, Hamblen, Grainger, Claiborne, Union, Knox, Sevier, Blount, Roane, Loudon, Monroe, and McMinn counties. The marble varies in color from cream, yellow, brown, chocolate and red, to pink or blue, in endless variety. The color results mostly from impurity in the form of iron. The color occurs in the rock in a variety of ways; sometimes scattered regularly, sometimes irregularly, often fantastically. Tests of the pure limestone show it to be very high in crushing strength—averaging 16,000 pounds per square inch—and to have a high resistance to absorption of water. The colors and character vary from quarry to quarry, and sometimes within a single quarry.

In addition to the Holston marble, a similar marble is extensively developed in the lower part of the Sevier shale in Sevier and Knox counties. This marble has been quarried to a small extent. A black marble is found in Washington, Green, Sevier, Blount, and other counties, in the eastern part of the State; brown and flesh-colored marbles are found in Jefferson and Hamblen counties; fawn-colored marble in Lawrence County, on the Highland Rim, and gray and red-variagated marble in Franklin, Lincoln and other counties of the Central Basin. Coarser marbles occur in Benton, Hamilton, and Henry counties.

A magnesian marble of impure quality occurs in the Knox dolomite. In Blount, Monroe and McMinn counties are conglomerate and breccias that have been successfully used as marble, the polished block resembling mosaic work. Tennessee marble was first used extensively in 1844 in the National Capitol at Washington, and afterward, in 1852, in the State Capitol at Nashville, since when there has been a steady demand for it. It has also been used extensively as an outside building material, as in the erection of the custom-houses at Knoxville, Chattanooga and Memphis.

Marl.—(See Green Sand).

Millstone grit.—Millstone grit as a commercial stone has practically passed away, its use having long since been abandoned, except in an occasional little neighborhood mill run by water-power. Stones suitable for millstones are abundant in the State. Among those that have been used are quartzite and gneiss, found in Johnson and Carter counties, partially weathered chert from the Knox dolomite from Claiborne, Jefferson and Knox counties (a true buhrstone), a silicified shell bed coming just under the Chattanooga Black shale, said to be equal to the French buhr, from Trousdale and Coffee counties, and fine-grained conglomerates from the coal measures.

Minerals.—The following list of minerals have been noted in Tennessee:

Albite,
Alisonite,
Allophane,
Alum,
Amphibole,
Anhydrite,
Apatite,
Asbolite,
Azurite,
Asphaltum,

Barite,
Bauxite,
Bornite,

Calamine,
Calcite,
Celestite,
Cerussite,
Chlorite,
Chalcanthite,
Chalcopyrite,
Chalcotrichite,
Calcedony,
Coal,
Copper,
Copperas,
Cuprite,

Diallage,
Dolomite,
Ducktownite,

Epidote,
Epsomite,

Fluorite,

Galenite,
Garnet,
Gold,
Graphite,
Gypsum,
Glauconite,

Harrisite,
Hematite,
Hornblende,

Jasper,

Lignite,
Limonite,

Magnetite,
Malachite,
Melaconite,
Melanterite,
Molybdenite,

Nitre,
Nitrocalcite,

Orthoclase,

Petroleum,
Psilomelane,
Pyroxene,
Pyrite,
Pyrrhotite,
Prolusite,

Quartz,

Rahtite,
Rutile,

Siderite,
Sphalerite,
Sahlite,
Smithsonite,
Sulphur,

Tremolite,

Wad,

Zoisite.

Metallic Paint and Mortar Colors.—Many low-grade ores, as well as some of better grade, are mined not for the metal they contain, but as paint, or for coloring mortar. The oxides and carbonates of iron, zinc and lead are so used. In Tennessee, Bradley, Cheatham and James counties supplied such material to the extent (in 1908) of 1,300 tons, and value of $16,100.

Mineral Springs.—Tennessee is blessed with a great abundance of mineral springs, in many cases situated amid attractive scenery, and supplying a great variety of chemical constituents. It would not be possible, in brief notice such as this, to even list all of the springs. In most cases the springs, whose locations are noted beyond, are supplied with hotels, ranging from the plainest, unpainted board buildings, to handsome modern hostelries. In many cases the hotels are surrounded by cottages. The following list is, in the main, based on one published by Crook's "Mineral Springs of the United States," with the addition of some well known springs omitted in that list. The list, however, makes no pretense of being complete, even as regards springs which serve as watering places, and which have hotel and other accommodations. At a later time a special bulletin will be gotten out, describing the various springs, which either serve as summer resorts, or whose waters are sold or otherwise extensively used. The list of springs is followed by the chemical analysis of a few of them, which will serve to show their chemical character.

SOME OF THE MINERAL SPRINGS IN TENNESSEE.

Anderson County.—Oliver Springs; 9 springs; hotel.

Bledsoe County.—S. Saratoga Springs (P. O. Pikeville); hotel and cottages; 2 springs.

Blount County—Melrose Springs (P. O. Maryville); 4 springs; 8 miles of Maryville; elevation, 1,500 feet A. T. (above tide). Montvale Springs; hotel and cottages; ele. 1,300 ft. A. T. Allegheny Springs; chaly. (chalybeate) and sul. (sulphur); 14 miles south of Maryville.

Campbell County.—Eagle Bluff Springs; 1 mile north of Jacksboro.

Clay County.—Wood Springs.

Cocke County.—Patterson Springs, near Birdsville.

Coffee County.—Pylant Springs.

Cumberland Springs.—Howard Springs (P. O. Crossville); 3 miles west of Crossville; 600 gallons per hour; 1900 ft. A. T.

Cheatham County.—Kingston Springs; sul. and chaly.; Willow Brook; Craggie Hope.

Davidson County.—Crocker Springs; 2 springs; 12 miles west of Nashville. Nashville Sulphur Spring (artesian). Lockeland (old), Nashville. Deep Cave, Nashville. Pioneer Lithia, Nashville. Richardson's Lockeland, Nashville. Buena Vista, Nashville.

Decatur County.—Dixon Springs (P. O. Perryville); 3 miles from Perryville.

Franklin County.—Cascade Springs; alk. (alkaline) and sul. Estill Springs; alk., sul. and chaly. Graham Springs; calc. (calcareous), alk, and sul. Hurricane Springs; alk. and sul. East Brook Springs (P. O. Estill Springs).

Grainger County.—Mineral Hill Springs (P. O. Bean Sta.); 10 miles from Morristown. Tate Springs (P. O. Tate Springs); 2 modern hotels and cottages; 1,400 feet. A. T.

Giles County.—Elkmont Springs, chaly.

Gibson County.—Gibson Wells.

Grundy County.—Beersheba Springs (P. O. Beersheba); 12 miles from McMinnville.

Hardin County.—Pickwick, White and Red Sulphur Springs.

Hawkins County.—Wright's Epsom Lithia Well (3 miles from

Mooresburg). Mooresburg Springs, chaly. Galbraith Springs (P. O. Galbraith Springs); 4 springs; 9 miles from Russellville.

Henderson County.—Hinson Springs (P. O. Hinson Springs); 5 springs; 24 miles east of Jackson.

Hickman County.—Primm Springs. Beaver Dam Springs; sul. Bon Aqua Springs; calc. and sul.

Jefferson County.—Conwood Springs; chaly. and sul.

Knox County.—Dixie Springs; artesian well.

Lawrence County.—Wayland Springs; sul. and chaly.

Macon County.—Red Boiling Springs (P. O. Red Boiling Springs); 3 springs; hotel; baths; 1,200 feet A. T. Upper Red Boiling Springs (P. O. Red Boiling Springs); hotel, baths, boarding houses; 25 miles by stage from Carthage.

Montgomery County.—Idaho Springs, St. Bethlehem, near Clarksville.

Morgan County.—Morgan Springs.

Putnam County.—Draper Springs; chaly. and sul. Bloomington Springs.

Rhea County.—Rhea Springs; alk., chaly. and sul. Morgan Springs; chaly.; 1,934 feet A. T.

Robertson County.—Hygeia Springs. Edward Springs, sul.

Sevier County.—Glen Alpine Springs (P. O. Newport); 12 miles west of Newport; 4 springs; 60 gallons per hour; 3,000 feet A. T. Line Springs (P. O. Line Springs); 30 miles east of Knoxville; 2,000 feet A. T.

Sumner County.—Castallian Springs.

Sullivan County.—Avoca Springs (P. O. Bristol); 6 miles from Bristol; 3 springs, flowing 30, 10 and 2,000 gallons an hour; 1,650 feet A. T.

Tipton County.—Glen Springs (P. O. Atoka); 7 miles from Atoka; 90 gallons per hour.

Unicoi County.—Unaka Springs (P. O. Unaka Springs); 9,000 gallons per hour; 2,000 feet A. T.

Van Buren County.—Robinson Springs (P. O. Chalybeate); cottages; 16 miles from McMinnville; 1,750 feet A. T.

Washington County.—Austin Springs; 5 miles Johnson City.

Williamson County.—Aqua Sanitas, Franklin. McEwen Springs, Franklin. Fernvale Springs (P. O. Fernvale Springs); 13 miles from Franklin; 1,400 feet A. T.

Warren County.—Faulkner Springs. Nicholson Springs.

Wilson County.—Horn Springs (P. O. Lebanon); 8 springs; 5 miles west of Lebanon. Hamilton, Horn Springs.

ANALYSES OF TENNESSEE SPRINGS WATER.

Grains in one Gallon.

	1	2	3	4	5	6	7	8
Alumina	2.00	.30	.03		.50	.12		
Aluminum sulphate								.15
Calcium carbonate	3.20	14.90	3.84	9.64	13.26	9.64	21.56	7.03
" nitrate			tr.					
" phosphate			tr.	.01			1.14	
" sulphate	4.80		.92		74.21	15.36	160.66	31.16
Iodide	tr.							
Iron carbonate		.60	.41	.54	2.40			.10
" chloride							2.99	
" oxide	11.20					.08		
" sulphate	6.40							
Lithium carbonate			tr.					
" chloride		tr.						
Magnesium carbonate		23.30	.47	7.10				5.75
" chloride		.54					.62	
" sulphate	11.20	6.18			12.00	7.97	32.91	
Nitric Acid							.02	
Potassium carbonate				.05				
" chloride								.44
" nitrate		.60						
" sulphate			.16	.27			1.54	
Silica		.36	.68	1.38		.58	2.70	.47
Sodium carbonate		146.91		1.58				
" chloride	.80	110.35	.07	.16	1.96	10.75	40.27	43.87
" sulphate	2.40	9.70	.26		4.51	1.03	8.50	
Loss	4.00					2.31		2.42
	46.00	313.74	6.84	20.75	108.84	47.82	272.91	91.39

1. Austin Springs, Washington County. Alpheus & Dove, Analysist.
2. Dixie Spring, Knox County. J. W. Slocum, Analysist.
3. Fernvale Spring, Williamson County. W. A. Noyes, Analysist.
4. Glenn Spring, Tipton County. W. T. Lupton, Analysist.
5. Montvale Spring, Blount County. S. B. Mitchell, Analysist.
6. Red Boiling Springs (No. 2), Macon County. John T. Anderson, Analysist.
7. Tate Spring, Grainger County. T. S. Andisell, Analysist.
8. Unaka Spring, Unicoi County. Safford & Wharton, Analysist.

In 1908, $60,129 worth of spring water was reported sold, about three-fourths for medicinal purposes, and the rest for table use.

Mortar colors.—(See mineral paints).

Nitre, or Saltpeter.—Though not an object of commercial interest today in Tennessee, nitre has been mined in this State during war times. Many of the caves in the limestone region contained earth in which is lime saltpeter (lime nitrate, or nitro calcite). During the War of 1812 especially large amounts of this earth were obtained from the caves, bleached, and the lye evaporated, the nitre being used for gunpowder. Some was also obtained during the Civil War.

Novaculite.—The writer here uses the term "novaculite" for what has been called "Camden chert" purely on its general resemblance to the well-known Arkansas novaculite, without having made either a microscopical or chemical examination. The stone has the same fine-grained texture (under the hand lens), with the color, etc., of the Arkansas stone. It differs in being highly fossiliferous, while no fossils have ever been found in the other stone. Whether it has any of the valuable qualities of the Arkansas stone as a whet-stone remains to be seen. At present its chief value is for making macadam roads, for which, when properly screened, it can hardly be equalled. Like the cherts, it tends to break down into small fragments, or splinters, that mat together, so that even when being handled in a wagon it is often necessary to use a pick to loosen the mass so that it may be handled. The novaculite of Tennessee occurs in a narrow strip on the west side of the Tennessee River, especially in Benton County. At Camden, it shows a thickness of 50 feet or more. It is being dug and extensively shipped from two pits just east of Camden. What has been said of the superiority of chert over limestone for macadam roads is equally true for novaculite, if not more so.

Oil and gas.—Tennessee has not as yet developed any large oil or gas pools. In 1908 this State reported no oil production, but four producing gas wells yielded 2,200,000 cubic feet. Many wells have been drilled for oil and gas, scattered over the State. Nearly all of these have had a show of oil or gas, and a few for a time produced well, and gave promise of a field. But ultimately all have played out without the hope being realized. About 1865-67 some wells were drilled on Spring Creek, in Overton County, that produced some oil. The wells were at first only from 19 to 52 feet deep, but were later deepened from 75 to 600 feet, as they ceased to flow at the shallower depths. The Newman well obtained about 2,000 barrels at 19 feet; when the oil failed, it was drilled down to 52 feet, when an additional 2,000 barrels were obtained. The Douglass well, 75 feet away, was 75 feet deep, and produced 30 barrels a day for a time; the Hoosier well, 250 feet from the last named, produced 5,000 barrels at the rate of 50 barrels a day, from a depth of 35 feet. After giving out it was deepened to 70 feet, again striking some oil. Where the wells were drilled the Chattanooga black shale is about 200 feet deep. It is apparently the source of the oil here as well as elsewhere. Wells drilled deeper fail to find oil. It has been estimated that somewhat over 10,000 barrels were obtained altogether here. This was hauled to Butler's Landing, on the Cumberland River, and to McMinnville. At various times since then attempts have been made in the same region to obtain oil and gas, resulting in several small wells. Some drilling is still in progress in the region, though apparently not getting oil in any quantity.

In addition to the preceding, several thousand barrels of lubricating oil were found near Algood, in Putnam County, on the Douglass property. Some oil was also obtained on Eagle Creek, in Overton County, and about 200 barrels on Jones Creek, in Dickson County, at a depth of 132 feet.

Interest in oil was renewed in Tennessee in 1891 by the striking of oil on the Rugby lands, two miles west of Glenmary, in Scott County. The oil was green in color, of 42° specific gravity Baumé. It was found at a depth of 1,266 feet. The well filled with oil for 164 1-2 feet up. The well was put down on Mr. W. G. Strubble's land. The Forest Oil Company put down two other wells on this same land, striking oil at 1,340 feet and 1,235 feet, but in smaller quantities. In 1895 two wells were drilled, getting green oil of 38.6° and 43.6° Baumé, and free from sulphur. One, which came in in July, flowed some 4,000 barrels, and the other some 50 barrels.

In January, 1896, a well at Bob's Bar, in Fentress County, 276 feet deep, came in flowing 50 barrels an hour. After 14 hours the oil caught fire and burned up the rig. In November the well was refitted and put to pumping, and up to 1900 it had yielded 20,080 barrels, making 17 to 20 barrels a day, pumping 7 to 9 hours. The National Transit Company built two tanks of 40,000 barrel capacity, and the output went into these tanks, not being marketed, for lack of transportation, for the location is 30 miles from a railroad. Of the numerous wells drilled in that region, the Reagan well in 1899 had a production of 2 barrels a day; the Rock House well flowed a little oil, and one or two others showed some oil or gas. After extensive drilling, all of the large oil companies abandoned the field and surrendered thousands of leases, some of the companies having expended as much as $50,000. Wells were drilled in Overton, Fentress, Pickett and Scott counties, to a depth as great as 2,793 feet. The yield of Bob's Bar is of light green color, with a specific gravity of 0.846 (35° Baumé), and free from grit.

The production of natural gas in Tennessee has so far been very slight. Many of the wells obtain a little gas, but there have been only a few that have obtained enough to pay for making any attempt to use it. A well in Franklin County has been used to light and heat one dwelling and run a six horsepower engine. The Battey well in Fentress County produces some gas. At a few other points enough gas is produced to light one or two dwellings, or to run a flambeau. In southwestern Davidson County a gas spring was ignited and burned for six months. Oil and gas seepages are abundantly reported.

The problem of finding oil and gas in Tennessee is one in which there appears to be great interest. A study of the facts shows a wide distribution of oil and gas. Most wells drilled have found at least a show, and many oil and gas springs indicate the abundance of those substances. Closer study shows a close association between the oil and gas, and the Chattanooga black shale, that is widely distributed over the State. The black shale is well known to contain a large amount of bituminous matter, which may be distilled off as oil or gas, leaving an asphaltic residual, which may run down into the underlying rocks. Such asphaltic streaks occur in the "blue phosphate" rock. On Blue Buck branch of Swan Creek, in Hickman County, it has run down into the crevices of the underlying limestone to a distance of twelve feet. In Overton County wells are found to have obtained their oil from strata within 150 feet above the black shale. The burning gas well in southwestern Davidson County is about 50 feet above the black shale, and so it goes. Unfortunately, in this State, the black shale is not overlain by an open, porous bed that would serve as a resevoir for the oil and gas. The Tullahoma chert is close grained, though the crevices may contain some oil, as apparently they have at Netherland. The black shale has been entirely removed from the Central Basin, but underlies all of the Highland Rim, in the escarpment of which it outcrops. It is, therefore, a possible source of oil under all of the Highland Rim and the Cumberland Plateau. In that area attention should first be given to any structural anticlines that may be found, especially to the northward extension of the Sequatchie Valley anticline, where well under cover, or northeast of Crab Orchard on the Tennessee Central Railway.

A second possible source of oil and gas in Tennessee (as judged by the experience of other States) is at the top of the Trenton limestone, from which is obtained the oil and gas of the Lima-Indiana field. Up to date this horizon has not proved productive in this State. Whether from lack of suitable reservoir for the oil, or for lack of oil is uncertain; the evidence would suggest the correctness of the first view. The horizon is lacking over most of the Central Basin. It outcrops in the foot of the Highland Rim escarpment and underlies the Rim and the Cumberland Plateau. As before, any broad, minor anticlines should be tested first. A third possible source of oil and gas is in the rocks of more recent age in West Tennessee. The oil and gas of the Gulf Coastal Plain in Texas, Louisiana and Oklahoma suggest the possibility of finding oil and gas in similar strata in this State. In a general way a north-south belt through the middle of West Tennessee would seem to offer the best chances.

From what has been said, it is evident that the Central Basin and the Valley of East Tennessee, are not recommended as areas offering favorable chances, though it can not be asserted that no oil or gas will be found in either district. If structure alone be considered, Murfreesboro would be an ideal spot, but unfortunately the rocks lying below most of the Central Basin, though often tested, have not as yet yielded oil anywhere in the Appalachian field. In the same way experience in drilling east of the Allegheny front, or Cumberland escarpment, from Pennsylvania to Alabama, has so far given only negative results. To the knowledge of the author, not a single well of the many drilled in that long belt has ever paid for itself.

Phosphate.—Tennessee ranks second in the production of phosphate rock, standing next to Florida. In 1907 the total production was 638,612 long tons, valued at $3,047,836. Four main types of phosphate rock are found: The "brown," from the leaching of limestones; the "blue and gray," bedded deposits; the "nodular," in shales; and the "white," probably redeposited from solution. The phosphate deposits appear to be confined to the western and northern parts of the Central Basin, and adjoining territory extending locally across the Tennessee River. The largest deposits have been found in Maury, Hickman, Lewis, Marshall, Perry, Williamson, Giles, Sumner and Davidson counties.

The "brown" phosphate is formed by the leaching of the Hermitage, Bigby and Catheys limestones of Trenton age and the Leipers limestone of Lorraine age. The original limestones contain a number of highly phosphatic bands, in which the phosphate of lime will run from 30 to 55 per cent, the rest being mainly calcium carbonate. When the latter is removed by rain water there is left a porous brown rock resembling sandstone, having from 70 to 82 per cent "bone phosphate," or lime phosphate. The rain water acts irregularly, as it gains access to the limestone through joints. Where the original rocks run high in phosphate the result is a firm "rock" phosphate. Where the original rock is low in phosphate, and that scattered, the result is a "sand," in which usually the proportion of sand and clay is high. Formerly only the "rock" was used; now the sand is washed, and when that is done thoroughly it is claimed to yield as high as 82 per cent of phosphate of lime.

The "brown" phosphate as mined occurs either as a "mantle" on benches or gentle slopes, or as a "collar" deposit following the outcrop of the limestone which yields it, according as the limestone outcrops on a gentle or a steep slope. The mantle deposits are rarely less than three feet thick, and often six feet, or even up to ten or twelve feet. The phosphate appears as a loosely coherent, porous, brown sandstone, lying in thin, horizontal plates in wavy lines, due to the irregular solution of the underlying limestone. The phosphate is mined without blasting.

The "blue and gray" phosphate is a bedded deposit at the base of the Chattanooga black shale. It has a thickness of from 4 feet down to nothing. It is variable in thickness and quality. To the southwest it runs into the Hardin sandstone. As a rule it does not run as high in phosphate as the "brown" rock, but for the manufacture of acid phosphate is superior to the latter, as it breaks down readily and does not require as much acid in its treatment, and dries out quickly after treatment. The rock is mined by stripping around the face of the hill until the overburden becomes too great, after which the bed is mined in the same manner as a thin coal bed, by running drifts and digging it out in rooms.

The "nodular" phosphate occurs as phosphatic balls, or nodules in the Maury green shale, and apparently of the same age. These nodules carry about 60 per cent of lime phosphate. Up to the present they have not been worked, as the difficulty of getting out the nodules is too great as compared with the mining of other types of the rock.

The "white" phosphates are found in Decatur and Perry counties. They appear to be recrystalized calcium phosphate, or apatite. They occur in the surface mantle of debris, sometimes as a matrix in chert breccias; sometimes as a solid laminated layer. The phosphate appears to have resulted from the solution of phosphate rock at a higher horizon, and its redeposition, either in caves or otherwise.

It has been estimated that there remain six or seven thousand acres of "brown" phosphate rock, equivalent to 20,000,000 tons. Exploration is constantly increasing the amount, though much of that amount outside of the present Mt. Pleasant district is not of as high grade; nevertheless there seems quite a probability that large quantities of high-grade rock will still be found. When the time comes that it will pay to mine the unweathered phosphatic limestone vast quantities of such rock will be available. The "blue" rock does not appear to have as wide a geographic extent, but from its higher grade than the unweathered limestone it will be immediately available. It has been estimated that 100,000,000 tons remain; later exploration will probably increase that. The "nodular" phosphate, while not as rich as either of the two preceding, has a much wider extent. In the distant future it may prove a large source of supply. It is claimed that continued exploration has shown much larger areas of "white" phosphate in Decatur County than was formerly suspected.

Pyrite.—Pyrite, or as is often called, "fool's gold," is the golden yellow iron sulphate. It occurs in minute quantities in most of the rocks all over the State, especially in the Chattanooga black shale. There are few places where it exists in any quantity. It has been worked on Stoney Creek, in Carter County, 12 miles northeast of Elizabethton, and 1,000 tons have been reported as mined in one year. Large quantities have been found in Moore, Cheatham and Greene counties, as well as in association with the copper ores of Polk County. Now that the sulphur fumes from the reduction of the copper of Polk County are being utilized in the production of sulphuric acid, the demand for pyrite in this State is not so active.

Salt.—No salt is being mined in this State at present. Salt has been found in many of the counties of the State, notably: Anderson, White, Van Buren, Warren, Overton and Jackson.

Anderson and White counties have produced some salt, the latter having had an output for a time of 50 bushels a day.

Sand and gravel.—Gravel has always been used extensively for roads, and the use of cement has opened up a new demand for both sand and gravel. In 1908 Tennessee produced 565,325 cubic yards of sand and gravel, with a value of $290,050. Most of this sand and gravel is dredged from the bottom of the Mississippi, Tennessee and Cumberland rivers. The principal producing counties have been Shelby, Davidson, Knox, Hamilton, Rhea, Decatur, Benton, Roane, Johnson and Carter, with other counties producing small amounts. Glass sand has been noted under that head.

Sandstone.—Sandstone is but little used in Tennessee, partly because it is not so widespread as limestone, nor so readily available to the larger cities, and partly because of the difficulty of getting out the rock of uniform and pleasing color. Probably the rock most used is the Bon Air sandstone, which occurs along the west part of the Plateau. The buildings of the University of Sewanee are built of that rock. It has a mottled buff color and not unpleasant appearance. Near Pikeville is a stone that in places is a uniform pink. It has been used in buildings at Pikeville, in the State Penitentiary, and elsewhere. These stones are worked readily when first quarried, but in a few days the surface tends to harden until it is almost as hard as granite. The Clinch Mountain and Chilhowee sandstones are hard, and are worked with difficulty. Flagstones abound in the counties of the eastern Highland Rim. In West Tennessee the Lafayette is sometimes cemented into a sandstone that can be used for the foundations of buildings. As a whole the use of sandstone in the past has been mainly for rough masonry work, as for bridge abutments, curbing, flagstones for sidewalks, etc., and its use in this way has been in a large measure supplanted by cement. In 1908 only 830 tons were reported as quarried, with a value of $1,650.

Shale.—(See clay).

Silica Rock.—The use, when ground up and sized, of decayed chert, for polishing powder has often been suggested, and during the past year a company has been organized to prepare such rock, at Black Fox, in Bradley County. There are many places where the cherts of the Tullahoma and the Knox dolomites weather on a large scale into a soft, porous rock that can usually be broken in the fingers. The development of the plant at Black Fox will be watched with interest.

Silver.—No silver ores have been found in Tennessee outside of the silver-bearing copper ores of the Ducktown region, in Polk County. There the metal is obtained as a by-product. In 1908 a total of 128,549 ounces were obtained, valued at $67,952. This was an increase of 43,017 ounces over the production in 1907. The gold and silver is recovered from only part of the ore, as the castings shipped abroad go unrefined.

Few metals have been hunted for more persistently than silver. Even in the few weeks since the establishment of the Survey many specimens have been brought or sent to the Survey, under the impression that they contained silver ore, in most cases accompanied by stories of Indians, marked trees, etc. Traces of silver have been found in most of the lead ores, but as yet not enough to pay for its refining. As regards the stories of Indians finding, or knowing the whereabouts of silver mines, a knowledge of the processes of metallurgy necessary to obtain the silver from its ore, and the fact that as a rule the ores of silver bear no resemblance to the metal silver, would at once stamp them as improbable, to say the least. Safford had this to say about such stories: "The numerous old Indian stories about silver mines, which are so common in East and Middle Tennessee, there being at least one, perhaps two, on the average, for every county, are entitled to no credit. To give specific account of them would require a volume, which, when written, would be worth practically nothing."

Slate.—No slate is at present produced in Tennessee. The metamorphosed slates of the extreme eastern counties, it is believed, form an inexhaustible supply. The slate is a pale green semi-talcose variety, very durable when free of pyrite, and splits readily into plates with smooth surfaces. The Wilhite slate has the necessary hardness, evenness and cleavage along the Little Pigeon River, and is well exposed over large areas, but not developed. Quarries have been opened in the Pigeon slate at many points, and slates and flags taken out for local use. In some cases the cleavage is across the bedding, and in others coincident with it. Slates are found in Cocke, Sevier, Blount, Monroe, McMinn and Polk counties.

Sulphuric Acid.—The copper ores of Ducktown are mainly sulphides of iron and copper. In smelting those ores large quantities of sulphur-dioxide and trioxide are given off. Where allowed to escape into the air these fumes are very destructive to vegetation and crops. Recently both companies have constructed plants for the concentration of those gases into sulphuric acid. The sulphur-dioxide is first converted into trioxide and then it unites with water in the form of steam to form sulphuric acid. In 1908, with only one plant in operation, the value of sulphuric acid produced was $151,000.

Zinc.—Zinc mining in Tennessee is still in the development stage. In 1907 the output reached 251,198 pounds, valued at $14,821. Zinc ores are confined to the magnesian limestones, or dolomites of the State, notably the Knox dolomite of the great Valley of Tennessee. The Knox dolomite is a grayish white rock, non-crystalline, and more or less filled with chert nodules. In the Great Valley of Tennessee this rock is sharply folded and faulted in long lines lying northeast and southwest, and outcrops in belts between belts of other outcropping rocks. Most of the ore that has been developed occurs in three of these belts; the first belt crosses Claiborne and Union counties near New Prospect, and six miles southeast of Tazewell. At least two mines have been opened on this belt. The second belt follows the Southern Railway along the valley of the Holston River for forty miles. It is from 50 to 700 feet wide. The third belt lies further south and near the French Broad River.

In all cases the ores are originally sphalerite, or zinc blende, sometimes associated with galena, or pyrite, and occasionally with chalcopyrite. It occurs in coarse masses, or stringers disseminated in the magnesian limestone. It is usually found only below the level of ground water, except sparingly. When the limestone containing the disseminated blende weathers down by dissolving, there results a clay at the bottom of which the ore accumulates; but the ore also weathers into Smithsonite or Calomine, the former being zinc carbonate and the latter the hydrous zinc silicate, formed by the action of CO_2 released from the limestone. These ores will be found immediately overlying the limestones and under the clay. The name "Buck Fat" is given by the miners to a variable mixture of clay with calamine and smithsonite. It may be "hard," or "soft," and is usually too low in zinc to be mined under present conditions.

Ores of iron and manganese, as well as lead, are commonly associated with the zinc, as well as dolomite and calcite, fluorite, quartz and barite. The ores appear to be closely associated with the occurrence of breccia along fault zones or anticlines in the Knox dolomite. Thus at New Prospect, near Powell River, in Union County, the ore forms a narrow zone, striking north 50° east. Just south of the crest of Powell Mountain, six miles southeast of Tazewell, Claiborne County, the ores occur near a fault in the tilted rocks which form the lower part of the Knox dolomite. The second zone of deposits are also in brecciated rock following several small anticlines, as can be seen at Mossy Creek near Jefferson City, Jefferson County. Where calamine and smithsonite are found accumulated through weathering of the limestones, it is usually true that the weathering had descended by cracks or crevices so as to leave the surface when exposed very irregular, the unweathered portions projecting up into the clay.

Zinc mining has been carried on in a small way since 1883, when a mill was erected on Mossy Creek. Zinc is known to occur in a number of places in the Middle Basin of Tennessee. These have not yet been exploited, nor have they been developed.

SURVEY BULLETINS.

The following bulletins have been issued by the Survey, and will be sent on request upon the receipt of postage as indicated. A list of the other parts of this bulletin are also given:

Bulletin No. 1.—Geological work in Tennessee. (Part A issued.)

A. The establishment, purpose, object and methods of State Geological Survey; by Geo. H. Ashley; 33 pages, issued July, 1910; postage, 2 cents.

Bulletin No. 2.—Preliminary papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others. (Part A issued.)

A. Outline introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; postage, 2 cents.
B. The coal fields of Tennessee, by Geo. H. Ashley (in preparation).
C. The iron ores of Tennessee, by R. P. Jarvis (in preparation).
D. The marble of East Tennessee, by C. H. Gordon (in preparation).
E. Oil Development in Tennessee, by M. J. Munn (in preparation).
F. The phosphate deposits of Tennessee, by Lucius P. Brown (in preparation).
G. The zinc deposits of Tennessee, by S. W. Osgood (in preparation).

Bulletin No. 3.—Drainage Reclamation in Tennessee; 74 pages. Issued July, 1910. Postage, 3 cents.

A. Drainage Problems in Tennessee, by Geoge H. Ashley; pp. 1-15; postage, 1 cent.
B. Drainage of Rivers in Gibson County, Tenn., by A. E. Morgan and S. M. McCrory; pp. 17-43; postage, 1 cent.
C. The Drainage Law of Tennessee; pp. 45-74; postage, 1 cent.

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