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MISSISSIPPI STATE GEOLOGICAL SURVEY

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BULLETIN NO. 20

GEOLOGY AND MINERAL RESOURCES OF MISSISSIPPI

By E. N. LOWE

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STATE GEOLOGICAL COMMISSION

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PREFACE

In the preface to the first edition of this Bulletin I stated that the Report had "been prepared to meet a growing demand among the school teachers of the State, as well as of the general public for one volume covering in a popular way the geology, geography, mineral resources, underground waters and soils of the State." It was an effort to summarize briefly in a non-technical way the information contained in all the previous published reports of the State Geological Survey.

In the preparation of this volume I have made use of Hilgard's Report on the Geology and Agriculture of Mississippi; Crider's Geology and Mineral Resources of Mississippi; Crider & Johnson's Underground Waters of Mississippi; numerous bulletins and publications of the United States Geological Survey by T. Wayland Vaughan, L. W. Stephenson, Edward W. Berry, George C. Matson, E. W. Shaw, and C. Wythe Cooke. Of course the writer's field notes have been freely drawn upon.

E. N. LOWE,

LETTER OF TRANSMITTAL

Office of State Geological Survey
University, Mississippi
November 30, 1925

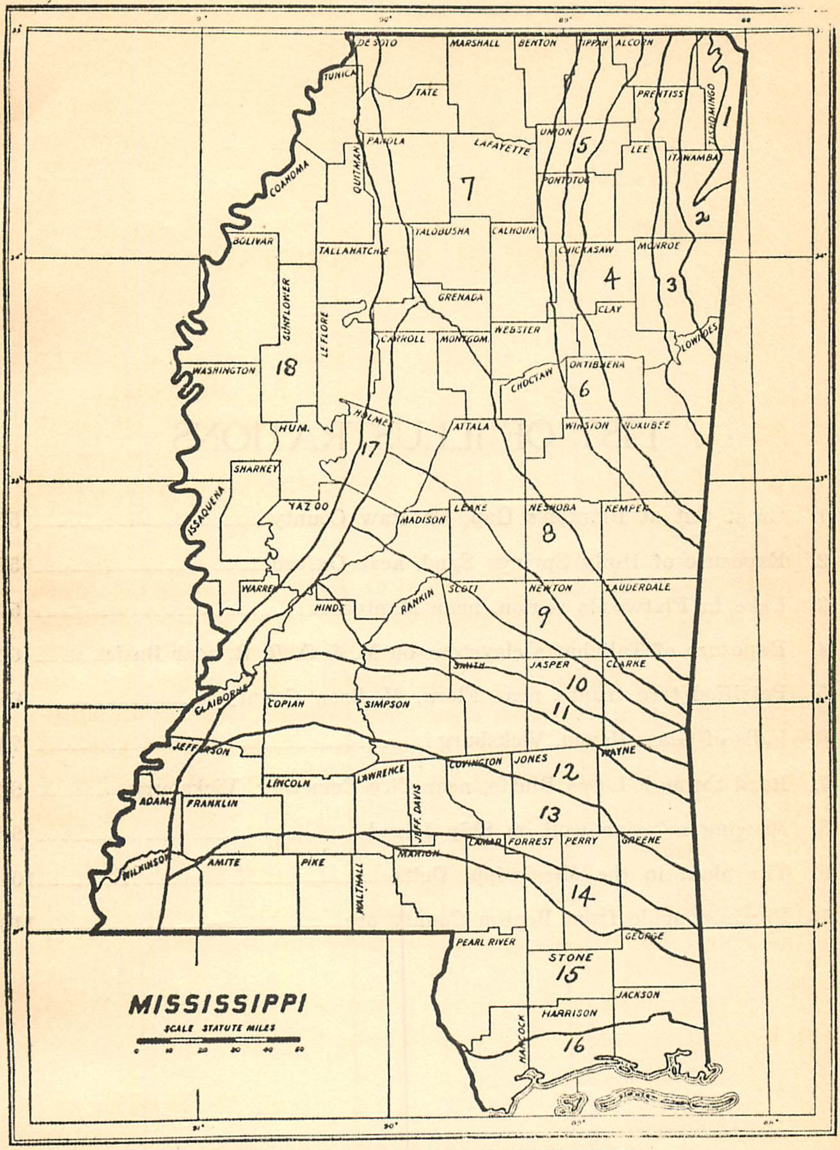
To His Excellency, Gov. Henry L. Whitfield, Chairman, and Members of the Geological Commission:

Gentlemen: To meet the demand of the public for a brief and non-technical presentation of the Geology and Mineral Resources of the State, several years ago this bulletin was prepared and published. The demand soon exhausted the first edition; a second edition was issued, which, in addition to the general public demand for it, became a part of the regular curriculum of the high schools and colleges of the State. Then the second edition was exhausted, and has been out of print for several years.

The demand for this bulletin is still insistent, and hence it has been revised and reissued as Bulletin No. 20; the chapters on soils and agriculture having been omitted.

Trusting that the volume will meet with your approval, I herewith submit it for publication.

E. N. LOWE,
Director.



SKETCH MAP OF GEOLOGY OF MISSISSIPPI

Legend:

Paleozoic.......... { **Mississippian**

Cretaceous....... { **2. Tuscaloosa**, **3. Eutaw**, **4. Selma Chalk**, **5. Ripley**

Eocene.............. { **6. Midway (Porters Creek)**, **7. Wilcox**, **8. Lower Claiborne (Tallahatta)**, **9. Upper Claiborne (Lisbon)**, **10. Jackson**

Oligocene.......... { **11. Vicksburg**, **12. Catahoula**, **13. Hattiesburg**

Miocene............. { **14. Pascagoula**

Pleiocene........... { **15. Citronelle**

Pleistocene....... { **16. Port Hudson**, **17. Loess**

Recent............... { **18. River Alluvium**

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CONSTITUTION OF THE EARTH

The body of the earth consists of matter in three forms—solid, liquid and gaseous. These are arranged in concentric spheres—the solid sphere being the rock or lithosphere, the liquid being the water or hydrosphere, the gaseous being the air or atmosphere. Water at ordinary temperature is liquid; at 32° F. it becomes solid; at 212° F. it becomes a gas; so the solid rock at high temperatures may become liquid and gaseous, while the air at low temperatures may become liquid, and even solid.

These concentric layers are not equally dense; air is the lightest, rock, the heaviest, and water intermediate between the two. The lithosphere, on account of its greater density, forms the central solid mass of the earth upon which the other two rest; the hydrosphere is the comparatively thin shell of water that rests upon the lithosphere; the atmosphere is the tenuous gaseous envelope that rests upon the water or hydrosphere over most of the earth's surface, and over the lithosphere where the hydrosphere is absent; so that we see these three shells arranged one upon the other in the order of their density.

They are constantly in motion and continuously intermingled. Both water and air penetrate the lithosphere, rock and air mingle with the hydrosphere, and rock dust and water vapor float in the atmosphere. These facts are of vast importance in the economy of nature. The interaction of atmosphere, hydrosphere and lithosphere produces conditions necessary to form soil, and renders life upon the globe possible.

Chemistry of Rock.—The rocks of the lithosphere (the solid crust of the earth) are composed of twenty-one chemical elements, eight of which make up 99% of the whole. These eight with their relative proportions are:

Oxygen	47.02%
Silicon	28.06%
Aluminum	8.16%
Iron	4.64%
Calcium	3.50%
Magnesium	2.62%
Sodium	2.63%
Potassium	2.32%

Oxygen unites in definite proportion with each of the others to form one or more oxides. The oxide of Silicon (SiO_2) unites with Aluminum Oxide (Al_2O_3) to form Aluminum Silicate, which is clay. Iron is not as frequently found combined with silica to form silicate, but a combined Potassium-Iron-Aluminum Silicate occurs in Glauconite, a greenish mineral formed on the sea bottom. Calcium, magnesium, potassium, and sodium silicates result from the combination of silica with the oxides of these elements. All these elements form other compounds besides silicates which occur in the rocks of the earth. Some very familiar and abundant minerals are the oxides, carbonates, chlorides, sulphides, sulphates, phosphates, etc. In many cases several silicates of complex composition enter into the formation of a rock. A rock so constituted, on exposure to the weather, crumbles and falls to decay more readily than rocks of simple composition.

Kinds of Rocks.—The earth's rocks are grouped into three great classes Igneous, Sedimentary or Fragmental, and Metamorphic, the classification being based upon the conditions under which each is formed.

Igneous rocks are those like obsidian, granite, diorite and syenite, which are glassy or crystalline in texture and usually complex in composition, consisting of minerals fused into a homogenous mass or aggregated together. Rocks of this class have solidified from a state of fusion. All the original rocks of the earth were igneous, though by no means are all the igneous rocks primeval, since rocks of the other types subjected to high temperatures, especially in the presence of superheated water, may fuse, and afterwards re-solidify in the form of crystalline rock.

Sedimentary or Fragmental rocks are those that have been derived from the breaking up and decomposition of other and older rocks by ordinary erosional processes. These rocks are not crystalline in texture, but the constituent particles are usually rounded and water worn, of varying degrees of fineness, from the finest clay and silt to cobble stones and boulders, sorted by the selective action of water currents usually, and deposited in horizontal layers. Such bedded structure is called stratification, and true stratification is confined to rocks of this class. Igneous rocks are often broken by horizontal fissures or joint planes, and metamorphic rocks frequently exhibit a false lamination, both of which simulate somewhat the bedding of sedimentary rocks, but true stratification does not occur in either of these classes. Stratified rocks occupy nine-tenths of the solid surface of the earth. Examples are such familiar forms as shales, sandstones, conglomerates and limestones.

Metamorphic rocks are those which become fundamentally altered from their original texture, and even from their original chemical and mineral constitution, by great pressure at considerable depths beneath the surface in the presence of mineral gases and heat. Either Igneous or Sedimentary rocks may suffer this metamorphism, since either may be subjected to the conditions required. Rocks of this class are crystalline in texture and the larger portion show banding, simulating stratification. Well known examples of Metamorphic Rocks are Gneiss, altered from the igneous rock, granite; Mica Schist, derived from alteration of the sedimentary rock, shale or mud stone; and Marble, formed from limestone.

From what has been said, it is evident that in tracing back the genesis of soils, the first step in the progress, for about nine-tenths of the earth's land surface, brings us to its source in some sedimentary deposit, either unconsolidated mantle rock, consisting of clay beds, mud beds, sand beds, gravel beds and sea-bottom ooze, or their consolidated representatives,—shales, corresponding to clay and mud beds; sandstones, to sand beds; conglomerates, to gravel beds; limestones, to calcareous oozes. The whole class of sedimentary rocks, however are derivative from pre-existing rocks as we have seen, and since the metamorphic class are formed from either igneous or sedimentary rocks, we are thrown back upon the igneous class of rocks as the original source of all other rocks. By far the largest part of the earth's mass is igneous rock, though compared with the sedimentaries but little of it shows at the surface. The bedded rocks are in places many thousands of feet thick, yet beneath them, wherever penetrated, are found the igneous rocks, which extend to unknown depths—perhaps even to the center of the earth.

As contrasted with the sedimentaries, igneous rocks are complex both in mineral and chemical constitution. Since the sedimentaries are derived from them we would expect both groups to be of closely similar composition. The reasons why they are not are given below in the discussion of Weathering. Suffice it to say, briefly, that in the process of change the soluble parts of the igneous rock are removed in solution and only the insoluble parts remain to make up the great mass of the resultant sedimentary rock.

How Sediments become rock.—All sedimentary rocks are at first unconsolidated or loose mantle rock. The bottom of the sea is the great arena of sedimentation and probably has been in all past times. Far out from shore muds and calcareous oozes are being deposited, slowly but surely building up the sea bottom. In the shallower waters nearer in towards the shoreline, coarser materials, such as fine sands, coarse sands, gravel, shingle, and cobblestones are filling in more rapidly. As these accumulate in successive layers, the layers first deposited become more and more pressed upon by those lying above, until a superincumbent load of hundreds, or even thousands of feet of thickness of such deposits, exerts a powerfully consolidating force. To vertical pressure may be added lateral compression in most cases, for the surface crust of the earth is constantly undergoing compression in an effort to accommodate itself to a shrinking interior globe.

Heat is an undoubted factor in the consolidation of most sedimentary deposits of great thickness. High pressure causes a rise of temperature in the body compressed. In addition to the heat of compression is to be considered the interior heat of the earth which rises at the rate of 1° F. for every 60 or 70 feet of vertical depth. At a depth of a few thousand feet the heat from this cause alone would be very appreciable. The chief influence of heat in promoting consolidation of rock is to be explained in its effect on the mineral content of the waters permeating the rock mass. This is intimately blended with the consideration of the next and most important factor.

All sediments under ground contain more or less atmospheric water occupying the spaces between their constituent particles. If the materials are loose and coarse-grained, as in the case of sand beds, the water is in considerable quantity and moves readily through the rock, the flow being in the direction of least resistance. Rain falling upon the earth sinks into it and passes downward permeating all the rocks. The water on passing through the atmosphere takes in solution certain gases which are found there—such as oxygen and carbon dioxide—and carries them down into the fissures and pores of the rock. Armed with these and other acids, it attacks the rocks through which it passes and dissolves out some of their ingredients. As the mineral-charged water descends to greater depths the solution becomes more concentrated by continuous additions. Finally, because of over-charging or of changed conditions, the mineral in solution begins to deposit, forming films coating the rock grains, or even partially filling the pore paces, the result being a cementation or gluing together of the rock grains. By this process unconsolidated beds of sand may become firmly cemented into a solid sandstone, beds of mud into shale, beds of marine oozes into limestone or chalk.

The most common cementing materials in rock are (a) Silica or Quartz (SiO_2), (b) Brown Iron Oxide ($Fe_2O_3H_2O$), (c) Calcium Carbonate or Lime ($CaCo_3$). Everyone is familiar with sandstone in some of its forms; it is not different from a sand bed solidified by cementation chiefly, but partly also by the two processes mentioned above. Everyone knows also that sandstones differ materially in color, hardness and durability. The differences are due usually to the cementing material. A sandstone with a cement of lime will yield quickly to atmospheric influences and disintegrate, because the cement readily dissolves away and allows the grains of sand to fall apart. Where the cement is silica the rock becomes quartzite, the most durable of stones, because the cement is practically indestructible by atmospheric agencies. Where Iron Oxide cements the grains of sandstone the rock is very durable and the color brown, a kind used very largely in the building of the handsome brownstone mansions on Fifth Avenue, New York.

The character of the cementing material of rocks, especially of sandstones, exerts an important influence in determining both the physical and chemical constitution of the soils derived from them.

Cementation of rock has been described as taking place at considerable depths beneath the surface. The zone of cementation is recognized by the best authorities as being deeply located, and that rock solidifies there chiefly must be so, because there cementation is most active, and there pressure and heat are greatest. Cementation, however, may occur at the surface, of which we have abundant evidence.

WEATHERING

Weathering is the sum of those changes produced by atmospheric agencies, which result in the conversion of rock into soil. It is a process of vast importance to the inhabitants of the earth, since upon it depends the very life of the earth. Weathering does not take place with equal rapidity everywhere, two very important factors influencing its rate being climate and character of rock. It is a complex and composite process, operating under two distinct, and in some respects, opposing phases. Below is shown a synopsis of weathering:

- WEATHERING
  - Physical Phase Rock-Breaking
    - Change of Temperature
    - Wedge Work of Frost
    - Organisms
      - Animals
      - Plants
    - Wind
    - Rain
    - Gravity
  - Chemical Phase Rock Decay
    - Oxidation
    - Carbonation
    - Hydration and Solution

As will be seen, the first phase or step in the process is a mechanical breaking up or comminution of the rock, brought about by several agencies. The second phase is a chemical decay or decomposition of the rock. Conditions favorable to the first are unfavorable to the second and vice versa. Considered as a whole, however, weathering is most favored by conditions that obtain in warm, moist climates. In Brazil, for example, soil formed *in situ* occurs in the Amazon Valley to a depth of three hundred feet.

All soil and mantle rock are moving slowly down to the sea because all land surfaces slope toward the oceans. The agencies of this transportation are rain, rivers, wind, ocean waves, organisms and ice. The processes of weathering act so slowly as to escape notice, and yet they supply loose material more rapidly than all agencies of transportation can convey it to the sea. The Mississippi in flood, with its muddy waters spread many miles across the country, carrying along sand and silt by the thousands of tons, and floating to the Gulf timbers, trees, and wreckage from the flooded lands, impresses us profoundly with the magnitude of its work. Yet, but for the work of weathering the mighty river would flow clear to the sea. Conversely, should it carry its greatest flood load every day of the year, it would still perhaps be unable to keep pace with the work of the weather in preparing soils in its drainage basin. Weathering, like a myriad-handed Midas, touches every square foot of land above the sea and forces it to yield its harvest of gold in rich and productive soils.

In order to simplify the discussion of weathering, we will consider the two phases separately. It is well, also, to apply the discussion to an imaginary mountain slope where the operation of all the agencies can be made plain, and then apply the principles brought out to other and more familiar cases.

Physical Phase of Weathering.—Let us imagine then a lofty mountain rising above the surrounding country. Its rocky summit reaches well into the region of frost. Day by day the sun warms, night by night an icy chill enwraps its rocky cliffs. Besides the daily vicissitudes, it must bear the brunt of winter snows and summer storms.

Change of Temperature.—In low altitudes and moist climates the atmosphere is dense and holds a considerable quantity of moisture in the form of invisible vapor. The density of the atmosphere and the water which it contains cause it to act as a blanket to the earth's surface. The heat from the sun by day passes through the blanket to the earth, but its intensity is mellowed in doing so. After the sun has gone down the earth tends to give up the heat it has received during the day, but the blanket of dense moist air holds the heat and prevents its rapid loss. Though the night is cool, owing to loss of heat, the protecting atmosphere prevents the extremes of temperature.

Such is not the case on high mountain tops. Here the enveloping air is quite thin and usually holds less water vapor than is the case in the lowlands. The blanket here is too thin to protect against either extreme of temperature. By day the sun blazes down in full intensity upon the bare rocks, which grow hot. In the high mountains of the deserts of South Africa, Livingston reported temperatures as high as 130° F. Rock, as compared with metals, is a poor conductor of heat; so that, while the surface may be hot, a few inches below the surface the rock is comparatively cold. Rock, like most other substances, expands on heating and contracts on cooling. Here we have an exterior shell of hot rock trying to expand on a cold interior. Strains are set up within the mass. After the sun's heat is withdrawn, the rarity and dryness of the atmosphere permit the rapid radiation of heat from the surface of the rocks, with the result that it begins to cool. Anyone familiar with mountains knows how cold the mountain air grows after nightfall. The rock surfaces lose heat more rapidly than the interior parts which have become somewhat warmed during the day, and since in cooling rock contracts, we again have stresses set up in the rock, but in the opposite direction—a cool outer shell trying to contract upon an unresponsive interior.

Day after day, season after season, year after year, these changes are in operation, with the result that the rocks begin to crack and shell off in pieces, varying from a few grains to hundreds and even thousands of pounds in weight. But the process does not stop here. The new surface exposed is subjected to the same conditions, resulting, sooner or later, in further disruption of the rock. And so the work goes on through the centuries; the mountain crags crumbling down become literally buried in their own wreckage.

Wedge Work of Frost.—What has been said in the above paragraphs refers to simple changes of temperature, but if the night temperature drops to a point below the freezing point of water, and if there is sufficient water in the rocks, as there would be during much of the year, another potent factor comes into play—the wedge work of ice. All rocks are broken by cracks or joint planes into blocks of different sizes. These joint planes are usually so small as to be sometimes invisible, but not too small for water to penetrate. Water from melting snow or from summer showers passes down into these fissures and freezes at night when the temperature falls below 32° F. Water expands 1-11 of its bulk in freezing, exerting an irresistible force in doing so. Hence it is as if a steel wedge were driven gradually with great force between the blocks—the fissure widens. This process is repeated again and again, and year after year, the crack growing wider gradually. Rock fragments and particles fall in from above and prevent its closing. This debris will hold more water, and on freezing the pressure is greater. Finally the block becomes loosened and dislodged, falling from the cliff. It bounds down the mountain side, breaking off fragments of rock here, dislodging loosened boulders there, and perhaps bursting into a hundred fragments before it finally comes to rest at the base of the mountain. Sometimes, when spring thaws are relaxing the grip of winter, the starting of one boulder may set in motion an avalanche of thousands of tons of rock. No sooner is a fresh surface of rock exposed by the dislodgement of a loosened block than the same process begins upon the new surface. Through the centuries the work goes on. If Time is the sculptor of mountains, then Ice is a most potent chisel with which he carves relentlessly and unceasingly.

Through the action of the two factors just discussed, change of temperature and wedge work of ice, the lofty mountains become scarred, transformed, lowered. Among the Rocky Mountains some peaks are literally buried in their own wreckage. But these agencies of destruction not only renew their attack upon the cliff's face as soon as a new surface is exposed, but continue work upon the fragments dislodged, breaking them into smaller and smaller pieces, so that loosened masses of rock matter, great and small, lie beneath the cliffs in great talus slopes, scores, and even hundreds of feet in thickness.

Organisms.—Burrowing animals loosen a considerable quantity of the smaller rock fragments in sinking their burrows, and open passageways for water and air beneath the surface, thus promoting more rapid weathering of the rock. Large animals traveling over the ledges dislodge loosened fragments which tumble down the slopes loosening and breaking up other fragments. These are not as important as the agents already discussed, but are by no means insignificant when we remember that their work is measured in centuries and even thousands of years. Trees growing upon the higher mountain slopes and cliffs are often blown down by severe winds, and in falling carry with them thousands of pounds of rock fragments entangled in their roots.

Wind.—Besides this indirect action of the wind in dislodging rocks, it acts directly in removing small, loose particles as fast as they form. On high mountain peaks the wind is usually strong enough to carry away dust and fine rock particles, and so keep the rocks swept clean, depositing elsewhere the materials picked up. In desert regions the wind finds most favorable conditions for action, drifting the dry sand into hillocks or dunes and carrying the fine dust to great distances in the upper currents of air.

Rain.—Moisture falling upon the mountain in the form of rain gathers up and washes off all the finer rock matter not removed by wind, and, as the water collects in furrows and gorges on the mountain side, it rushes downward with great force, carrying large quantities of loosened rock matter to the gentle slopes and valleys. If it fall as snow, on melting in the spring it rushes down to the streams, which become muddy torrents. If, instead of melting directly, the snow forms glaciers, these frozen masses, rockshod creep down the valleys tearing off, grinding up, and carrying along many tons of rock from the mountain above. In all cases the mechanical work of atmospheric water is to remove rock waste to lower levels and expose fresh surfaces of rock to the weather.

Gravity.—The work of all these agencies is reinforced by gravity. Every particle of matter of the globe feels the unremitting pull of gravity drawing it toward the center of the earth. Whether loosened by temperature changes, by frost, by organisms, by wind or rain, gravity co-operates and draws the mass down to lower levels. The ocean basins are the lowest levels on the earth, hence all rock waste travels toward the oceans—from the mountains and hills to the plains, from the plains to the river valleys, from the valleys to the seas. The wind carries dust high above the lands, seeming to offer an exception to this rule, but it is only apparent. Sooner or later gravity gets the better, the dust settles upon the land, the rain washes it into the valleys, and thence the streams carry it to the sea.

Weathering in Arid Regions.—What has been described as taking place on high mountain peaks finds its counterpart in deserts and other arid regions of the globe. The absence of moisture in the atmosphere permits the sun to blaze with untempered vigor upon the exposed rocks during the day, while from the same cause the heat is rapidly radiated by night and the rocks grow cold. Owing to the lack of rainfall the surface is unprotected by a coat of vegetation from these sudden and exccessive changes of temperature, which result in the disruption, crumbling and gradual comminution of the rock. The winds sweeping over these regions take up the dust in great quantities and transport it to distant parts where it settles. The great loess deposits of Northern China, several hundred feet deep and spread like a blanket over many thousand square miles of plains and mountain sides, have been regarded as wind-blown materials. The coarse material, as sand, is carried along near the ground and heaped in ridges or dunes.

CHEMICAL PHASE OF WEATHERING.

So far the changes noted have been entirely physical—a mechanical breaking up of the rock. But, while this is the prominent phase of weathering on mountain tops and the desert areas, it is but the first step in a series of changes by which soils are formed. The next step is chemical, which brings about a decay of the rock, a change in its composition.

Not Prominent on Mountain Tops or in Deserts.—We have noticed that the conditions most favorable to breaking up of rock are those of cold, dry climates. The reverse conditions of moisture and warmth favor chemical decay of rock. However, chemical decay of rock does take place in deserts and on cold mountain tops, as seen in the stained and discolored surfaces after exposure to the weather. It is not prominent because the physical changes are so much more rapid that they over-shadow the chemical.

Conditions.—The atmosphere is a mechanical mixture of gases. Its principal constituents are Nitrogen, 79%, Oxygen, 21%, Carbon Dioxide, about 3 parts in 10,000 of the atmosphere. These are practically invariable in amount. A fourth important ingredient is water vapor, which is variable at different times and in different localities. Of these constituents nitrogen is inert, while the other three play important parts in rock decay.

A new steel ax will remain bright indefinitely in dry air, but if the air be moist the ax will rust within a very short time. In this case the water and oxygen of the air have united with the steel forming a yellowish brown coat of iron rust, which is hydrated oxide of iron. In the same way rock in a dry atmosphere would undergo little if any chemical change, but placed in a moist air would slowly undergo decay, the nature of the change depending upon the composition of the rock. Moisture, then, is a necessary condition of rock decay. The moisture is furnished by the rain falling upon and sinking into the rock. Rainwater always absorbs oxygen and carbon dioxide in falling through the atmosphere, so that some one, or perhaps all three of these agents attack the rock on coming in contact with it.

Why More Active in Valleys than on Mountain Tops.—We can readily see now why the exposed rocks of mountain tops undergo chemical changes slowly. The rocks being bare, hold but little moisture, most of that falling upon them flowing away; the wind and the sun soon dissipate by evaporation what remains, and the surface of the rock quickly becomes dry before the agents have had time to attack effectively. After the rock has been broken up and dislodged from the parent ledges by the agents already discussed, and lie in blocks of large size as talus slopes against the base and sides of the mountain, the surface exposed to the atmosphere is much greater than before and the attack of the chemical elements in the water of the atmosphere becomes more active, the greater activity being due to two causes: first, on account of the greatly increased surface, second, because the blocks lying in a heap will retain more moisture than the same rock in an exposed ledge. All rocks absorb some moisture when exposed to rainfall and the larger the surface the greater the absorption in the same kind of rock. A solid block of rock three feet square presents a surface of fifty-four square feet; the same mass broken into blocks one foot square will present a surface of three hundred and twenty-four square feet. The absorption increases even in a greater ratio, as will be explained presently, and since atmosphereic water always contains oxygen, carbon dioxide, and minute quantities of nitric acid, with the water, the rock absorbs into itself the elements that promote decay.

From what has already been said it is evident that the finer the division of the rock the greater will be the surface exposure, and the greater the absorption and consequent chemical decay. But another factor enters into the problem here. Large blocks, loosely thrown together in the manner seen in talus slopes, have open spaces and cavities between them that allow free circulation of air, and since the air of mountain tops and of arid regions where the talus slopes occur most commonly, is usually dry, even though rain should fall and moisten the exposed rock surfaces, the ready passage of drying air soon evaporates the moisture and leaves the surfaces dry. Hence chemical activity, which is dependent on moisture, is comparatively insignificant in its results. We have seen that the tendency is for the larger blocks to break into smaller ones and these crack and shell off still smaller fragments, with the result that the pieces lie more closely together and the little fragments fall into the interspaces, clogging and finally filling them. As a consequence the water that falls finds large absorptive surfaces as it percolates among the small close-lying particles, and the drying air circulates with such difficulty that before it has time to dry the rock, chemical decay sets in actively.

As the rock matter of mountains moves farther and farther down the slopes, it is broken into finer and finer particles, and at the base of the slopes and spreading into the valley flats the material has become so finely divided and the particles lie so closely together that the moisture is perennial, that of one rain not being entirely dissipated before the next renews the supply. The rock particles being therefore subjected to continuous chemical action, crumble and decay into soil. Materials from the slopes are constantly being added by the heavy showers which wash down the finer loose particles and spread them out on the flats.

Hydration.—One of the processes of rock decay is the chemical union of water with certain mineral constituents of the rock. This is called hydration, and by it the mineral usually becomes softer and more soluble. Limestone becomes soluble because of a union of its elements with water containing carbon dioxide. Most of the potash and alkalies contained in the true soils result from the solution of certain hydrated minerals called zeolites.

Oxidation.—Atmospheric water always contains in solution oxygen gas with which it attacks everything oxidizable. Iron is a very abundant element in most rocks and is readily attacked by oxygen; so also to a less extent is magnesia. Most igneous rocks are very complex in constitution and are readily attacked by these chemical changes, by which some of their constituents are reduced to solubility and the whole mass crumbles to soil.

Carbonation.—In the case of igneous rocks, while oxygen attacks some compounds, as above noted, carbon dioxide unites with others in producing carbonates which are dissolved out. A ferro-magnesian silicate with lime, as diorite, may on weathering become coated with a white film of calcium carbonate. It seems possible that primarily all the calcium carbonate of the earth may have been derived from the decay of igneous rocks.

We have made thus distinct the two prominent steps involved in soil formation, the first being physical, the second chemical. By the first the rock is broken up and comminuted to a degree of fineness to hold water; by the second this water holding in solution the active elements of the atmosphere attacks the large surface exposed by the particles collectively, reducing some of the rock matter to solution, the rest crumbling to fine soil. While we have discussed the two steps separately, and used the mountain to illustrate the distinctness of the two phases of weathering, and to show how the chemical is largely dependent upon the mechanical process, let it be borne in mind that both processes go on all the time and everywhere. We seldom see the two so well differentiated as on the slopes of a high mountain. On the bare ledge of rock where the chemical phase is not apparent, it is feebly active, but masked by the much more active physical phase. At the base where the particles are very small the physical phase is not entirely quiescent, but here the chemical finds its best conditions and over-shadows the other. In desert regions conditions akin to those on the mountain top exist, and physical weathering is dominant; the reverse is true in warm, moist climates, as at the base of the mountain, the chemical activities being far more apparent than the physical.

Vegetation and Humus.—A true soil consists of more than finely divided rock matter in a process of decay; humus, or decaying vegetable matter, is also present. When the rock particles, as at the base of the mountain, are fine enough to hold moisture, chemical decay becomes active and the mass will hold in its pore spaces water having in solution not only the atmospheric gases but also soluble rock matter. The seeds of plants find lodgment, absorb the moisture and germinate; the root penetrates the mass absorbing the water and mineral solutions, the stem shoots up and spreads the leaf into the air. Plant life is established. Other forms invade the area, and the usual struggle for possession begins. Year by year and century by century the remains of plants living and dying upon the spot become mingled with the rock particles. In course of time the surface for several inches or feet in depth becomes darkened and mellowed by this addition and by the more complete decay of the rock. The water contains, besides the mineral matters in solution, humus derived from the decaying vegetation. This mass has now become a true soil, and should man take possession of it for his own crops he would find it strong and productive.

How Soils are Formed on Level Surfaces.—So far this discussion of weathering and of soil formation has described the process as it occurs on a mountain side. But most of the soils of the earth have not been formed on mountains, but upon low and comparatively level lands; and this is especially true of Mississippi, where no mountains exist. What then is the difference in the process acting here rather than on mountain sides? The two phases of weathering—physical and chemical—are active here as there, but very unequally, the physical or mechanical breaking up of the rock being inconspicuous except locally, while the chemical decay is prominent. Joint cracks and fissures in the rock allow the frosts to get in and increase the spaces for water to enter and work the destruction of the rock. Changes of temperature assist. But, altogether, the changes are silent and inconspicuous, the processes of rock decay progressing deeper and deeper, a vertical section presenting every step in the transition from perfect soil at the surface through imperfect soil and rotten rock to perfect rock several feet below.

How Vegetation Took Possession of the Rock.—If we imagine the original surface to have been solid rock these changes must have come about very slowly. Long exposure to sun and storm and frost would cause some less resistant parts to crumble slightly. The wind would sweep away, or the rain would wash the loosened grains of rock dust, and wherever a slight depression occurred, even though not larger than a thimble, some of it would be deposited. This little pit would conserve moisture to a slight extent after all the other rock surface was dry, so that rock decay would progress there more rapidly and the quantity of loose particles would increase. Soon the spores of some low plant, as lichens and mosses, would take possession of these little spots and germinate. A growth of these plants would further conserve moisture, their rhizoids would penetrate some little depth into the rock, and their bodies would, year by year, contribute some decaying vegetable matter; all of which would further promote the decay of the rock and would produce a beginning soil.

These colonies of low plants would gradually spread from the original foci, and, little by little, as the years and centuries passed would eventually take possession of the whole surface, making a deeper and more perfect soil, and so prepare the surface for a higher growth of vegetation. Conditions necessary for the higher types of plants are more moisture, greater depth of soil, and more humus. When the pioneer mosses and lichens have prepared a soil suitable for higher types these latter gradually supplant them in a great measure, driving them to the least favored spots. Ordinary low herbaceous plants succeed the lichens and mosses and further prepare the soil by adding depth, moisture and humus for a growth of shrubs, and these in turn for trees.

Trees require the greatest depth of soil in order that the roots may give the trunk firm and safe support. Until such depth of soil is attained under the action of the lower forms, trees cannot exist. Hence the trees, especially trees in a forest, represent the highest type of plant covering for the soil. Under the forest cover maximum of moisture is conserved, maximum of humus is supplied, and maximum rate of rock decay results. We may be sure that forests did not first possess the land, but came after a long period of preparation of the soil.

Undoubtedly in much of the southern part of Mississippi, the gradually emerging sea bottom was an expanse of unconsolidated sand beds—they are yet only partly consolidated—and the earliest vegetation perhaps underwent a somewhat different development. Pure sand is always a sterile and usually a dry soil, so that the first plants, while perhaps not lichens, were drouth-loving herbaceous species, capable of subsisting upon a minimum supply of water and plant food. These, by the addition of humus, prepared the way for shrubs and later for trees.

The cone-bearing trees are the great xerophyte or drouth-enduring group of trees, hence the trees to take first possession would naturally be pines and related conifers. In such a soil evolutionary changes would progress slowly. The whole region is still in the pine stage, but had conditions remained undisturbed, after long periods of time the pine forests would have added humus until the soil would have been enriched with sufficient plant food and moisture to support hardwood trees, which would have eventually supplanted the pines. In fact, we have much reason to believe that the northern parts of the State have passed through or are now passing through the pine stage, the invasion of hardwoods having proceeded from the older lands to the north.

Physiographic Regions of Mississippi

The surface of Mississippi is divisible into nine topographic regions, which conform quite closely with the geologic structure of the State. As will be brought out in the discussion later, these regions differ not only in physiographic characters but in soil types and in natural vegetation, and exert a pronounced influence upon the industrial development of its inhabitants.

In the extreme northeast corner of the State the Tennessee River forms the boundary for a short distance between Mississippi and Alabama, while the Mississippi River with its numerous and tortuous meanderings forms the western boundary from the line of Tennessee to that of Louisiana, a distance of nearly 500 miles. These are the only streams that wash the soil of Mississippi which do not rise within the borders of the State. With the exception of a few small streams tributary to the Tennessee River, the whole drainage of the State is southward into the Gulf or westward into the Mississippi.

The southern extremity of the State has a coast line of 85 miles along the Gulf of Mexico, the mainland itself lying several miles inland of a chain of low sand islands, the intervening shelving bottom being covered by the shallow waters of the Mississippi Sound—a famous fishing ground for oysters, shrimp, red snapper and other marine fish.

Tennessee River Hills.—Occupying the two extreme northeastern counties of the State and adjacent parts of those counties bordering them on the west and south, is a region of considerable elevation and rough topography. The hills reach an altitude of 650 feet, with an occasional point of 700 feet, and are rugged and steep; the streams of the east slopes, which flow through narrow deep ravines, pursue short swift courses to the Tennessee. It is a region of wild and picturesque beauty, farm houses and fields being sparsely scattered along the broader parts of the valleys. The hill tops and slopes bristle with forests of pine, oak, and hickory; to these in the valleys are added black walnut, sycamore, tulip tree, maple, and cucumber tree, with an occasional umbrella magnolia where the soil is rich and shaded. Alder fringes the borders of the streams in the low wet flats.

The soils of the hills are thin, red, sandy, and pebbly loams; those of the bottoms are rich, black, sandy loams.

Toward the south the region loses some of its ruggedness and numerous productive farms may be seen. The western and southern slopes of these hills are less precipitous and the creeks flow more slowly toward the Tombigbee.

The geological formations of this region are the indurated limestones, sandstones, and chert beds of the Paleozoic Group, overlapping whose western and southern borders are the loose sands, clays and gravels of the Tuscaloosa and Eutaw of the Cretaceous.

Black Prairie Belt.—Lying immediately to the west of the region of hills just described is a broad low-lying belt of land of slight relief. In all its characters this region is the antipode of the other. Its surface is not only nearly level, but consists of open prairies almost devoid of tree growth, but having a rich herbaceous flora of prairie-loving species, like the prairie clovers, mellilotus, compass plants and milk weed, besides abundance of good grasses.

The soils are black, calcareous clay loams, that do not, in the level areas, drain perfectly, but are very strong and productive. Throughout the region are areas of gentle elevation. Though the eye could scarcely detect the elevation these areas can be easily noted miles away by the stunted growth of black jack and post oak that usually crown them. The soil is an infertile red or yellowish clay or sandy loam, entirely different from the characteristic soil of the region.

The Black Prairies lie at a considerably lower level than the eastern hills, the altitude in the northern part being upwards of 400 feet. The surface slopes southward, having an altitude at Macon of 179 feet. The region is a broad belt running from the northern border of the State southward and turning slightly eastward, touching the eastern line of the State in Noxubee and the north half of Kemper county. Less than ten miles wide in the northern part it broadens southward, reaching its greatest width west of Aberdeen where it is more than twenty-five miles wide.

This whole region marks the outcrop of the Selma Chalk, or Rotten Limestone of the Cretaceous, which forms the bedrock from which the black prairie soils are derived. The region is one of fine farms, prosperous towns and rapidly growing wealth.

By referring to the accompanying sketch map of the State all these regions now under discussion may be noted and their boundaries traced.

Pontotoc Ridge.—As the name would indicate, this is another region of high lands, bordering upon the west side the northern half of the Black Prairies. It is a small wedge-shaped region, broadest where it enters the State in Tippah and Alcorn counties, runs southward and comes to a point at Houston, in Chickasaw County.

This ridge is a backbone averaging more than 500 feet high and parts the waters that flow into the Tombigbee on the east from those that feed the Pearl River and the westward flowing tributaries of the Mississippi. Bordering the main crest on either side are rugged broken hills that drop suddenly to the lowlands of the Prairies on the one hand and those of the Flatwoods on the other.

The region is one of picturesque beauty, but the surface looks too broken and the soil too red and sterile to suggest successful agriculture. And yet this is a region of prosperous homes and farms. The towns of New Albany, Pontotoc and Houston are lively business points.

The soil is on the whole a red sandy loam derived from the weathering of the sands and marls of the Ripley formation. It is peculiarly well adapted to the growth of the Elberta peach, and is very much more productive of general farm crops than its appearance would indcate. The region is one of dense fine hardwood forests.

Flatwoods.—A narrow band of low flat land borders the Pontotoc Ridge on the west and sweeps in an open crescent around the western and southern margin of the Black Prairies. It is nowhere very wide, varying from two to eight miles. It is so much lower than bordering areas, is so distinctly marked off, and its surface is so nearly featureless in its typical phase, that it has been universally called the Flatwoods by the settlers, and was likened by Crider to a broad river bottom. In places, however, the surface becomes distinctly hilly.

The soil is uniformly a gray and sticky clay that retains water tenaciously and on drying cracks and becomes of stony hardness. It is difficult to cultivate, and on the whole is not highly productive. Most of it needs drainage badly. The region is not extensively farmed, but was originally densely covered with forests of post oak, Spanish oak and loblolly pine. In many parts the forests are now being cut for lumber and the lands are being cultivated.

The geological formation underlying the Flatwoods is the Flatwoods or Porter's Creek Clay, a tenacious gray joint clay, differing but little from the soil to which it gives rise.

North Central Plateau.—This region embraces all of that portion of North-Central Mississippi lying between the Flatwoods on the east and the bluffs overlooking the Delta on the west, and extending from the border of Tennessee south to a line drawn approximately from Canton to Meridian. It includes the greater part of sixteen counties. As the name suggests, the surface was originally that of a plateau sloping gently southward and westward. The highest railroad point is on the Illinois Central Railroad near Holly Springs, the altitude being 609 feet, though neighboring points reach considerably higher.

In the more northern part of the region where it passes into Tennessee, the original level expanse of the old plateau is still quite evident, but over most of the area the drainage channels have been cut so deeply and intricately that the topography is decidedly rough.

The characteristic soil over the whole area is a yellowish brown loam containing much silt and clay. This is spread like a blanket over many counties of the State and varies in thickness from fifteen to two or three feet. Lying just beneath this loam, over almost the whole area, is a variable thickness of red sands, formerly called the Lafayette formation, but now believed to be weathered Eocene materials. The prevailing sloping surfaces of the land, the yielding mellowness of the soil, and the treacherous support of sand beneath, which outcrops on the hill slopes, and is easily attacked by the weather, render this region one peculiarly susceptible to erosion. Marked evidences of rapid erosion are to be seen in many places. When the soil is properly handled erosion may, in a large measure, be prevented.

Productively this brown loam is perhaps the most generally useful soil in the State, being well adapted to a variety of crops. The geologic formations underlying this region are the Lignitic or Wilcox and the Claiborne. These are prevailingly sands and clays, but over much of the area they contribute little to the soil which is either the brown loam alone or mixed with the red sands above mentioned.

The region was originally forested with a mixed growth of pine, Spanish oak, black jack, white oak, chestnut, and hickory. The merchantable timber has now been largely cut away in the northern parts, though considerable timbered areas exist farther south.

Jackson Prairie Belt.—Immediately south of the North-Central Plateau is a region of gently rolling lands with numerous small prairies interspersed. Much of the surface, however, is, or originally was, covered with forests of pine, oak, and hickory.

The area of this Prairie Belt is not as extensive as the preceding region. It reaches across the State from the bluffs of the Mississippi to the line of Alabama in a narrow belt running a little south of east, the extreme width of about 40 miles being in Yazoo and Madison counties, but the average is not more than half that. The city of Jackson lies in the southern edge and gives name to the region.

The characteristic soil is a black calcareous prairie soil, very similar to that of the Cretaceous prairies, though the prevailing soil of the area in the western part is the brown loam already described. The soils are very rich and the region is one of the most prosperous in the State.

The geological formations underlying this region are the Jackson and part of the upper Claiborne, consisting of calcareous clays, marls and soft limestones.

Long Leaf Pine Hills.—The whole southern half of Mississippi south of the Jackson Prairies, to within a few miles of the Gulf, is a topographic unit, resembling closely the North Central Plateau in surface features and in soils.

It slopes gently from an altitude of more than 400 feet at its northern border to less than 100 feet toward its southern border where it drops sharply down to the low-lying level Coastal Pine Meadows.

That part lying west of Pearl River is more elevated than farther east, some of the hills rising to 500 feet near the Mississippi Bluffs.

While the general surface of this region, like that of its prototype farther north, is maturely dissected, giving it an uneven topography, there are large areas of gently rolling or nearly level land. The one striking feature of the whole region is the forests of long-leaf pine, which originally covered its surfacce in one unbroken expanse.

The soils of this region are red and yellow sandy loams derived from the Pliocene, which is the prevailing surface formation east of the Pearl River. In the higher regions farther west the brown loam overlies the Pliocene to a great extent. As a result, the pine forests show a decided sprinkling of hardwood species, which increase westward.

Coastal Pine Meadows.—Lying between the Long-Leaf Pine Hills and the Gulf is a low-lying region of slight relief, known as the Coastal Pine Meadows. This region borders the Gulf like a penumbra 5 to 15 miles wide, but occasionally, especially around bay heads, widening to 25 or 30 miles. It is nowhere as much as 100 feet above sea level, seldom as much as 50 feet, and gently slopes to sea level at the Gulf beach.

The surface is gently rolling, approximating a monotonous level toward the Gulf. Ground water lies near the surface over the whole area, coming to the surface in occasional depressions forming marshes and swamps which tend to follow lines roughly parallel with the coast. Near the coast an occasional sand ridge, 10 or 15 feet higher than surrounding parts, marks the position of former beach dunes, now fixed and clothed with a vegetation which varies from carpet grass and sand peas to tall pine forests.

All the streams flowing through this region are sluggish and tortuous, with sandy bottoms and clear, amber-colored peaty water.

The soil is sandy and grayish in the higher-lying parts, and in the intervening low, wet meadows, where water usually stands, it becomes black and peaty.

The whole area is clothed with an open growth of long-leaf and Cuban pine, and on the lower wet and acid soils occurs an undergrowth of characteristic species, resembling that of northern bogs.

Loess or Bluff Hills.—Skirting the eastern margin of the Yazoo Delta is a range of rugged precipitous hills known as the Loess or Bluff Hills. All streams flowing through them have cut deep narrow gorges, whose sides in many places stand in vertical walls. This region of hills varies in width from 5 to 15 miles and follows the eastward curve of the Delta margin from Memphis to Vicksburg, thence southward it hugs the east bank of the Mississippi River to the Louisiana line.

While the Bluff Hills might not properly be considered a distinct topographic unit, since topographically they represent merely the intricately and deeply dissected margin of the plateau lands to the east, yet considered with reference to their soils, they constitute an easily recognized soil region. This is all the more noticeable since the region maintains its unity of character from the line of Tennessee to that of Louisiana, though it overlaps in this distance several different geological formations.

The bluffs stand 150 to 250 feet above the Delta; the hill slopes are so steep as to be difficult of cultivation, and the valleys are too narrow and inaccessible to afford very extensive farming. Still, on account of the extremely fertile soil, the region is one of the most productive in the State, and in spite of its rough topography is extensively farmed.

The soil of this region is the brown loam, though it is somewhat more silty than farther east, and is here underlain by a yellowish calcareous silt, the loess, which varies in depth from 30 to 90 feet at the edge of the bluffs, thinning eastward, to the margin of the region, where it feathers out. On the hill slopes the mixture of the loam and loess makes a very fertile soil, with characteristics entirely distinct. The tree growth where it has not been cut over is magnificent in proportions and of the finest grades of white oak, yellow poplar, basswood, red gum, ash and beech.

Yazoo Delta.—This region embraces all that great flood plain deposit of the Mississippi River and its tributaries lying on the east side of the great river between Memphis and Vicksburg. It is a low lying featureless expanse, sloping gently southward. Its altitude at the Tennessee line is 200 feet and at Vicksburg 100. The whole region was originally heavily timbered with forests of red, white, and overcup oak, elm, ash, cypress, red gum, tupelo gum, pecan, hickory, cottonwood, maple, magnolia, beech, basswood, and hackberry. The two species of gum formed more than 50 per cent of the whole. Large forests still remain, but, on account of the valuable hardwood, are being rapidly cut over and the lands prepared for cultivation.

While the average relief of this region is slight, the higher lands lie adjacent to the streams, the interstream areas being low and more or less swampy. The whole region would profit greatly by drainage.

The soils are all alluvial and among the most fertile on earth. Two general types are found, the distribution of which maintains a definite relation to the topography. A dark, mellow, sandy loam generally occurs on the higher grounds near the streams, while a dark, tough, sticky clay occupies the lower areas back from the drainage courses. Both are very productive under proper conditions, but the black mud or "buckshot" must be drained to make it produce well.

Until the completion of the levee, the annual overflows of the Mississippi retarded very much the development of the Delta. Since then development has been rapid, and with the completion of drainage schemes now being pushed in most parts of this region, about two thirds of the lands now unused will be reclaimed.

RECENT GEOGRAPHIC CHANGES.

While successive elevations and depressions of the land have repeatedly marked the course of geologic history in Mississippi, some of the oscillations of the earth's surface have left their record so lately that we have good reason to believe they extended into the present epoch, if, indeed, the changes are not yet in progress. Where an uprising or a down-sinking of a land surface washed by the seas takes place, even though slightly and very slowly, the shore line is shifted. If the land rises, the shore line is shifted toward the sea, if the land sinks, the sea necessarily encroaches upon the land, covering some that had before been above sea-level.

Modifications of the Gulf Coast.—Bays and estuaries are usually to be regarded as submerged lower ends of river valleys. Valleys are cut down and widened out by processes that operate on land surfaces; they are not formed beneath the sea, because river currents lose their velocity and cutting power on reaching the ocean. Bays, like Mobile Bay and Pascagoula Bay, were, therefore, valleys formed in the land when it stood higher than today. They are salt water bays now because the land adjacent to the Gulf has sunk down until the waters of the Gulf extend to the heads of the bays. Chesapeake Bay is a notable example of the "drowning" or submergence of a large river valley with numerous tributary valleys. When the valleys on the Gulf Coast were forming it is quite probable that the shore line was at least as far out as the chain of islands off the coast, 12 to 15 miles.

Along the streams flowing into the Gulf and along the Gulf Coast itself are to be seen at intervals great heaps of shells that have been left by prehistoric fishermen. Both in America and in Europe these shell heaps, called in Europe "Kitchen-middens," seem to mark the sites of ancient tribal feasts in which the chief article of diet was shell fish. These were held at points convenient to the source of supply. At the present time they are found along Pascagoula River and the Gulf Coast, often partly submerged, suggesting the probability that the lands were higher when they were placed there. Tribal feasts would hardly have been held on land so low as to have been permanent marshes or to have been covered part of the time by high tide. Further, on Pascagoula River the shell heaps near the present mouth show the basal portion of the heaps to be made up almost entirely of fresh water shells, above which the shells are of brackish water species, while those toward the top of the heap are salt water shells such as are found today extending up the river. Supposing these shell heaps to have been used by many successive generations of fishermen, we would be led to infer that at the time of the first feasts the land was high enough to prevent the entrance of salt water into the river so that only fresh water shell-fish lived in it; later the sinking of the land caused the salt water of the Gulf to mingle with the fresh water of the Pascagoula, making it brackish, and supporting only shell-fish that inhabit brackish water; still later sinking of the coast had gone on till the mouth of Pascagoula River had become a bay of salt water supporting oysters and other salt water forms, as it does today.

A map of the Mississippi Coast made in 1764 by Eman Bowen shows Pascagoula Bay as being at that time a large open salt water bay half as wide and nearly as long as Mobile Bay. At the present time there is little of the bay left. The Pascagoula River passes into the Gulf by two mouths, all the intervening region being low tidal marshes filled with coarse rushes and salt marsh growth. The obliteration of the bay is no evidence of renewed elevation of the land, but is due to other causes, chief among which is the filling in by the stream with detritus and with sawdust, vast quantities of which have found their way into the river from adjacent saw mills. The dense growth of marsh vegetation is each year adding many thousands of tons of peaty matter that helps to build up the marsh lands. If submergence is still in progress the process is so slow that the down sinking has been outstripped by the upbuilding activity of the stream and marsh vegetation.

The bottom of the sound between the mainland and the islands is in most places of hard clay which seems to be identical with the clays of the late Biloxi formation. The islands themselves, however, seem to be of sand built upon a base of black and peaty mud that becomes more sandy eastward and more clayey toward the west. The source of this mud is doubtless the fine sediment brought down by the Mississippi and Pearl Rivers and distributed along the coast by offshore currents, the waves and tides adding sand from the Gulf.

The islands are built up above the water by materials dropped when the breakers touch the shallow water of the current-built bars, and by winds drifting the sands along the beaches into hillocks and ridges called dunes. Much of the peat exposed on the beaches beneath the sands is made in the marshes between the dune ridges, and later exposed by the cutting of the waves.

Stream Terraces.—All the larger streams of the state exhibit along their courses a system of terraces or benches, which may be traced on the sides of the valleys for long distances. These terraces are not shelves cut out of the rocks of different degrees of hardness in the valley walls, but are composed of river deposits which have been left on the valley sides in successive steps as the waters receded. These fringing shelves follow the windings of the stream valley, being seen first on one side then on the other, or may often be traced upon both sides for a greater or less distance.

Most of our streams show at least three, often more, terraces, occurring at different heights on the valley side like steps. The highest terraces are the oldest, the lowest being the latest formed. The high terraces being the oldest are usually not well preserved, but are cut into fragments by long erosion. In the language of everyday life the latest and lowest terrace is called the first bottom, the next higher terrace being called the second bottom. The second bottom is usually six to ten feet higher than the first bottom, and forms wide level tracts of excellent agricultural lands. The first bottom is rich agricultural land also, but subject to overflow during high water, while the second bottom overflows only at long intervals and at extreme high water. The third terrace is 25 to 30 feet higher than the second and not subject to overflow. It is usually not so extensive as either of the first two, but in some instances is a broad expanse, especially in the angle made by the junction of two large streams. The uplands forming the rich agricultural region north of Hattiesburg, between Bouie and Leaf Rivers, is a third terrace deposit. Large areas around Caledonia in Lowndes County are third terrace deposits. Jackson is in part located on third and probably fourth terrace deposits of Pearl River. Grenada is on second bottom of Yalobusha River.

The Mississippi River has in places at least six terraces, though that number cannot usually be made out. The Loess deposits are on high terraces of the Mississippi, the elevation of the deposits showing it to lie nearly always at a lower level than the interior uplands.

Being a deposit made by water each terrace should show an even surface with a slight uniform slope down stream. As a matter of fact the terraces along the Mississippi do not always show these characteristics. Some of them show distinct irregularities, points down stream being higher than points up stream. These irregularities are due to warping or bending of the earth structures after the deposition of the terraces. These deformations must be very recent since the oldest terraces are themselves not older than Pliocene time.

The river terraces have not been traced with certainty to the Gulf Coast, but it seems reasonable to suppose that the oscillations that took place during Pliocene and Pleistocene time had some relation to the different levels of the Mississippi River during the same time, when the greatest of these terraces seem to have been formed.

OUTLINE OF GEOLOGICAL HISTORY.

Primaeval Condition of the Earth.—Of the primaeval condition of our globe there is still considerable difference of opinion. Any opinion entertained must be based upon hypothesis rather than upon scientific demonstration. And yet science has cleared up much of the darkness originally surrounding the subject, and has forced within narrower limits the field of hypothesis. Today students of cosmogony, or earth genesis, are divided between two leading hypotheses: First, the Nebular Hypothesis of Laplace; second, the Planetesimal Hypothesis of Chamberlain. The two resemble each other in some respects, and yet the differences are fundamental.

Nebular Hypothesis.—This was elaborated by the French mathematician, Laplace, in 1796, since when it has held sway without serious opposition, until very recently. According to this hypothesis, the original condition of the Solar System was that of a great luminous nebula. The matter of the nebula was in an incandescent gaseous state due to intense heat. The nebula assumed a spherical shape under the influence of rotation caused by its own gravitation. As the nebula became more condensed rotation became more rapid. Finally the shrinking interior separated from successive rings of nebulous matter, which in rapid revolution about the central mass, broke, and each condensed into a sphere revolving about the central nucleus. Losing heat by radiation, these spheres became liquid and finally solid. These constitute the present planets of the Solar System, of which the earth is one, the central residual mass being the sun.

How long these changes required no one knows very definitely, but many million years have undoubtedly passed since the astral state of the earth's development.

Planetesimal Hypothesis.—This was elaborated in detail a few years ago by Professor Chamberlain of Chicago. Astronomers have in the past observed with wondering admiration many beautiful spiral nebulae in the heavens. Each consists of two arms closely or loosely coiled about a denser central mass. In each arm at intervals are to be noticed brilliant nuclei. The spectroscope reveals the important fact that these nebulae are composed of solid matter—not gaseous.

Dr. Chamberlain's hypothesis postulates that our Solar System was originally a spiral nebula, not of superheated gases, but of small discrete solid bodies, icy cold, massed together, like a swarm of bees, into a dense cluster having the shape of the spiral nebula. These he called planetesimals. The bright nuclei in the arms of the nebula represent the beginning planets, each of which exerts gravitational action upon all the planetesimals coming within the sphere of its influence. According to this hypothesis each planet, as well as the central mass, which represents the sun, continues to grow by accretion as long as planetesimal matter comes within its gravitational control. By the impact of the in-falling bodies, by mass condensation, and by radioactivities among the products, heat is generated within each planet sufficient to cause volcanic and other igneous phenomena. The bright nuclei revolve in orbits about the central mass, just as our planets revolve around the sun.

There is much to be said in support of both hypotheses, but the most recent discoveries of science throwing light upon this subject seem to favor the Planetesimal Hypothesis.

Stages of Earth Development.—Under whichever hypothesis we view the genesis of our planet, many millions of years intervened between the initial stage of development and its present condition.

Under the Nebular Hypothesis there was first the *Astral* æon, of a nebulous, and finally a liquid, globe, luminous with intense heat. After this came a *Lithic* era, in which the rock matter of the earth had become sufficiently cool to solidify, but the waters still formed about this solid center a thick vaporous envelope. Still later the rock globe had cooled until the waters condensed, forming warm universal seas.

Until now no life had been possible upon the heated globe, but after many æons had passed the rock crust and the waters had sufficiently cooled to permit the advent of life. The first living forms were almost surely aquatic, swarming in the shallow, warm oceans. These forms perhaps had the essential characteristics of both animal and vegetable life of the most primitive types.

Under the Planetesimal Hypothesis the following stages are recognized: 1. The Astral Aeon, during which the globe was embraced in the luminous, cold, spiral nebula. 2. The Molten Aeon, in which the star matter had become superheated by condensation and dissolved into a molten sphere, surrounded by a dense atmosphere. 3. The Lithic Aeon, in which the globe gradually lost heat and developed a solid crust. 4. The Volcanic Aeon, an era of great volcanic activity, in which great floods of lava escaped through the broken crust from the heated and partly molten interior. 5. The Sedimentary Aeon. This is the era of atmosphere activity, rains being precipitated and causing erosion of the highlands with concomitant sedimentation in submerged depressions of the earth's crust. It is probable that the beginning of the æon was marked by a globe still warm, enveloped in dense, dark, vaporous clouds from which at frequent intervals fell torrents of warm rains drenching the lands and dissolving, eroding, and loosening the rock masses, spreading far and wide on the shallow sea bottoms the waste of the land. While atmospheric agencies were cutting down the lands, forces within the earth were elevating the continental masses even more rapidly. Finally the water cooled sufficiently to support life, and living beings began their regime, which has continued until this day.

The inauguration of life upon the earth must not be confused with man's advent, which was many millions of years later. Compared with some of the lowest organized slimes on the sea-bottom man is but an infant of yesterday.

Life Upon the Earth.—The Astral period of the earth's development was very long—probably many times longer than all subsequent time. During this period life was impossible. After the solid crust of the globe had appeared, surrounded by wide-spreading seas, and enveloped in clouds, a long Azoic (without life) Period supervened. It seems improbable that we have now any visible record of this remote period in the earth's rocks. It is probable that the oldest rocks exposed on the surface of the earth are a series several thousand feet thick in the uplands of Canada. These rocks are mostly volcanic, indicating a period of intense volcanic activity; but interstratified with the volcanic deposits are thick beds of stratified sedimentary rocks, which do not reveal any recognizable fossils, but exhibit deposits of limestone, graphite, and other minerals which are regarded as probably of organic origin. These rocks are for the most part highly metamorphosed and their structure much disturbed and folded, as would be expected in rocks that have persisted since the dawn of earth history. This great system of rocks might well be called the *Eozoic* system, since they represent the historic record of earth during the long period when primordial life arose out of the previous chaotic conditions, maintained a precarious struggle for a long time, and finally established itself.

It is recognized as a geologic fact that life first established on the earth was of the lowest types, both animal and vegetal. These were followed in successive periods by more and more highly developed forms, until the present era, when the reign of man began. The geologic development of the earth, as revealed in these life changes, was not regular and uniform throughout all time, but was marked by long periods of comparatively quiet conditions succeeded by rapid changes both of geography and of life forms, amounting to geologic revolutions. Since the life record of the earth consists of fossil remains of ancient life forms entombed in the rocks of each period, these revolutionary changes may be regarded as the closing chapters of each volume of earth history written in the rocks by nature herself. Looked at from this point of view, there are six such volumes of earth history, five of which are completed, closed and bound, the sixth being still open and receiving additional chapters as the earth changes take place.

The six volumes are, beginning with the first, and naming them in orderly succession:

[1]1. Azoic (without life), a period preceding the advent of life.

2. Eozoic (dawn life), a period during which life began and established itself.

3. Paleozoic (ancient life), a period when life, mostly of invertebrate forms, became abundant and very varied.

4. Mesozoic (middle life), a shorter period than either of the above, characterized by the dominance of vertebrated forms of animals, especially of gigantic reptiles.

5. Cenozoic (modern life), a period when such forms of life as we see about us today became predominant, some mammalian quadrupeds being of immense size.

6. Psychozoic (mind life), characterized by the appearance and rapidly increasing ascendancey of man, until he has now established undisputed dominion over the land, the seas, and the air.

The chief characteristics of the Azoic and Eozoic eras have already been briefly outlined. The true life history of the earth begins with the next era, the Paleozoic, when recognizable fossils appeared.

The Paleozoic Era.—This was a long era, characterized by increasingly complex physical geography and increasingly abundant and diverse life forms. The rocks are limestones, sandstones, shales, with interstratified beds of iron ore and coal, and locally, of gypsum and salt. Igneous rocks are also common.

The era is composed of five periods, distinguished from each other by radical changes in life forms, coincident with changed physical conditions.

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[1]In recognizing Azoic and Eozoic eras of earth history we are not following exactly present usage. The Azoic era as used here corresponds to the earlier part of the Archeozoic of Chamberlain and Salisbury. These oldest known rocks contain no evidence, direct or indirect, of the existence of life. The Eozoic embraces the later Archeozoic and the Proterozoic, in which are found the earliest vague records of living beings.

The recorded history of the earth resembles that of man himself, in that long periods of quiescence, during which physical changes were gradual and inconspicuous and the life of the globe showed no marked changes, alternated with periods of rapid and often revolutionary changes in physical geography, with corresponding rapid evolution of living beings.

The animal life of any considerable area of the earth at any one time is called a *fauna*, the vegetable life of the same area and time being called a *flora*. Except at the very dawn of life upon the earth, the faunas and floras existing upon it have embraced numerous and varied forms, the conditions under which they lived being very diverse, and their life problems correspondingly complex. Each fauna and flora that has occupied the earth is the resultant of inherited impressions plus environmental conditions under which it is forced to exist. Each living being, both animal and vegetable, is possessed of inherent qualities by which it seeks to fit itself to its life relations. This has been so in all past ages and will continue to be so in the ages to come, and it is only thus that each individual sustains its life and that a species perpetuates itself. As already stated, life relationships are complex, relating on the one hand to physical environment, on the other to biotic environment. An individual or species that cannot adapt itself to the physical conditions under which it must live, or cope with other living beings striving to live under the same conditions, is forced out of the race for life and becomes extinguished.

It is thus that we explain the well-known geologic fact that during a long period of quiescence, when the earth's surface seems practically at rest, the fauna and flora of that period become fixed, or show very gradual evolution. They have adapted themselves to the conditions, and until conditions change the fauna and flora persist. However, should the previously stable surface of the earth become restless, should mountains be upheaved where before were plains, should the seashore rise or fall so as to compel the recession or advance of the sea, at once a fierce struggle would begin among the inhabitants of the disturbed region. Each species would strive to adapt itself to the changed conditions. Some are more plastic and virile than others, and when a period of rest under new conditions finally supervenes, it will be found that many groups have passed out of existence, unable to accomodate themselves to the change; others have been able to persist only by developing new species, the old having succumbed. The more plastic groups change into new forms, the fixed species become extinct.

During the long geologic record from the dawn of life until now there have been many changes in the earth's fauna and flora. These changes, with the evidences of concomitant physical changes, form the basis upon which geologists have divided the geologic history into eras and periods and epochs, each having its peculiar assemblages of life forms.

The five periods of the Paleozoic Era are, in succession, 1, Cambrian; 2, Ordovician; 3, Silurian; 4, Devonian; 5, Carboniferous.

Cambrian.— This period consists of rocks more or less metamorphosed.

The sandstones become quartzites, the limestones become marbles, the shales become slates. These changes, however, are by no means universal, much of the rock of the period showing no metamorphosis.

At the beginning of the Cambrian most of the North American continent was a land surface, that land being composed of the highly complex and metamorphosed pre-Cambrian rocks. A shallow sea washed the eastern shores of this pre-Cambrian continent, extending from the Gulf of St. Lawrence down the depression occupied by Lake Champlain and Hudson River, along the Appalachian region west of the Blue Ridge Mountains, and thence through Alabama perhaps as far as the present Gulf of Mexico. On the west side this continental mass was bordered by a similar sea from western Canada, through the Great Basin of Utah and Nevada to the Grand Canyon region.

During this period the sea gradually advanced over the continent, until at its close practically the whole of North America, except areas around Hudson Bay, was under water.

The life of the Cambrian period was undoubtedly quite varied, though only a fragment of the record has been recovered. The Cambrian rocks lie mostly deeply buried beneath later rocks. The species that have been recovered are all invertebrate animals, mostly brachiopods, a group of marine shells now almost entirely extinct, and trilobites, a form of crustacean related to the king-crab. Some stemmed echinoderms, a few gastropods and pteropod shells, and toward the close of the period, a few straight-shelled cephalopods related to the nautilus, appeared in the Cambrian rocks. No land animals, no land plants, and no vertebrated animals had appeared. The climate of the period was probably uniform over the continent.

Ordovician.—The gradual sinking of the continent during Cambrian times continued without interruption into the Ordovician period. There was a deepening of the sea during the early part of this period. The first deposits were sandy limestones, indicating by the presence of sand the nearness of the shore line. Later the sand disappeared, and by the middle of the period the deposits were limestones such as are today laid down in warm coral seas, not necessarily deep, but free from land-derived sediments. Toward the close of the period the formations laid down were extensive mud deposits which have consolidated into shales and slates. These indicated that the land surfaces were rising above the sea and that the washings from the nearby land were being carried down by streams and spread out on the shallow sea bottom. It is probable that the lands were not high, otherwise the streams would have been more torrential, bearing coarse material to the sea.

The life of the Ordovician was much more abundant and more varied than that of the Cambrian. It was also more highly organized; corals were abundant, star-fishes were numerous and of higher types, brachiopods and cephalopods were abundant. The straight-shelled cephalopods were plentiful, but a curved-shelled type, more like modern forms had appeared. Most important of all, as showing the progression from simple to complex forms, vertebrated animals appeared for the first time. These were fishes of a low order and of small size that had barely appeared as precursors of later developments.

Silurian.—Through the Cambrian and first half of the Ordovician the downward sinking of the continent almost obliterated the lands above water at the beginning of Paleozoic times. The latter stages of the Ordovician inaugurated the reverse movement by which the continent has been gradually reclaimed. This upbuilding process has had many and serious interruptions, at least once resulting in almost a submergence of the western half of the continent. Early in the Silurian the lowlands bordering the seas became higher and the streams swifter, for we find conglomerates (rock made of boulders and pebbles) and coarse sandstones deposited instead of the mud of the close of the previous period. About the middle of the period the lands began again to be lowered, either by downward movement or by long denudation by which the highlands became cut down approximately to sea level. During this middle stage of development when the lands were low, little terrigenous materials were deposited. Limestones which predominated over widespread areas, were derived chiefly from comminuted shells and corals and other lime-secreting organisms. The closing epoch of this period, besides limestones and shales, exhibits rather extensive salt deposits. These salt beds probably tell the story of minor oscillations of a low coastal flat, in which the salt water of the ocean, after flowing into shallow broad depressions, became cut off by gentle emergence and deposited salt by evaporation of the water. The climate was probably at least semi-arid.

The life of the Silurian was much more abundant and varied during the middle epochs when the great limestone deposits were being made. Conglomerates and sandstones, such as characterize the early part of the period, are formed under conditions not favorable to abundant life, and even were fossils deposited with those rocks they would hardly be preserved.

The limestones, however, teem with marine life, corals especially, showing great variety of structure. While the great groups of animals, already mentioned as occurring in the Ordovician, are found here also, they show decided differences from preceding forms. During this period, for the first time, land plants and an air-breathing, land-inhabiting creature made its appearance—a scorpion, somewhat like those of today.

With the Silurian closes what is ordinarily called the Age of Invertebrates. Vertebrated animals, indeed, appeared before its close but they were small, lowly organized, and unimportant features of the life of the time. The Invertebrates were the rulers, some of the crustaceans and chambered shells being several feet in length.

Devonian.—During the early part of the Devonian the sea once more spread out over broad areas of previous land surfaces, and extensive limestones were deposited—the lands had probably been worn down in the meantime to near sea level. Then an uplift brought down sands from the land

and spread sandstones upon the limestones. Once more the land was reduced to base level and limestones deposited; then extensive deposits of mud revealed a surface again rising above the waves, and the period closed with immense deposits of coarse sandstones. The material for these sandstones was brought by rapidly flowing streams from elevated uplands nearby the shore line. The streams were overloaded by coarse sediments derived from the rapid erosion of the land. The most important area of erosion was an old land surface of crystalline rocks lying to the east of the Paleozoic shore line. This was elevated into mountain masses, and the residuum from long decay of its rocks furnished the materials of the closing epoch of the Devonian.

The life of the Devonian is even more varied and abundant than the earlier periods of the Paleozoic. All the groups of invertebrates are abundantly represented, but by higher and more complex forms than their predecessors. The brachiopods, trilobites, and cephalopods are highly ornate and handsomely sculptured, showing advanced stages of development. Land plants become abundant, mostly tree ferns and related forms, forming jungles and forests, presaging conditions that were to follow. One group of low plants known as Rhizocarps were so abundant in this period that their spores are believed to have furnished the oil and gas found in the rocks of the Devonian.

The great and characteristic development of this period, however, is the wonderful expansion of the Vertebrate group of fishes. These occur in very varied forms and of great size. Their nearest related forms of living fishes are the sharks and lung fishes. They were largely armor-plated, sluggish in habits, with cartilaginous skeletons and vertebrated tails. Their teeth were flat crushing plates that lined the jaws and roof of the mouth like pavement blocks, being well-adapted to crushing the shells of the crustaceans and shell-fish that formed its food. These great fishes were the rulers and depredators of the Devonian seas.

Carboniferous.—This long period began with a marine stage during which limestones were deposited in the interior of the continent, and thick beds of coarse sandstone in the eastern region. Marine life in abundance swarmed in the clear warm interior seas, mostly invertebrates, however, for the bizarre and cumbersome types of fishes so characteristic of the Devonian seas, were much less abundant now, many of them having disappeared altogether.

The chief characteristic of this period was not its marine life, but its land plants. These, we have seen, had appeared and become fairly abundant in the Devonian, but during the latter part of the Carboniferous they overshadow in their abundance every other form of life. The areas of all the interior of the continent, where in the earlier part of the period the sea had been depositing limestones, now emerged and formed extensive low, level land surfaces. These lands were wide-spreading swamps over thousands of square miles, upon which grew in impenetrable forests and jungles the plants of the time. These were numerous species of tree ferns, such as grow in the tropics today; *lepidodendra* (scale-tree),fifty to seventy-five feet high, related to our club mosses of today, which are only a few inches high; *sigillaria* (seal), similar to *lepidodendron*, but unbranched, while the latter are widely branched, with clubbed extremities, and *calamites*, which were trees related to the scouring-rush of today.

It is an interesting fact that the nearest living relatives of all these forms are swamp and moisture-loving plants, and it is almost sure that they were equally so in that day. The conditions under which they grew must have been those of extensive swamps having uniform temperature. As the vegetation grew in rank profusion and died or dropped its leaves, these fell into the water beneath and formed peat. Through countless generations of trees this process continued, the peat accumulating to great depths. Then a submergence brought the sea over the area, and deposits of sandstones and limestones covered the peat beds. Then emergence again brought the swamps and peat bogs into existence, which in course of ages were again submerged.

This alternation of conditions continued for a long time, and ended in a period of recession of the sea except from limited depressed troughs where sterile, and in places, salt-bearing, strata were deposited. This final stage is known as the Permian, characterized by very unique and strange life forms, as shown by fossils that have been found.

The great peat beds throughout the interior of the continent under their heavy burden of rock-cover have consolidated into coal, and form one of our most valuable natural resources. At the end of the Carboniferous period the Appalachian region, which had been throughout the whole Paleozoic era an area of sedimentation, was slowly crushed up by lateral pressure into the Appalachian mountain region, the rock strata being strongly arched and folded. This Appalachian revolution closed the Paleozoic volume. A new volume, the Mesozoic, is opened by the inauguration of new conditions after the revolution.

During the Paleozoic, in spite of the repeated oscillations of the land, a gradual emergence of the continent took place, so that at the close of the Paleozoic most of the present North American continent was above water. A large area in the west was still covered by the sea, and all of the southern Atlantic and Gulf Coastal Plains were still submerged, embracing all of Florida, the southern half of Georgia and Alabama, all of Mississippi, except possibly very small exposures in the extreme northeast corner, all of Louisiana, and a broad strip of southeastern Texas.

The Mesozoic Era.—The Mesozoic Era, or middle period of geological history, was much shorter than the Paleozoic though in many places the rocks are thousands of feet in thickness, indicating great lapses of time. Three periods are recognized: 1. Triassic; 2, Jurassic; 3, Cretaceous, the last of which was longest, and of far more importance in North America.

Triassic and Jurassic.—In the eastern parts of this country limited deposits of estuarine sandstones were made in narrow trough-like depressions during Triassic and perhaps Jurassic times. In the valley of the Connecticut River is one of the most notable of these deposits. These sandstones are brown in color, rather fine-grained, and retain ripple marks, rain drops, and great bird-like tracks, that were left when the sands were freshly exposed by the retreating tides. In the valleys of eastern Virginia and North Carolina similar deposits were made, but interstratified with the rocks are beds of coal showing that at intervals these basins became converted by emergence into swamp lands which supported peat-forming vegetation for long periods.

In the western parts of the continent extensive deposits of red sandstones with interstratified gypsum and salt probably indicated deposits on land, somewhat like those made in the arid West today in wet weather lakes. The salt and gypsum were deposited under arid climatic conditions. These red beds were probably of Triassic age, but on the Pacific slope large limestone deposits are of marine Jurassic.

Cretaceous.—The Triassic and Jurassic were periods during which the continent was standing above water, except in limited areas; but with the Cretaceous began a period of wide-spread submergence, especially in the western parts of the country. The Cretaceous seas teemed with life, and limestones and marls were deposited on the sea floor rich in remains of the life of the period. To what extent submergence occurred on the southern Atlantic and Gulf Coastal plains is not definitely known, but at the close of the period the continent was enlarged by uplift in that region, exposing in land surface a broad strip of limestones and marls that were Cretaceous sea-bottom. In the west the Cretaceous sea advanced over the land until finally waters from the Gulf of Mexico met those from the arctic sea and spread out in an interior sea over much of the continent between the Mississippi River and the Rocky Mountains. With the close of this period the seas receded and left thick deposits of limestone and chalk, rich in fossils.

The Mesozoic Era is the Age of Reptiles, just as the Devonian had been the Age of Fishes. While the forms of life were very abundant and varied, the predominant and characteristic forms were reptiles. These were of varied types and often of enormous size. Undoubtedly some of these reptilian forms weighed several tons. They were carnivorous and herbivorous in habits, the herbivorous forms being more often bulky and unwieldly in size and of sluggish habit. Some lived in the seas, some walked among the jungles of the land, some spread broad wings and flew through the air like gigantic bats. Some of the flying forms had a wing spread of at least twenty feet; some that sported in the sea had a length of forty to fifty feet, while some of the land forms were of such size that a single thigh bone was six feet long and large in proportion.

The Cretaceous outcrop in Mississippi is marked by the prairies of the northeast counties, the soil of which is derived from the underlying soft limestones. Pontotoc Ridge marks the outcrop of marls of the uppermost Cretaceous. Both of these will be described in detail later.

The Cenozoic Era.—At the end of the Mesozoic a continental uplift brought the continent substantially to its present state. East of the Mississippi River the chief differences were in the Gulf Coastal Plain, especially that part representing the Mississippi River embayment. Here a wide triangular area with its apex at the mouth of the Ohio River was still under water. This embayment embraced all of Mississippi except the northeast Cretaceous lands, all of Louisiana, and broad areas in Texas skirting the Gulf Coast.

During the Cenozoic Era, which embraces two periods, the Tertiary and Quaternary or Pleistocene, this embayment became gradually filled out, as will be shown in the discussion of Mississippi geology.

The Tertiary Period, which is the longest and most important in its relation to the geological record, has four recognized divisions: Eocene, Oligocene, Miocene, and Pliocene. These are all represented in Mississippi. The additions made during these four epochs in the Mississippi embayment were both marine and fresh water deposits, and were made in broad bands successively farther and farther south, the oldest being the most northern, the youngest the most southern.

During Pleistocene time a blanket formation of no great thickness was spread over the outcropping edges of the older formations in this region. The character of the material indicates a wind-blown deposit.

The life of the Cenozoic Era is the culmination of creative effort in that direction. All the invertebrate groups are present, all the higher groups of plants had appeared, all the vertebrates of modern types, including man himself, culminated during this era. In fact, life as we know it today is the latest phase of development of this era.

The highest group of vertebrates, the mammalians, culminated during the Pleistocene in varied and often monstrous forms, man by his superiority gradually gaining the ascendency over them.

GEOLOGY OF MISSISSIPPI.

We have spoken of the Azoic and Eozoic Eras of earth history as being of very great duration, much longer than all the later history of our globe. During these illimitable ages we have no evidence that any part of the present State of Mississippi was land surface. No rocks of age approaching these remote times have been found within the state. Just what the condition was in the Gulf Coastal region we have no direct way of knowing. It is entirely possible that the region was alternately sea bottom and land surface many times before any positive record of its history was left in the rocks. Mountain chains may have been upheaved and worn down to sea-level, the lands may have sunk down beneath seas teeming with life, long before the inauguration of the up-building processes by which the present lands came into existence.

DEVONIAN.

The oldest rocks that are known to occur in Mississippi are fossiliferous limestones of Devonian age. As we have seen in the preceding chapter, the Devonian was a period of the Paleozoic Era. Our geologic history begins after that of the more northern parts of the continent was already nearing completion.

Yellow Creek Beds.—In the bluffs and ravines near the Tennessee River, in Tishomingo County, is a series of dark gray and blue shaly limestones that underlie all the later formations in that region of the state. These beds outcrop in bluffs and steep slopes along the lower part of Yellow Creek, and other small streams flowing into the Tennessee and along the bluffs of the Tennessee itself. At the mouth of Bear Creek, eight or ten miles toward the southeast, they form the bases of the hills and bluffs, the top of their outcrop being marked by springs and seeps. At certain levels these dark limestones contain a fauna of marine shells of Devonian age, corresponding to the New Scotland beds of New York. These limestones are towards the top quite shaly and cherty, indicating that, while the deposits were made on a sea-bottom, considerable mud was being brought into the Devonian sea and intermingled with the marine sediments. So far the fauna discovered in these beds laid down on the old sea-floor consists for the most part of brachiopod shells, crinoids and trilobites.

Along Yellow Creek these Devonian beds reach a maximum exposure of about 100 feet, but are much less at the mouth of Bear Creek, the dip being toward the southeast. The Tennessee here runs in a broad trough cut out of these and overlying beds. The total thickness of the Yellow Creek beds as revealed in a deep well, near old Eastport at the mouth of Bear Creek, is about 450 feet.

MISSISSIPPIAN OR LOWER CARBONIFEROUS

The Yellow Creek beds represent a horizon toward the base of the Devonian series of rocks, all the middle and upper members of the series being absent at this place. The formations immediately overlying the Yellow Creek beds consist of thick beds of chert of Lower Carboniferous age. A long period of time intervened between the deposition of the two series, during which the sea had receded from this region and dry land appeared and was subjected during the interval to the usual weathering and erosion of land surfaces. As a result of this erosion interval the Carboniferous rocks are said to lie uncomformably upon the Devonian beds. A break in the record, made by uplift of a sea-bottom into land and then a resubmergence, results in an unconformity.

Lauderdale Chert.—The Carboniferous formations of Mississippi are represented in the region of the Tennessee River by the Lauderdale Chert, which immediately overlies the dark shaly limestones of the Devonian. This formation consists of stratified beds of siliceous chert, finely jointed, especially on exposed surfaces, causing the beds to break down into angular fragments well adapted to use as a road material.

At McMaster's water-mill on Little Yellow Creek, ten miles from the Tennessee River, the Lauderdale Chert beds are 20 feet thick; on Whetstone Creek several miles to the southeast, 100 feet thick, and at the mouth of Bear Creek, still farther southeast, they reach the thickness of 250 feet. It will thus be seen that it thickens decidedly toward the southeast

Chert, of which this formation consists chiefly, is an impure variety of flint, the impurity being clay in varying proportion, often with iron as a coloring matter. The chert of this formation is light gray to cream color, having little iron, but often large proportions of clay. It is of flinty hardness and makes an excellent road material.

In the vicinity of Bear Creek, two miles from old Eastport, beds of snow-white pulverulent silica, or tripolite, ten to twenty feet in thickness, have been mined in the past, the material being sold for an abrasive. This material is interstratified with the chert, and often passes into it laterally, so as to suggest its derivation from the chert, perhaps by processes of weathering. Microscopic examination of the tripolite failed to discover any organic remains which could have given rise to the deposits.

White clays of the Cretaceous formations in the same region are found to be rich in fine silica, and are probably derived from weathered chert of this period reworked during Cretaceous times.

This formation, like the preceding, has a limited outcrop within a few miles of the Tennessee River, being exposed in steep slopes of this river and its tributary creeks or branches. At the mouth of Bear Creek the prominent ridges are almost entirely made up of chert beds of this formation. Its extension toward the south is limited by overlying later formations.

Tuscumbia Limestone.—Lying immediately upon these cherts is the Tuscumbia Limestone, correlated with the St. Louis Limestone of the interior of the continent. As would be expected of beds dipping southward, the outcrop of these limestone beds lies to the south of that of the Lauderdale chert, indicating a progressive uplift of the series from north to south. The formation consists of blue or gray cherty limestones, the lower portions being more cherty than those above, indicating the transition from the conditions under which the Lauderdale chert beds were deposited. In its upper portions the limestone becomes more pure.

At certain horizons the limestone is quite fossiliferous, the fossils so far discovered being invertebrates such as crinoids, corals, trilobites and mollusca. One of the most characteristic is a large coral, *Lithostrotion Canadense.*

An uppermost member of this formation is a light-colored limestone of oolitic texture, a rock composed of small rounded grains like fish eggs.

The rock is drab-colored and takes a good polish. The characteristic fossil of this rock is a crinoid, *Platycrinus Huntsvillei*. The outcrop of this oolitic limestone in Mississippi is limited to a few miles square in eastern Tishomingo County about midway between Iuka and Tishomingo City. Elsewhere it is covered by later formations though in Alabama it outcrops over an area of nearly 1,100 square miles.

Hartselle Sandstone.—The upper part of the Mississippian, or Subcarboniferous series of rocks consists in Alabama of two groups, (a) Bangor Limestone and (b) Hartselle Sandstone. These groups correspond to the Chester group of the interior of the Continent. In northwestern Alabama the Bangor Limestone is much more prominently displayed than the overlying sandstone, though the latter thickens decidedly toward the west. In Mississippi the limestones are not at all prominent, but the sandstone members outcrop in conspicuous rugged bluffs along Bear Creek in southeastern Tishomingo County, and on Bull Mountain Creek in northern Monroe and adjacent regions.

The Hartselle Sandstone is a thick-bedded, rather coarse-grained light gray sandstone, non-fossiliferous generally, attaining a thickness of at least 100 feet along Bear Creek. To the east of Tishomingo City Bear Creek runs between high cliffs of this sandstone. The outcropping of this rock forms some of the most picturesque and rugged scenery in the state. The most westerly outcrop of this sandstone is at Bay Springs, on Mackey's Creek.

As a building stone this rock is of excellent quality, standing satisfactorily the usual tests. A block in the Geological Survey cabinets at the University shows the handsome appearance of the stone when dressed by the stone cutter.

These beds form the southernmost outcrop of the Paleozoic series in Mississippi, and dip beneath the Cretaceous beds, which overlap them on the uplands of all this region. The presence of thick sand beds at the top of the Carboniferous overlying the marine sandstones indicates a decided change in the physical conditions toward the close of the period. Where before a quiet sea of some depth received deposits chiefly from the comminuted shells and remains of disorganized marine life, now swift streams began to bring down from the land large quantities of sand, often coarse, and deposited it on the sea floor. This change was probably brought about by an uplift of the lands bordering the sea, with a rejuvenation of the streams; or possibly a change in the direction of the offshore currents might have brought to this shore materials previously deposited elsewhere. Then, as now, it was quite possible for sand deposits to be made on one part of a shore, while mud or limy deposits were being made along another part. It is certain that, from whatever cause the change in the character of the deposits, a complete change in marine life inhabiting this shore must have been coincident with it. As these sandstones are barren of fossils it is probable that most of the marine fauna was driven into less disturbed waters.

By usage adopted by the United States Geological Survey within the last few years, in order to correlate the Alabama formations with those of Tennessee, previously named, the Lauderdale Chert and the Tuscumbia Limestone of Alabama are included in the Fort Payne Chert of Tennessee. Similarly the Hartselle Sandstone is disposed of as a member of the Bangor Limestone formation, the sandstone member separating an upper and a lower limestone member of the formation.

Unfortunately the Coal Measures which are so characteristic of the true Carboniferous Period, and which are so rich a source of mineral wealth to the regions where they occur, do not extend into Mississippi. No true coal need be looked for in our state, though lignite of very good quality is not uncommon in the later formations.

CRETACEOUS FORMATIONS.

A very long interval occurred between the deposition of the latest Paleozoic rocks in this state, and the next oldest formation. The transitional Permain, the Triassic, and the Jurassic, all so well developed in the west, are absent in Mississippi and the rest of the Gulf Coastal region. The Mesozoic Era is represented here only by the Cretaceous formations, which bring that era to a close. Since there were no deposits being made in this region or in the whole Appalachian region to the north, we have reason to believe that during that long time the Appalachian region, the southernmost margin of which we have just been studying in the Paleozoic formations of the state, was an uplifted land area undergoing erosion. In deed the structure of the region farther north indicates that it was not only a land surface, but an intensely folded mountain region, the mountains perhaps rising much higher than now.

Tuscaloosa Formation.—Undoubtedly during this period of mountain-making the continental border was uplifted into land far to the south of the present exposures of the old rock. This is shown by the fact that the Tuscaloosa formation at the base of the Cretaceous lies uncomformably upon the hard Paleozoic rocks. At the beginning of Cretaceous times the old land surface sank beneath the sea and received upon its eroded surface the beds of the Tuscaloosa. These consist in their lower part of dark gray, brown and lignitic clays and lignite in thin beds. In contrast with the Carboniferous rocks upon which they rest, these Cretaceous beds are unconsolidated, although the dark clays and lignites are compact and relatively impervious, giving rise to springs where covered by loose sands along the valley sides.

Above the clay beds the formation becomes more sandy, the sands being of variegated colors, loose, rather coarse, and frequently cross-bedded. Among the sand strata clay lenses and discontinuous clay beds are frequent, the bedding being notably irregular, as is deposited from turbulent streams or worked over by waves and conflicting currents. The upper parts of the formation are of lighter colored clays, the clay often being pure enough to be used for making stone ware. Associated with the sand in much of its outcrop immense deposits of chert gravel characterize the Tuscaloosa. Not uncommonly in the midst of the gravel deposits will appear a lens of white clay, or clay may pass laterally into sand-beds within a few rods. The sands often assume a deep red color from weathering, passing down into darker colors. The lignitic clays frequently contain leaf impressions. The seams of lignite are usually thin, and rarely more than two feet thick. It is often dense and black like coal, and contains occasional small masses of a yellowish-brown fossil resin.

The beds of the Tuscaloosa are distinctly unconformable upon the Carboniferous, and dip toward the south and southwest at the rate of 25 to 30 feet to the mile. Their thickness in western Alabama is estimated to be 1000 feet, but it is much less in Mississippi. At Corinth the Tuscaloosa is 270 feet thick, and thickens southeastward toward the Alabama line.

Unlike the Paleozoic formations, which are exposed only in very limited areas along the edges of deep ravines and river valleys, the Tuscaloosa beds form the surface terrain over a long narrow belt of country five to fifteen miles wide and extending from the Alabama line to the border of Tennessee. This area embraces the northeastern part of Lowndes County, the east half of Monroe, a narrow strip along the eastern border of Prentiss and Alcorn, and overlaps the Paleozoic in Tishomingo and Itawamba counties. The Tombigbee River forms the western boundary north of Monroe county, and from there to the Alabama line it lies a few miles west of the Tuscaloosa outcrop.

This formation has every appearance in Mississippi of having been deposited by fresh waters. Alternating swamp and shallow water conditions probably existed, during which the lignites and lignitic clays were deposited. The sands and gravels of the middle parts of the formation show such erratic and irregular structure as to suggest deposition in turbulent, swift waters.

Economically the extensive deposits of chert gravel are a most important product of the Tuscaloosa, being a very valuable paving and road-making material. The pottery and stoneware clays have been but little developed, but promise more in the future.

Eutaw Formation.—The Tuscaloosa formation passes by gradual transition into the next division of the Cretaceous, the Eutaw, so called from the type locality in Alabama. This is prevailingly a sand formation, with occasional intercalated clay beds, which may pass laterally within a few rods into sand beds. The basal parts of the formation differ little from the Tuscaloosa, consisting of strikingly variegated sands of red, yellow, blue and other colors. These sands, are distinctly micaceous and conspicuously cross-bedded. Beds of the formation, both sands and clays, are discontinuous and variable over short distances, very much as in the Tuscaloosa. The upper beds become glauconitic and calcareous toward the top, merging into the overlying Selma Chalk of the Prairie region. These uppermost green sand beds are highly fossiliferous, the commonest forms being the large spirally twisted shells of the oyster family, *exogyra ponderosa*, and the coiled chambered shells of the Ammonite group. Some of these are of immense size.

The uppermost calcareous beds of the Eutaw pass by gradual transition into the overlying Selma Chalk. The best exposure showing this contact is at Plymouth Bluff on the Tombigbee, four miles north of Columbus. About ten feet at the top of the bluff on the west side of the river is light blue calcareous clay of the Selma Chalk; below this is five feet of unconsolidated green sand containing oyster shells. Immediately below this is a 12-inch projecting ledge of indurated green sand. In this ledge are found numerous close coiled chambered shells, one foot or more in diameter. About 12 to 14 feet of the bluff, from this ledge to the water's edge, is dark gray to dark green calcareous sand. All of this bluff but the uppermost 8 to 10 feet is Eutaw. The river bluffs at Columbus expose only Eutaw material, the contact with the Selma being two or three miles farther west.

The area of outcrop of the Eutaw is a narrow strip 5 to 10 miles wide, just east of the Tombigbee River in Monroe and Lowndes counties, but extending on the west side of the river to the north of these counties, passing through the western part of Itawamba, east-central Prentiss and eastern Alcorn. The surface presents rough and eroded topography as compared with that of the Selma area west of it.

Selma Chalk Formation.—This division of the Cretaceous was called by Hilgard, "Rotten Limestone," but that name has been discarded by most geologists and the name Selma Chalk substituted. This name is taken from the town of Selma, Alabama, where the formation is typically exposed.

This formation is of marine origin, having been deposited on the Cretaceous sea floor as a highly calcareous mud teeming with the shells and other fossil remains of the marine life of that time. Its outcrop is much the most extensive of the Cretaceous formations in the state, and is marked by the region of so-called "black prairies" of northeast Mississippi, though the Selma outcrop is more extensive than the prairies proper. It is a region of slight topographic relief, presenting a gently undulating surface naturally devoid of trees, except a growth of rather undersized oaks on the more elevated ridges, and usually a fine hardwood growth on the larger stream bottoms.

The region embraces a broad belt running nearly north and south, the south half curving slightly eastward, through several counties of northeast Mississippi. The belt enters Alcorn County on the north and passes a little west of the center in a band six miles wide, occupies the west third of Prentiss, and the southeast corner of Tippah, nearly all of Lee, and a narrow strip on the eastern border of Union and Pontotoc, the east half of Chickasaw and west third of Monroe, all of Clay except a little of the western part, the northeast third of Oktibbeha and the west two-thirds of Lowndes, practically all of Noxubee and the extreme northeast corner of Kemper.

The material of the formation is a semi-indurated limestone of rather constant characteristics throughout its outcrop, though showing three distinct phases from bottom to top. The basal portions are very sandy, the sand having been worn by the waves and streams from the older lands of the sandy Eutaw and spread upon the bottom of the Selma sea. These sands, however, are highly calcareous, and become more so upward until they disappear, indicating that the adjacent lands had been worn down and the streams no longer deposited sands on the sea floor.

The streams, however, were still carrying fine sediments such as clay for instance, and mixing it with the comminuted remains of marine life which accumulated on the sea-bottoms. This is shown in the fact that the middle portions of the Selma consist of a tough, clayey limestone, called "blue rock," because of its color. The proportion of clay is such that formerly before artesian wells were known in this region cisterns were dug into this "blue rock," and so impervious is the material that they held water without cementing. On account of this quality the middle Selma forms an excellent cover to confine the waters contained within the Eutaw aquifers, furnishing perfect artesian conditions.

Toward the close of the period the lands bordering the Cretaceous sea had been worn down to a plain practically at sea level. This is shown by the fact that during that time no land-derived sediments were deposited on the sea bottom, but the calcareous remains of marine life gradually built up the sea floor with deposits of almost pure calcium carbonate. So pure is the limestone that analysis shows frequently 95 to 98 per cent pure lime carbonate. The best representatives of this purer limestone, which are nearly white and usually called "chalk," are found in the railroad cuts at Okolona, at Osborne, in the bluffs of the Oaknoxubee River at Macon, and near Prairie Point.

Occasional temporary and probably local interruptions of this deposition of pure limestone occurred from time to time in slight uplifts which revived the streams, causing them to spread sand again upon the sea floor. These sand deposits were not pure but gave a decidedly sandy character to the rock formed during these intervals. These sandy limestones are notably developed in the vicinity of West Point, Shannon, Tupelo and Starkville.

At the close of the period a decided change was inaugurated. Considerable uplift in the northern parts of the state as far south as Houston brought large deposits of sand again into the seas, mixing it with the limy accumulations; at the same time a greenish, granular mineral known as glauconite (a silicate of iron, potash, magnesia and alumina) began to form a notable proportion of the sea bottom accumulations. These changes inaugurated the next period, the Ripley, which will presently receive attention.

Let it be remembered that the land surface of Mississippi has emerged from the sea by successive uplifts, so that the land has been growing by repeated additions of marginal sea bottom. For example, at the close of the Paleozoic all the old hard rocks described in previous pages, which during Paleozoic time were sea bottom or low swamps about sea level, were uplifted into high and dry land. How far south this uplifted land extended we do not yet know, but that it was much farther than the outlines of the present Paleozoic area in the state is a certainty, for a great break, or unconformity, occurs between these rocks and the Cretaceous which overlie them. This break is interpreted to mean that at the end of the Paleozoic time a great area of old sea bottom was uplifted into land and remained above water for a very long interval, during which time this land was wearing down by erosion, just as our land surfaces are doing today. Finally about the beginning of Cretaceous time this eroded land surface began to sink beneath the sea, and when the Tuscaloosa deposits began, practically the whole land in Mississippi had again become sea bottom, with the shore line in the vicinity of the Tennessee River. We know that this took place because the unconsolidated Cretaceous deposits overlie the uneven eroded surface of the Paleozoic rocks up to that point.

So too, at the end of the Tuscaloosa all the present outcrop of that formation was uplifted into land. Similarly, at the end of the Eutaw all the present area occupied by that formation was elevated into land surface, but since the Eutaw passes without a break into the basal Selma, or is said to be conformable with it, the shore line at the close of the Eutaw was coincident with the present Eutaw-Selma contact, except in limited areas where some of the overlying Selma may have been removed by later erosion, uncovering Eutaw strata.

At the end of the Selma time, some green sand or glauconite, as well as terrigenous sands, had entered into the formation of the rocks of the closing period, due to local uplifts of the old Eutaw lands. Then came the bodily upheavel of the whole Selma area into land, imprisoning within its rocks innumerable shells and remains of both vertebrate and invertebrate life. That these seas swarmed with life is shown by the fact that immense shells of various types, as *ostrea*, *exogyra*, *gryphea*, and *radiolites*, as well as shark teeth and bones, are often found in countless numbers on exposed slopes of the Selma Chalk.

The thickness of the Selma in Mississippi is at least 1000 feet toward the south but thins out northward, near the Tennessee line, to 350 feet. The deposits are entirely marine, and for the most part laid down in quiet water, so that from their character and thickness and the known rate of accumulation of such sediments we are safe in concluding that the Selma was of longer duration than all the rest of Cretaceous time recorded in the rocks of Mississippi.

Ripley Formation.—This, the uppermost division of the Cretaceous in Mississippi, receives its name from the town of Ripley, in Tippah county, where it outcrops characteristically. Conditions were less uniform during this period than during the preceding, as shown by the diverse character of the deposits, consisting of sandstone, limestone, glauconitic sands and marls. From Houston north to the Tennessee line this formation consists of alternating beds of glauconitic sandy marl and limestones as exhibited in the series of ridges known as Pontotoc Ridge. South of Pontotoc Ridge both the material and topography assume the character of and are continuous with the Selma Chalk, though recent study has shown the fossils to be of Ripley age. This is true, however, of only a narrow zone extending along the western border of the Selma. Near the Alabama line the material again assumes more of a sandy and marly character. This passage laterally of the coarser sandy material into the finer-grained, purer limestone need not be surprising, though it was for a long time misleading. It probably indicated quieter and deeper water, with a more distant shore line, in the region where limestone was deposited—conditions which had persisted from the Selma times.

The most notable and characteristic of the Ripley materials is the Owl Creek marl, a blue, sandy marl exposed along the bluffs of Owl Creek, three miles northeast of Ripley. This marl is exposed at intervals from Pontotoc to the line of Tennessee, presenting little variation of characters, and teeming with fossils wherever found. The fossils are usually very friable, but in many cases the irridescent nacreous layer of the shells is beautifully preserved. The most common fossils are the shells, *ostrea, exogyra, gryphaea, trigonia, baculites, scaphites,* sea urchins of several genera and occasional fish teeth. On exposure the marl weathers to an Indian red soil of high fertility.

The Owl Creek beds are the most noted collecting ground in the country for Ripley fossils, many geologists having visited the locality near Ripley since the time of Hilgard, the discoverer of the marl beds on Owl Creek. It has been recently discovered that the McNairy sand, a member of the Ripley, extends from Tennessee through Tippah county and makes up the greatest thickness of the Ripley. These are coarse, cross-bedded, varicolored sands, slightly fossiliferous in places, and are largely developed in the rugged Hatchie Hills of eastern Tippah County.

The Ripley period was closed by the elevation above sea level not only of the zone of Ripley rocks now exposed, but perhaps of a much larger area to the south and west, for the next formation deposited, the Tertiary, overlies the Ripley unconformably, indicating, as already explained, a period of elevation, erosion and depression, between the two periods of deposition.

TERTIARY FORMATIONS.

The close of the Ripley time brought to an end the Cretaceous Period and the Mesozoic Era. The middle age of the earth's history had passed, and the Cenozoic, or modern age of the earth began. A great revolution in the history of life on the earth occurred at the end of the Mesozoic. This is not conspicuously evident in the physical break between the earlier and later formations, but the change in life forms was complete. Very few, if any, species living in Cretaceous times passed the dead line into the Tertiary. This does not mean that there was a cataclysmic destruction of all life at the end of the Cretaceous, with a subsequent recreation under new forms. But it does mean that during the transition interval, the record of which is lost so far as our present knowledge goes, the conditions of life changed so rapidly that a concomitant rapid evolution of living creatures took place, so that when somewhat normal conditions were established and the life record again began to be written in the rocks, the forms were all different—new species had replaced the mediaeval ones, and a new story was being written.

MIDWAY GROUP

The beginning of the Tertiary record in Mississippi is contained in a series of marine limestones and marls and fresh water clays and estuarine sandstones referred to the Midway Stage, the name having been first used by the Alabama Geological Survey for a locality in that state.

Clayton Formation.—The lowest beds of the Midway consist of about 60 feet of hard, semi-crystalline limestone and glauconitic sandy marls of the Clayton Formation (named from Clayton, Alabama). The full thickness of these beds is not always found in one locality. The lowest member consists of 15 to 25 feet of the yellowish hard limestone, which weathers into strikingly rough surfaces, often due to outstanding fossils. The rock is abundantly fossiliferous, the commonest form being a conical spiral univalve, *Turritella Mortoni*, whence it is often called the Turritella rock.

Overlying this rock is 20 to 40 feet of greenish-gray glauconitic marl which weathers into a yellowish red sand.

The Clayton beds overlie the Ripley unconformably, and outcrop along the crest and the west slopes of Pontotoc Ridge. The weathered marls of this formation give rise to much of the red soils of Pontotoc Ridge. The characteristic limestone of the formation is best exposed in Tippah County, especially overlying the Owl Creek marls of the Ripley in the vicinity of Ripley. The Clayton marls, however, form the surface red soil around Chalybeate, Cotton Plant, Blue Mountain, (east of the town), and New Albany, and probably around Ingomar, Pontotoc and Houston. These beds overlap the Ripley marl along the St. Louis and San Francisco Railroad at least two miles east of New Albany. The soils of this formation support fine hardwood forests.

Undoubted marine conditions existed during the Clayton Period, for the limestone and marls contain marine shells.

Porters Creek Formation.—This formation receives its name from Porters Creek, in Hardeman County, Tennessee, where it is typically exposed. Hilgard called it Flatwoods, and that is what it is popularly called in this state.

This formation consists of about 150 feet of dark gray clay, which usually does not show distinct stratification, weathers nearly white, and on drying breaks into rounded nodular masses that shell off in conchoidal thin plates. It forms a dense, cold, wet, clay soil difficult to cultivate, especially in wet seasons. The name suggests its flat, even topography, which has been likened to a large stream bottom. It is not always so level, however, very considerable hills occurring in its area. The Flatwoods clay is naturally covered with forests of oak and pine, very inferior, however, to the rich tree growth of the Pontotoc Ridge.

The outcrop of the Porters Creek Clay is typically a low, flat region skirting the Pontotoc Ridge on the west, passing south along the western border of the Ripley and Selma Chalk, thence eastward out of the state through Noxubee and Kemper counties. It is three to six miles wide, seldom as much as ten.

These clays are nonfossiliferous, except occasionally, where they become lignitic, indistinct leaf impressions occur. In Alabama the basal portion of these clays is black, and calcareous, and contains marine fossils, but these fossiliferous clays do not occur in Mississippi except sparingly near the base. The whole formation, with that exception, so far as we have yet discovered, is fresh water deposit, probably laid down in shallow quiet waters with low surrounding lands, whose streams carried only the finest sediment.

The thickness of the Porters Creek Clay is at least 150 feet, and dips westward at an angle of a minimum of 15 feet to the mile. The average dip is more probably not less than 25 feet to the mile.

Tippah Sandstone (Crainesville of Harris, [1]).—In the first edition of this bulletin we gave the name of Tippah Sandstone "to a series of marine or estuarine fossiliferous sandstones and underlying sands prominently exposed in the broken hills and ridges of Tippah County." Later examination of the literature of the Midway revealed the fact that G. D. Harris had described in 1896 beds representing apparently the same horizon at Crainesville, Hardeman County, Tennessee. Hence, by rule of priority, the name Crainesville would apply to the Mississippi beds, but for the fact that Harris did not make clear what was included in his Crainesville horizon. He apparently recognized no divisions of the Midway, but regarded it as "a stratigraphic and paleontologic unit." Since in the opinion of the writer three easily identifiable subdivisions of the Midway group exist in Mississippi, all of which are perhaps of formational value, the name Tippah Sandstone, originally given to the topmost division, is here retained.

The formation, as here designated, embraces a series of sandstones, usually fossiliferous, and speckled with glauconite grains. These sandstones are gray to greenish-gray in color, weathering often to yellowish. The individual beds are one to two feet thick, and are interbedded with gray or greenish sandy clay, showing more or less glauconite. The sandstones and unconsolidated sands predominate toward the top of the formation, while clays are more prevalent below, grading into the gray clay of the Porters Creek at the base.

The formation is approximately 100 feet thick in Tippah county. A generalized section of the formation in northern Tippah is about as follows:

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[1]The Midway Stage, by G. D. Harris, 1896. Bulletin of American Paleontology, Vol. 1, No. 4.

		Feet
8.	Reddish and yellowish unconsolidated sand	20-30
7.	Gray clay, non-fossiliferous	5
6.	Gray sandstone, rather coarse-grained, speckled with glauconite	1- 2
5.	Gray cellular sandstone, glauconitic, weathering to yellowish stains	2
4.	White and yellow unconsolidated sands	10-15
3.	Gray, laminated sandy clay, with soft gray sandstone partings, somewhat glauconitic	10-15
2.	Dark bluish-gray sand	8
1.	Dark gray, shaly lignitic clay, becoming darker below	10

The Tippah beds overlie the gray clays of the Flatwoods formation, forming a narrow outcrop between the western edge of the Porters Creek and the eastern edge of the lowest Wilcox. At numerous places in northern Tippah the Porters Creek Clay outcrops in the bases of the hills and the surrounding low lands, while the Tippah beds cap the higher hills. This is notably seen to the west of Walnut. At Blue Mountain a great thickness of the Porters Creek Clay is seen to be capped by thick deposits of the sands, sandstones, and sandy clays, in places fossiliferous, of the Tippah formation.

Outcrops of this formation have not been definitely located south of Tippah County, but it probably extends southward through western Union and Pontotoc counties, and has been described by Harris as reaching northward into Tennessee.

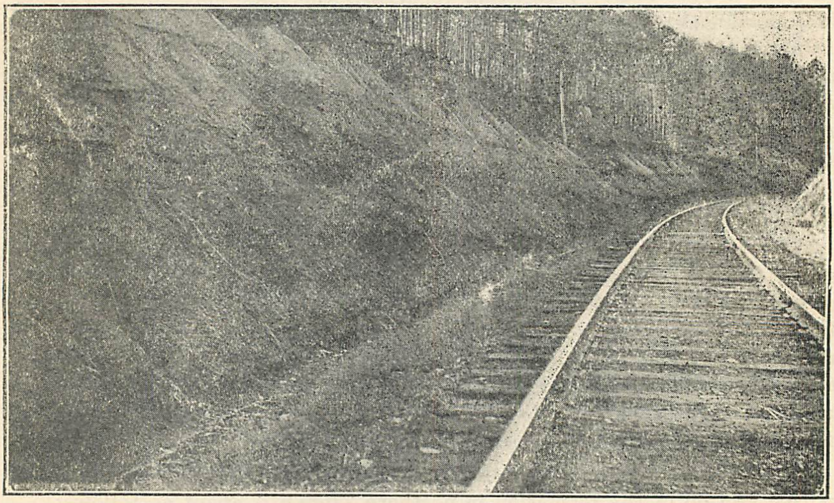

FIG.1.—Great cut at Blanton's Gap 1 1-4 mile northeast of Ackerman, Choctaw County, showing the type exposure of the Ackerman division of the Wilcox.

WILCOX GROUP

A great group of early Tertiary beds of clays, variegated sands, lignite, and carbonate iron ore was called by Hilgard the Lignitic, but later the United States Geological Survey adopted the name Wilcox from Wilcox County, Alabama, where it is typically developed. This group has a maximum thickness of 1500 feet, and its outcrop embraces all the north-central plateau of Mississippi. It is the most extensive division of the Tertiary series of formations occurring within the state, embracing all the area from the line of Tennessee southward and southeastward to the Alabama line, lying west and south of the Flatwoods and extending to the bluffs overlooking the Delta as far south as Grenada. Thence it is bordered on the west and south by the lower division of the Claiborne group through Montgomery, Attala, Neshoba, and Lauderdale counties. Its distribution can best be made out by reference to the map accompanying this report. It embraces part or all of eighteen counties of North Mississippi.

In Alabama several divisions of the Wilcox are recognized, the divisions being based upon the occurrence of fossiliferous marine marls. These divisions, with the exception of one, cannot be traced into Mississippi. In this state the Wilcox beds are fresh water and swamp beds and concretionary deposits of carbonate or spathic iron ore. While the deposits show marked irregularity and discontinuity in most places, individual beds being difficult to trace any considerable distance, the general character of the deposits changes with a fair degree of regularity in passing from the lowest to the highest beds of the group. These changes are four in number, and are recognized by the Mississippi Geological Survey as a basis for making the following divisions: 1, Ackerman Clays; 2, Holly Springs Sands; 3, Grenada Clay and Lignite beds; 4, Wood's Bluff beds.

Ackerman Clays.—This division receives its name from Ackerman, in Choctaw County, where Blanton's Gap, on the Aberdeen Branch of the Illinois Central Railroad exposes a fine section of gray and lignitic clay and lignite. The lowermost beds of the Wilcox are prevailingly gray and lignitic clays and lignite, at bottom differing but little from the clays of the Porters Creek formation with which they are in contact. In fact the line of division is arbitrarily drawn between them except near the Tennessee line where the Tippah sandstone separates them. The clays of this formation are more distinctly stratified than those of the Porters Creek beds, more variable in character and color, often quite sandy and bluish, or greenish, and not often closely jointed in conchoidal shapes as are those of the Porters Creek.

Lignite in beds of considerable thickness and of good quality is of frequent occurrence in the Ackerman beds, for which characteristic Hilgard called the whole group Lignitic. Associated with the bluish and gray clays and sandy clays are occasional thin beds of carbonate of iron. These beds are seldom more than a few inches to one foot in thickness, but frequently very pure. More frequently the iron is in the form of concretions, being lenticular in shape, and flattened in the direction of bedding planes. This iron is usually light gray in color and of dense, fine grained, homogeneous texture.

This formation has a width of outcrop in north Mississippi of about 22 miles, and deep wells at Oxford, Holly Springs and Water Valley indicate that it has a thickness of about 600 feet, and a dip westward of between 25 and 30 feet. The sands of the middle Wilcox overlap this near the Tennessee line, so that its outcrop becomes very narrow. In east Mississippi the divisions of the Wilcox are not as marked as in north Mississippi.

This formation occupies more than the eastern third of the Wilcox outcrop, and the surface topography varies from gently rolling near the Flatwoods to decidedly rolling and hilly farther west, though the hills are not as broken as in the area of the overlying sandy formations which border it on the west.

The deposits seem to be entirely fresh water, no marine beds of this formation having been found in Mississippi. It is probable that during the formation of these beds the land was very low and level, much of it being peat swamps, like the Dismal Swamp of Virginia today, and much of the area below water receiving fine clay sediments from the low surrounding lands. No fossils have been found in the deposits indicating marine conditions; only fossil leaves and tree trunks associated with the lignite, giving an index of the vegetation that grew in the low swamp lands. These are for the most part of species that find their living representatives more abundant in subtropical and tropical climates indicating warmer conditions during the early Wilcox Period than we have today in the same regions. E. W. Berry has discovered in the Wilcox beds of Mississippi species of plants that indicate estuarine conditions, but these were found in the Grenada beds just beneath the Claiborne when marine conditions actually began; the fossiliferous beds probably marked the transition from the fresh water to marine conditions.

Holly Springs Sands.—The deposition of the Ackerman clays came to a close by the uplift into high, dry land of the region now occupied by the outcrop of that formation. Then followed a period in which great sand deposits were made in the regions immediately to the west of and over-lapping the Ackerman clays. It is difficult to picture what the conditions must have been during the deposition of these sands. They were undoubtedly deposited in water, and there is every reason to believe that the deposits were made in fresh water. The very irregular lamination, and the coarse material indicate that the water currents were strong and variable, not unlike what we find in river channels or along sandy beaches.

These beds receive their name from Holly Springs, in Marshall County, in the vicinity of which the formation shows numerous and characteristic exposures. The formation is prevailingly sandy, the sands being rather coarse-grained, usually decidedly micaceous, and varying in color where exposed in outcrops from white to yellow, red, and purple. Red and yellow are the prevailing tints at and near the surface owing to oxidation

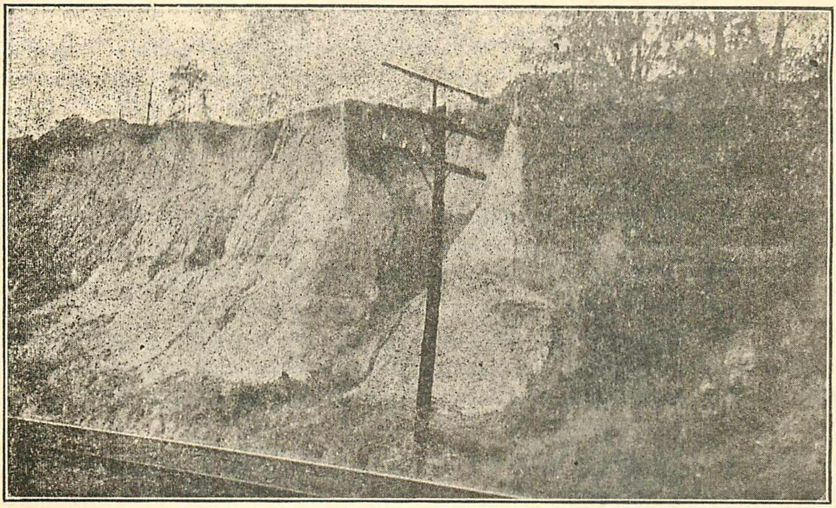

FIG. 2.—Exposure of the Holly Springs Sand, member of the Wilcox Group, in a cut on the Illinois Central Railroad, just south of the station at Oxford.

of their contained iron by weathering; below the surface the color becomes bluish or greenish on account of the protoxide condition of the iron coloring matter. Not unfrequently, especially in beds along which water passes freely, deep-seated sands are white and unconsolidated, due to the bleaching out of the coloring and cementing element—iron—by underground water currents.

The sands of this formation show cross-bedding, and other irregluarities of stratification suggestive of river deposits, which suggestion is strengthened by the frequent presence of thin strata of white or pinkish clays with leaf impressions, very much as leaves would become enclosed in fine clay deposited along the quiet reaches of a river.

There is a distinct zone of clay perhaps 100 or more feet thick extending through the middle of these sands separating more or less completely the lower half from the upper half. These clay beds are pink or white ball clays, and adapted to the manufacture of stoneware. This clay zone separates the upper and lower parts of the Holly Springs formation into two distinct artesian water horizons, the water of the upper division being confined beneath the clay and lignite of the Grenada beds, to be described presently.

One of the chief interests of this sand group from a geologist's point of view, is that Hilgard misinterpreted it for a much later formation, which he called the Orange Sand, or Lafayette. The existence of such a formation in the vicinity of Oxford, which is Hilgard's type locality for the

Lafayette, is extremely doubtful, and if it exists at all there, is but a thin veneering only a few feet thick, instead of 200 feet, as stated by Hilgard.

This division of the Wilcox is not prominently exposed south of Grenada, due, perhaps, to the overlapping of the Claiborne formation. The narrowing of the Wilcox outcrop south of Grenada, the small development of the Holly Springs beds, and the total absence of the Grenada or uppermost beds, suggest strongly that the Claiborne has overlapped and covered these beds from that point southward. That the Claiborne has actually in the past overlapped these formations farther than today is shown by more or less extensive Claiborne outliers capping the hills several miles east of the main outcrop, and entirely surrounded by Wilcox materials.

In Lauderdale County two miles northeast of Marion a very deep sand cut, 160 feet by barometric measurement, exposes perhaps the whole thickness of the Holly Springs sands in that vicinity. So that it is quite probable that the formation south of Grenada is partly overlapped, but thins out as well.

The outcrop of this formation is hilly and broken in most parts, the maturely eroded segments of an original plateau 450 to 650 feet above sea level. The maximum thickness of this formation is about 750 feet.

Hatchetigbee or Grenada Beds.—These beds whose last name is called from the town of Grenada, where they are exposed in a thickness of about 150 feet on the Yalobusha River, were first called by Prof. Safford the "Bluff Lignite," because their chief characteristic is lignite or lignitic clay, and are exposed chiefly along the edges of the bluffs bordering the Mississippi Delta. The clays of the formation vary from gray to black or dark brown. They are frequently said to be chocolate-colored; usually, however, the chocolate-colored clays become pinkish on drying and show abundance of fossil leaf impressions. The clays are frequently micaceous and somewhat sandy, the sand often appearing as silvery-white, fine sandy partings between thin pink laminae. This character is well exhibited at Grenada and at Duck Hill. Lignite is rather common in thin beds of chocolate-brown color, of fair quality, and of limited areal extent.

These beds outcrop along the bluffs from the Tennessee line southward. The most southern outcrop is one mile northeast of Duck Hill, south of which it disappears beneath the Claiborne. The width of outcrop is not very well known for the reason that it is almost entirely covered by later formations. Only an occasional cut exhibits its presence at all in the bluff region. It outcrops eight miles east of Hernando, DeSoto County, but it is not present six miles east of Sardis, Panola county, the sands of the Holly Springs beds appearing in an exposure.

South of Duck Hill, in Montgomery County, the Grenada beds disappear beneath the overlapping Claiborne, and do not reappear until in the vicinity of Meridian, where they come to the surface again. The materials in the two widely disconnected outcrops show similar characters, that of the eastern region being somewhat more sandy and micaceous. Where they outcrop in the high hills locally known as "the mountain," southeast of Meridian, they directly overlie, to a thickness of 100 feet, fossiliferous marine deposits of the Wood's Bluff Formation.

In the first edition of this bulletin we said, "It is quite possible that these clay and lignite beds represent the Grenada beds as exposed in the bluff region." Since that date (1916) it has been definitely proved by paleontologic evidence as well as by stratigraphic position, that the beds around Meridian are identical with those at Grenada, and that both are to be correlated with the Hatchetigbee formation of Alabama.

A number of fossil leaves collected at Perdue's Cut near Meridian were examined by E. W. Berry,[1] who reported as follows:

"It will be seen that of the 14 species identified from Meridian, three occur in the lower Wilcox or Ackerman formation, eight in the middle Wilcox or Holly Springs Sand, and twelve, or all but the two new species, in the upper Wilcox or Grenada formation. In addition it should be noted that several recorded from the middle Wilcox are found only near the top

FIG. 3.—Artificial lake near Mantee, Webster County, made in Flatwoods clay of Midway Group.

of that division, so that the present assemblage would be referred unhesitatingly to the upper Wilcox or the Grenada formation, even were its stratigraphic position unknown." Ten miles would be a fair estimate of the average width of outcrop. Assuming 25 feet dip to the mile would give the

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[1]U. S. Geol. Survey Professional Paper No. 108-E. 1917.

formation 250 feet thickness, which is, perhaps, about correct. High grade clays in great quantity are common in these beds.

Wood's Bluff Formation.—This formation receives its name from Wood's Bluff, on the Tombigbee, in Alabama, where there is an exposure of the full thickness of the formation. Until recently this formation was not positively known to occur in Mississippi, but was found during 1915 exposed in a new railroad cut two miles south of Meridian, where it consists of a basal member of marine marl of yellowish glauconitic sand, highly fossiliferous, the fossils being in good condition and easily collected from the loose sands at the base of the cut on the Memphis and Meridian Railroad, the excavation of which has recently been completed. The thickness of these fossiliferous marls is not positively known, but probably at this point is from 25 to 35 feet. Large gray, calcareous, mushroom-like nodules rich in fossils have been laid bare by the railroad excavation. Above the marls, lignitic clays and lignite are exposed on the neighboring hill to a thickness of at least 75 feet, representing the Grenada beds as exposed in the bluff region. So far, however, no underlying marls have been detected anywhere in that region, and until such are found it is impossible to correlate, with absolute certainty, the two sets of lignite beds. About 75 feet of yellow sand overlies the lignite beds at Seymour's Hill, Meridian, which may be either uppermost Wilcox or basal Claiborne; the typical Claiborne rock overlies it at the top of the hill.

During this Wood's Bluff stage the sandy marls were doubtless deposited in the shallow water of the sea margin, receiving numerous marine shells with the sands. Afterwards the water became fresh by uplift, and only swamps prevailed in the region with accumulation of peat, alternating with deposits of clay in the swamp waters. A gradual subsidence prolonged this process until the clay and lignite layers reached a great thickness, after which it was again submerged and covered with thick deposits of sands, probably the inauguration of the Claiborne submergence.

CLAIBORNE GROUP.

The Claiborne formations in Mississippi consist of hard quartzitic rocks, sands, claystones and glauconitic marls and clays, mostly of marine origin. These beds form a wide belt stretching across the state from the Alabama line to the Delta lowlands in a direction slightly north of west. Their outcrop is somewhat wider toward the west than on the eastern side of the state. This group embraces two rather distinctly-marked formations, the lower called the Tallahatta, and the upper the Lisbon, both names, as well as the name of the whole group being taken from Alabama localities.

Tallahatta Formation.—The lower division, called by Smith of Alabama the Tallahatta Buhrstone, and by Hilgard the Siliceous Claiborne, consists of several hundred feet of materials, the character of which suggested the names.

This formation appears in Mississippi in two very well marked phases. These are: 1, Winona Sand; 2, Basic Claystone.

The *Winona Sand* as found in the western part of its outcrop, especially well developed around Winona, Vaiden, and eastward into adjacent counties, consists largely of glauconitic sands and clayey sands that weather to an intense Indian red color where exposed at the surface. This material is marine in origin and locally abundantly fossiliferous. These deposits extend as far north as Grenada, the glauconitic sands indurated into hard sandstone boulders, appearing on the high hills between the Bogue and Yalobusha rivers several miles east of the town, and less noticeably two or three miles west of Grenada. Half a mile up the Bogue from the wagon bridge near Grenada the hills expose uppermost Wilcox lignitic clays at the water's edge, which are overlaid by highly ferruginated stratified sands—probably Claiborne—to a thickness of 75 to 100 feet.

On the Southern Railroad, both east and west of Winona, are characteristic deposits of this material, that at Elliott, three miles east of Winona, being especially striking. From Winona southward on the Illinois Central Railroad frequent outcrops of the material are seen as far south as Vaiden and Beatty. Five miles southeast of Vaiden this soft, highly ferruginous, fossiliferous sandy clay phase passes beneath the white quartzitic sandstone of the upper Tallahatta. The topography in this region is irregular and hilly, but not so broken as in the hard rock phases of the middle and uppermost Tallahatta. The thickness of this division of the Tallahatta in northwest Mississippi is estimated to be about 350 feet.

In east Mississippi in the Lauderdale hills the materials of the Winona beds change from highly ferruginated glauconitic sands, fossiliferous in numerous places, to white and yellowish coarse sand frequently cross-bedded and non-fossiliferous. This sand constitutes a good water horizon in the regions south of Meridian. In the hills southeast of Meridian these basal sands of the Tallahatta are 110 feet thick. At Lost Gap, six miles west of Meridian, they are 75 feet thick and lie unconformably upon the sandy lignitic beds of the Wilcox, and pass conformably up into the overlying Basic Claystone.

Basic Claystone.—The upper phase of the Tallahatta formation outcrops characteristically in the high broken hills—so called "mountains,"—southeast of Meridian, Lauderdale County, in northern Clark County, and in the high ridges between Meridian and Newton through which the Alabama and Vicksburg Railroad has tunneled at Lost Gap, six miles west of Meridian. On the Mobile and Ohio Railroad in the vicinity of Basic City, Clarke County, a series of deep cuts typically exposes this phase of the Tallahatta in picturesque cliffs. The beds here consist of 20 feet of white quartzite at the top, beneath which at least 100 feet of yellowish white claystone in thin beds forms the faces of the cliffs below the quartzite. These beds dip to the south at a rate varying from one foot in 100 yards to three feet in 100 yards. This dip, however, is in excess of the general dip of the formation. Beneath the claystone, beds ten feet thick of a semi-indurated, grayish glauconitic sand appear in the more northern cuts, and near Bullard's Switch all these materials are seen to overlie an unknown thickness of yellow micaceous sands which come to the surface. Similar sands underlie the claystone at Meridian and at Lost Gap, and the three localities probably mark outcrops of the same bed. At Seymour's Hill, two miles southeast of Meridian, and at Lost Gap, the claystone is a very notable and characteristic deposit. It is quite light—almost as light as wood—of a uniform cream-color, except that on joint faces the surfaces are iron-stained, and often within the blocks, bounded by joint planes, handsome reddish and yellowish curving parallel lines occur, simulating lamination, but which do not follow lines of lamination. This material, to the naked eye, shows few impressions and casts of fossil shells, but under the microscope is seen to be largely made up of the siliceous shells of minute diatoms and radiolarians. Glauconite in notable quantities occurs in the material both underlying and overlying the claystone, which is itself rather a diatomaceous earth than a clay stone, as heretofore called. These characteristic east Mississippi Tallahatta deposits do not appear to occur west of Newton County, beyond which the claystone passes laterally into the sandstones and quartzites of the Tallahatta in the western part of the Claiborne outcrop.

The western phase of the Basic Claystone outcrop is characterized by successive beds of hard quartzitic rock which is usually of light gray color, and shows on the surface frequently very marked rounded prominences suggesting concretionary structure. At several places these structures take on unique and interesting forms. These beds are not of uniform hardness, but may pass within a short distance from a true quartzite, hard enough to batter a steel hammer, to a soft sandstone which crumbles easily under moderate blows of the hammer, and may even pass into unconsolidated sand beds. While the sands of the basal phase of the Tallahatta are highly ferruginated and frequently rich in fossils, the sands associated with the quartzite beds of the middle phase are usually light gray or white, and non-fossiliferous. That both phases are marine in origin is demonstrated by the marine fossils so abundant in the red clayey sands at Winona, Vaiden and Beatty, the red color of which is due to weathered glauconite, a marine deposit, and by the fossiliferous glauconitc marl beds often interstratified with the beds of quartzite. This zone of outcropping Claiborne quartzites and sandstones occupies the upper part of the Tallahatta area, extending nearly across the state. In the west it begins four miles west of Grenada, passes southeast several miles west of Vaiden, is crossed by Big Black River southeast of Vaiden, outcrops both east and west of the towns of West and Hoffman, north of Durant, through Attala County in the vicinity of Kosciusko, and through northeastern Leake and into Neshoba County. An iron-stained quartzite in Lauderdale County several miles east of Meridian, if Claiborne at all, is the base of the Tallahatta, and of different horizon from the western belt of quartzites.

Concretionary structure is so commonly found in these lower Claiborne quartzites that their formation seems to have been largely by solution and redeposition of silica along certain zones, rather than by metamorphism, as suggested by Crider. It is not at all improbable that this process of solution and redeposition of siliceous matters may have occurred also in the Wilcox, especially in the sandy phases . In either case, the consolidation of the beds into quartzite might have been at any time subsequent to deposition of the sands.

That the Claiborne beds of Mississippi are mainly marine in origin is shown by the presence of marine shells in abundance in most of the beds. After the period of swamp and fresh water conditions occurring in the Wilcox, the shoreline sank and the sea advanced upon the land, depositing first coarse sands and later the finer textured deposits of calcareous gray marls of the Wood's Bluff formation of the latest Wilcox. At the close of this period swamp conditions, with peat deposits and fine silts and clays intermingled with vegetable detritus, again prevailed for a while, and then another sinking down of the land inaugurated the Claiborne period. During this period the deposits made were somewhat varied, the earlier parts being highly siliceous the later rich in calcium carbonates. Glauconite, which is a marine deposit made in moderate depths, was laid down in greater or less quantity with the other and more abundant materials, throughout the whole preiod.

The thickness of the Tallahatta formation in Mississippi has been estimated to be 220 feet. Recent investigation would seem to indicate that twice that figure would be a moderate estimate.

Lisbon Formation.—The upper division of the Claiborne Group was called by Hilgard Calcareous Claiborne, but by Smith of the Alabama Geological Survey, has been renamed the *Lisbon Formation,* from Lisbon, Alabama. This name has been generally adopted, and is used by the United States Geological survey. The materials of the Lisbon formation consist in the lower parts of marine marls and calcareous sands, in the upper parts very largely of lignitic clays and lignite.

The lowest member we have named the *Enterprise Green Marl,* from the town of Enterprise, in Clarke County, where it is well exposed. This member is composed principally of fossiliferous marl beds that vary in color from light gray to dark green, the depth of color being largely determined by the relative proportions of glauconite, or green sand. The lighter colored marls are highly calcareous and often clayey, showing abundant evidences of comminuted shells. The dark green marls, however, are also highly fossiliferous, fish teeth, oyster shells, sea urchins, and numerous other fossils being abundantly found. Undoubtedly, during this time the sea extended over south Mississippi as far north as Enterprise, the waters abounding in varied forms of marine life, whose shells and remains accumulated on the sea floor, and mingling with smaller quantities of land-derived sediments, resulted in the marls of this formation.

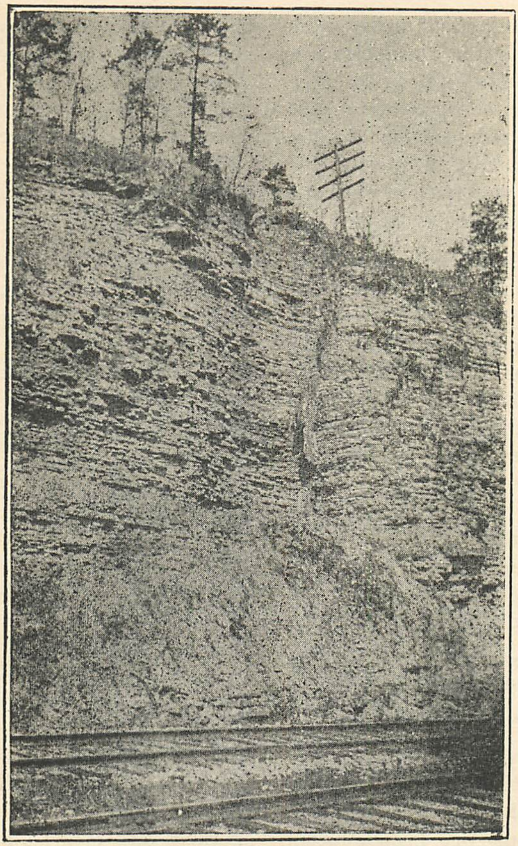

FIG. 4.—Exposure of Tallahatta Claystone in a cut on the M. & O. Railroad, half a mile above Basic, Clarke County. Note the thin bedding of the rock. At the top, not well shown in the picture, is a bed 2 to 4 feet thick of white quartzite.

Four miles northwest of Enterprise at Dunn's Water Mill these green marls, rich in fossils, overlie the claystone of the Tallahatta, which forms here a picturesque, vertical wall 65 feet high on Chunky Creek. The same marl beds outcrop in the bed and banks of the Chickasawhay River at and below Enterprise. In this vicinity the weathered marls have by a process of concentration of the contained iron formed extensive deposits of a low grade brown ore. On the Chickasawhay half a mile below Enterprise the green marl becomes indurated and forms a bluff 12 feet high on the east side of the river. This indurated bed shows abundant flat sea urchins, called *Scutella lyelli*, as well as oysters, shark teeth, and other fossils.

Decatur Sand, is the name by which we have designated a persistent series of unconsolidated sand beds that overlie the Enterprise Marl. These sands are 18 to 25 feet thick where exposed, of white to yellowish color, and non-fossiliferous. They are probably marine in origin, since they are sandwiched between the marine Enterprise beds and the marine fossilferous marls of the Wautubbee. They are probably conformable with the Enterprise beds, but are rather sharply and perhaps unconformably separated from the Wautubbee. The known outcrops are mainly in southeast Mississippi, near Enterprise, Wautubbee, and Decatur.

The Wautubbee Marls constitute the most extensive division of the Lisbon, since other members of the formation have unimportant outcrops. The Wautubbee beds are all marine, consisting of highly calcareous and fossiliferous marls, of gray to almost white color, or of darker bluish and greenish tints, due to the presence of glauconite. In the vicinity of Newton and a few other localities these marls pass vertically into clays or sands which are often lignitic and fossiliferous.

The Wautubbee marls are locally rich in marine fossils, exhibiting a very characteristic fauna. The large saddle-shaped oyster, *ostrea sellaeformis*, is especially abundant.

These beds in southeast Mississippi have a thickness of about 100 feet, and dip southward at a rate of 23 to 25 feet to the mile. The thickness in west Mississippi is perhaps as great, though not so evident.

The topography of this zone, which borders the Jackson prairies on the west, becomes more level than that of the Tallahatta, even assuming the prairie character in the western parts of the area.

In the uppermost part of the Lisbon the marls give place to lignitic clays, sands, and lignites. This phase of the formation is sufficiently persistent to justify its consideration as a distinct member under the name of the *Cocksfield.* This name was given to the Claiborne outcrops at Cocksfield Ferry, [1] Louisiana, and the characteristic clays and lignite extend across Louisiana and have been encountered at several points in Mississippi, gradually thinning out toward the east. These indicate a decided change in the conditions of deposit. The presence of lignite with sometimes abundant impressions of leaves of land and marsh plants, shows that marine conditions have given place to low swampy sea-margin flats upon which grew rank vegetation. This condition persisted, however, only for a comparatively short time; for the Jackson formation which follows inaugurated marine conditions again.

The Cocksfield beds in southeast Mississippi are only 30 to 40 feet thick, although Hilgard mentions a great thickness of lignitic material in the old penitentiary well at Jackson. The outcrop of this member of the Lisbon formation in Mississippi is not sufficiently marked to command attention, the topography differing in no essential from that of the Jackson group, which it borders on the north. The soil, like that of much of the

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[1] T. Wayland Vaughan, Am. Geologist, Vol. 15, page 220, 1895.

Jackson area, is a silt loam of loessal origin spread over the surface of the Cocksfield outcrop.

The Cocksfield in the vicinity of Jackson, as interpreted from well records, is about 200 feet thick, and thins out to 90 feet in Scott County, while wells in Clarke County show about 30 to 40 feet.[1]

JACKSON GROUP

One of the most interesting groups of Tertiary formations in the Gulf Coastal Plain is that of the Jackson, named by Conrad for the type locality, at Jackson, Mississippi, from which fossils of this group were first collected and described. Many of these fossils described by Conrad are figured in the first Report on the Geology and Agriculture of Mississippi, by Prof. B. L. C. Wailes, published in 1854. This report is now very rare, but the accurate illustrations of Jackson fossils make it very desirable to possess by students of Mississippi geology.

The Jackson beds outcrop across the state in a zone which widens westward, being from 35 to 40 miles wide near the bluffs of the Mississippi flood-plain, but having an average width of less than 20 miles. Owing to the gradual filling in of the Mississippi embayment, which took place more rapidly in the region of the present river, the Jackson formations outcrop across the state in a nearly east and west direction. The deep indentation of the Gulf Coast line, which at the beginning of Tertiary time had extended as far north as the Ohio River, had been obliterated, and at the beginning of Jackson time the shore line extended across Alabama, Mississippi, and Louisiana in a line almost east and west, in a general way parallel with the present coast.

The materials of the Jackson consist of limited clay and lignitic deposits intercalated with fossiliferous sands and marl beds toward the base, above which a thick deposit of yellowish or bluish clay marl makes up the greater part of the thickness of the group. The close of Jackson time was marked by the deposition of sands of gray, yellow, and white color. Coincident with these changing materials we have recognized three formations belonging to this period: 1. Moody's Branch Marl; 2. Yazoo Clay; 3. Forest Hill (Madison) Sands.

Moody's Branch Marl.—The lowest member of the Jackson Group receives its name from Moody's Branch, a small tributary of Pearl River within the city limits of Jackson, which has cut a narrow gorge in this formation just before debouching upon the flood plain of the Pearl. The characteristic material of the formation is a dark green, speckled, calcareous sandy marl. This is rich in glauconite, and filled with numerous species of finely preserved fossils. These are mostly univalve shells, though bivalves are also abundant; echinoids, shark teeth, crabs, and many others, are

[1] Priority has established the name Yegua for this phase of the Claiborne.

common. This locality on Moody's Branch and an outcrop of the same beds in south Jackson, at the junction of Town Creek and Pearl River, are the classic collecting grounds for geologists who look for Jackson fossils. In certain narrow zones at Moody's Branch the beautifully preserved shells are so crowded together as to make up the greater part of the deposit. These glauconitic marls pass downward into lignitic clays with nodular lime concretions projecting from the vertical walls of marl, passing at the base of the outcrop on Moody's Branch into thin beds of lignite. Above they merge into a grayish yellow calcareous clay very similar to that at Yazoo City.

An outcrop which is almost a duplicate of that at Moody's Branch, is exposed in a deep gorge on Garland Creek, four miles northeast of Shubuta, Clarke County. At this locality the fossiliferous sandy member is 35 feet thick, while at Moody's Branch it has a thickness of 25 feet. Shell marls of this member outcrop at number of points throughout Scott, Jasper, Smith and Clarke counties.

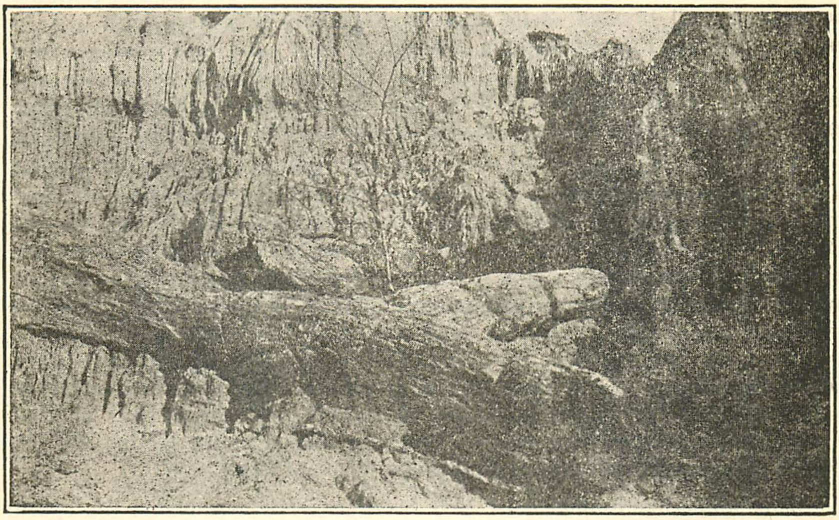

FIG. 5—Petrified Tree Trunks, exposed in an amphitheatre washed in the hills near Flora. A number of trunks are exposed, the largest being 5½ feet in diameter and 15 to 20 feet long. The embedding material is gray and whitish sands of Pliocene age.

The outcrop of the Jackson is a region of gently rolling surface having an elevation above sea level of from 300 to 400 feet. Much of the surface is open praririe , the rest being clothed with undersized oak and other hardwood growth. In the central portions a belt of short-leaf yellow pine runs north and south through Scott and Jasper, extending into the sandy Claiborne and Wilcox regions farther north. The soils of the region consist of residual clay soils from the Jackson beds, in the western parts silt loams of loessal origin, and in much of the eastern parts reddish clayey sands of later date. The true priarie soils are derived from the Jackson formations, and are black or gray in color, very tenacious and heavy, the black soils being highly calcareous, the gray soils much less so, but containing considerable gypsum.

Yazoo Clay.—In the bluffs at Yazoo City at least 180 feet of the Yazoo Clay is exposed, forming all the lower parts of the bluff. A capping of 85 to 100 feet of loess of much later date overlies the Yazoo Clay. This clay as exposed here, consists of dark-colored lignitic clay strata toward the base, with thin lignite beds at some points near Yazoo City. The bulk of the exposure, however, consists of drab or yellowish calcareous clays, showing heavy bedding and distinct jointing. These clays show frequently white specks or shell impressions, and large oyster shells are common; smaller fossils are frequent, but not well preserved.

At Jackson this clay member is sandy towards the bottom, and contains numerous small bivalve shells, and large *pinnae,* a bivalve with silvery lustre. Towards the top the clay is tough, free of sand, and weathers into a black, sticky, clayey prairie soil. While the Yazoo Clay is calcareous and undoubtedly marine, as evidenced by its fossil content, lignitic bands occur in it at intervals indicating temporary swamp conditions, at least locally.

The most interesting and notable fossil found in these beds around Yazoo City and southward to Satartia is that of the *Zeuglodon,* a fossil whale that lived in the seas of Mississippi during that time. This animal attained a length of from 70 to 80 feet, and must have weighed several tons. Vertebrae of this animal in the museum of the State University at Oxford measure each 8 to 10 inches in diameter and 14 to 16 inches long. Only the vertebrae are usually found, but jaws have also been discovered, showing a formidable and peculiar dentition. The front parts of the jaws were armed with sharp conical teeth like those of a reptile, while the molar or back teeth had two fangs implanted in sockets, and the crowns showed sloping tuberculate cutting edges. The yoke-shaped molar teeth gave the animal its generic name (Zeuglon=yoke, odon=tooth.).

This whale-like animal must have been very common during the epoch when the Yazoo Clay was being deposited on the sea-bottom, and it must have been an animal that frequented the waters at no great distance from shore, for we find its bones usually associated with clays, often lignitic, of off-shore deposits, and mingled with remains of other creatures that do not live in the open seas, such as shrimps, crabs, and such forms.

The zone of calcareous clays with Zeuglodon bones extends across the state from the Yazoo bluffs, through Madison and northern Hinds, Rankin, Scott, Jasper, Smith, and Clarke counties, and on into Alabama. The thickness of these beds has not yet been accurately made out, owing to irregularity of dip. At Yazoo City the bluffs expose nearly 200 feet, and the outcrop extends 25 or 30 miles further south, so that with even a very slight dip southward these clay marls would be at least 300 feet thick. There is some evidence, however, that the beds may even dip northward or lie nearly flat, in which case we might have exposed in the Yazoo bluffs practically their whole thickness. Locally in the face of the bluffs just below Yazoo City the beds dip at a rather high angle toward the east, but evidence points to this as being due to slump and creep on a large scale, the faces of the bluffs for miles presenting a series of steps or terraces due to mass movement of successive periods of this creeping clay. The city water works reservoir at Yazoo City situated upon the high bluffs has been ruined by the slow creeping of this clay underlying it. Around Satartia in Yazoo County, Zeuglodon bones of large size have been found to be common. One and one-half miles south of Satartia, on Locust Grove Plantation, a deep ravine cut in the face of the bluff revealed 12 to 15 feet length of the vertebrae in place in dark lignitic clay, as if the carcass of the prehistoric monster had been stranded upon a low, marshy shore where peaty and earthy deposits intermingled. These bones are not uncommon in the calcareous clays of Madison, Hinds, Scott, Jasper and Clarke counties.

Forest Hill (*Madison*) *Sand*.—Sandwiched between the Jackson marine beds and the marine marls of the overlying Vicksburg lie a series of sand beds that may belong to either group. These sands were first noted in Madison County, and hence the above name was suggested for them in the first edition of this bulletin, but, as pointed out by C. Wythe Cooke, this name is preoccupied, and Cooke suggests the name Forest Hill, from a locality a few miles west of Jackson.

The sands are distinctly stratified, often showing pronounced dip, are non-fossiliferous, prevailingly of gray color, but varying from gray to yellow and white. A few miles west of Madison, in southern Madison County, these sands interstratified with gray clays form the greater part of the notable hills in that section which show a capping of the Vicksburg limestone; the bases of the hills rest upon the Jackson clays. In the face of the bluffs several miles south of Satartia, Yazoo County, the same gray sands with interstratified thin gray and lignitic clays and lignite bands overlie the typical Jackson clay marls which contain Zeuglodon bones. These sand outcrops extend along the bluffs to a known distance of three miles, and ten miles further south on the land of E. A. Archer, a well struck sand beds at a depth of 18 feet, above which Vicksburg marls and limestones were penetrated. Assuming these to represent the same sand formation as seen on No-Mistake Plantation three miles south of Satartia, a very considerable thickness would be indicated. Crider estimates the thickness of these beds to be 50 to 75 feet, based upon the outcrops observed in Madison County. The maximum thickness observed at any one point is 85 feet, which is probably the maximum thickness of the formation.

Seven miles southwest of Jackson the east slope of Forest Hill shows at the base typical Jackson clay soils, at the top undoubted Vicksburg limestone and marl, while between the two lie 57½ feet of gray sandy clay, gray sand and yellow sand, all dipping strongly toward the west. The yellow sands at the bottom merge by gradual transition into the Jackson clays, indicating apparently a closer relationship of the sands with the Jackson formations than with the Vicksburg.

The sandy character of the uppermost Jackson member is traceable eastward along the line of contact with the Vicksburg. However, in the most eastern outcrops in Wayne County no such sandy member of the Jackson lies in contact with the Vicksburg, but seems to pass beneath the fossiliferous Red Bluff beds of the Vicksburg. At the wagon bridge over the Chickasawhay at Shubuta the bluff on the east side exposes 30 feet of Red Bluff material at the top, 70 feet of typical greenish gray calcareous Jackson clay, and 25 to 30 feet of fossiliferous sands. This may represent the sand member farther west, though not here lying at the contact of Jackson and Vicksburg. It is also possible that the Madison Sands of west Mississippi are represented stratigraphically by the Red Bluff beds, though the absence of fossils in the sands makes the correlation as yet problematical. (Cooke has, since the publication of the above, correlated the Forest Hill sands with the Red Bluff beds of east Mississippi.)

The thickness of the whole Jackson was estimated by Crider to be 350 to 450 feet. It is at least that, and probably more. As before stated, it is probable that the northern parts of the formation north of Jackson have slight, if any dip southward, but south of Jackson the dip is strongly toward the south. W. D. Langdon reported, "Six miles above Byram the strata show a dip of about 20 feet in a hundred toward the south. * * * Still farther south the strata dip southward very rapidly, as much as five feet in a hundred." The latter dip would be at a rate of 264 feet to the mile, which is excessive. The dip observed by Langdon was probably local. Calculations based upon recent well drillings indicate a dip southward of the Jackson beds of approximately 45 feet to the mile. A calculation made on the Tallahatta beds of the Claiborne, which perhaps dip uniformly with the Jackson beds, showed between Meridian and Basic a dip of 44 feet to the mile. With this dip and the width of the outcrop which it has we could safely infer a greater thickness of the Jackson than 450 feet, but unfortunately the disturbance in the northern parts of the group takes away the basis for an accurate calculation, so that Crider's estimate will be accepted as probably correct.

Cooke gives the thickness of the Jackson in western Mississippi at about 600 feet, 230 feet at Jackson and 150 feet at Shubuta, Clarke County.

The very pronounced folding in the Jackson region has produced a marked anticlinal or dome structure that has recently commanded a good deal of attention on account of oil possiblities under this anticline.

VICKSBURG GROUP

All formations described in the foregoing discussion of the Tertiary period belong to its Eocene division. This embraces the earliest of the

Tertiary divisions. Others are recognized by geologists as Oligocene Miocene, and Pliocene, named in the order of their age. We find them outcropping southward in the same order, the oldest to the north, the youngest to the south. By referring to the map accompanying this Report these formations will be seen outcroping in nearly parallel zones across the state following the rule just stated, the oldest being farthest north and east, the others in succession southward.

The Jackson age closes the Eocene, the Oligocene beginning with the Vicksburg. This does not mean that any great revolution has taken place. While the Eocene formations present to the paleontologist very marked differences from those of the Oligocene, to the general reader of this Report the paleontologic grounds upon which the divisions are made are not very evident. To these readers it will be much easier to see why certain beds are called Jackson beds and certain others are called Vicksburg beds, than to know why the Jackson beds should be called Eocene and the Vicksburg beds Oligocene. The reason for this is obvious: The Eocene and Oligocene are distinguished from each other and from other co-ordinate divisions upon purely paleontologic grounds, presupposing an intimate knowledge of fossils, while the Jackson and Vicksburg beds usually have certain physical characteristics which the ungeological observer may soon learn to distinguish with fair accuracy.

The Vicksburg was named by Conrad from the type locality where he first studied it. While three members or formations should perhaps be distinguished one of which, at least, is not found at Vicksburg, the typical beds of the Group are exposed in the bluffs of the Mississippi River and in the gorges of tributary springs and small streams within the limits of the city of Vicksburg. The beds outcrop in a narrow zone across the state, through Alabama and Georgia, and form a prominent division in the geology of Florida.

The typical Vicksburg beds consist of highly fossiliferous marine limestones and marls, occurring in alternating beds one to three feet thick. The marls are yellowish or grayish in color usually sandy, and have an abundance of typical Vicksburg fossils well preserved. The limestone is hard, semi-crystalline, and of gray to bluish colors, that on weathering become yellowish. In some localities this limestone, both the yellow and the blue, has been found to take a fine polish, so that it could be used for building purposes. The beds are thin, however, in most places, and would be difficult to quarry on account of its mode of occurrence.

These beds are exposed at Vicksburg in the gorge of Glass Bayou and near the National Cemetery to a thickness of 75 feet, the whole overlain by 25 to 75 feet of Loess silt, or Bluff Formation, as it is commonly called. Below the limestones six feet of gray friable marl is exposed, and beneath this in the vicinity of Vicksburg lie 25 to 30 feet of lignitic clay and lignite. Dark-colored clay 18 feet thick has been observed seven miles southwest of Jackson within a few feet of the base of the Vicksburg, only a few feet of fossiliferous limestone and marl lying below it. Two feet of lignite and fifteen feet of lignitic clay underly the Vicksburg limestone at the "Cave," near Sylvarena, Smith County. This lignite phase toward the base of the Group is rather persistent across the state as far east as Smith County.

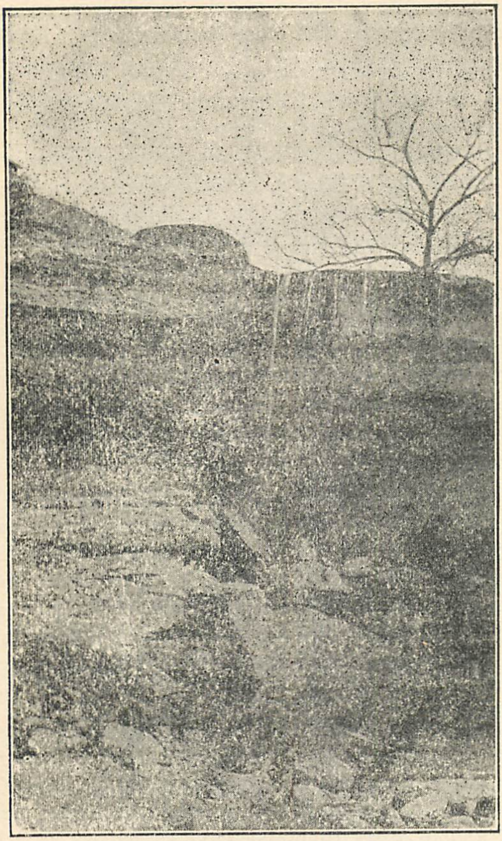

FIG. 6—Falls of Glass Bayou, Vicksburg, showing a good exposure of the Vicksburg Limestone and Marl beds in alternating strata.

Since the day of Conrad and Hilgard the exposures in the bluffs at Vicksburg have been classic collecting ground for students of the Vicksburg Group.

C. Wythe Cooke, [1] investigating and correlating the Jackson and Vicksburg groups of Mississippi, Alabama and eastward into Florida, recog-

[1] Correlation of the Deposits of Jackson and Vicksburg Ages in Mississippi and Alabama, by Charles Wythe Cooke. Journal of the Washington Academy of Sciences. Vol. VIII, No. 7, April 4, 1918.

nizes three divisions which he regards as of formational value. These are enumerated from top to bottom:

Byram Calcareous Marl, which receives its name from the town of Byram on Pearl River, six miles south of Jackson; *Marianna limestone*, named from Marianna, Florida; *Forest Hill Red Bluff* deposits, having two distinct facies, and the *Red Bluff Clay* in east Mississippi.

The *Byram marl* is typically exposed in the banks of Pearl River at Byram, where the formation consists of sandy glauconitic marls, with intercalated thin beds of impure limestone, clay and sand. These beds are richly fossiliferous, bearing a characteristic fauna. It was from the marls of this horizon as exposed in the bluffs at Vicksburg, that Conrad obtained his type fossils of the Vicksburg Group.

The Byram marl is 42½ feet thick at Vicksburg, 70 feet thick on the Chickasawhay River in east Mississippi, but thinner at intermediate exposures.

The Marianna Limestone underlies the Byram Marl conformably, and is rich in fossils of numerous species, although locally lignitic clays and even beds of lignite occur within the formation, showing local transitions from marine conditions.

The upper 20 or 30 feet of the formation consists of beds of hard limestone and indurated marl, mostly of bluish-gray color, with thin, soft marly partings sandwiched between them. Because of their hardness these beds form conspicuous bluffs and ledges, and in the vicinity of Vicksburg they are the most distinctive feature of the Vicksburg group, forming a ledge over which drop several picturesque waterfalls. Cooke called this member the *Glendon Limestone*, using the name of a locality in Alabama.

The typical *Marianna Limestone* underlies the Glendon Limestone in the counties of east Mississippi and eastward into Alabama, Georgia, and Florida. This is a soft, cream-colored limestone, of homogeneous hardness, and showing little evidence of stratification. It is locally called "chimney rock," because it is sawed out of the quarries by the settlers and used for building chimneys. The rock is easily cut into blocks of convenient size and shape, and hardens on exposure. Chimneys so constructed are common in Smith, Jasper and parts of Clarke and Wayne counties.

This "chimney rock" is 50 feet thick in east Mississippi, but thins westward to 20 feet at Brandon. It does not extend to the Bluffs at Vicksburg, but has been identified near McRaven in Hinds County, where it has a thickness of 12 to 15 feet. This rock is rich in fossils, prominent among which are *Orbitoides mantellii*, *Pecten poulsoni*, and *P. perplanus*.

In the Vicksburg area the typical Marianna "chimney rock" is replaced by the *Mint Spring* calcareous marl member, which receives its name from Mint Spring Bayou, the falls of which are just south of the entrance to the National Cemetery at Vicksburg. The marl here is a soft, gray, fossiliferous deposit, exposed 10 to 12 feet thick beneath the falls. The same ashen gray unconsolidated marl is exposed beneath the falls of Glass Bayou at the end of Washington street, near Centennial Lake. Here, as at Mint Spring Falls, the soft marl weathers and slumps away, leaving the hard Glendon Limestone layers standing out in ledges over which the water of the streams is precipitated, making picturesque falls.

The marl has abundant fossils in good state of preservation, making good collecting.

The Forest Hill Sand has already received attention in the discussion of the Jackson. Recently Cooke has correlated it with the Red Bluff beds of the basal Vicksburg; it will receive no further discussion here, only to state that under present interpretation it is placed[1] in the Vicksburg group as a distinct facies of the Red Bluff formation.

Red Bluff Formation.—In the banks of the Chickasawhay River near Hiwannee, the river bluffs expose beds of fossiliferous marls and clays that have been placed stratigraphically in the base of the Vicksburg. The fossil fauna of these beds is more closely related to the typical Vicksburg than to those of the Jackson. They have, therefore, been placed in the Vicksburg, but are sufficiently distinct to be regarded as a separate member or formation of it under the name of the Red Bluff.

These beds, exposed to a thickness of 60 feet, consist of greenish-gray joint clay, with a few large well-preserved shells near the water's edge. Eight or ten feet above low water they pass into a zone two feet thick of reddish weathered marl, full of small fossil shells, mostly gastropods. Gray or purplish clays weathering red extend to the top of the hill.

The Red Bluff horizon is also found below the railroad bridge over the Chickasawhay one and one half miles south of Shubuta, and capping the bluffs of the same stream at the wagon bridge just below Shubuta. Its westward extension is correlated with the Forest Hill Sands. As suggested on a previous page, it is probable that the sands occurring at the Jackson-Vicksburg contact find their eastward extension under a different character in the Red Bluff beds. The distribution of the Vicksburg Group will be best made out from the map which accompanies this Report. It is a very narrow zone that has a general east and west strike across the state.

The beds of this group have at numerous points near its southern border a decided dip to the west. North of Jackson, however, in southern Madison County the level of the Vicksburg limestone capping the hills is such that they lie far below the level they should have if the dip near the southern border were continued northward. This can be accounted for only by supposing there has been a disturbance with bending of the strata along an axis running generally east and west about the latitude of Jackson. At Byram, six miles south of Jackson, the Vicksburg beds outcropping in Pearl River show distinct undulations, rising and falling beneath the water's edge very noticeably. This was perhaps a southward gentle expression of the disturbance that died out in that direction.

This disturbance of the Vicksburg strata in Mississippi seems to be the eastward expression of the great break in the strata in northern Louisiana, called the Alabama Landing Fault, though so far no actual break in the strata has been discovered in Mississippi.

GRAND GULF GROUP

Hilgard placed all of Mississippi south of the Vicksburg Limestone in the outcrop of what he called the Grand Gulf formation, except a narrow coastal zone which he regarded as of later date. A good deal of doubt and confusion has existed about the age and limitations of the Grand Gulf since Hilgard's day. Hilgard himself expressed his doubts as to the unity of the formation. Within the last few years close and careful study of the Grand Gulf has been made, and as a result, the old Grand Gulf formation has been broken up into several formations.

Beginning below and ennumerating them in order of age, these formations are: [1] 1. Catahoula Sandstone; 2. Hattiesburg Clay; 3. Pascagoula Clay. The Catahoula lies in contact with the Vicksburg, and is, together with the Hattiesburg Clay, of Oligocene age, the Pascagoula being of Miocene age.

Catahoula Sandstone.—This formation receives its name from Catahoula Parish, where it is typically developed. It consists of alternating beds of sandstones, sands, and clays, the arenaceous sediments predominating. The most conspicuous member, and the one giving name to the formation, is a gray sandstone of variable hardness, and ranging in texture from a coarse grit to a sand so fine as to resemble clay. The grains are mostly quartz, but in the finer phases a small proportion of clay is present, so that locally the soft rock has been crushed and used for white wash. At the base of the formation where it lies in contact with the Vicksburg limestone, the material of the Catahoula consists of beds of gray and lignitic clays and lignite overlain by gray to white soft sandstone. At the old State Quarry at Mississippi Springs, Hinds County, and in the immediate vicinity, 50 feet of Catahoula material is exposed, consisting of dark gray and lignitic clays capped by 25 feet of gray sandstone in beds 2½ feet thick, the thicker beds being coarse grained and showing distinct cross-bedding. From the old quarry at the base of the hill was taken the stone used in constructing the basement of the Old Capitol at Jackson. Four miles south of Byram on Pearl River the Catahoula sandstone lies in contact with the Vicksburg limestone. In the southern outskirts of Brandon the gray clays of this Group outcrop above the level of the fossiliferous Vicksburg limestone nearby. The most notable outcrop of this sandstone and accompanying clays and lignites near its northern margin is at Star, on the Gulf and Ship Island Railroad. The rock here is almost white, of uniform texture, and has been

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[1] G. C. Matson and E. W. Berry, U. S. G. S. Prof. Paper 98-M, The Catahoula Sandstone and its Flora. 1916.

quarried for structural purposes. It is rather too soft for this purpose, however, and is liable to exfoliate under the influence of the weather.

Marcasite, a form of iron sulphide, occurs very commonly in the clays of this formation, and to a less extent in the sandstone. In the latter it weathers to yellow oxide discoloring the stone and giving rise to hardened nodular surfaces of mottled appearance. It is most common in lignite and lignitic clays, being weathered out by atmospheric waters coming in contact with the material, and giving rise frequently to so-called "alum" springs and wells, the iron sulphide being converted by the free oxygen of the water into iron sulphate, which is the same as copperas. In certain sections this leaching of acid waters from the rocks is such a prominent feature that the settlers have created an industry by accelerating the process in hoppers devised for the purpose and selling the product as acidine, or under some other name. In Jefferson County at points on Cole Creek this mineral commanded attention more than 60 years ago.

Cooper's Well, Brown's Wells and others in south Mississippi receive their waters from the Catahoula materials which are frequently mineral-bearing. Numerous wells and springs of this region are highly mineralized because their water is drawn from the Catahoula.

Gypsum and salt are not uncommon in the Catahoula formation, though none has yet been found in commercial quantities.

A notable outcrop of the sandstone is at the type locality, Grand Gulf, a decadent shipping point on the Mississippi River eight miles northwest of Port Gibson. Here the rock outcrops on a high point overlooking the river flat, the material presenting a succession of beds 30 feet thick, consisting of alternating clays and sandstones; the typical Grand Gulf Rock which forms the jutting point of the hill, is very hard and quartzitic, the grains being embedded in a porcelain-like matrix. It is a very striking-looking rock, but does not stand weathering well. The Grand Gulf rock is not extensively developed in southeast Mississippi, but is prominent in the southwestern part. In Rankin, Copiah, and Claiborne counties its resemblance in places to massive masonry has led to many so-called discoveries of ancient ruins. The old Grind Stone Ford on Bayou Pierre, where the Natchez Trace crossed that stream, received its name from the outcrop in the river banks of the hard Grand Gulf rock.

This rock and the accompanying clays are usually devoid of fossils, except remains of vegetation. Fossil palm-trees were reported by Hilgard as being found by him near Winchester, Wayne County; "The trunks are prostrate, many of them washed out of their matrix by the river, and resemble common 'old logs.' They retain their roundness, are quite light and porous when dry, but absorb water like a sponge, allowing of its being squeezed out. Two cuts of a common saw will readily sever a trunk 12 inches in diameter. Most of them are dicotyledons, a smaller number conifers, and next to these, tree palms, one trunk of which was about 8 inches in diameter, its fibers pulling out of the soft lignite mass, like those of a corn-stalk out of its pith." The stump of a tree palm in the Geological Survey collection at the University indicates a tree that must have been 14 or 15 inches in diameter This specimen came from Wayne County, but instead of being lignitized like those described by Hilgard, is silicified, showing the structure distinctly. A specimen of the wood submitted to E. W. Berry for examina-tion proved the species to be *Palmoxylon remotum* Stenzel.

The Catahoula is conformable with underlying Vicksburg beds and with the overlying Hattiesburg Clay.

No marked deformation of the Catahoula has been discovered in Mississippi, though minor bendings are recognizable at a few places especially near its northern border, where it underwent slight folding when the Jackson anticline was uplifted. The thickness of this formation in Mississippi as given by Geo. C. Matson, is about 400 feet, the dip being 21 feet to the mile toward the south, 23 feet to the mile toward the southwest,

That the Catahoula beds were laid down under swamp and strand conditions, as asserted by Berry, is proved by the frequent presence in them of lignite and lignitic clays, by the physical characters of the terrigeneous deposits, and especially as pointed out by Berry, by the fossil plants, which are largely tropical strand species.

Hattiesburg Clay.—In the high bluffs of the Mississippi River at Fort Adams, Wilkinson County, a somewhat different phase of the old Grand Gulf complex is prominently developed. The material where exposed is a sandy clay rock of light gray to brownish gray color, with a cementing material of reddish-brown to purplish iron oxide, "which prevades it in irregular and distorted veins, and which, forming the hardest portion of the mass, gives the weathered surface a very rough and nodular character." This material is associated with softer clays, forming altogether at Loftus' Heights near Fort Adams, an outcrop of 170 feet thickness in the river bluffs.

This Davion rock, as it was called by Wailes, the first State Geologist of Mississippi, strikes eastward, and is represented in the vicinity of Hattiesburg by a great thickness of massive blue and gray clays, which often show purple mottlings on weathering. These clays are occasionally lignitic, and near McCallum, a few miles south of Hattiesburg, have furnished identifiable plant remains. At Hattiesburg the clays of this formation are exposed in the banks of the large streams and on the lower slopes that border them. The gently undulating upland upon which the Normal College is situated is underlain by this clay, which was encountered to a great thickness in the deep well at the college. Railroad cuts between Hattiesburg and Ellisville expose the Hattiesburg Clay at numerous places.

In much of the area marking the outcrop of the Hattiesburg Clay, the formation is covered by a greater or less thickness of sand and pebble deposits of later age, so that relatively little of the Hattiesburg is exposed.

The thickness of the Hattiesburg is given by Matson as being 450 feet in central and western Mississippi. Since it lies conformably upon the Catahoula it has the same dip as the Catahoula.

Pascagoula Clay.—Along the Chickasawhay River from the Mobile and Ohio Railway crossing to its confluence with Leaf River, beds of fossiliferous green clays outcrop in the bluffs at numerous places. The fossils of these beds are oysters, *gnathodons*, and others of salt water estaurine habit which fact together with the calcareous, and, in places, glauconitic nature of the material, indicates the marine or estaurine character of the deposits. At McInnis' Ferry, Leakesville, the bluffs exhibit 19 feet of non-fossiliferous bluish clay in the river banks; a bluff six miles above Leakesville is reported to expose 50 feet of laminated clay of the same formation; Roberts' Ferry, 13 miles below Leakesville, exposes 15 feet of the clay, which along this part of the river is fossiliferous, fossil oyster shells being found in many of the tributary branch ravines. Similar bluish and greenish clays are exposed in the banks of Pearl River near Columbia.

The Pascagoula formation overlies the Hattiesburg unconformably, indicating that at the end of the Hattiesburg there was a submergence of previous land surfaces in the southern part of the state, followed by salt water deposits of the Pascagoula. That conditions did not become truly marine may be inferred from the nature of the materials and from the fact that fossils so far discovered in the Pascagoula indicate near shore estaurine conditions.

The unconformity between the Hattiesburg and Pascagoula marks the division between the Oligocene Tertiary and the Miocene Tertiary. The Catahoula and Hattiesburg along with the Vicksburg, are Oligocene; the Pascagoula is Miocene. A very pronounced unconformity separates the Pascagoula from the overlying Citronelle, which is of Pliocene age.

The Pascagoula is 400 feet thick in Mississippi, and dips southward about 20 feet to the mile.

CITRONELLE FORMATION.

During Pliocene time extensive deposits of red sands and sandy clays were made over much of the region in south Mississippi occupied by the Grand Gulf outcrop. It is possible that the later formations of the Grand Gulf were mostly deposited on the low coastal flats—perhaps at times even below sea level. But with the opening of Pliocene times either great floods of fresh water covered south Mississippi making deposits upon the eroded surface of the Grand Gulf, and even spreading across the state farther north coarse red sands and chert gravels to a thickness in places of 50 to 100 feet, or the shore line was rapidly depressed and re-established at no great distance south of a line drawn through Vicksburg, Jackson, Newton and Waynesboro, and waves worked into shore deposits the great quantities of sand and gravel brought down from the highlands by the large streams.

Perhaps the most problematical formation occurring within the state has been the so-called Lafayette or Orange Sand, which embraced the coarse red and yellow sands and chert gravels referred to above. Dr. Hilgard applied the name Orange Sand (which he afterwards changed to Lafayette for the county of that name) to all the surficial red and yellow and variegated sands and gravels which are so widely found throughout the state. Deposits which he referred to the Lafayette have been found from the River Bluffs to Alabama, and from Tennessee to the Gulf. Assuming these numerous disconnected deposits of red sands to be of one age and to represent one formation, he advanced the theory that the Lafayette was deposited by floods of fresh water descending from the north laden with sand and gravel. These floods deposited the material in heterogeneous way over the whole submerged surface of the state.

Investigation for several years has thrown great doubt on Hilgard's concept as applied to Mississippi geology. Most sandy formations by surface oxidation may produce red sands. This is the case at the type locality of the Lafayette. The numerous red and yellow sand outcrops around Oxford, which formed the basis for Hilgard's Orange Sand, or Lafayette, are now known to be weathered residuum from sandy Wilcox which underlies it. The red Lafayette of Pontotoc Ridge is proved to be partly Cretaceous, partly Eocene; the Lafayette Sands which Hilgard elaborately described and figured near Cypress, Tennessee, on the Southern Railroad, is shown by Stephenson to be the McNairy Sand member of the Ripley; the Lafayette east of Corinth is residual from the Eutaw Sands. So much of the so-called Lafayette of north Mississippi has been proved not to be Lafayette that its existence in that part of the State is very doubtful. In most of the uplands of north Mississippi where the Lafayette has been regarded as typically developed, red sand deposits are extremely common—are, in fact, the dominant surface feature. The sands are now known to be residual from sandy formations of various ages from the Eutaw of the Cretaceous to the Claiborne of the Tertiary.

Where gravel deposits occur bordering the Mississippi Bluffs their mode of occurrence and relative elevations as compared with the interior sand deposits, lead to the inference that they are river terrace deposits. These terrace gravels occur at different levels, but it is probable that the highest and oldest may be continuous with the great gravel beds that swing eastward in south Mississippi. If this interpretation be correct, during Pliocene time the Great River was depositing along its course high terrace gravels; at the same time the waves of the Gulf were working into gravel beaches, extending far eastward, such gravels as the river delivered to the sea.

These Pliocene gravels and sand have few fossils to indicate their age or the conditions, whether marine or fresh water, under which they were accumulated.

Recently, however, these deposits have been carefully studied by [1] Matson and renamed *Citronelle Formation* from a locality in Mobile County,

[1] G. C. Matson and E. W. Berry, U. S. G. S. Prof. Paper 98-L. The Pliocene Citronelle Formation of the Gulf Coastal Plain and its Flora, 1916.

Alabama. Fossil plants discovered in the formation were determined by E. W. Berry to be Pliocene. The Citronelle, as here recognized, embraces the great deposits of red and yellow sands and chert gravels widely distributed over south Mississippi and adjacent Gulf border states. These sand and gravel deposits overlie unconformably the older formations whose outcrops are thus largely concealed, and toward the coastal regions pass beneath all Pleistocene deposits. The older Terrace gravels following the course of the Mississippi River form part of the Citronelle.

Matson says of the Citronelle: "The Citronelle formation differs from both the older and the younger formations in being predominently sandy with many lenses and scattered pebbles of chert gravel. To understand fully the application of the name it is necessary to know the mode of deposition of the formation.

"After the Miocene strata had been laid down the Coastal Plain was eroded into broad, shallow valleys having approximately the same positions as the present streams. These valleys were filled by the deposition of Pliocene alluvial sands and gravels, and near the coast the deposits extended across the interstream areas. This filling formed a broad plain, which later was partly eroded, while the same time the margin of the formation was pushed farther seaward, and three successively lower plains were built, their sediments resting on the older deposits. The original deposit formed a new plain, which was represented also in the stream valleys. Some portions of the deposits were doubtless reworked by the waves, especially in the interstream areas, and this accounts for the more complete rounding of the pebbles in portions of the seaward areas of the formation than in the stream valleys, and the development of flat plains with shallow ponds in the interstream areas.

"The closing stage of the deposition of the successive plains is marked by the fine sandy silts laid down at flood stages while the streams were eroding their beds to lower levels."

PLIOCENE HISTORY OF MISSISSIPPI.

Shaw[1] has recently discovered an interesting series of changes that took place in Mississippi during Pliocene time. Extensive erosion took place on all uplands of north and central Mississippi, during which an erosion cycle was practically completed, the whole surface being at first cut into valleys and ridges, producing a region of rough typography. Gradually the valleys were widened, the intervening ridges narrowed, and eventually cut into disconnected hills. The final stage was a nearly level peneplain with here and there outstanding higher points, which geologists call monadnocks.

It is possible, as suggested by Shaw, that there were several successive

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[1]The Pliocene History of Northern and Central Mississippi, By Eugene Wesley Shaw, U. S. G. S. Prof. Paper 108-H, Feb., 1918.

cycles of erosion developed upon this and the regions to the immediate north, as indicated by more than one series of monadnocks, the co-ordinate peaks of each series reaching a uniform height corresponding to the surface of a previous peneplain.

During this period of erosion to the north the southern parts of the state were somewhat lower than now and presented no great irregularities of surface. Streams flowing toward the Gulf in ill-defined channels, laden with the debris from the eroded lands farther north, spread across the country depositing the materials in broad sheets. This process in time built up a well-marked terrace of even surface. This terrace has been called the Brookhaven Terrace because it is prominently developed around Brookhaven, in Lincoln County. It extends across the state in a general east-west direction in a zone 60 miles wide from north to south. The general elevation of this terrace is approximately 550 feet above sea level in the northern part, and drops to 450 feet at its southern border. The terrace surface is deeply eroded and only at intervals the original surface is evident.

The Mississippi River during Pliocene time brought down the products of erosion during the cycles of erosion to the north. Consequently, remnants of the Brookhaven Terrace are found bordering the Bluffs as far north as Memphis.

Sardis Terrace.—During the period of deposition of the Brookhaven Terrace we may assume that the surface of south Mississippi was neither rising nor falling appreciably with regard to sea level. At the end of this period, however, an uprising of the land *en masse* occurred. This was probably not great and was followed by a period of quiescence, during which the streams built a lower terrace similar to the first. This has been called the Sardis Terrace, because of its notable development near Sardis, in Panola County. It extends along the river bluffs to Vicksburg and Natchez, mostly in erosion remnants, and thence eastward across south Mississippi, 25 to 30 miles wide in the western part and narrowing eastward. The elevacation of this terrace is 400 feet at Sardis. It is deeply eroded, but the general surface is more nearly level than that of the Brookhaven Terrace.

Two other terraces developed in the same manner as those discussed have been identified, the Canton Terrace, and the Loxley Terrace.

Canton Terrace.—The broad level uplands "underlain by sandy clay with gravel here and there, at an altitude of somewhat less than 300 feet above the sea," constitutes the Canton Terrace. This terrace extends east and south from Canton, covering large areas as far south as the vicinity of Jackson. Along the Mississippi this terrace is one to three miles wide, stretches eastward into Alabama and westward into Louisiana, and borders the streamward and seaward margins of the Sardis Plain. It is 12 to 15 miles wide in the western part and narrows eastward toward the Alabama line.

Loxley Terrace.—Named from Loxley, Baldwin County Alabama, is the lowest and most southern of these terraces, and borders the seaward margin of the Canton Terrace. This terrace is 40 to 50 feet lower than the Canton Terrace, and has a gentle slope toward the Gulf. The present width of this terrace is 10 to 15 miles, though erosion remnants indicate an original width of 30 miles.

All these terraces are represented in remnants of greater or less extent along all the larger streams of the state, and these stream deposits become confluent toward their seaward border, giving rise to broad plains sloping gently southward.

Erosion has been active on the unconsolidated materials of the terraces, cutting down their original level surfaces into valleys and divides. The effects of erosion are progressively greater on the older terraces, the Brookhaven Plain having suffered the greatest erosion, and the Loxley Plain the least.

PLEISTOCENE FORMATIONS.

The Pleistocene epoch embraces the period in our history after the Pliocene and before the inauguration of present conditions. The land life of the times differed, especially in the higher forms, from that of today; in the life of the sea the change was less noticeable. In Mississippi geographic changes were of minor importance, small additions having been made to the area of the state along the Gulf coast and on the lower Mississippi.

Port Hudson Formation.—The lowest member of the Pleistocene in Mississippi was first identified by Dr. Hilgard at Port Hudson, Louisiana, on the bluffs of the Mississippi River. Where the two are found together the Port Hudson always overlies the Pliocene sands and gravels described above, and underlies the loess of the river bluffs, which will receive attention presently.

The formation at its type locality consists of massive greenish, bluish, or gray clays containing driftwood, pebbles and mastodon bones. In places interstratified with this clay is white indurate silt or hardpan, and often near the top of the clays are porous calcareous concretions, and ferruginous concretions at a lower level. The deposits are river and swamp accumulations. Near Port Hudson below these deposits were found 3 to 4 feet of brown peaty matter, with cypress stumps, showing that the accumulations had been made upon the site of an old cypress pond. At that time all the land bordering Lake Ponchatrain and the adjacent parts of southern Louisiana were either shallow margins of the Gulf or salt marshes. The mouths of the Mississippi opening north of Lake Ponchatrain spread Port Hudson clays across that part of Louisiana and along the region of "Pine Meadows" on the Mississippi Coast. In this region the river clays were deposited in shallow salt water, and hence contain marine fossils. This marine phase of these deposits, which consist of alternate beds of blue clay and sand to a thickness of at least 200 feet, has been called the Biloxi beds, because definitely established at Biloxi in boring the city well. The sand beds of the Biloxi formation are an easily available and excellent source of artesian water along the coast. The deeper wells derive their water from the Pliocene or older terranes.

During Pliocene time the great elephant-like creature, the mastodon, lived and browsed through the forests of Mississippi, as well as other parts of North America. Doubtless in quest of the luscious herbage that fringed the river marshes and swamps, this ponderous creature not infrequently found its footing treacherous, and was mired in the soft, oozy quagmires. Their remains have been found both in the Port Hudson and the loess bordering the Mississippi, in blue muds that tell their own story.

The later deposits of the Biloxi formation extend into the present epoch, occasional freshets of the Mississippi carrying mud and silt through the lake and along the Gulf coast as far east as Mobile Bay. The Nita crevasse in 1890 exemplified this in a remarkable way.[1]

Natchez Formation.—In the River bluffs at Natchez, overlying the older gravel deposits of the Citronelle, is a mass of reworked gravels and sands which seem to be of early Pleistocene age. The materials of the formation are derived in part from the older Pliocene deposits and in part from the glacial drift coming from the north. This deposit differs from the older Pliocene gravels in that it contains in considerable proportion rounded pebbles of igneous rock derived from the glacial drift. Brown oxide concretions of various, often bizarre forms, are common.

The Natchez formation underlies unconformably the loess of this region. The distribution of this formation is not well known, but is most conspicuous at Natchez, where it has been studied. It was a river deposit at a time when the Mississippi was surcharged with waters and debris from the melting glaciers to the north. In the bluffs at Natchez it has a thickness of 75 to 85 feet .

Since its deposition an east-west axis of elevation has arisen in the latitude of Natchez, so that these terrace deposits dip both to the north and to the south.

Loess, or Bluff Silt.—This is in many respects the most interesting geological formation found within the State. It has long commanded attention because of its unique physical character, its fossil content and topographic expression, its problematic origin, and its close resemblance to deposits along some of the rivers of central Europe and in the high plateaus of Asia. From what has been said it will be readily seen that the loess is of wide distribution in both hemispheres, and any theory of its origin must take account of this fact.

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[1] E. A. Smith, L. C. Johnson, and D. W. Langdon, Jr., Report on the Geology of the Coastal Plain of Alabama, 1894, p. 30, et seq.

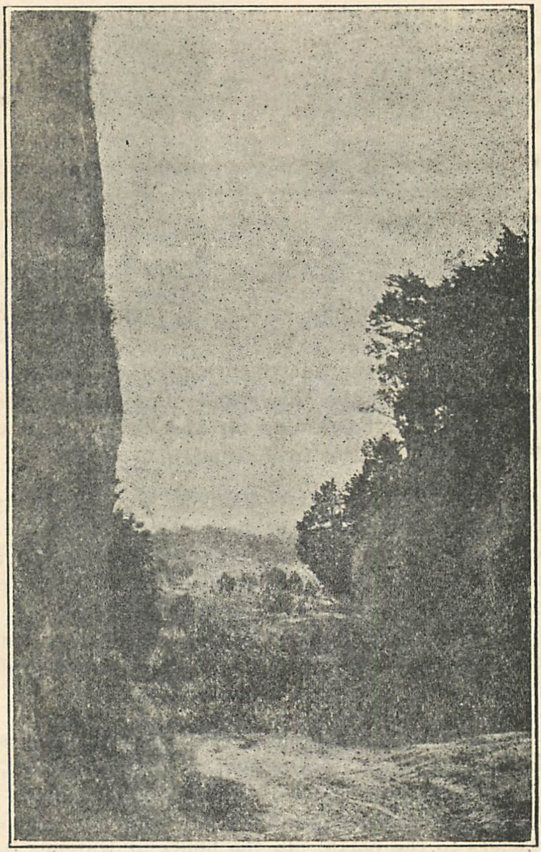

FIG. 7.—Road through the Loess Bluffs, near the City Cemetery, Vicksburg.

In its distribution in Mississippi the Loess or Bluff formation, as the latter name would suggest, is limited to the high bluffs which border the Mississippi River on the east side from the Louisiana line as far north as Vicksburg, thence swinging around with the line of bluffs far east of the river, and finally coming back to the river border just below Memphis. On the floodplain of the river no loess deposits occur, only river alluvium of very different character. The high bluffs, which form the walls of the great trench cut by the river in a previous epoch, are clothed with a blanket of loess 25 to 75 feet thick, which is thickest near the river and thins eastward to a distance of 10 to 20 miles. In places these bluffs are 250 to 300 feet above the floodplain, all the lower portions of 150 to 200 feet representing the depth cut into the older formations. There can be no doubt that this was done by the present river, but not in this epoch.

This material is a uniform tawny or buff-colored homogeneous silt that tends to stand in vertical cliffs on weathering, making a striking and rugged topography. To the practiced eye loess topography can be distinguished at long distances. Stratification is usually absent, though in places horizontal stratification is distinct. This is strikingly shown near Big Black River three miles west of Edwards, Hinds County. In the deep cuts in the National Park at Vicksburg irregular stratification showing cusps and depressions simulating dune structure have been noted in one or two places.

The material of the loess is very fine, the particles of uniform size, and mostly siliceous. In mass it is friable, being easily crumbled in the hand, but vertical walls that have stood for many years bear markings cut into them years ago, showing little tendency to weather or wash by run off of rain water, the material being very porous, so that rain sinks into it instead of flowing off the surface. Capillarity brings moisture to the surface in vertical cuts, so that they become coated with green mosses. Some of the old roads in the Bluff region are wildly picturesque as they wind beneath the twilight glooms of heavily wooded cliffs.

The loess contains abundance of snail shells of several species in excellent state of preservation. These are to be seen specking with white the buff-colored walls, and can be readily removed in perfect condition by picking them out with a penknife. All these shells are of land species. Aside from the distinguishable shells much calcareous matter is contained in the loess. This is dissolved out to some extent by rain water and redeposited near the base of the loess as irregular columnar concretions.

Besides snail shells, a number of species of fossil mammalians have been discovered in the loess of Mississippi and adjacent parts of Louisiana. These embrace a species of tiger, two of bear, two of gigantic ground sloth, two of tapir, one species of horse, one of deer, one of bison, one of elephant, and one of the gigantic mastodon. These are all extinct species, and, as seen, a number of them are tropical forms, such as the elephant, the tapir and the sloth. The mastodon was much the most common.

What then is this loess and how was it formed? What has been its history, and of the region where it occurs, during its deposition? Let it be remembered that the loess of Asia envelopes in deposits having all the characteristics of Mississippi Bluff Silt the surfaces of high plateaus and the slopes of mountain ranges. The loess blanket has not been laid down on a level as we would expect of a water-laid cover, but sweeps up the mountain slopes at different levels, enveloping hill and valley much as snow blanket would do. The snow is able to cover all alike because it sifts down upon all surfaces from above. Could the loess of Asia have been laid in the same way? In the interior of Asia are great arid plateaus upon which dust storms are of frequent occurrence. The winds whip up the tawny dust, carry it into the upper air in great clouds, drift it along until finally in ascending the encircling mountains, the dust is spread out over all the surface in sheets. This process has been going on for many ages until, it is hardly to be doubted, the loess (or dust) deposits have accumulated to the thickness and extent we find them now. The process must have been slow, but geological time is very long when looked at from the point of view of human history, and the result, such as we see it today, was entirely possible. But will this explain the loess of Mississippi? Two prominent facts have always stood in the way of accepting the theory of wind action as an explanation of the loess of our region. First, our climate precludes the idea of an arid surface from which the material could be blown; second, the close coincidence of its occurrence with the old river terraces has always suggested irresistibly the idea of river deposition.

Both objections may be entirely fallacious. In geologic time many changes of climate have taken place, and during Pleistocene time these climatic changes were notable.

During Pleistocene time climatic conditions were such that great ice sheets, called glaciers, accumulated in the northern half of North America and slowly pushed southward grinding into rock flour the surfaces exposed to their action. The advancing edge of this great ice sheet finally reached its limit at about the latitude of the Ohio River, at which the ice melted as fast as the sheet advanced. After a long stationary period the climate became warmer (and almost certainly more arid), and the ice sheets receded and perhaps entirely disappeared. Then a moister and colder period brought down the glaciers again for a time, and then came another retreat northward. These alternating changes took place several times, each glacial advance resulting in the grinding up of more rock material into fine dust and pushing much of it along to the glacier front. All streams that flowed away from the glacier front bore great loads of this rock flour and other glacial debris and deposited it along their courses.

Now, only streams flowing away from the main centers of glaciation show deposits of loess along their banks. The loess has been shown to have a rather definite relation in its distribution to the old glacial deposits. The material of the loess differs from the ordinary river silt, which is highly oxidized, and resembles closely glacial rock flour in being largely unoxidized material and in showing considerable proportions of rock particles that must have come from the glacial regions.

It would seem then that this loess might be of glacial origin. But what evidence of being wind-blown? The Mississippi was the great channel through which the waters of the melting glaciers passed to the Gulf. Its great channel had almost certainly been previously cut out of the uplands many miles wide. The stream was permanently overloaded with debris and made extensive deposits along its course. There must have been then, as now, seasonal changes, part of the year when the great river flats were covered with shallow silt-depositing water from the melting glaciers, and other times when the river dwindled to threads of water creeping through wide wind-swept flats of glacier silt. The winds were prevailingly from the southwest and swept up the finer silt, depositing it on the high bluffs and adjacent uplands toward the east. These periods of high and low water may have been not only seasonal but also secular. Shaw[1] found thin partings of vegetable matter to occur not infrequently in the loess that shows stratification, and it is probable that thin coatings of vegetation at times took possession of the loess surfaces and furnished lodging places for numerous snails that were destroyed and covered by succeeding deposits.

The absence of all water stratification, and usually of any sort of stratification, and the presence of dune structure at least locally at Vicksburg, and the absence of any fossils except of land species, add strength to the Eolian theory of the origin of the loess.

The mammalian species were doubtless preserved in the loess in marshy ponds between the hills where they came to drink or to get the more abundant supply of food to be found there.

Yellow or Brown Loam.—This is the name which has been given to a phase of the loess which some have regarded as simply a surficial modification due to weathering, but which Hilgard believed to represent a closing phase of loess deposition. There is evidence to support both theories, but the weight of evidence is perhaps in favor of Hilgard's interpretation. This loam usually overlies the loess to a depth of 18 feet to 2 or 3 feet, and, like the loess, thinning eatward, but at a lower rate. It extends much farther to the east than the loess. The material is a yellowish brown silt loam, having a higher percentage of clay than the loess, more iron, less lime, and no fossils. It forms the surface soil over large areas in the western half of the State. The average texture is much finer than that of the loess, and, assuming it to be wind-blown, this fact would be sufficient to account for its wider distribution eastward. Its chief importance is as an agricultural soil.

RECENT OR PSYCHOZOIC PERIOD.

No distinct break forms a demarcation between Pleistocene time with its manifold changes and the Recent, which embraces changes still in progress, in bringing about which man is a very important factor. Streams and weather are cutting down the uplands, transporting the land wastage to lower levels, making flood plain deposits along their lower courses, and carrying much to the sea which waves and off-shore currents spread along the seabottom. Waves of the oceans are busy cutting away the edges of the continents at some places while at others waves and currents are adding to the continental border materials brought from the interior uplands by the streams. The unresting surface of our globe is constantly rising up in some areas while in others it is sinking down, and these changes of level may take place either by sudden and convulsive earthquake shocks that

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[1]Oral Communication.

strike terror into the heart of man, or by slow massive movements which the observations of a generation would scarcely detect. The slightest earthquake shock is heralded abroad by the press of the country, yet the observations of geologists have detected the far more important and impressive fact that the region of the Great Lakes is slowly being canted or tilted so that, if the movement continues, in a few thousand years the Lakes will empty through a gap near Chicago into the Illinois River and thence down the Mississippi, as actually happened during Pleistocene time. How many of the inhabitants of Chicago realize that the earth beneath them is moving?

The importance of man's agency in modifying geologic conditions on the earth may be seen in the wide-spread removal of the forests and the stirring of the surface soil, accelerating surface erosion of the uplands and slopes, with subsequent filling of streams and bays; in the separation of continents and the connecting of oceans by great canals; in dredging and opening of harbors; in constructing great irrigation channels by which water is carried to the deserts and worthless wastes are made fruitful; in his incalcuable influence in destroying from the face of the earth undesirable or dangerous species of wild creatures, both animal and vegetable, and propagating for his own benefit those species useful to him, often carrying them to great distances from their natural habitat and introducing them in new places, thus interfering with the biological balance which nature had established.

These are but a few of the many ways in which man has for several thousand years been exerting a potent influence as a geologic factor, and so great has been the aggregate result of his activities, and the cumulative effect so marked, that this may indeed with the greatest propriety be called the Psychozoic Era of earth history, for, whereas in former periods brute strength availed in establishing supremacy of species, in this age the dominance of man is due to his superior intelligence. It is to be hoped that the man of the future will maintain his dominion not only by force of superior intelligence but by a higher moral and spiritual development as well. Whether the human era on the earth will end in a millennium or an Armageddon will depend upon man's control over himself.

UNDERGROUND WATERS OF MISSISSIPPI

Ground Water.—In most parts of Mississippi flowing springs are familiar objects, and in all parts wells sunk into the ground strike water at a greater or less depth. This water, which apparently springs from mysterious sources within the earth, is really of surface origin, and does not differ in source from that of the rivulet that flows over the surface after a shower.

All water that falls upon a land surface in any of its forms of rain, snow, sleet, or hail, is disposed of in one of three ways: Some immediately evaporates from the surface into the atmosphere; some quickly runs off the surface into the streams, and some sinks into the ground, travels a greater or less distance underground, and finally issues as springs, or is tapped by wells and so brought back to the surface. The amounts that will take these three different directions will differ very much under varying conditions. Climate, topography, character of rock material, and ground cover, are important controlling factors. In a climate of average rainfall, on a level or nearly level surface underlain by loose porous rock material, and protected by a forest cover, we would expect a maximum of water falling upon that surface to sink into the ground, and a minimum to run off. Reverse the conditions and suppose the climate dry, with light rainfall, the surface broken into steep slopes, bare of vegetation and underlain by impervious rock, and we see at once that very little water falling would sink into the ground, but there would be a maximum of run-off and evaporation. The rate of precipitation would also be an important factor. A given amount of water falling as slow gentle showers would pass into the earth in much larger quantity than if the same amount fell upon the same land surface in a sudden and violent cloudburst. In the first case the porosity of the soil allows the water to sink as rapidly as it falls, with consequent slight run-off; in the second case, a few inches of the surface soil quickly becomes saturated with water and can hold no more, but the rain falls too rapidly for it to sink and make room for more, with the result that the falling torrents rush off the surface, usually carrying much of the surface soil with it. The greatest cloudbursts known in this country occur in the arid regions of the West, where the torrents rush off the surface with destructive violence, although the underlying rocks are dry.

That part of atmospheric water which sinks into the ground becomes what we call ground water. Ground water increases from the surface downward, because gravity draws the great mass of the water to greater depths, and that which remains near the surface is drawn upon by evaporation, tending to exhaust it. Below a certain depth which varies in different places and in different seasons, the rock structures of the earth become saturated—that is, their entire pore space is filled with water. The level at which this occurs is called ground-water level, or the *water table.*

Water tends to seek a level, as is well known, and on a free surface invariably does assume a level. The water table beneath any land surface, however, is not a perfect level, but conforms in a general way with the surface beneath which it lies. For instance, if a land surface has hills and intervening valleys, the level of ground water will also have hills and valleys. The water table will probably lie at the surface in the valley, forming springs at the bases of the hills, while beneath the hill its surface will rise considerably above the valley level. While gravity tends to draw the body of water down to one common level, friction of the rock particles in which it lies prevents this. In dry seasons the water table under the hills may sink approximately to the level of the valley floor.

Thus, then, we see the source of ground water in the rains that fall and sink into the earth. All rock material beneath the water table is saturated with water, that is, contains within the pore spaces all the water they can hold. Different rocks can hold different quantities of water according to difference of porosity. The following table is instructive as showing amount of water (in quarts per cubic foot) that common rocks will hold:

Amount of water absorbed by some Common Rocks.
(In quarts per cubic foot.)

Granite	1-100— ¼
Limestone (dense)	¼— 1¼
Dolomite (including porous limestone)	1— 5
Chalk	4— 8
Sandstone	2— 6
Sand	8—10
Clay	10—12

It will be seen that clay heads the list in quantity of water it is capable of holding, owing to its greater porosity. Well drillers, however, are aware of the fact that clay beds do not usually yield water in wells. Coarse sandstones, sands and gravel beds are the most common water-bearing beds, because while their average porosity is less than that of clay, the size of the pore spaces is much larger, and causes them to give up water freely, while clay holds it tenaciously. Beds of coarse material like sand or gravel are said to be pervious, because the water passes readily through them; clay beds and similar materials of very fine porosity are said to be impervious.

Artesian Water.—The rocks beneath a land surface are usually of several kinds; in Mississippi they are all stratified rocks lying upon each other in horizontal or gently sloping beds. These are pervious and impervious, according to kind. Water from springs and shallow wells that receive their supply above the first impervious layer is called surface water; that derived from water-bearing beds below the first impervious stratum is called artesian water. Artesian water when tapped, may or may not flow at the surface, according to conditions present. Wells that flow out at the surface do so because of hydrostatic pressure. This pressure occurs as a result of certain conditions, the most important of which are the following: 1st, there must be a pervious stratum lying beneath an impervious bed, and better still, between two impervious beds; 2d, the pervious bed must outcrop at the surface in areas extensive enough to permit of absorption of large quantities of water; 3d, the outcrop must be in a region of sufficient rainfall to promote absorption; 4th, the pervious stratum must dip beneath a region lower than the area of outcrop; 5th the impervious beds must not be broken in continuity by joint planes or fissures sufficient to allow the water to escape freely.

Under the above conditions rain falling upon the region of outcrop passes down into the previous stratum, or as it is usually called the *aquifer* (water-bearer). Gravity, and the pressure of water added after every rain, cause the water to flow down to the lower levels. When the aquifer is full, or approximately so, the water at the lowest levels of the aquifer, being unable to escape owing to the impervious confining beds, is under heavy pressure of the column of water above it. A well tapping the aquifer there will flow at the surface, the water being often shot up to considerable height on relief of the pressure. The height and volume of the flow will be determined by the height of the outcrop and the size of the pore spaces of the aquifer. Friction in passing through the rock will prevent the column of water of a flowing well from ever rising quite to the level of the outcrop.

WATER HORIZONS OF MISSISSIPPI.

Some of the formations entering into the geologic structure of Mississippi are prevailingly of sand, gravel, or other open-textured material, while some are of clay, shale, or other close-textured rocks. The first class forms the most notable aquifers, the latter the intervening confining rocks. The aquifers constitute the Water Horizons of the state.

Consulting the chapter on the Physiographic Regions of Mississippi it will be seen that nine such regions are recognized. Perhaps a tenth might be added in the coastal flats near the Gulf, though here they have been treated as a subdivision of the Long Leaf Pine Hills.

These physiographic regions correspond rather closely with the geologic structure, though not exactly. Thus the Tennessee River Hills region embraces all the geologic formations older than the Selma Chalk. The Pontotoc Ridge embraces the outcrop of the Ripley formation of the Cretaceous and the marine or Clayton beds of the Eocene Tertiary. The North Central Plateau embraces the divisions of the Wilcox and of the Claiborne groups.

In discussing the underground waters of the state each topographic region will be considered separately, the water horizons being referred to their proper geologic formations so far as known.

Tennessee River Hills.—As before noted, this is, on the whole, a region of broken topography, and embraces the highest lands in the state. These highlands, however, pass into still more elevated regions in the adjacent parts of Alabama. The gravel and sand beds of the Tuscaloosa and the coarse sands of the Eutaw form an important aquifer. Beneath these lie the clay beds of the Tuscaloosa which form an effective lower confining bed, but in the eastern parts of the region there are no upper confining beds, the water of this horizon being reached in shallow wells, or surface wells. The area over which these gravels and sands outcrop constitutes what is called the *catchment basin* of this water horizon, and is 2000 miles in extent, only part of which is in Mississippi. In the western part of the area, owing to the dip of the strata and to an upper confining bed in the Upper

Eutaw, artesian water is obtained, and along the large stream valleys flowing wells may be had. Those of shallow depth of about 100 to 250 feet furnish good water; deeper wells going to 375 to 400 feet strike water highly mineralized. A well at Amory struck the hard Carboniferous rock at a depth of 373 feet. The base of the Cretaceous, consisting of 133 feet of coarse gravel and sand, furnished abundant water, but highly mineralized. A flowing well at Gattman, Monroe County, is reported to receive its water from the gray sandrock of the Carboniferous. Its depth is 623 feet.

At Caledonia on the Buttahatchie a well 140 feet deep struck such a heavy flow of water that it was impossible to put down the casing. Large quantities of sand and clay were discharged until the well was finally choked up with it.

In the northern parts of the region, where the Cretaceous gravels overlie the Carboniferous rock, abundant springs mark the line of outcrop on valley sides. The Lauderdale chert beds form an important source of strong wholesome springs in their region of outcrop in the immediate vicinity of the Tennessee River, where its contact with the underlying shaly limestone is exposed on the slopes.

At Columbus and other points in Lowndes County on the Tombigbee, flowing wells are found at a depth of 420 to 680 feet. Numerous wells along the river valley strike flowing water at 200 to 300 feet depth.

Northeastern Prairie Belt.—From the nature of the material underlying the soil of this region it will be readily understood that springs and shallow wells are rare. Where sand beds overlie to a considerable thickness the Selma limestone, as in some cases of possibly Lafayette material or river terrace deposits, or where a locally sandy phase of the Cretaceous material is itself underlain by the impervious blue clayey limestone, springs may be obtained, but such localities are not common, and are limited in extent.

In this whole region the Selma limestone, with its dense, clayey texture, forms an impervious upper confining bed, beneath which the thick water-bearing beds of the Tuscaloosa-Eutaw sands dip at a rate of 15 to 35 feet to the mile. These sands are very thick, and carry abundant water, making the conditions in the prairie region favorable for artesian wells. A well has only to penetrate the Selma chalk and tap the water supply of the Eutaw sands beneath. On the western edge of the prairie region, as at Starkville, the whole thickness of the Selma must be penetrated to reach water. Wells at Starkville reach the Eutaw aquifer at 900 feet, at Osborne it is reached at 485 feet. Along the eastern border the Selma thins out and the water-bearing sands are reached within 250 to 300 feet of the surface.

Flowing wells are obtained only in the eastern half of the prairie belt, in the western half the water rising only to within pumping distance. At Starkville the water rises to within 120 feet of the surface. The increasing distance from the source, with consequent retardation due to friction in passing through the said strata, prevents the water column from reaching the surface. Few wells receive water from this aquifer west of Starkville. The increasing depth and increasingly mineralized water, and the presence over most of the regions farther west of a shallower aquifer, deter efforts to reach the deeper one.

It has been discovered that certain horizons of the Selma rock are distinctly sandy, and outcrop at intervals. These sandy strata may prove to be aquifers, furnishing an explanation for some of the irregularities that appear in the depth of wells in the prairies. At Sherman, Pontotoc County, on the western edge of the Selma outcrop, artesian water is struck at a depth of 250 feet, and rises to within 40 feet of the surface.

Pontotoc Ridge.—This being a region of considerable relative elevation it is not surprising that flowing wells are not obtained on the uplands. The Ripley and Clayton formations whose outcropping edges form the Ridge are very largely sand and sandy marl formations with interbedded limestones, furnishing good artesian conditions. The exposed edges of the sandy strata receive rain water and it is carried with the dip of the strata beneath the surface toward the westward.

Shallow wells reach water at 30 to 40 feet on the uplands. This is slightly calcareous, but otherwise good potable water. Springs are common along the eastern border of the Ridge, in places, at least, seeming to mark the contact between the Cretaceous and Tertiary formations. Artesian water is obtained near the eastern border of the Ridge, as at Wallerville, at a depth of 110 feet below the railroad level. The water stands within 30 feet of the surface. At Pontotoc artesian water is reached at 250 feet, but wells are non-flowing. A few miles below New Albany flowing wells are struck at a depth of 25 feet in the Tallahatchie bottoms.

At Ripley shallow wells strike water at 35 to 40 feet; artesian water is obtained at Bobo's Mill at a depth of 250 feet, and rises to within 40 feet of the surface.

Flatwoods.—This is a narrow region of low relief. The Pontotoc Ridge, which borders it on the east in its northern half, is decidedly higher and forms the catchment area for the sandy formations of the Ripley and Clayton, which dip beneath the clays of the Flatwoods. These clay beds are dense and water-tight forming a confining cover above these water-bearing beds. Under these conditions we would expect flowing wells in the Flatwoods region, and such is the case. Near the eastern border of the region flowing wells are reached at less than 100 feet depth, the depth increasing westward at a rate of 15 feet to the mile. The water-bearing stratum is in this case the sandy marl of the Clayton. Beneath this at greater depths water may be obtained from the Ripley beds.

South of the Pontotoc Ridge there seems to be no water-bearing stratum between the Selma Chalk and the Porter's Creek Clay of the Flatwoods. Consequently wells have been put down to from several hundred to one thousand feet depth without success. At Scooba, on the eastern edge of the Flatwoods ,the town well is 1260 feet deep, and flows at the surface. At Myrtle, five miles west of New Albany and on the western edge of the Flatwoods, wells reach artesian water at 280 feet, but do not flow, the water being from the Ripley formation. At Ecru the Hattox well is less than 90 feet deep, but flows freely. At Toccopola, just west of the Flatwoods, in Pontotoc County, a deep well at the intersection of the principal business streets is 380 feet deep. This well furnishes abundance of good water, which probably comes from the Ripley sands. At 70 feet a water horizon was struck in the base of the Wilcox, which rose to within 8 feet of the surface.

In this region shallow wells and springs are rare. Toward the western border, and in the southern part where certain sandy formations outcrop, shallow wells may be had at 25 to 40 feet owing to the depth of the underlying clay. Springs may occur on valley sides.

North Central Plateau.—This is a large region occupying many counties between the Flatwoods on the east and the Bluff Hills on the west. It is for the most part, a maturely dissected plateau of 400 to 500 feet above sea level. While large areas are nearly level, most of the area is cut up into rather broad stream valleys and intervening ridges and hills. The larger valleys are 150 to 200 feet below the level of the highlands of the watersheds. The formation outcropping over most of the Plateau is the Wilcox of the Eocene Tertiary. This is at least 1200 to 1500 feet thick in the northern counties and has several divisions, some of which are water-bearing.

The lowermost division, which we have called the Ackerman beds, from the town of Ackerman in Choctaw County, consists largely of clay and lignite, neither of which yields water. This division is therefore barren of water, except in certain rather restricted areas underlain by sand beds that have limited outcrops. By referring to the geological map accompanying this report it will be seen that all of the area embraced in the Ackerman division of the Wilcox is a region of few wells. Springs occur where sand beds outcrop on valley sides, but sand strata in this region are not common or extensive. Deep wells are of uncertain occurrence, many borings proving barren of water. A deep well put down at Houlka failed to get water. Deep borings at Holly Springs, Oxford, and in southwestern Calhoun County on the Skuna, all failed to get water at depths of 600 to 900 feet, the borings stopping in the "black dirt" of the Ackerman beds. At Holly Springs, Oxford, and Grenada, however, good water is struck above the black dirt at depths of 250 to 300 feet, in the middle division of the Wilcox.

On Yocona River local flows are obtained east of Oxford at depths of 125 feet. These are probably from a small aquifer within the Ackerman formation.

The sandy hill region, especially well-developed in north-central Mississippi, marks the outcrop of the Holly Springs Sands, a member of the

Wilcox series immediately overlying and outcropping to the west of the Ackerman division just discussed. This is a broad belt of rather coarse red, yellow, white and variegated sands, of numerous valleys and dividing ridges. It is therefore a region of many wells and springs. The water supply is abundant and of excellent quality, though on account of the altitude of the region flowing wells cannot be obtained except in large stream bottoms in restricted areas, as already mentioned. The wells at Holly Springs, Oxford, Coffeeville and Grenada all get their water from the Holly Springs Sands. So also do all the wells along the main line of the Illionis Central Railroad between Grenada and Memphis. These sand beds dip beneath the overlying formations to the west of this line and furnish water to all the flowing wells on the lower slopes of the bluffs next to the Delta, and of the northern part of the Delta.

The uppermost division of the Wilcox in north Mississippi consists of about 150 to 200 feet of lignitic clays and lignite, and being typically exposed on the Yalobusha River near Grenada is called the Grenada beds. This member is not water-bearing, owing to the impervious nature of the material, but forms the upper confining beds above the Holly Springs aquifer. Numerous strongly flowing wells receive water from beneath these beds all along the Delta front. At Charleston, Tallahatchie County, flowing wells are struck at 450 feet depth; at Batesville at 300 feet depth, and at Holcomb, Grenada County, at 300 feet.

Flowing wells are obtained from the middle Wilcox sands all over the northern third of the Delta, increasing in depth westward with the dip of the water-bearing beds, the depth varying from about 500 feet in the eastern part of the Delta, to 1200, or even more, in the western part.

Toward the southern and eastern outcrop of the Wilcox the sandy middle Wilcox beds are less noticeably developed than in North Mississippi. They are present, however, and furnish artesian water in middle and southern Lauderdale County at accessible depth. Wherever these beds overlie the lignitic clays of the lower Wilcox on the valley sides strong free springs are abundant. One such near Marion, a few miles north of Meridian, has been used to develop power to run a water mill. Wells at Lauderdale strike artesian water at 108 to 130 feet depth. The wells flow if located on low ground. Flowing wells from the same source are reported from Walthall, in Webster County, though on the uplands of all the counties within the outcrop of these beds flowing wells cannot be obtained.

Claiborne Horizons.—The chief water-bearing beds of the Claiborne Group belong to the Tallahatta, or Buhrstone. Most of the Tallahatta may be water-bearing, but the largest water supply is furnished by the loose sand beds that lie toward the base, underlying the so-called claystone and often interstratified with the quartzite beds. These sand beds dip beneath the latter formations in a general direction south and southwest, at a rate that averages about 25 feet, though in places locally as much as 44 feet to the mile.

The location of the Tallahatta outcrop may be traced on the accompanying map, the regions supplied by water from it being to the south and west. Within the region of outcrop artesian wells may be had at depths of 75 to 175 feet, furnishing good water that flows at the surface where the well is on low ground. At Siding, a few miles west of Meridian, flowing wells are struck at 75 feet depth; at Meehan Junction, at 175 feet; at McDonald, north of Newton, artesian non-flowing wells are struck at 156 feet, and at Kilmichael, on the Southern Railroad east of Winona, water from the Tallahatta is had at 86 feet, but is non-flowing. Along all stream bottoms in this region flowing wells are had at slight depth.

Farther south and west the depth increases at a rate of about 25 feet to the mile. At West, Holmes County, the formation furnishes flowing wells at 160 to 425 feet; at Durant flowing wells at 375 to 400 feet; at Newton non-flowing wells at 300 feet; at Enterprise flowing wells at 156 to 250 feet, and at Shubuta flowing wells at 280 to 425 feet. This horizon may be struck at greater depths farther away. At Thornton, in the Yazoo Delta, at 700 feet flowing water is had from this horizon; at Louise flowing wells are struck at 920 feet depth; at Indianola at 1290 feet flowing water is perhaps from the same horizon; at Collins, in Covington County, non-flowing wells are obtained from this horizon at a depth of 1487 feet.

The water is of excellent quality, but in the wells in southeast Mississippi has an amber tint, though perfectly free from mechanical sediment. The color is due to colloidal organic matter.

The Lisbon beds are not notable as water-bearing, but the formation has certain open-textured sandy phases that furnish water. The horizons from which the non-flowing wells in and around Jackson obtain their water supply at a depth of 650 to 800 feet have been believed to be within the Lisbon, but are probably Tallahatta. Other wells that are referred generally to the Tallahatta may some of them derive their water from the Lisbon. The wells at Newton may receive water from this horizon.

Jackson Horizon.—The Jackson beds are not generally water-bearing; until a few years ago they were not known to carry water at all. It is now well known that the uppermost beds of the Jackson (or basal beds of the Vicksburg) consist of a thickness of 50 to 75 feet of open textured sands which carry water. This water-bed is struck south of its outcrop at no great depth, but the region furnished by water from this source is not large, so far as at present known. In the vicinity of Canton, Madison County, non-flowing wells strike water at 60 to 65 feet in sands which must belong to the Jackson; the same is true two or three miles west of Madison; a few miles west of Jackson wells sunk on the uplands strike water at 45 to 50 feet in sands of Jackson age; at Pocahontas, Hinds County, wells strike water in Jackson sands at 56 feet depth; at Laurel, in Jones County, non-flowing wells 300 to 400 feet deep are believed to obtain water from the Jackson horizon; a well at New Augusta, Perry County, 744 feet deep and yielding flowing water has been referred doubtfully to the Jackson water-bearing sands.

Late Tertiary Water Horizon.—The Vicksburg Group is not known to be a water bearing horizon. Of course it is very probable that locally water may be furnished by these beds, but no wells are at present known to get water from that source. A spring with slight chalybeate properties on the Alabama and Vicksburg Railroad just east of the Pearl River crossing at Jackson is either from upper Jackson or basal Vicksburg. It is probable that the Stafford Spring, near Vossburg, receives its water from the Vicksburg.

Aside from possible sources in the Vicksburg, all of Mississippi south of the Vicksburg outcrop gets its water from late Tertiary formations, the Catahoula, Pascagoula, and Citronelle.

As before stated, the Catahoula consists of beds of sands and sandstone, clays, and occasional beds of lignite. The Pliocene or Citronelle red sands which are so prominently developed in the southern counties overlap the Catahoula and Hattiesburg formations in such a way that the region where they come to the surface is covered almost everywhere with a coating of the red sands. These are thin toward their northern edge but thicken toward the Gulf coast|

In all of the Grand Gulf area springs and shallow wells strike water at the base of these overlapping sands from a few feet to 25 or 30 feet depth. The water is of good quality, but uncertain in quantity, in dry weather sometimes disappearing, especially where the sands are thin.

In the Catahoula itself water is common in the sands that are interstratified with the blue and gray clays. The water of the Catahoula is not always good. It is often struck beneath blue clays or "gumbo," as the well-drillers call it, which is rich in marcasite or in lignitic matter. These substances give the water a disagreeable taste and odor. The numerous mineral wells and springs of south Mississippi derive their water from the Catahoula. Cooper's Well, Brown's Wells, Lowe's Wells, Rawls' Well, old Brandywine Springs, old Burnet's Wells, and numerous others, derive their waters from the Catahoula. They are all now or formerly have been noted for their medicinal properties.

Not all the waters of the Catahoula are mineralized however; deep wells both flowing and non-flowing tap the water-beds of the Catahoula at numerous places in south Mississippi. At most points north of the coast counties the veneering of Pliocene sands is not thick and wells may get water within the Catahoula at depths of 50 to 100 feet, but the lower and stronger water horizons of the formation are struck at increasing depth southward. At Wesson, Copiah County, this horizon is reached at 121 feet, but the well does not flow; at Brookhaven, Lincoln County, water from the Catahoula is obtained at 165 feet, the well not flowing; at Laurel deep wells get water from the Catahoula at 210 to 370 feet depth, but do not flow; at Hattiesburg this horizon is struck at 350 feet, at Columbia, at 420 feet. The last two localities get flowing wells. The depth reaches 540 to 1,000 feet in the coast counties, the average depth being about 600 feet, and nearly all the wells flow, furnishing good water, but slightly mineralized.

The red Pliocene (or Citronelle) Sands overlie the older formations, but pass beneath the Biloxi Clays several miles back from the Gulf Coast. These sands, in the southern counties, yield an abundance of good water. In the region of low coastal flats which mark the landward extension of the Biloxi formation these sands are reached by deep wells, and the water being confined under pressure beneath the clay beds of the Biloxi, on being tapped by borings rises to the surface and flows out usually in great volume. In the coast towns and on the coastal islands this is the most valuable source of water. The water is freestone and contains no appreciable mineral.

The Pliocene water-beds can be reached in the coastal region at from 200 to 300 feet. Farther north, beyond the overlapping confining beds of the Biloxi formation, the bottom of the red sands is usually reached before an adequate supply of water is obtained, the depth to the water-bed increasing southward. For instance, at McComb good wells are to be had at 105 feet, deeper, farther south and shallower, farther north.

Pleistocene Water Horizons.—The Biloxi Beds consist of alternating beds of dense gray and blue clay and water-bearing sands, extending from the surface down to a depth of about 200 feet. The upper 100 feet of this seems to belong to the recent or present epoch, the lower 100 being of Pleistocene age, and representing apparently the Gulf Coast extension of the Port Hudson of the lower Mississippi. The outcrop of these beds embraces the coastal flats or "Pine Meadows" along the Gulf Coast, reaching from 5 to 40 miles inland, with an average much nearer the first than the last figure. The immediate surface layers are sands that show in places low beach ridges and hillocks, due partly to former wave action and partly to wind action. The lower depressions are permanently wet and swampy, because of imperfect surface drainage and impervious clay beds a few feet beneath the surface, preventing under-drainage.

Shallow wells sunk 10 to 15 feet deep in the surface sands strike water, but it is brackish and unwholesome. Wells that pass through the first clay beds strike water at 25 to 35 feet, which rises to within a few feet of the the surface. This water is often good, but may be abominable, if struck beneath or just above black muck beds, such as are frequently encountered in this formation. In the deeper parts of the formation the water is abundant and usually of good quality, and may rise to the surface, though this is not to be counted on.

In the region of the Bluff Loess bordering the Mississippi River, water may be struck in shallow wells in the sand and gravel at the base of the loess at 35 to 75 feet depth, but the wells will not flow. The water is usually hard owing to the presence of lime leached from the loess. Deeper water may be derived from the underlying water horizons.

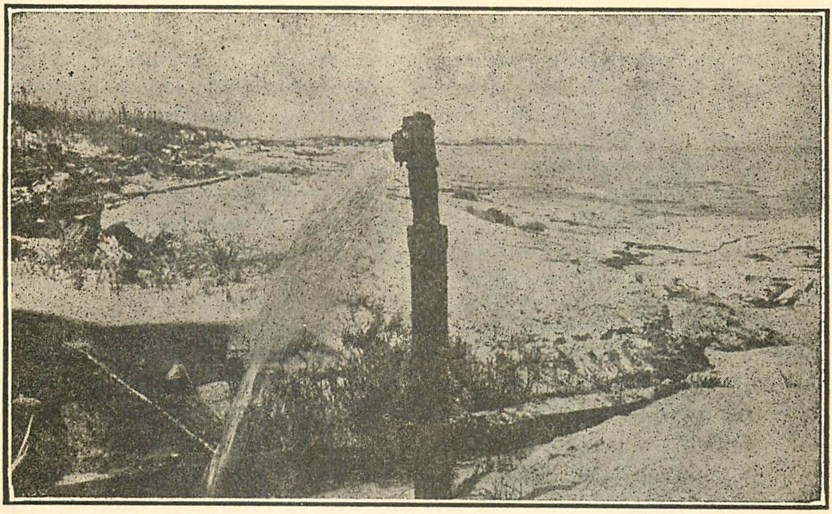

FIG. 8.—Flowing artesian well on Ship Island. Ship Island Light House in back ground.

In the Delta lowlands, besides the deep sources of water which furnish such magnificent flowing wells from the Wilcox, Claiborne, and other water horizons, water may be obtained in shallow wells driven into the sands of the river alluvium. The wells are from 50 to 80 feet deep. The water is not to be recommended.

MINERAL RESOURCES OF MISSISSIPPI

The people of Mississippi have given their attention so exclusively to agriculture in the past that few realize that the state has any other resource, aside from timber, which is already becoming a rapidly diminishin one. That the state has important mineral resources awaiting development seems not to have commanded general attention. This in great part arises out of a misconception of what is meant by mineral wealth. Aside from iron, the metallic minerals are much less important as a national resource than the non-metals.

The development of metalliferous deposits, such as gold, silver, lead, copper, and iron, is spectacular, and never fails to excite public interest, because they so often offer possibilities of great individual wealth; but so far as the general welfare of the country is concerned, excepting iron, the non-metals are far more important and indispensable national resources than the metals.

CLAY.

Clay is not, strictly speaking, a mineral, but a mixture of several minerals, of which the most abundant and characteristic are kaolinite and two or three related minerals (hydrous silicates of aluminum). With these are usually associated in lesser quantities free silica (sand), mica scales, iron, lime, and other minerals, as well as organic matter. Sand and mica reduce the plasticity of clay—the chief property for which it is valuable; iron colors it red or other dark colors; lime in quantity reduces fusibiltiy and often discolors the product; organic matter is readily removed by burning, leaving no bad effect.

Clay that is comparatively free from all minerals except the aluminum silicates is said to be pure. The purest clays are usually residual, that is, those derived by weathering from immediately underlying rocks, though some very pure clays occur also as a result of transportation and redisposition by water.

The chief physical properties of clay are: *Plasticity*, the property of being easily moulded when wet into any desired form and retaining it on drying. This varies greatly, a high degree of plasticity being desirable. *Shrinkage*, the property of shrinking or occupying less space after drying or burning than before. Excessive or irregular shrinkage is undesirable. *Tensile Strength*, the property of holding together under stress, as in a building. Ordinary air-dried brick clay has a tensile strength of 60 to 75 pounds per square inch, pottery clay 150 to 175 pounds per square inch. *Fusibility*, the property of melting under heat. Under high temperatures all clays will fuse, the temperature of the fusing point varying greatly in different clays. As it is often very important to know the degree of fusibility of a clay this is tested by a series of clay cones called Seger cones, of known fusibility, the lowest fusing at 590 degrees Centigrade (1094 Fahr.), and the highest 1670 degrees C. (3038 Fahr.). Placed in a furnace with the cones, the cone which fuses at the same temperature with the clay to be tested determines its fusibility. *Bonding power*, the property of tenaciously cohering in a solid mass. This may be reduced by many extraneous substances, as sand, mica, organic matter. *Porosity*, the property of absorbing moisture. This varies with the texture of the clay, and should not be great in brick clays, especially in northern climates, where absorbed moisture might freeze and disrupt the structure into which the brick were built. *Color*, this is important especially in the higher grades of clay, when stoneware, pottery or ornamental tiles or brick are to be manufactured from the clay.

In the eyes of the public of our state clay is considered of little or no value. According to the reports of the United States Geological Survey on Mineral Resources of the country, the clay products of the United States in the year 1920 aggregated a valuation of $373,500,000. Of all mineral production of the country *Clay* stood *Third* in valuation, being exceeded only by coal and iron, in the order named. In 1912 the Clay Products of the United States exceeded in valuation all the gold, silver and lead combined produced by the United States, including Alaska, during the same period.

Coal, iron and oil are recognized the world over as the "great civilizers" —indispensable to modern progress—and in the light of the above figures clay may be considered a fourth.

Clay products have steadily increased from year to year, the greatest increase in value being in pottery clay products. For the whole country brick and tile constitute about 4/5 of the whole clay values, pottery products about 1/5. In Mississippi the latter constitute about one-half of one per cent, although our potential resources in pottery clay products would justify a much higher percentage. The brick and tile products in Mississippi in 1912 (in normal pre-war conditions) had a valuation of $589,093; pottery products, $12,706. Compare these figures with the $172,811,275 of the whole country for that year and we are at once struck with the comparative insignificance of our productive clay wealth. Unfortunately we stand nearly at the bottom of clay producing states of the Union, those standing below us having practically no clay resources to develop.

The average price of common brick in Mississippi for 1909 was $6.15 per thousand. During the same period the state produced 1,871,000 front brick valued at $22,554, and drain tile valued at $62,605(quantity not given). No vitrified and no fancy and ornamental brick were produced. A very little terra cotta or other ornamental clay products were manufactured in the state, so far as reported. There is some encouragement in the fact that, while the drain tile credited to Mississippi in 1907 was valued at $18,200, in 1909 drain tile had increased to a valuation of $62,605, showing an increased attention to the needs of our swamp lands. Interest in tile drainage, will grow with accelerated pace in the future with return of normal conditions.

That Mississippi is not justified in holding her present low position as a clay producer is shown by the fact that her productive clay wealth is trifling when compared with her undeveloped clay resources. The state's potential wealth can hardly be estimated.

In about half the counties of the state, embracing the western half, exclusive of the Delta, the Brown Loam, a loessal deposit of Pleistocene age, forms a blanket 4 to 15 or more feet thick, lying upon the surface of the uplands. It is a homogeneous yellowish-brown, silty clay; is easily accessible, occurring at numerous railroad points throughout the state. The material is soft and easily worked, and is an excellent clay for plain red brick and drain tile. A little sand usually has to be added, but abundance of suitable sand in most of the area where this loam occurs immediately underlies it.

Few states in the country have a more abundant supply of good brick and tile clay.

In the lowlands of the Mississippi Delta are large deposits of blue "buckshot" clay, thousands of acres in extent and several feet deep in the poorly drained areas, which burns a fine red brick and drain tile. A plant at Clarksdale, in Coahoma County, uses this material exclusively, with an admixture of non-plastic material from the same pit. In the southern counties of the state, where the Brown Loam occurs, it is rather more sandy than in the northern counties, except in the region lying west of lower Pearl River. This and the Pliocene, or so-called Lafayette, clayey sands constitute the chief brick-making material of this part of the state. But these brick are not so good as those made of the more loamy phase of the material.

In the Flatwoods region of North Mississippi a number of brickmaking plants use the gray clays of the Porter's Creek formation, and immediately west of this region the clays of the Ackerman beds of the Wilcox furnish good brick material in abundance. In the prairie belt of the northeastern counties brick of good quality are made from residual clays of the Selma Chalk. In a few cases brick plants use alluvial clays of the second bottoms of the streams. On Pontotoc Ridge brick plants are located upon the residual clays of the Clayton and Ripley formations at New Albany and Pontotoc, and the brick made is of good quality. In the Tennessee River Hills region excellent brick are made from the Tuscaloosa clays and from high terrace clays along the larger streams.

It will thus be seen that probably no county in the state is without abundance of good clay suitable for the manufacture of common brick and drain tile.

Mississippi as yet produces no vitrified or ornamental brick and tile. In northeastern Mississippi a carboniferous shale occurs in one or two counties which is probably adapted to the manufacture of vitrified brick. This undoubtedly exists in sufficient quantity to justify the erection of one or more plants on it. The chief difficulty in this case would be lack of transportation facilities.

Much of the white clay of the state, the distribution of which will be given presently, is well adapted to the manufacture of ornamental brick and tile of high grade. The raw material, as well as the manufactured product, brings a better price in the market than the common red brick, and it is surprising that so little effort has been put forth to develop the deposits, some of which are advantageously located with regard to transportation.

The white ball and pottery clays of Missisippi are distributed, for the most part, in the northern half of the state. Beautiful white and cream colored clays of Tuscaloosa (Cretaceous) age are widely distributed in Tishomingo and Itawamba counties, and underlie much of these counties in beds 8 to 15 feet or more in thickness, the overburden being gravel beds 2 or 3 to 25 feet thick. These clays are quite clear of impurities, except for considerable quantities of free silica in some deposits. This silica occurs in the form of very fine snow-white powder, the presence of which reduces the plasticity of the clay. However, it can be washed out, and is itself a useful by-product.

FIG. 9.—Tile Plant in the Mississippi Delta

Similar beds of white and pinkish clays are widely distributed in Marshall, Lafayette, Benton, Yalobusha, Grenada, Panola, Webster, Lauderdale and Kemper counties, the beds ranging from 3 or 4 to 15 feet in thickness. These deposits are of Wilcox age (early Tertiary), and are very pure except for small quantities of iron oxide in the pink clays. On burning, however the color does not deepen, the plain burned ware being a delicate pink color. These deposits are less continuous than those of Cretaceous age, occurring mostly in large lenses. The clays are very plastic, those in the vicinity of Oxford having been from time to time used in class work for clay modeling.

In Tallahatchie County, near Enid, pits of high grade clay have within a few years been opened and considerable quantities of the clay shipped to northern buyers. The clay is exceptionally clear of impurities, is highly plastic and very refractory under heat. In quality it approximates the German clay. The deposits are very extensive and have no great overburden. These clays will doubtless become commercially important.

A few small potteries are established on these deposits, but the possibilities are much greater, since the Wilcox clay deposits aggregate millions of cubic yards in extent, and very much of it is accessible to transportation.

In total clay resources Mississippi stands high among the states but, as just shown, it is nearly all unproductive capital awaiting development.

PORTLAND CEMENT

Portland Cement is not a natural product, but an artificial combination discovered in 1824 by Joseph Aspdin, a bricklayer of Leeds, England.

It receives its name from its resemblance to the oolitic limestone of Portland, England. It was first manufactured in the United States in 1875, but the industry showed little development until 1890, since then a great demand for the material has brought about a rapid expansion of the cement business.

Portland cement is made from a mixture, consisting chiefly of limestone, which must have approximately the following composition: Lime Oxide 62 per cent, Silica 21.75 per cent, Aluminum and Iron Oxide together, 10.5 per cent. A very small percentage of magnesium carbonate, sulphur and alkalies may be present without deleterous effect. Very rarely will a natural rock be found to have the required composition, the materials generally used being an argillaceous (clayey) limestone, with which is combined more clay or a purer limestone, according to the proportion of lime in the limestone.

The proper proportions being obtained, the materials are ground to a fine powder and well mixed. The mixture is then burned in rotary kilns, which are steel cylinders 5 to 7 feet in diameter and 60 to 150 feet long, lined with fire brick to resist the intense heat. These cylinders are set in a slightly inclined position and are slowly revolved by machinery, the cement mixture being fed in at the upper end and the fuel at the lower end. Under the influence of gravity and rotation the material slowly passes down the cylinders, being subjected to temperatures ranging from 300 degrees to 3500 degrees Fahrenheit. This heat gradually drives off moisture and other gases and finally causes the lime, silica, alumina and iron to combine chemically forming a partially fused mass known as "cement clinker." This clinker, on cooling is crushed to fine powder, which constitutes the Portland Cement of commerce. This possesses the property of "setting" on the addition of water, forming an artificial rock of great durability.

It seems to be the opinion of constructing engineers that Portland Cement will without doubt be one of the most extensively used of structural materials in the future. The growth of cement manufacture in this country has been phenomenal. The Portland Cement made in the United States in 1884 was 100,000 bbls.; In 1895 was 990,324 bbls.; In 1905 was 35,342,812 bbls.; in 1910 was 77,785,141 bbls., with a valuation of $68,752,092; in 1913 was 92,087,131 bbls., with a valuation of $92,557,617. Of the 92 million barrels produced in the country in 1913, the Southern States, exclusive of Texas, produced only about 5½ million barrels. The whole number of producing plants in the United States in 1913 was 126 of which 13 were located in the South, including four in Texas. The Cement Age says, "The one drawback to an otherwise satisfactory condition is that which attracted attention a year ago, namely, the increasing demand for cement in localities far removed from the large mills. In other words, were it possible to transport to other localities some of the mills that are now in rather congested districts, making a more even distribution with reference to demand and carrying charges, it is safe to say that the present capacity of the country would soon fail to supply the demand, so rapidly does the consumption of cement increase." The argument is that with plants located in sections of the country which now have none or very few, the demand would be increased. That the demand increases more rapidly than the supply is shown by the fact that in spite of the rapidly increased production the price has steadily gone up.

In 1914 and 1915 there was a dropping off in cement industry, owing to the economizing of the output incident to the war, but in 1916 production had come up to 91,521,198 bbls., with a valuation of $100,947,881. In that year there were in operation 113 Portland Cement plants throughout the country, six plants having suspended since 1913, and six having been established, of this number, 20 plants were operating in the south in 1916.

The South is poorly supplied with cement plants. Mississippi has none at all, and yet the state has an unparalleled system of waterways—to say nothing of our excellent railroad facilties—with outlets to the world, which furnish the cheapest transportation for cement products. Furthermore, Mississippi, which now produces not a barrel of cement, has billions of tons of rock which tests have proved to be suitable to the manufacture of Portland Cement. Nearly the whole prairie belt in northeast Mississippi is underlain by an argillaceous limestone 300 to 800 feet thick, the rock having an overburden of only a few feet of residual soil. This limestone in most places is suitable for cement material, the residual soil furnishing clay for admixture with the limestone when that would be required.

The belt of limestone of the Vicksburg formation stretching across the state from east to west and several miles wide furnishes another region of the state where cement rock in large quantities lies at the surface, or beneath a thin covering of soft sands. On the whole, this limestone is higher in lime and lower in silica and alumina than the prairie rock of northeast Mississippi, but clay in abundance occurs nearby to supply the deficiency.

Beds of blue aluminous limestone of Devonian age outcrop in ledges 30 to 60 feet thick for several miles along the Tennessee River in Tishomingo County. This, with slight admixture of other material, would be well adapted to the manufacture of Portland Cement. Hilgard called it "Hydraulic Limestone" because of its quality of setting under water after being burned. Its location on the Tennessee River would facilitate transportation over large areas by water, the cheapest of all transportation.

The possibilities of Mississippi in cement manufacture are practically limitless, so far as raw materials are concerned. Cheap transportation is necessary to the success of a Portland Cement plant. The product is bulky and the margin of profit small, making the careful selection of a location for the plant imperatively necessary. A cement plant should never be located upon a single railroad line, but always if possible, on two competing lines, or better still, where both railroad and water transportation are available. Points in Mississippi where transportation would be favorable are Vicksburg and Jackson on the Vicksburg Limestone; Artesia, West Point, Tupelo and Starkville, on the Cretaceous Limestone, and on the Tennessee River, near old Eastport, in Tishomingo County, on the Devonian Limestone. In the first and last instances water transportation to the whole Mississippi Valley could be had, and since the opening of the Panama Canal, to the Pacific coast, North and South America and the Orient as well.

In view of these facts there seems no good reason why Mississippi cement resources should not command the attention of capital looking for profitable investment.

FUELS.

Lignite.—Lignite is a fuel of organic origin, in fuel value between wood and coal. It is often mistaken for true coal, but differs from coal in being immature. Both are derived from woody matter, and are interbedded with other rocks. Lignite, like coal, was accumulated in peat swamps. The vegetation of which it is composed grew and died on the spot where it is found, falling into the acid, amber-colored waters of the peat bogs, where instead of undergoing complete decay, some of the gases of vegetable tissue escaped while the residue accumulated as a dark brown to black pulpy mass. This mass is called peat, and is the macerated residue of woody tissue of plants which have undergone partial decay under water of swamps and bogs. Peat is accumulating in numerous places in the State today, notably in the Delta counties and in the "Coastal Pine Meadows" of south Mississippi.

The accumulation of peat is at the surface. Imagine a peat bog submerged and covered with great thicknesses of sediments. With heavy pressure and a long period of burial in the earth and by loss of gases, as above referred to, the relative proportion of carbon is increased, and the peat becomes firm and dark brown or black. This we call lignite. If the process were continued long enough the lignite would be converted into coal. Lignite is black or brown, often shows distinctly the vegetable tissue of which it is composed, has usually a dull lustre, is lighter than coal but heavier than wood, cracks or breaks into fragments on drying, burns with a yellow flame, and emits abundant smoke and a disagreeable odor.

Chemically, lignite is composed of carbon, hydrogen, oxygen and nitrogen, and the fuel value has a definite relation generally to the proportion of carbon. The analysis of a coal or lignite for economic purposes is to determine the amounts of fixed carbon and volatile matter (combustible ingredients), and of water and ash (non-combustible constituents). Lignite and coking coals are high in volatile matters, and are therefore useful for making gas, while anthracite coal is high in fixed carbon and very low in volatile hydrocarbons. Lignite that has not more than 5 per cent of ash is pure, that is, has no admixture of earthy matter, which may vary in quantity up to 50 per cent, when it becomes earthy lignite or lignitic earth or clay.

The fuel value of coal or lignite is measured in Thermal Units, the British Thermal Unit being the standard. A British Thermal Unit is that amount of heat sufficient to raise one pound of water through one degree of temperature Fahrenheit. Taking bituminous coal from Kentucky to have a fuel value of 14,319 B. T. U., and bituminous coal from Carbon Hill, Alabama, to have 12,449 B. T. U., lignite from Choctaw County, Mississippi, has a fuel value of 10,071 B. T. U., lignite from Texas has a fuel value of 9,904 B. T. U., lignite from Yalobusha County, Mississippi, has a fuel value of 9,706 B. T. U., and lignite from North Dakota has a fuel value of 9,491 B. T. U., it will be seen that the Mississippi lignites compare very favorably with those of other parts of the country, and stand not very far below some of the bituminous coals. On account of the high proportion of volatile hydrocarbons in all of our lignites they would be especially well adapted to the manufacture of gas.

Owing to the high percentage of water contained in Mississippi lignites they would not prove satisfactory fuels as taken fresh from the mine; and on drying, with few exceptions, they slake and crumble to pieces, making the handling of them difficult where thus used. For some years past the United States Bureau of Mines and the United States Geological Survey have published results of experiments with coal and lignites in the manufacture of producer gas, and perhaps the most hopeful outlook for our lignites lies in that direction.

The committee in charge of the Coal-Testing Plant of the U. S. Geological Survey at St. Louis (1904) reports on results of tests on coal and lignite as follows: "Probably the most important of the results accomplished has been the demonstration that bituminous coals and lignites can be used in the manufacture of producer gas, and that this gas may be consumed in internal-combustion engines for development of power, with a fuel economy of over 30 per cent. The use of producer gas made from anthracite coal, from coke, or from charcoal for power purposes, and of producer gas from bituminous coal in steel works, etc., is no new story; but the demonstration of the possiblity of utilizing bituminous coal and lignite in the gas engine is a decided advance in the economical combustion of coal for power. * * *

"Of scarcely less importance are the results obtained in the use of lignite in the gas-producer plant. It has been shown that a gas of higher quality can be obtained from lignite than from high-grade bituminous coals, and that one ton of lignite used in a gas-producer plant will yield as much power as the best Pennsylvania or West Virginia bituminous coals used under boilers. It appears, in fact, that as coals decline in value when measured by their steam-raising power, they increase in value comparatively as a fuel for the gas-producer. The brown lignites on which tests were made at the coal-testing plant were from North Dakota and Texas, and the unexpectedly high power-producing qualities developed by them in the gas producer and gas engine give promise of large future developments in these and other states in the Far West, where extensive but almost untouched beds of lignite are known to exist." And what is said of the West applies equally well in Mississippi.

Both lignite and peat have been found satisfactory as fuel in the older parts of the world when ground to a fine powder, partially dried, and then compressed under very high pressure into briquettes, using a small percentage of some resinous substance to act as a binder to give cohesion to the compressed mass. Briquettes so made are almost as firm as anthracite coal, do not soften and crumble under water, and burn with a hot steady flame like bituminous coal.

While no experiments have been made on Mississippi lignites either in the gas producer or when made into briquettes, there can be no doubt that they will yield results equally satisfactory with the western lignites when so used, and we may confidently look forward to a time at no great distance in the future when the thicker beds of Mississippi lignites will be developed.

Lignite has been found in more than twenty counties of the State, most of the known outcrops being in the Wilcox Group of north central Mississippi.

In the Tuscaloosa beds of Itawamba and Monroe counties lignite of cretaceous age occurs, but no thick beds have been found. Most of the Wilcox lignites, and all of available thickness, occur in the Ackerman and Grenada divisions of the group. In the middle sandy group very little lignite occurs, and then only thin beds a few inches to a foot in thickness. A bed of lignite to be available should be not less than three feet thick. The great lignite-bearing beds are the Ackerman, whose outcrop can be seen on the map. Every county within its outcrop shows lignite. The best that has been investigated is from Webster County, though Calhoun and Lafayette have deposits that may prove to be equally good.

The thickest beds of lignite reported are in Holmes and Madison counties. The beds on Phunegusha Creek, near Lexington, Holmes County, are 7½ to 8 feet thick, and beds at Shenoah Hill in the edge of the Bluffs, three miles east of Tchula, are 6 feet thick. Both localities are within the Tallahatta Claiborne. At Coal Bluff on Pearl River, in eastern Madison, the lignite is five feet thick. This bed probably represents the Cocksfield horizon of the upper Claiborne.

Lignite beds of limited thickness occur in the Jackson, Vicksburg and Grand Gulf groups, but none of commercial importance.

Peat.—As already stated, peat is a brown or black pulpy mass resulting from the partial decay of vegetable matter in water. The texture may plainly show vegetable tissue, or may be so fine as to appear to the naked eye as a dense black mud, but even in such cases under a high power lens vegetable tissue may be detected. When pure, peat is composed entirely of vegetable tissue, but it may show different degrees of impurity owing to admixture with it of more or less sediment. All gradations may be found in peat bogs and swamps between pure peat and black peaty mud.

Beds of peat may vary both in lateral extent and in thickness. In Mississippi the most extensive peat deposits are now being formed in the lower parts of the Yazoo-Mississippi Delta; in other parts of the state the deposits are usually small areas between neighboring hills or ridges kept wet and swampy by the presence of ground water at the surface. The "reed brakes" of many of the central counties are peat bogs. The surfaces of these "brakes" are often studded with coarse sedges and shrubs in clumps, all the intervening areas being soft and spongy black mud, often covered by a foot or so of amber-colored water. A pole pushed down into this mass may go many feet before encountering solid ground below, or may not reach it at all. A peat bog cut through by the Alabama & Vicksburg Railroad at Lost Gap, 6 miles west of Meridian revealed 6 to 8 feet of black peat. Small peat bogs are of rather frequent occurrence in Newton and Neshoba counties, and in the "Pine Meadows" near the Gulf Coast.

No survey of the peat deposits of the State has as yet been made, but will be undertaken at a later date by the State Geological Survey.

Oil and Gas.—Within recent years new and enormously productive oil and gas fields have been discovered in states adjacent to Mississippi, especially Louisiana, Texas, Oklahoma and Arkansas. These discoveries have stimulated interest in oil and gas possibilities throughout the whole Gulf region.

This excitement naturally extended to Mississippi, especially since the geological structure of the state is sufficiently like that of Louisiana to warrant reasonable expectations of oil accumulation.

About twenty years ago a well was put down for oil in the vicinity of old Eastport, near the Tennessee River, of which no accurate data is obtainable. It is said to have reached a depth of about 750 feet when it was abandoned. This well was sunk in the Devonian shaly limestone, and is reported to have emitted a strong odor of oil when discontinued. There seems to have been no anticlinal structure at the locality.

About 1910 a well was drilled in Attala County, near the village of Gladys. The well was started on low ground and the factor determining its location was the escape of considerable quantities of inflammable gas in a marsh. This was almost surely marsh gas. The well was put down 800 to 1000 feet and was abandoned without encountering oil or gas. By another report the well was put down 1900 feet.

About the same time three wells were sunk for oil at Toomsuba, in Lauderdale County. The drillings were carried on with an exasperating air of secrecy, so that a representative of the Geological Survey could obtain no satisfactory data. It is not certainly known how deep these borings went, but it has been reported 2300 to 2500 feet. The wells were abandoned.

In the year 1915 a well was sunk for oil on Judge Jeff Truly's place in western Jefferson County. The escape of gas from a lake was the exciting factor which determined the boring. This well was put down to a depth of 2575 feet, but no oil was encountered.

In 1911 a well was sunk for oil at Laine, Jackson county, three miles northeast of Pascagoula. Gas in large quantities escaping from the salt marshes, had excited interest. A local company was formed and the well put down on the slope of a well-defined old beach ridge. This well was abandoned at a depth of 3010 feet after encountering warm salt water and a little gas, but no oil.

A second well by another company was put down in 1913 at Bellevue, in South Pascagoula. This was abandoned at a depth of 560 feet. Since then no less than eight other wells have been drilled in Jackson County in depth varying from 2000 to 4000 feet. Some gas but no oil was encountered.

It has long been known that a marked disturbance of the strata existed in the vicinity of Jackson, Hinds County, and in 1912 the writer expressed the opinion, at a meeting of Jackson citizens, that the area around Jackson offered possibilities of oil and gas, basing that opinion upon the favorable structure, escape of gas from the Edwards Hotel well, and upon a knowledge of the geological formations as compared with those of the north Louisiana field.

In 1915 O. B. Hopkins, of the U. S. Geological Survey, made a detailed survey of the Vicksburg and Jackson areas. His investigation proved the existence of two monoclinal folds in the Vicksburg area, both running approximately east and west. One ran a little south of the city limits, the other about 15 miles north of the city. These structures were reported as offering reasonably favorable conditions for oil accumulation.

In the Jackson area Hopkins found a wide doming of the structures and regarded the Jackson territory as favorable for oil and gas prospecting.

The publication of Hopkins' report brought many prospectors into the state, especially into the Jackson region. In this area the Altas Oil Company of Shreveport, put down a well to a depth of 3,079 feet, and abandoned it without finding oil. The Arkansas Oil and Gas Company, a branch of the Benedum-Trees Company, of Pitssburg, Pa., put down a well to a depth of a little over 3,000 feet and abandoned it. In 1920 and 1921 two other wells were drilled six miles south of Jackson. These wells were put down only about 1600 feet, encountering a little oil. During the present year, 1925, another well 3 miles north of Jackson has been drilling, but at present depth, 2000 feet, no production has resulted.

In the Vicksburg area a local company, the Mississippi Oil, Gas and Investment Company, had already put down two wells on the southern monocline. The first well went down to a depth of 3462 feet, and was abandoned without striking oil. The second well was put down 2630 feet, with the same result and abandoned.

Neither of the two wells in the Jackson area probably went deep enough to strike the oil-bearing sands of the Caddo field. Both seem to have stopped in the Selma Chalk, and the sands that furnish oil in the Caddo field lie beneath the Selma.

.In northeast Mississippi, both in the Cretaceous belt and in the uplands of the Paleozoic outcrop, several wells have been drilled. Two wells in Tishomingo county penetrated into the Knox Dolomite, and were abandoned, one of them making a small show of oil. The prairies of the northeast counties have received little development. A well at Wallerville, Union County, struck a good show of gas just beneath the Selma Chalk, but further drilling proved unproductive. A well at Houston, Chickasaw County, had a show of oil in the base of the Cretaceous.

The Delta has had three wells drilled, all in Washington County, but so far no production. North central Mississippi, in the deep well near Winona (4260 feet) and one in Grenada County, has received partial test of its oil possibilities. Farther south the deepest well in the state was drilled to a depth of 5150 feet, and stopped in the base of the chalk, Southwest Mississippi has had a few inadequate test wells, none of which were drilled deep enough. The Bluff Region has had several wells drilled; one in southern Holmes county, and three farther north, in Tallahatchie County. So far production has not followed any of these tests.

Altogether about 65 wells have been drilled for oil and gas in Mississippi, without success so far; but these do not condemn the territory, because few of these were located on structure, and most of them were not drilled deep enough to reach the Cretaceous sands.

Speaking generally of the prospects of discovering oil and gas in Mississippi, it may be said that thus far the "Saline Dome" structures with which oil and gas have been found to be so frequently associated in the Beaumont and Jennings oil fields, and in the coastal regions of Texas and Louisiana generally, have not been discovered in Mississippi, although they have been diligently looked for. If they exist here at all a very detailed examination will be necessary to find them. Of course, not finding them makes a search for oil and gas in south Mississippi less favorable owing to excessive depth.

STRUCTURAL MATERIALS.

Structural Materials consist of those which find their principal usefulness in the construction of various works, as public and private buildings, bridges, walls, public highways, etc.

Cement and Brick are so important that they have received special attention already in the discussion of Portland Cement Materials and Clay. Besides these, however, the state has other materials that are commanding some attention now, and will become more important in the near future.

Building Stone.—Mississippi has never put upon the markets of the country building stones of any variety, but there are some deposits within the State worthy of attention.

In the old Carboniferous outcrops near Bear Creek, in Tishomingo County and adjacent regions, extensive deposits of a heavy-bedded light gray sandstone outcrop in prominent ledges 20 to 30 feet high. This rock is of medium fine texture, homogeneous throughout, firm, easily quarried and makes a very handsome block when dressed by the stone-cutter. It has a crushing strength of more than 12,000 pounds, absorbs only a small percentage of moisture on exposure, and does not chip or exfoliate on exposure to the weather. It is in every respect a good building stone and deserves to be more widely known. A quarry has been opened upon a spur of the Birmingham branch of the Illinois Central Railroad near Tishomingo City. The same rock outcrops on Mackey's Creek at Bay Springs.

In the same general region and extending into Alabama, is an outcrop of light-colored oolitic limestone (oon=egg, lithos=stone, so-called because of having coarse rounded grains like fish eggs) which ought to make a good building stone. It is very similar in character to the Bedford Limestone, which is so well known.

The Selma Chalk of the Cretaceous is not generally well adapted to use as a building stone, being too soft. In some localities, however, it would afford a fair quality of building stone. The lighter phase which contains a very low percentage of clay, is soft when quarried, but on drying hardens to a firm rock of uniform texture and buff color. Rock of this character is found near Okolona, Osborne, Macon and other points.

The Tallahatta Claiborne at numerous points across the State, notably in Holmes, Attala, and Lauderdale counties, is exposed in beds of quartzite, or indurated sandstone. The stone is usually in beds one to three feet thick, often several successive beds being separated by thin sandy or marly partings. The rock varies from light gray to white in color, but is often stained to yellow or brownish color by iron oxide. The texture of the sandstone is fine, and it varies in hardness from a soft friable mass to a perfect quartzite which will batter a steel hammer. The rock often changes character and hardness within very short distances, and for that reason would not be a very satisfactory building material. It has had a local use as road metal, but the quality of uncertain hardness unfits it for a good road metal.

The Vicksburg formation furnishes a limestone that has commanded some attention. The limestone outcrops from Vicksburg across the state to Waynesboro. In the western part of the outcrop the rock occurs in ledges of alternating hard semi-crystalline gray limestone and soft sandy beds of marl. An exposure may show a dozen or more hard ledges of 12 to 24 inches in thickness, with intervening soft marl beds. This is the character of the outcrop in the river bluffs at Vicksburg, which is duplicated at Brandon. In Jasper, Smith, and Wayne counties the upper 15 to 25 feet consists of this material underlain by thick, massive, yellowish, soft "chimney rock," so-called because it is quarried by sawing out blocks which harden on drying, and are locally used for building chimneys. Chimneys so constructed look neat and are quite durable. The material might also be used as a fair building stone. The harder ledges are of good quality for building stone, and take as handsome a polish as marble, but the quarrying is not very satisfactory, and owing to the thinness of the ledges blocks of large size could not be had.

In places this limestone would make a satisfactory building stone to put upon the market because of the beauty of its coloring and because the hardest ledges take a handsome a polish.

The Grand Gulf Sandstone has been quarried for local use at the type locality, Grand Gulf, at Mississippi Springs near Raymond, from which the rock in the old State Capitol was taken; also at Star, Rankin County, and at other places. The rock is light gray in color varying to nearly white, and in hardness varies from a friable mass that crumbles under the touch to a hard quartzite. It often contains marcasite, which weathers out leaving little cavities, and stains the rock with iron oxide.

This rock occurs in beds a few inches to several feet in thickness and quarries easily. At Star, where it is nearly white, and has received some attention, it has a crushing strength of more than 4000 pounds. This would be a satisfactory sandstone, but the lack of uniformity of hardness and of color, and the prevalence of marcasite in the rock has interfered with its use for building purposes.

Road-Making Materials.—A decade ago a decided awakening to the necessity of good roads spread over the State. This was at first started from a few foci, where certain enterprising and public-spirited citizens had worked to good purpose until their counties or beats became infected with their enthusiasm and issued bonds for the improvement of the road system of their localities. From these few points where the vast improvement of the roads proved a valuable object lesson to all travelers, the desire for better roads spread generally over the State. The crusade for improved farm methods, improved farm life, and diversified crops, with better market facilities, which has been vigorously and effectively waged all over the State, called forth a demand that better roads should be constructed and maintained, as a corrollary to the development of diversified farming.

Recognizing the necessity for organized effort looking to this end, a State Highway Association with a volunteer membership of citizens throughout the state was formed, which had for its purpose the promotion of good roads propaganda within the state. This was an important step in the right direction, but a step further was necessary in order to accomplish the desired results. In those states where the best results had been obtained this had been accomplished through an official State Highway Commission, a body the membership of which were either elected or appointed because of their fitness to serve in that capacity. Accordingly, in March, 1916, a bill passed the Legislature creating a State Highway Commission, empowering them to elect a State Highway Engineer, and to enter upon a program looking toward the construction of a system of adequate highways in the state. Since its organization, the State Highway Department, under the supervision of a competent Commission, and through the efforts of a judicious and virile Engineer, has systemitized road building in the state, and is rapidly constructing first class highways throughout the state. Many of these are Federal aid trunk highways, connecting with similar highways throughout the country.

Few states of the country are better supplied with first class road material than is Mississippi, and yet, if we may judge by the fact that often road materials are brought into the State at heavy expense, many people of the State need to be educated to the knowledge that Mississippi has abundance of road-making materials equal to any that can be brought in from outside sources. The essential facts about our road-making materials are given in the following few pages.

Those who desire more detailed information should get Bulletin No. 16 of the Mississippi Geological Survey.

The road materials of Mississippi consist of chert gravels, bedded chert, limestones, ironstone, sandstones, quartzites, sand and clay.

Sand and clay in approximately the right proportions to make sand-clay roads are found abundantly in several counties of the State. About the proportions necessary for sand-clay roads would be 25 to 35 per cent of clay, the rest being sand. In Rankin, Jasper and parts of Smith counties, as well as large areas of southwest Mississippi, sand-clay mixture occurs, so that where the roads are properly graded, raised in the center and drained at the sides, excellent roads as smooth as macadam and almost as firm can easily be maintained. No special preparation is required, further than should be observed in the construction and maintenance of all roads. In wet weather, of course, to prevent the formation of ruts and "chuck" holes the road should be frequently dragged. This fills in the ruts, packs down the road bed, and promotes the rapid drying of the surface. Under proper care this kind of road need never become soft and boggy or full of ruts and mudholes.

In many places in the State the public roads present sandy stretches which make heavy pulling. Where clay can be conveniently had a number of loads should be spread upon the sand roads, sufficient to make the sand-clay mixture. Or if sticky and boggy clay stretches occur in the roads, these should receive a sufficient quantity of sand to make the sand-clay mixture. In either case such treatment, repeated if necessary until the right proportions are obtained, will correct the defect and, if properly cared for afterwards, insure good results.

Sandstones and quartzites, as seen in the chapters on Geology, occur at a great many points in the State, representing several geologic horizons. The oldest of these are the Sub-Carboniferous sandstones of Tishomingo and Itawamba Counties. What we have designated as "Hartselle Sandstone" is a thickly bedded, light gray, medium fine grained sandstone which is sufficiently hard to make a fair road-metal, though its best use would be for building. No experiments have been made with this rock as a road-metal. Another sandstone which occurs in the same general region is sufficiently rich in asphaltic matter so that it would prove a valuable top dressing if developed.

The sandstone and quartzite of Claiborne age, which are distributed across the State through Holmes, Attala, Leake and Lauderdale counties, offer in much of their outcrop, good material for road-metal. Where the rock is developed into a quartzite the material is of excellent quality, but the sandstone phases are too soft to be satisfactory road material. The quartzitic phase may be seen around West in Holmes County, in the vicinity of Kosciusko, and east of Meridian in Lauderdale County.

The Grand Gulf Sandstone which outcrops in many places south of the Alabama and Vicksburg Railroad is nowhere fit for road-metal. The rock is generally too soft, and where it assumes the quartzitic character the deposits are not sufficiently extensive to have more than local use.

The limestones of the State have not been experimented with to any extent for road building purposes, but that some will prove as good for road-metal as any limestone brought into the State is more than probable. Devonian and Carboniferous limestones of Tishomingo County, while limited to a restricted area of the State, outcrop in sufficient abundance to be commercially important, when once developed. No transportation lines reach these deposits, but they lie near enough to the Tennessee River to be easily accessible to that stream. The quality of these limestones for road-metal is equal to that brought in from states farther north, and these sources of supply should be developed. An intelligent appreciation of our own resources in this direction is a desideratum. Can we imagine Illinois sending to Mississippi for road material? No more should Mississippi expect to send to Illinois for such materials. Illinois has absolutely nothing along that line that Mississippi cannot duplicate *in just as good quality.* Mississippi contractors have unfortunately developed a hypermetropic eye that sees good things far away, but is blind to the good things lying at their very feet. Let Mississippians put on the proper glasses to correct this defect of vision and begin to look for the good things to be had at home. Every order for road-metal sent out of the State helps to develop the resources of some other State at the expense of our own. Let us keep our dollars at home.

Chert is a hard siliceous rock of light gray to brown color and of very fine texture. It is a variety of flint and is very hard. As a road-metal angular chert is ranked among the best. It is not excelled in hardness by any rock used in road-building, is tough, resisting wear well, and possesses in its composition a little clay which as the angles are worn off fills in the spaces and sets into a firm mass. This quality makes it preferable to any purely siliceous rock. The Novaculite of southern Illinois, which has found its way into Mississippi at high cost to the purchaser, is in no respect superior to the great deposits of rounded chert gravels found near the Tennessee River in northeast Mississippi. These are entirely distinct from the great deposits of rounded chert gravels found in the same region of the State. The chert occurs in horizontal strata outcropping at the surface on hill slopes, showing a thickness of 50 to 75 feet on the Tennessee River. The strata show parallel bedding from one to several feet thick, closely jointed, so that for some distance down from the surface the rock consists of loose angular fragments, which with little handling would be ready for road-metal. Thousands of tons of this material can be scooped up with steam shovels before having to quarry and crush the firm unbroken rock.

These deposits are extensive enough to build all the roads the State would need for a century. So far no railroad has penetrated to this region. They lie easily accessible to the Tennessee River, by which the material could be transported to the Tennessee and Mississippi valley regions.

These deposits are among the most valuable of all our resources, and should be developed without delay.

In the construction of the public roads radiating from Vicksburg Illinois Novaculite was used as a covering; in West Point this Novaculite was used as a base for concreting the streets of the city. And yet the Mississippi chert would have been in no respect inferior to the material used, and it is not improbable that if that material had been available it would have been used in both cases. A recent Legislature passed a bill looking to the erection of plants to crush limestone for agricultural purposes. Would it not be equally advisable for the State to establish at small cost, compared with the great benefits to be derived, crushing plants on these great chert deposits and make available for the people this source of first class road material? It is not desirable for the State to enter into development of this nature to the exclusion of private enterprise, but if private enterprise will not develop resources so much needed at this time, they should be developed at State expense and furnished to the people at cost of operating the plants. Nothing should be left undone to encourage to the utmost the construction of a perfect public road system in the State.

Chert Gravels consist of rounded water-worn gravels of chert. Enormous deposits of these gravels are found in two distinct belts in Mississippi, one in the northeast corner of the State in the vicinity of the Tennessee River and the headwaters of the Tombigbee, extending as far south as Columbus; the other in the western part of the State following the Mississippi River bluffs, and spreading across the State in the southern counties. All these gravel deposits are waterlaid materials, usually in thick beds showing evidences of stratification. In places the gravels are intermixed with calcareous or sandy clays, in others the gravels contain only pure sand, as if thoroughly washed.

The gravel deposits of northeast Mississippi, chiefly of Cretaceous age, are very light gray or yellowish chert pebbles, subangular in shape, showing often slight effects of wear by currents which deposited them. The material is so nearly identical with the bedded chert in the same region that it is almost certainly derived from that source. The subangular condition and the poorly sorted state of the gravels, ranging from half an inch or less to 6 or 7 inches in diameter, point to transportation for only short distances, probably from the local chert beds. These gravel beds occupy the surface or lie a few feet beneath the surface throughout Tishomingo, Itawamba, and Monroe counties in beds 25 to 75 feet thick. The supply is practically unlimited and very much of it is accessible to railroad transportation. The largest pits that have been opened are near Iuka. Much of the gravel in the southern extension of this belt has been reworked by the Tombigbee and occurs along that stream in pleistocene terraces. These reworked gravels have been mostly well washed, and are better fitted for concrete work than for road material. Farther north, however, these gravels have a cement of whitish calcareous clay which sets very firmly in the road bed. They are widely known in northeast Mississippi and adjacent parts of Alabama, and are with justice highly esteemed on account of their excellent qualities for road construction.

The only defect of this gravel is the very considerable number of large masses, too large for road uses, which it contains. This may be obviated either by screening or by crushing the masses.

The chert gravels in the western parts of the State differ from those just considered in being more uniform in size, more rounded and water-worn, brownish in color instead of yellowish-white or gray, and in having generally a more sandy and somewhat less tenacious cementing material. The gravel is usually associated with Indian-red clayey sands imperfectly stratified. In the road bed the general impression received by the traveler over roads coated with this gravel is that of a red road, while the northeastern gravel road is white or nearly so. To any one knowing the characteristics of the two gravel belts the distinction can be made as far as the roads can be seen.

The western gravels occur in deposits a few feet to 70 or 80 feet thick, and are usually interstratified with red sands that have heretofore been regarded as of the Lafayette formation. It is more than probable that the deposits do not all represent the same age, ranging, perhaps from Pliocene through Pleistocene time.

These gravels have been very largely used along the various lines of the Illinois Central Railroad, where pits have been opened. A pit on the Yazoo and Mississippi Valley Railroad was opened at Rosetta a good many years ago and large shipments of gravel made to New Orleans and other points in Louisiana and Mississippi. Large pits from Crystal Springs, Brookhaven, and southward through the State into Louisiana, ship gravel for road-building. The pit at Weathersby, Simpson County, on the Gulf & Ship Island Railroad furnishes a rather peculiar gravel. The average size of the gravel is not more than half an inch in diameter, and there is very little variation in size. These gravels are firmly cemented together into masses by a uniform brown oxide cement. It is good road-making gravel, but not superior to others that are without this characteristic.

A large pit at Olive Branch, DeSoto County, shows an immense deposit of excellent gravel. This pit is well equipped for shipping gravel.

The western gravels have the advantage of those of the eastern belt in being more uniform in size and requiring no screening, while the eastern gravels, on the whole, have a more tenacious cement. Both, however, soon set into a firm road bed.

IRON ORES.

Brown Iron Oxide is very generally distributed as a coloring matter and a cement in most of the rocks and soils of the State. In certain localities, however, it has formed accumulations of some extent and reasonable purity. Since, however, all known deposits within the State where it is of possible commercial importance, are of secondary origin, this will be discussed in connection with the primary deposits from which it is derived.

Bog Iron Ore is a form of hydrated oxide of dark gray to brown color and usually quite cellular, having a worm-eaten appearance like rotten wood. This structure is due to its mode of deposition around grass, leaves, and twigs. Bog ore is formed by deposit of iron from iron-bearing waters. These are atmospheric waters which sink into the ground, come in contact with iron in the protoxide state, take it in solution, and carry it along until some outlet is reached where the water discharges into a swamp. Here the iron is oxidized by the atmosphere and deposited around grass, roots, twigs, and other objects. The largest deposits of this kind of ore known in Mississippi are in Chickasaw County west of Houston, but limited deposits are common in all parts of the State.

North Mississippi Carbonate Ores.—The most extensive deposits of iron known to occur in the State are in the form of Carbonate, or Spathic ores. These occur either in thin beds or in lens-shaped concretions, interstratified with gray or lignitic clays. In either form the deposits are made in fresh water swamps and the ore probably accumulated, if not simultaneously with the enclosing clay beds, at least during the same geologic epoch. The deposition of Carbonate of Iron instead of the oxide resulted from the combination of carbon dioxide produced by the decay of vegetation in the swamps with the protoxide of iron, in which state the iron was held in solution in the water, as in the case of Bog Ore.

However accumulated, carbonate iron ore has been found in considerable quantities in parts of Mississippi, and in its unoxidized state is often mistaken by well drillers and others for "flint" rock, which it is often called. The name suggests some of its qualities. It is a very dense and heavy light gray rock with so fine a grain that a broken surface looks like that of flint. While to the well-driller the rock seems hard, it is so soft that a pen knife will easily mark its surface. On touching a drop of acid to the powdered rock effervescense occurs, due to escape of carbon dioxide gas. A freshly broken surface is light gray in color, but on exposure to the atmosphere gradually turns brown or red owing to conversion of the carbonate of iron to the oxide. Masses that have been long oxidized on the surface present crusts of "iron rust," while the interior may be the characteristic light gray color. These characters will distinguish this iron ore from any other rock.

In the clays of the Tuscaloosa formation in northeast Mississippi considerable quantities of this ore have been found in the form of great lenticular concretions embedded in the clays. It is reported as plentiful in parts of Tishomingo and Itawamba Counties.

The largest deposits of these ores found in the State occur in the basal or Ackerman beds of the Wilcox Group, the distribution of which lies just west of the Flatwoods, and may be seen from the map accompanying this report. These beds are prevailingly of gray and lignitic clays, and the iron carbonate occurs for the most part as large flattened concretions embedded in the clays. Occasionally continuous beds of the ore a few inches to a foot or more thick may be seen. Both the beds and concretions may be seen in the great cut at Blanton's Gap near Ackerman. However, the best known deposits of this ore are in Benton County in what is known as the Potts Camp District. The ore-bearing zone, which runs approximately north and south, is several miles wide here, the most westerly outcrop being in the hills and ridges just west of Tippah River, two miles west of Potts Camp. The eastern outcrop is in the vicinity of Hickory Flat.

The region is one of rough topography, the hills and ridges presenting one or more—usually three—horizons or iron ore outcrops. These are said to be noted by the large boulders of ore lying along the hillsides. Stripping the surface material reveals the horizontal bedding of the ore, the great lenticular masses weighing each from 100 to 1000 pounds, or even more, lying in sheets, only the edges of which outcrop around the hills. Much of this ore has been laid bare in this district, but by far the larger amount remains hidden in the hills. Nearly all wells in this district strike the ore at depths of from 15 to 25 feet.

Analysis of this ore has shown that the carbonate is almost theoretically pure, and yields on roasting, so as to expel the CO_2 gas, about 60 per cent of metallic iron. All ore that has been long exposed at the surface is oxidized, so that large quantities of the brown oxide ore are to be found on the hill slopes. This is at times rather highly siliceous, but the average iron content is about 50 per cent. One of the most deleterious impurities of all iron ore is phosphorus. If an ore contains even as much as one per cent of phosphorus it is useless for the manufacture of steel and the highest grades of malleable iron. Few iron ores in the United States are suitable for steel manufacture without an admixture of Swedish ore to reduce the percentage of phosphorus. The Mississippi carbonate ores from this district are so low in phosphorus that they would make high grade steel without admixture with other ore.

FIG. 10—One hundred and twenty tons of Pig Iron, made by the Winborn furnace from Benton County ore.

The ores in this district have been found in sufficient quantities to be of commercial importance. A few years ago a company prospected the territory around Potts Camp, Winborn, and Hickory Flat, and found ore of sufficient quantity and grade to justify development. Accordingly a small charcoal furnace was erected at Winborn, large quantities of ore were mined and placed at the furnace, and 125 tons of pig iron was made. The furnace then shut down and has not been in operation since.

This belt of ore extends north into western Tippah, east of Ashland, in Benton County, and southward through eastern Lafayette, Yalobusha, and Calhoun counties. The continuation of this belt is seen in eastern Webster County, near Reform, and at Ackerman, in Choctaw.

South Mississippi Carbonate Ores.—In 1887 some excitement was started at Enterprise, Clarke County, over discovery of iron ore in that vicinity. Some prospecting was done, and a carload of ore shipped to Birmingham and smelted, but the enterprise was abandoned without further development. The Enterprise iron ores are entirely different in origin and physical character from that in the northern areas. The ore is or was originally, a carbonate ore, though largely converted into the hydrated oxide by surface influences.

This ore is unique in having originated by the weathering of a marine marl of Claiborne age. The unchanged marls are rich in carbonate of lime, and are dark grayish-green in color, due to the presence of large proportions of glauconite. This is an iron-bearing mineral which on weathering has its iron changed largely into oxide, giving the whole mass a rich Indian red color. The ore as taken from the ground is therefore a rich yellowish-red or dark red color, soft and shaly, having a clayey aspect, and is rich in Claiborne fossils, mostly impressions and casts, or nuclei. The material is so soft it can be removed from the pit more easily than clay. In places the marl is quite sandy yielding a highly siliceous ore.

The ore deposits are rather widely spread over Clarke County, especially the western part, are nowhere more than 6 to 15 feet thick, and overlie the greenish-gray calcareous marls from which they are derived.

The most notable outcrops are along the banks of the Chickasawhay River at Enterprise, and a few miles west and northwest of Enterprise. It is also reported ten miles east of Enterprise.

These are not high-grade ores, seldom running above 35 per cent of iron, and often below 25 per cent. The average would probably be not far from 30 per cent. Analyses show all the ores to be rather high in silica, 10 to 15 per cent, and to contain more phosphorus than is desirable for the manufacture of steel, but would be suitable for making cast iron.

TRIPOLITE.

Near old Eastport landing on the Tennessee River is a deposit of white, very finely pulverulent silica, or tripolite. This material on microscopic examination does not show the presence of organic remains, but appears to be derived by a process of disintegration from the chert beds of the Sub-Carboniferous formations. At a point about three miles south of Eastport a mine was formerly opened into this material near Bear Creek. The old mine tunnels may still be seen running several hundred feet into the hills, and looking like tunnels in a snow-bank—the walls, floor and roof are so white. The material is so firm that the walls of the tunnels have never caved, though the mine was not timbered. It was mined and put upon the market as an abrasive. No development has taken place for several years.

The deposits are 16 to 20 feet thick and seem to underlie a considerable territory in the vicinity of the Tennessee River. This tripolite is 98 per cent pure silica, and would make a good glass if washed, the unwashed material containing a little clay which gives the glass a clouded opalescent aspect. It should also be useful as a polishing powder, for making dynamite, scouring soaps, fire-proofing for safes, steam pipes and boilers.

MINERAL PIGMENTS.

Pure Ochres have not as yet been discovered in Mississippi, but ochreous clays very rich in pigments have been found in a number of places. At a number of points in Tishomingo County the Tuscaloosa Clays have become so deeply impregnated with iron oxide that they make a desirable pigment. These red clays have been known for many years, but no development has ever been undertaken. They are dark red in color, and of uniform tint throughout except for small specks of white scattered through the mass. The quantity has never been investigated thoroughly, but sufficient is known to justify the belief that quantities of commercial importance occur at accessible distance from the railroads. To insure a bright colored pigment the clay should be roasted, after which the freedom of the clay against all other impurities would insure a pigment of good quality.

In Lauderdale County a few miles east of Meridian are large deposits of deep purple sands, which on washing, yield bright red pure ochre, as much as 25 per cent of a given volume of sand proving to be ochre easily removable by washing. A sample of this, as well as of the ochreous clay above described, are to be seen in the State Geological Survey Cabinets. There can be no doubt that this ochre will be of commercial value if developed.

The purest grades of carbonate iron ore from north Mississippi on roasting will make a red pigment which deserves testing. In other parts of the country similar ores of inferior quality to the Mississippi ore have been used to make pigments of the highest quality; there is no good reason why the Mississippi ore should not yield even better pigments.

Lignitic clay has been used as a pigment, making grays of different tints. Mississippi has such an abundance of excellent lignitic clays that they command little attention, yet they can be made the base of commercial pigments if properly developed.

Bright yellow ochreous clays occur at numerous places in the State, but surprisingly little has been found that seems to be in sufficient quantity to justify working. Some limited deposits occur on the Southern Railroad just west of Winona; some of more extensive outcrop and lighter color —almost canary yellow—occur in the Tuscaloosa clays of southern Tishomingo County. The clay is very pure, plastic, and bright yellow. The deposit is four or five feet thick, and seems to be of uniform color throughout.

MINERAL WATERS.

Almost every section of the State has recognized mineral wells and springs, known in their immediate localities for their curative properties. A considerable number, however, as Iuka Springs in Tishomingo County, Cooper's Well in Hinds County, Arundel Springs in Lauderdale County, Brown's Wells in Copiah County, Stafford Springs in Jasper County, Castalian Springs and Owen's Wells in Holmes County, Allison's Wells in Madison County, Robinson's Springs in Hinds County, and Mammoth Springs in Forrest County, are more widely known.

The mineral waters sold in 1912 by ten wells and springs within the State aggregated a valuation of $126,241.00. This will doubtless be greatly increased in the future. But the chief source of revenue from the mineral wells and springs of the State lies, not in sales of water, but in the accomodation of guests who spend greater or less time at the resorts. Most of the wells and springs mentioned above, as well as others, are well equipped with hotel accomodations, and receive large patronage. They are quite largely resorted to by health seekers, as well as those seeking recreation, not only from Mississippi, but from adjoining States, and to some extent even from distant States. Commodious hotels give their patrons all modern comforts.

The Geological Survey has collected data on the mineral waters of the State, including analyses that have been made of them, and some notes on their therapeutic value, but these would take up too much space here, and will be incorporated in a report on the Underground Waters of the State, soon to be issued as a bulletin of this Survey.

MARLS.

A marl is a natural mixture of clay and lime carbonate, in which the latter may reach as high a proportion as 40 per cent to 50 per cent. Other ingredients may be present in variable quantity, for example, organic matter and sand, especially "greensand" or glauconite, may be present in considerable quantities. Phosphorus and potash are also frequently present.

Marl may be used for various purposes dependent upon its composition. Usually the ingredient that gives it value is lime carbonate. A highly calcareous marl may be used instead of limestone in the manufacture of Portland Cement. We have seen how the glauconitic marls at Enterprise give rise to iron ores that may eventually be used in the manufacture of pig iron. One of the chief uses to which marl has been put is as a fertilizer. Most soils in Mississippi are deficient in lime. Limestone soils are proverbially rich and productive, consequently agriculturists have been looking for a cheap and effective method of applying lime to the acid soils of the State. The application of marl is one way in which the demand may be met. Marls are generally friable and crumble easily. This is especially true if the marl contains large quantities of shells, as is frequently the case. This quality would remove the necessity of crushing, and at the same time the shells being carbonate of lime would add greatly to the lime content of the marl. The higher the percentage of lime the greater the fertilizing value. If the marl should contain appreciable quantities of phosphorus its fertilizing value would be all the more enhanced.

A limestone with less than 75 per cent of lime carbonate could hardly be used to advantage as a fertilizer application, because of the added expense of crushing. A soft marl, however, with 50 per cent of lime could be used. Of course, the higher the percentage of lime either marl or limestone contains the better results are obtained from its application. If either should contain phosphate in appreciable quantities an equally good or even better result might be obtained with a lower lime content.

The Marls of Mississippi are all low in phosphorus and potash, so far as examined. In none does the phosphorus reach as much as one-half of one per cent, potash in a few instances reaching as high as nearly two per cent, the highest being found in greensand marl on Garland's Creek, Clarke County, and near Vaiden in Carroll County. The lime content varies from 50 per cent up to 75 or 80 per cent, the highest being generally along the outcrop of the Vicksburg Group. The limestones of the State range higher in lime than the marls, some showing as high as 80 per cent to above 95 per cent of lime carbonate. High grade limestones outcrop near Okolona, Artesia, Osborne, and Macon on the Cretaceous belt, and at Vicksburg, Byram, Brandon and Bay Springs on the Vicksburg outcrop.

AMBER.

Amber is a fossilized vegetable resin, translucent to transparent, and of a light yellow color, it takes a high polish, and is of value for various ornamental purposes. It has been obtained in occasional masses one to three inches in diameter in the Tuscaloosa clays of Tishomingo County. The resin is brittle, and crushes easily, is gray to yellow in color, and generally opaque, though some beautifully transparent masses have been found.

In the pit of the French Clay Company near Charleston, Tallahatchie County, a mass of very handsome amber is reported to have been found in gray clays of upper Wilcox age. The mass filled a cavity said to be as large as a football. No record is kept of what disposition was made of the amber.

FULLER'S EARTH.

Fuller's Earth is a highly siliceous, light and porous clay, which has the property of absorbing coloring matters from vegetable and mineral oils. It is usually of gray or buff color, and is devoid of plasticity. Owing to its peculiar property it is largely used to clarify oils. A successful Fuller's Earth should not only clarify crude oils, giving them a colorless or light amber tint, but should be susceptible of repeated use, and should leave the oil without disagreeable taste or odor.

While some Fuller's Earth is produced in the United States, the best grades have in the past come from England.

In 1911 Fuller's earth was discovered on property of Governor A. H. Longino, in Smith County, which by practical test was found to clarify oil equally well with the English earth. The deposit is probably extensive, but as yet has not been developed.

Within the last two or three years large quantities of Fuller's Earth have been discovered near Leesdale, Adams County. Preliminary tests would seem to indicate this to be of a good quality. This, or another deposit extends into the adjacent parts of Jefferson and Franklin counties, and gives promise of important developments in the future.

Another extensive deposit has been reported in Yalobusha County, but has not yet been tested.

BAUXITE.

Bauxite is, strictly speaking, not a mineral, but a combination of several minerals, all hydrated oxides of aluminum, which together constitute bauxite, the ore of the white metal aluminum. This mineral is found abundantly in all clays, but in such a state of composition as to make it unavailable, owing to the difficulty of extracting it from combined silica.

During the winter of 1921-1922 bauxite in commercial quantity and quality was discovered in Mississippi. A deposit of the material in Tippah County had been noted by Dr. Hilgard in his Report (1860), but its nature had not been recognized, as the commercial use of bauxite is of more recent date.

The rediscovery of this material in Tippah, and its identification as bauxite, led to a detailed search for other deposits, with the result that tonnage on a commercial scale has been located. This ore occurs in the base of the Wilcox formation of the lower Eocene, closely associated with the gray clays lying immediately above the contact with the Midway. The ore bodies are in the form of lenses, and occupy a north-south zone four to six miles wide immediately west of the Flatwoods (see sketch map), for the most part capping the hills in beds from one to sixteen feet thick, with slight overburden of red sands. The bauxite has the appearance of being made up of pea-like concretions, whence it is said to have "pisolitic," (or rock-pea) structure. It varies in color, chiefly on account of the iron present, a high proportion of iron oxide giving the ore a dark, iron-like appearance and causing it to be heavy and very hard and rock-like. The character of the ore resembles very closely a ferruginous pebble conglomerate, and has been called locally "peanut rock." Absence of iron from the ore leaves it a pale yellowish-brown or gray color, and soft.

The discovery of bauxite in Mississippi in commercial quantity, owing to the demand for the mineral and its comparative rarity in the United States, at once attracted attention, and during the summer of 1922 the Mississippi Bauxite Company gained large holdings in the bauxite area, and carefully prospected and tested their ores. The holdings of this company are mainly in Tippah and Pontotoc counties, though several other counties bordering the Flatwoods show the presence of the ore.

Two of the most important deposits in Pontotoc County, East and West Smoky Top, contain an estimated total of ore of 350,000 to 400,000 tons. Morse [1] says of the bauxite reserves of Mississippi:

"The deposits which have been prospected are estimated to contain more than 1,000,000 tons of low-grade material; as well as 403,000 tons of bauxite, 40 to 60 per cent Al_2O_3, and 145,000 tons of bauxite 50 to 60 per cent Al_2O_3."

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[1] Morse, Paul Franklin, Bauxite Deposits of Mississippi; Mississippi Geological Survey Bulletin No. 19, 1923; p. 187.

WATER POWERS OF MISSISSIPPI

In this report will appear a brief, non-technical discussion of some of the power sites that the present survey has brought to light. Detailed reports on these power sites have not yet been published, and cannot be until the Geological Survey has available an adequate printing fund. However, the manuscript maps and field data are now in hand, and the preparation of the report covering the work will be undertaken during the winter, with a view to printing in the spring. Statements made in this report as to horsepower will therefore be understood as preliminary, and in the complete report may be modified somewhat.

The estimation of water power must be based upon several factors: (1) The average cross-section of the stream, based upon numerous measurements of width of channel, plus numerous measurements of depth, to arrive at an average of each. The average cross-section is the product of the average width multiplied into the average depth. As both of these will vary with the water stage in the stream, it will readily be seen that measurements, to be entirely reliable, must be made at all seasons of the year. (2) The average velocity of the current must be obtained. As the current of our streams varies with the seasons, numerous measurements by means of current meters should be taken at intervals throughout the year in order to get the average. (3) The average cross-section multiplied into the average velocity will give the average discharge in cubic feet per second.

The above measurements, so easily stated, are very difficult to make, and entail no little labor and hardship on the part of the field men to whom the work is intrusted. In the field work of the State Water Power Survey all the required measurements have been made so far as these were possible. With limited field help, necessitated by our small working fund, the work has progressed less rapidly than we hoped, but the results materializing give us confidence that at no distant day in the future Mississippi will utilize these water powers to develop much-needed industries.

Only two streams were surveyed with Federal cooperation—Pearl and Strong Rivers. In advance of work these seemed to present the best possibilities for power development. In the course of the work we have been gratified to find that there are in our state other streams that present as good possibilities; and still others not yet surveyed are promising.

In the estimates that follow it is to be understood that all figures are subject to revision; these estimates, in other words, are preliminary not final, but are sufficiently definite to form a basis for practical inquiry into their availability for the sites considered. The detailed report on the Water Power Survey will appear later as a special report, with maps and diagrams.

PEARL RIVER NEAR GEORGETOWN

The largest power possibility in the state is on Pearl River, between Hopewell and Georgetown. Here the uplands approach the stream, and a dam 40 feet high is possible. The water level at low water is 200 feet; to the top of the channnel is 230 feet. A dam, therefore, 30 feet high would be only the length of the channel's width, or 300 feet. If the dam were made 40 feet high a wing dam of 2-3 of a mile long would be necessary to tie to the uplands on both sides.

The volume of water has not yet been estimated in detail, but in this, as in the sites on Strong River, the work has been done in greater detail than in other streams, but the data have not yet been fully worked out. Sufficient data are at hand, however, for us to estimate approximately the power to be not less than 3,000 horsepower. In the later report all data will be given and accurate results presented.

PEARL RIVER AT BRIDGE 2½ MILES ABOVE EDINBURG, LEAKE COUNTY

At this point the valley of Pearl River narrows from a width of two miles to 1350 feet. The stream here cuts through the rocky Tallahatta formation, and the bluffs and bottom of the river are hard sandstone. A dam 30 feet high and 1350 feet long could be built here. The velocity of the stream immediately above the dam site is not great, the volume of water at low stage not exceeding 160 cubic feet per second. Hence available power that may be developed, about 600 horse-power; for half the year this could be greatly increased. Inundated lands, 11,105 acres, mostly wild, uncultivated swamp lands.

STRONG RIVER

Two dam sites are feasible on Strong River—one at Bridgeport bridge, the other above the Gulf and Ship Island Railroad bridge at D'Lo. At the first locality the water level is 206 feet, the height from water level to the upland bordering the channel is 239 feet. Hence a dam 30 feet can be constructed, the main body of which will be 300 feet from side to side of channel, and a wing not to exceed five feet high and 300 yards long. This dam will develop perhaps 1,500 horsepower.

The upper dam, 30 feet high will be approximately 300 feet long. A dam 60 feet high can be built by tying to the uplands with a 30-foot dam 2-3 of a mile long. The upper dam will develop equal power with the lower dam, or more, if the higher dam is constructed.

CHUNKY RIVER AT THE RAILROAD BRIDGE AT CHUNKY STATION

Here an unusual condition exists: The Alabama and Vicksburg Railroad crosses Chunky River one-half mile east of Chunky Station; the river makes a great bend of several miles and is again crossed by the railroad 521 yards east of the first crossing. At both points of crossing the river channel is cut down into the rather hard rock of the Claiborne formation, the walls standing practically vertical; the river has about ten feet of fall between the two bridges. A dam 300 feet long and 15 feet high at the west crossing, with a canal paralleling the railroad track from this dam to the river at the east bridge will develop a fall of 25 feet just below the bridge. Volume of water, 337.4 cubic feet per second; land inundated, 680 acres, which is swamp and overflow land not used; estimated horse-power that can be developed, 1,154. This, it is understood, is low water estimate. During about six months of the year this power can be increased at least fifty per cent.

CHUNKY RIVER JUST BELOW STUCKY'S BRIDGE, 5½ MILES BELOW MEEHAN JUNCTION, ON THE ALABAMA AND VICKSBURG RAILROAD

Here the river has a high steep bank on both sides, but that on the west side is consiredably lower than the opposite bank. The stream channel is cut here, as at the first locality, into the solid rock of the Claiborne formation. A dam 25 feet high will require on the west side a low levee six feet high and about 2,500 feet long to tie it to the upland. The main body of the dam, which should be of concrete, will be only 200 feet long; the volume of water (low water stage) is 701.27 cubic feet per second; horsepower to be developed, 1,457; acreage of land that will be submerged, approximately 1,280 acres, mostly wild lands unused.

LEAF RIVER AT CROSBY'S BRIDGE, SEVEN MILES WEST FROM ELLISVILLE, ON LONE STAR TRAIL, BETWEEN SEMINARY AND ELLISVILLE

At this point the river is rather swift and narrow. A dam 150 feet long, which should be of concrete or other solid masonry, would span the channel. A 20-foot dam would not have to be flanked with a levee, but a higher dam would require a flanking dirt dam a mile and a quarter long. The volume of water is 1,175.58 cubic feet per second. A 20-foot dam will develop 2,500 horsepower; a 25-foot dam will develop 3,340 horsepower. Higher dams up to 70 feet can be built, but the necessary height of the flanking levees and the large area that would be subjected to inundation, would probably prohibit the higher dams. With a 20-foot dam the acreage submerged would not be large, being wild, uncultivated lands.

BOGUE HOMO RIVER

This site is three-fourths of a mile above the bridge on New Augusta and Richton road. Here a dam can be constructed 25 feet high, the central part in the channel of the stream would be 150 feet long, built of concrete, with a wing dam six feet high and 1,000 feet long; the volume of water is 327 cubic feet per second; power developed, 900 horsepower, area overflowed, not excessive, and of little value.

BLACK CREEK

This site is four miles north of Brooklyn, Forrest County. A dam 20 feet high, consisting of 150 feet of concrete or masonry spanning the channel, and a dirt levee of 600 feet tying the dam to the bordering high land. Volume of water, 211 cubic feet per second; power developed, approximately 300 horsepower.

HASHUQUA CREEK

Locality three miles east of Fern Springs, and 21 miles east of Louisville, Winston County. Dam 40 feet high and 550 feet long, tying into the rock walls of the gorge. Volume of water, 92 cubic feet per second; power developed 592 horsepower. This is the site of an old yarn mill, which was run by water from a dam eight feet high. With the greater height of dam that is indicated above and with the additional fall gained by construction of a conduit two miles long carrying the volume of water further down stream, thus giving an increase of 16 feet fall, the horsepower above mentioned, 592, can be obtained.

BUTTAHATCHIE RIVER, NEAR COCHRAM'S BRIDGE, 16 MILES EAST OF ABERDEEN

A dam 30 feet high is possible here, the total length of the dam being about 5,000 feet, of which 250 feet will span the channel, and should be made of concrete or other solid material; the rest of the length of the dam will consist of a flanking levee on one side 10 feet in height. Volume of water, 475 cubic feet per second; horsepower developed, 1,080; acreage inundated, approximately 5,500.

BEAR CREEK, AT OLD FISH TRAP OF THE TISHOMINGO LAND AND LUMBER COMPANY, THREE MILES EAST OF TISHOMINGO.

This dam site is in the high broken region of Tishomingo County, and the hard sandstone and limestone formations of the Palezoic have been cut into by the stream, forming picturesque gorges. Here a dam 60 feet high is feasible, the length of which will not exceed 325 feet. This dam should be entirely of concrete or masonry, and tied into the hard rock walls of the gorge. The volume of water is 366.3 feet per second; horsepower developed, 2,534; acreage submerged, 2,700, all wild, uncultivated, rocky soil.

MACKEY'S CREEK AT OLD BAY SPRINGS IN SOUTHEASTERN TISHOMINGO COUNTY

Length of dam 220 feet, all of concrete, tying the two solid rock vertical banks of the stream; height of dam 30 feet. Volume of water 193 cubic feet per second. Horsepower available 640. Acreage inundated 500, mostly of little value.

These embrace the greater part of the projects that have been investigated up to date (November 1, 1923), but other small powers have been located. The work is still in progress, and the greater part of the state has not yet been covered. Numerous small streams in many parts of the state present conditions like those on Hashuqua, where the sources of the streams fed by great springs and coming down out of the upland gorges can be harnessed so as to produce for local development several hundred horsepower. Besides these, other large powers doubtless exist on streams that the Survey has not yet had time to investigate.

AMITE RIVER, ONE-HALF MILE BELOW BATES MILL BRIDGE

This locality is 16 miles west of McComb, and about 8 miles east of Liberty, Amite County. Here the bluffs narrow down to a width of 650 feet, and are almost vertical, the material being clay and ferruginous sandstone. The dam required here should be 650 feet in length and 40 feet high and should be constructed of masonry throughout. Horsepower developed at stream flow of 300 cubic feet per second would be approximately 1,364, which could be increased during the greater part of the year. This would be sufficient to furnish McComb and surrounding towns with light and power.

We append a list of some of the power sites within the state that have been reported upon.

Site	Possible Horsepower
Amite River	1,150
Bear Creek	2,500
Black Creek	300
Bogue Homo River	900
Buttahatchie River	1,080
Chunky River, at R. R. Bridge at Chunky Station	1,154
Chunky River, 5½ miles below Meehan Junction	1,457
Hashuqua Creek, 3 miles east of Fern Springs, Winston Co.	592
Hatchie River	2,500
Leaf River, at Crosby's Bridge	3,000
Mackey's Creek, Tishomingo Co.	640
Pearl River, near Georgetown	3,000
Pearl River, near Edinburg	2,000
Strong River, at Bridgeport Bridge	1,500
Strong River, at D'Lo	1,500
Tangipahoa River	2,500

APPENDIX

Table of Altitudes

All altitudes given are railroad station elevations, except those marked "U. S. B. M.," which are taken from elevations given by U. S. Geological Survey or Coast and Geodetic Surveys.

ABOVE SEA LEVEL IN MISSISSIPPI

	Feet
A. & M. College	424
Abbeville	366
Aberdeen	203
Ackerman	522
Albin U. S. B. M.	150
Alfrey U. S. B. M.	157
Algomar	414
Alligator U. S. B. M.	163
Amory	214
Anding	255
Anguilla	107
Arbo	305
Arcola	115
Artesia	233
Ashwood	271
Askew U. S. B. M.	185
Austin U. S. B. M.	196
Baird U. S. B. M.	121½
Baldwyn	374
Banks U. S. B. M.	200
Barnet	310
Batesville	346
Baxterville	400
Bay Springs	406
Bay St. Louis	21
Beauregard	474
Beaumont	93
Beauvoir U. S. B. M.	26
Bee Lake	101
Belen U. S. B. M.	171
Belmont U. S. B. M.	570
Belzoni	124
Benoit	137
Bentonia	204
Beulah	143
Bexley	117
Biloxi	22
Blanton	97
Blue Mountain	461
Blue Springs	416
Bobo	164
Bogue Chitto	384
Bolton	216
Bond	305
Booneville	505
Bovina	243
Boyle	137
Bradley	324
Brandon	396
Braxton	347
Brookhaven	500
Brooklyn	155
Brookville	269
Brushy U. S. B. M.	106
Bucatunna	150
Buford Lake U. S. B. M.	160
Bugg's Landing U. S. B. M.	371½
Burdett	120
Burnside	399
Burnsville	467
Byhalia	386
Byram	264
Canton	224
Carlisle	159
Carnes	310
Carriere	67
Carpenter	159
Carrollton	229
Cary	99
Castalian Springs	266
Cedars	111
Centreville	374
Chancy	151
Charleston	179
Chatawa	258
Chunky	312
Clack, 4 mi. wst. of U. S. B .M.	204
Clarksdale	173
Clayton	192
Cleveland	139
Clinton	324
Coahoma	177
Coffeeville	241
Coldwater	238
Coles	175
Collins	274
Columbia	145
Columbus	250
Como	367
Commerce U. S. B. M.	201
Corinth	456
Cotton Plant	415
Courtland	263
Craig	129
Crawford	310
Crenshaw	189
Crevi U. S. B. M.	180
Cruger	134
Crystal Springs	463
Cub Lake U. S. B. M.	205
Cynthia	366
Dancy	312
Danforth	184
Dahomey	137
Darling U. S. B. M.	169
Decatur Jct.	408

	Feet
Dennis	605
Deeson	153
DeSoto	208
D'Lo	290
Doddsville	124
Donovan	143
Dragg U. S. B. M.	190
Drew	136
Dry Grove U. S. B. M.	375
Dubbs U. S. B. M.	181
Duck Hill	251
Duffee	357
Duncan	157
Dundee	190
Dunleith	124
Durant	265
Durham	162
Eden	123
Edinburg U. S. B. M.	368
Edwards	223
Egremont	103
Egypt	300
Ellisville	240
Ellisville Jct.	203
Elliott	235
Enterprise	258
Epps	255
Erata	271
Eskridge	299
Essex	164
Ethel	430
Eubanks	200
Evanston	155
Evansville U. S. B. M.	192
Expose	160
Falcon U. S. B. M.	170
Falkner	466
Fayette	292
Fernwood	334
Flora	250
Florence	298
Fontainbleau	20
Forest	481
Fort Adams U. S. B. M.	55½
Fort Loring	134
Friar Point	171
Fruitland Park U. S. B. M.	304
Gattman	290
Geren	149
Glass	99
Glen	494
Glendora	144
Gloster	434
Glover U. S. B. M.	212
Gluckstadt	261
Golden	550
Graham	309½
Grenada	193
Greenfield	311
Green Grove	161
Greenville	125
Greenwood	143
Greenwood Springs	301
Gulfport	19
Gunnison	153
Guntown	381
Halls Spur U .S. B. M.	489
Hamburg	400
Hammell	342
Haney	275
Hardy Station	260
Harrison Station	320
Hartman	395
Hathorn	547
Hattiesburg	143
Hazlehurst	460
Heathman	121
Heidelberg	316
Helm	127
Hermanville	200
Hernando	390
Heucks	500
Hickory	322
Hickory Flat	401
High Point	547
Hillhouse	157
Hillsdale	237
Hinchcliff U. S. B. M.	167
Hintonville	146
Holcut	500
Hollandale	111
Holly Bluff U. S. B. M.	98
Holly Springs	602
Holly Wood	199
Horn Lake	267
Houlka	362
Houston	324
Howard	150
Howiston	195
Hubb	135
Hudsonville	480
Inda	167
Indianola	117
Ingomar	364
Insmore	32
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