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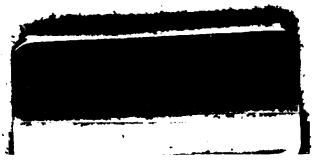

GEOLOGY

AND MINERAL RESOURCES OF KANSAS.

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In the Eastern Part of the State, the Loess and other Quaternary Formations cover much of the Bed Rock, but not so extensively as the Plains Marl of the West.

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GEOLOGY

AND

MINERAL RESOURCES

OF KANSAS.

By ROBERT HAY, F. G. S. A.

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GEOLOGY AND MINERAL RESOURCES OF KANSAS.

BY ROBERT HAY, F.G.S.A.

[NOTE.—In the First Biennial Report of this Board, 14 years ago, Prof. B. F. Mudge, and, in the Third Biennial, Prof. Orestes St. John, expounded the geology of Kansas as then known. There has been increase of our knowledge since that time, and it was intended here to make a full note of the bibliography of the subject, but it would unduly increase the length of this paper; and it is the less necessary as the writer gives scarcely a fact that is not within his own knowledge, or is verified by direct reference to authors.]

TOPOGRAPHY.

The general character of the topography of Kansas is simple. A glance at the map shows that the direction of the streams is easterly, with a trend to the south. This shows that the general slope of the region is from the west towards the Mississippi river. It is a part of the great plains. The elevation of the land near the eastern line of the State is about 1,000 feet; but this is reduced, where the rivers cut the boundary, to 750 feet at Kansas City, 800 feet at Fort Scott, 817 feet at Chetopa, and to 734 feet above sea level at Coffeyville. On the west line of the State, the greatest elevation, which is south of the Smoky Hill valley, is a little over 4,000 feet, which is reduced where the Republican, Smoky, Arkansas and Cimarron enter the State from Colorado. There are no mountains. The valleys are all valleys of erosion, and about their sides are hilly districts—some rugged with fantastic forms, others with flat-topped mounds and long promontories. The prairie of the interfluvial spaces is level or gently rolling, with the gradual westerly rise. The valleys of the eastern third of the State often present rocky, precipitous escarpments, and are picturesque with abundance of timber. The middle third has but little native timber, but now has numerous plantations and orchards. The western part may be said to be destitute of timber, but plantations made by settlers are beginning to vary the grassy plains. It is trite to say that the topography is dependent on the geology, but it generally takes something more than passing observation to see this. The map gives several illustrations. The great bend of the Arkansas southerly and the narrowing of its valley before leaving the State are due to the opposition of the harder beds of the carboniferous rocks which dominate the flint hills; and the same is true of the Republican, which has cut through the flint beds near Fort Riley, where it is reinforced by the waters of the Smoky. The high prairie is from 200 to 500 feet above the neighboring valleys; but these differences of elevation are less as we go west. Between the Smoky and Arkansas is a large basin area, without surface outlet. There are similar smaller areas in the northwest, all of which are related to the latest geological changes. We now proceed to general

GEOLOGY.

Persons not versed in geological studies are apt sometimes to question thus: "If there is coal or salt or gypsum in Barber, Ellsworth, Brown or Bourbon county, why not in Chautauqua or Cheyenne, Rush or Riley?" It is because such minerals, though widely distributed, are confined to certain formations or groups of formations. To understand, then, the mineral resources of Kansas, it is necessary to have

some knowledge of the order in which the rock formations are found. Such systematic knowledge is GEOLOGY. We shall, as briefly as is consistent with clearness, present the geologic order of the formations, so that the exposition of the occurrence of the minerals which are now being mined or quarried for our use may be properly understood.

Kansas is a large State. Its geological structure is not discovered in a day. Only in the years 1864–'65 was there any continuous effort made by the State authority to ascertain its geologic structure—its mineral wealth. Since then, a few seasons' work by a member of the United States Geological Survey, a little work at different times by earnest geologists on their own account, some investigations by the Kansas Academy of Science, and occasional work under the auspices of the State Board of Agriculture, have been the means of increasing our geological knowledge of the State. There have been *some thousands of prospect holes* drilled or digged all over the State, some of which have had success in developing some mineral industry, but by far the greater number were efforts utterly wasteful, not even contributing to our knowledge of the rocks beneath the surface, as the drillers preserved no record of the strata passed through. Some records have been preserved, and these, in the hands of geologists, have aided in making systematic the knowledge we now possess.

There are two great classes of rocks, which are based on their origin. They are IGNEOUS and AQUEOUS. The former, sometimes called PLUTONIC, or, in reference to their relative age, ARCHÆAN, are at the bottom of all other rocks, or are protruded through them in mountain chains or peaks. The surface geology of Kansas knows nothing of them, not even of the more recent forms, as lava or trap. In two places only in the State have igneous rocks been reached beneath the surface: one in the southern part of Woodson county, where, many years ago, some quartz found on the surface led some persons to prospect for silver and gold! There some igneous rock was found only a few scores of feet beneath the surface, as if there had, in a small area, been some protrusion from below before erosion had cut the surface down to its present level. More recently, the drill at Paola, at a depth of 2,100 feet, having passed through all the stratified rocks of the region, entered igneous rocks of the granite type, in which it remained 400 feet.

The *aqueous* rocks are otherwise called *stratified* because they are found in *strata* or layers, lying one above another, the bottom ones being the oldest. These are grouped together for convenience of nomenclature, and Dana gives the following as the principal divisions:

Quaternary, or age of man.
Tertiary, or age of mammals.
The age of reptiles.
Carboniferous age.
Devonian, or age of fishes.
Silurian, or age of invertebrates.

Another grouping, with regard to the fossil forms, as related to their modern or ancient appearance, is indicated by the terms:

Cenozoic, including tertiary and quaternary rocks.
Mezozoic, including the reptilian age.
Paleozoic, including carboniferous, Devonian and Silurian.

All of these are again divided and subdivided. The mezozoic has three main divisions, and the tertiary three. It will be seen from the following tabular form that some of these are missing in Kansas, none below the sub-carboniferous being on the surface in the State (though silurian rocks have been reached by the drill in some deep holes in the eastern counties), and some mezozoic and cenozoic groups are absent:

THE ROCKS OF KANSAS, IN DESCENDING ORDER.

PROF. MUDGE'S STATEMENT (1878).			PRESENT KNOWLEDGE (1892).	
150 feet.	Alluvium. Bluff or loess. Loose drift.	Post-tertiary. (Quaternary.)	Alluvium. Loess. Later gravel. Earlier gravel. Gumbo, hard-pan, and moraine drift.	150 feet.
1,500 feet.	Pliocene.	Tertiary.	Pliocene, The plains marl.	175 feet.
			Miocene, The Loup Fork (tertiary grit).	50 feet.
		Cretaceous.	Montana Group.	100 feet.
			Colorado Group { Niobrara.	400 feet.
200 feet.	Niobrara.		Colorado Group { Benton.	200 feet.
260 feet.	Fort Benton.		Dakota Group.	360 feet.
500 feet.	Dakota.		Comanche Peak beds.	75 feet.
			Trinity sands.	75 feet.
2,000 feet.	Permian. Upper carboniferous.	Carboniferous.	Permian { The red-beds.	900 feet.
			Permian { Salt measures.	300 feet.
			Permian { Upper Fort Riley beds.	2,500 feet.
			Permo-carboniferous { Lower Fort Riley beds. Manhattan beds.	
600 feet.	Coal measures.		Upper coal measures. Lower coal measures.	
150 feet.	Sub-carboniferous.		Sub-carboniferous (Keokuk).	150 feet.

We will briefly describe the main characteristics of the *epochs* as we now know them, first noting that the only considerable errors in the estimates of thickness in Professor Mudge's statement are due to the fact that the western part of the State had been very slightly explored, and the region of the *red-beds* was entirely unknown. The dip of the strata, generally, from the east to past the middle of the State, is west by north. This was assumed to continue, and as the elevation of the surface was known to be greater on the west line, and as the existence of the shales of the Montana group was not suspected, the greater thickness of the tertiaries was a natural conclusion. Professor Mudge had begun to think that some beds would ultimately be classed as miocene.

SUB-CARBONIFEROUS.

The rocks of this *epoch* are confined to one division — *the Keokuk* — which is in the upper part as developed elsewhere. It consists of massive beds of somewhat porous limestone, though in places it is sufficiently compact to be used as a building stone. Scattered through it, in parts quite numerously, are dark, flinty nodules. Many are almost pure flint, but most are of the less pure variety known as chert. Beds of chert, or cherty limestone, are also intercalated with the thicker beds of limestone. In many parts both the limestone and the chert contain the characteristic fossils of the age. The surface of this formation was eroded by long exposure as dry land before the coal measures which followed were laid down upon them. This is seen

in the irregularity of the bottom of the measures. There is a small patch of the coal measures in a hollow east of the Spring river, at Baxter Springs, surrounded at higher levels by the limestones of the Keokuk. And, again, there is a larger area of the coal-measure formations on the top of a considerable elevation across the Missouri line, just east of Joplin. Besides its irregularity of surface contour, the Keokuk has been disturbed by seismic agencies. In places — as at Galena — some of its limestone beds are tilted at a considerable angle, and the contained cherty beds have been broken into sharp fragments. It is here that the lead and zinc ores are found. The mode of their occurrence will be discussed further on. The area that the sub-carboniferous outcrop occupies in the State is very small. The southeast corner of the State — less than two townships of Cherokee county, and approximately bounded on the west by Spring river — is the region that now occupies so prominent a place in public attention on account of the abundance of the ores above mentioned.

This Spring river line is an important one. Roughly parallel to it are the outcrops of the other formations in the State to the extreme west, which will be seen by reference to the map. Following the topography of the surface, these outcrops are at successively greater elevations. With exceptions due to erosion, this line of the Spring river, carried north by east into Missouri, and south by west into the Indian Territory, is the eastern boundary of the

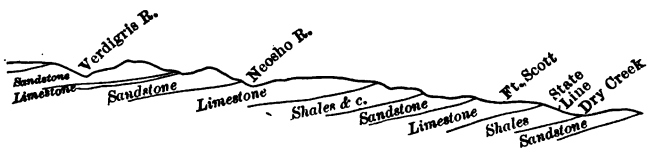
COAL MEASURES,

Which we shall now consider. These lie unconformably on the eroded surface of the Keokuk, but there is no such separation of unconformity between the coal measures and the Permo-carboniferous, or of them and the Permian. They pass gradually into those above, the fossils and the lithology being alike on a gentle gradient. The formations at the top of the series are, however, vastly different from those below, and merit the distinction of names, though the dividing lines are somewhat arbitrary.

The coal measures consist of three kinds of rock formations — sandstones, limestones, and shales. In these are enclosed the beds of coal, which do not occupy any where more than one-twentieth of the thickness assigned to the coal measures, and over large parts of the area there is no coal at all. Still a few square miles, with one bed of coal 30 inches thick, would be a rich district, and there are several such districts in eastern Kansas. *The bottom of the lower coal measures is the richest horizon of the formations.* It is in this horizon, not far from the Spring river boundary, that we have the Weir City and Scammon coal field, of Cherokee county, and the neighboring coal fields of Frontenac and Pittsburg, in Crawford county. The Fort Scott or Mound coal of Bourbon county, is higher in the same division. A thin seam in the northwest of Bourbon county, I should place near the top of the lower coal measures. A thick bed of limestone in the west of Bourbon, which slopes down to the Neosho river in Allen and Neosho counties, and passes into Montgomery, may possibly be regarded as the top of the lower coal measures. The Thayer coal seam and one at Howard and Stockton, which latter is possibly near the horizon of the coal of Osage and Shawnee counties, may all be called in the upper coal measures, whose upper limit may be found in the strata which cross the Kaw valley west of Wamego. Still some seams of coal are found at higher horizons, though they are thin and of little use. Examples are found in the north of Pottawatomie county, and in the strata of the Fort Riley section, on Humboldt creek, in Geary county. The Leavenworth coal, found over 700 feet deep, is in the lower coal measures. The recent borings at Alma, McFarland, and Cherry Vale, though revealing no seams of thickness workable at the depths reached, also illustrate the fact that the best place for coal is at the bottom of the coal measures.

The coal measures contain more persistent beds of sandstone than are found in any other group in Kansas except the Dakota. Sandstones are more variable, where of any great extent, than limestones, and often change into arenaceous shales, and these again to clay shales or back to sandstone. This is also true of their thickness. If beds have considerable vertical extent, they are frequently separated by partings of arenaceous shale, which in places are several feet thick. The coal measures of southeast Kansas are, however, characterized by three very persistent sandstone horizons, and they probably also extend north of the Kaw river, though there more hidden by quaternary formations. They are partially revealed in Shawnee and Douglas counties, and there is a small area in Nemaha and Pottawatomie. The sandstones of the southeast are, however, so well marked that they have become of great economic value. A brief account of the succession of strata in the region under discussion will be in order.

At Nevada, in Missouri, and on Dry Creek, some miles nearer Fort Scott, in Kansas, there is a sandstone from 50 to 80 feet thick. It enters the State south of Liberal, in Crawford county, and is developed over more than half of Cherokee county, where it yields flags of fair quality, and some thicker beds on the southern mounds. East of Fort Scott it becomes covered with light clay shales, and these in turn by the two seams of coal and the limestone bed known as the "cement rock," which is four or five feet thick. Another covering of shale of a few feet, and we begin to get the rough layer limestone which is seen in Fort Scott city, and develops further west into the heavy beds of Pawnee and Paint Creek, 70 feet thick. Above this, further west, come more shales, which quickly change into sandstone, and we have a broad sandstone plateau, stretching from the Little Osage river through Bourbon, northwest Crawford, into Labette county. It is the flagstone plateau. It has the famous quarries of Bandera, Gilfillan, and Pawnee. Above this is the thin coal seam and some shales, and then the mounds and promontories on the Bourbon-Allen county line are capped by the heavy, massive limestone that slopes westerly to the Neosho, and which contains the Iola marble beds and probably those of Montgomery county. West of this is another sandstone horizon, yielding the flags of Yates Center and the heavy beds at Fall River. The tracing of the eastern limits of these various beds north and south has not been done except in parts, and it is only provisionally assumed that sandstone in Miami county is about the same horizon as that at Yates Center. On the west line of Woodson the thin seam of coal is covered by a ledge of limestone, above which again are shales and another sandstone, which have been cut through by the Verdigris river to this coal horizon. (See section.) A section somewhat similar to this, made through the southern tier of counties, would show a similar succession of strata, with a general thickening of the strata, and illustrations of the changes which take place in the same horizon. For example, the bed of *Mound coal* so conspicuous near Fort Scott, with its accompanying cement bed, crops out on the bank of the Neosho river in Labette county, a few miles north of Oswego, but the coal is no longer coal. It is a hard, black slate, of no value as fuel. Other coal seams not far from the same horizon have a local development. Another



Section showing sandstones from east of Fort Scott to the Verdigris.

fact as to the coal beds should be borne in mind. None of them has a very great extension at right angles (nearly east and west) to the Spring river trend. The Cherokee seam, on which the Pittsburg and Weir City coal fields are situate, extends north by east into Missouri, and in the opposite direction into the Indian Territory, but it is only three or four miles wide. The Stockton coal is probably carried through Osage county and north of the Kaw river, in Jefferson county, but the greatest width of the coal field in Osage is only eight or ten miles.

PERMO-CARBONIFEROUS.

The rocks of this series are found from the northeastern counties, Brown, Nemaha, and Marshall, to the south line of the State, in Chautauqua and Cowley. The name has been given because there is a change in the lithology, both of the limestone and shales, to those of a Permian type, while some of the coal-measure features are still retained. This is more true, however, of the fossils. Coal-measure forms are carried well up into the Permian, and so-called Permian forms begin in the top of the coal measures. What I have called Manhattan beds in the geological scheme I have not had the opportunity to work out in detail. I may say that they contain limestone, having some good building stone, and some buffy, limy shales that make good hydraulic cement. They also have the gypsum beds of Marshall county and Pottawatomie. They, with a very gentle dip, disappear to the west under the Fort Riley beds, which, as a whole, include at the top the beds (Nos. 11, 12, 13 and 14 of the section) which I have called Permian, on the authority of the Russian geologist, Professor Tchernichew, who visited the neighborhood of Fort Riley in the summer of 1891, in company with H. S. Williams, of Cornell University, and who recognized these beds as similar to typical beds in his own country, whence, in the province of Perm, they had their name. We give the whole section, as follows:

FORT RILEY SECTION.

	Strata.	*Fossils.*	*Thickness.*
14.	Impure limestones, with some flints and numerous geodes	A univalve	10 feet.
13.	Light colored shales, with lavender flag beds	Athyris, pecten, pleurophorus	50 to 60 ft.
12.	Buff limestones with shale partings, changing to shales with limestone ledges	Pecten, nautiloidea, athyris, meekella, hemipronites, martinia, fenestella, euomphalus, synocladia, schizodus	30 to 40 ft.
11.	The Fort Riley main ledge. A buff magnesian limestone in one thick ledge, with a thinner ledge resting on it. In places the ledges are continuous up into the layers of 12	Pecten, allorisma, martinia, athyris, retzia, hemipronites, synocladia, fenestella	6 feet.
10.	Shales, light colored and laminated	Producti, allorisma, chonetes	15 "
9.	The upper flint beds. Limestones containing numerous flint nodules, and separated by definite layers of flints	Producti, chonetes, allorisma, martinia	25 to 30 ft.
8.	Shales, alternate colors, gray, greenish, maroon, brown	No fossils	30 feet.
7.	Limestone. The mid-shale bed, varying from a laminated, flaggy layer to a solid building stone four feet thick	Planorbis, and another univalve, allorisma, meekella, myalina, hemipronites, producti, etc	6 "
6.	Shales, alternate colors, as No. 8	No fossils	16 "
5.	The lower flint beds. The Wreford limestone. Flints as in No. 9. Parts of the beds are silicified in localities as if by infiltration	Crinoids, syntrilasma, athyris, retzia, pinna, meekella, producti, cup corals	25 "
4.	Shales. Bands of maroon and greenish gray, with a seam of coal on Humboldt creek.	No fossils	16 "
3.	Limestone in cuboidal or rhomboidal blocks. In places oölitic. A seam of coal under it on Humboldt		4 "
2.	Shales, and buffy slate		10 "
1.	Slate, bluish and hard	Occasional discinæ	10 "

A few miles west and southwest of Fort Riley and Junction City the eroded surface of these upper beds, as low as No. 12, begins to show fragments of creta-

ceous sandstones (Dakota), and in Clay, Washington and Saline counties the Dakota beds are in place on these buffy limestones and shales. No. 5 is worked for lime at Wreford, in Geary county, and in the Neosho valley in Morris county, and it crops out near the top of the bluffs on the east of Three Mile creek, on Fort Riley military reservation. West of Three Mile creek, No. 11 begins to show at the top of Sheridan Bluffs, overlooking the old city of Pawnee. It is seen as a bold ledge in Grant Cliff, on the other side the Kaw river, and in Sherman Heights, on the Republican side of the reservation, and for many miles in bold points up the Smoky and Lyons creek, and over the divide, in the Neosho valley of Morris county. Doctor Hayden noted its topographic prominence 40 years ago. It is there in the Cottonwood valley and on the Walnut, in Cowley county. It is this ledge and the thinner ledges of No. 12 that yield the light-buff, soft-working but solid building stones of Junction City, Strong City, Florence, and Winfield. The rocks of this series persist across the State. Nos. 5 and 9, coming to the surface, give character to the flint hills of several counties. It is at the top of 13 or in 14 that saccharoidal gypsum of Saline county occurs, and probably also the more selenitiferous beds of Washington county and Sedgwick county.

We have mentioned that north and west of Fort Riley the Dakota sandstones come on the buff and lavender Permian beds. This is not so in the southern part of the State. In the north, the sinking of the sea bottom, which had allowed the continued succession of the beds from the beginning of the coal measures, was arrested, and elevation began. A coast line was formed, and land surfaces began to be eroded till the time of the Dakota. In the south, however, subsidence still continued, and the

SALT MEASURES

were deposited in shallow waters, probably coast lagoons and land-locked bays, where evaporation was as powerful as in the Red Sea or tropical regions of to-day. There is a little limestone; but besides the salt the salt measures consist of light and dark gray shales, themselves more or less impregnated with salt. Over a large part of the area where they are known to exist, fully half of their 300 feet of thickness is solid salt. These beds outcrop in Sumner county, where the salt has been largely leached out. The rest of their eastern margin is hidden. They do not come between the upper Fort Riley beds and the Dakota at Salina or McPherson, but they are in force at Kanopolis, Ellsworth, Lyons, and Hutchinson. The exact eastern margin north of Wellington will only be revealed, if ever, by the drill. The western and northern extent can only be learned by the same methods. The pivotal line of oscillation, about which the northern Permian rose and the southern beds continued to sink, is an interesting object for future investigation.

THE RED-BEDS.

The strata, which from the top of the salt measures to the plateau above the gypsum in Barber county, are over 800 feet thick, and are so conspicuous for their brownish ruddiness, form the country rock from the east line of Harper, Kingman and Reno counties, in a triangular area, stretching to its greatest length on the State line to west of the 100th meridian. There are, perhaps, 4,000 square miles, much of which, especially in the northern part, has the red strata hidden beneath the "plains marl" and other tertiary and quaternary formations; but the beds appear in every river valley — in every deep ravine. The more northern appearances are on the north fork of the Ninnesquah, and, to a small extent, near the great salt marsh in Stafford county. They also appear well defined on the east side of Cow creek, north of the Arkansas river, northeast of Nickerson. Certain strata showing in the bank of the Smoky Hill river, near Lindsborg, and also on the head of the

Cottonwood, 18 miles east by south of Lindsborg, though somewhat different from the average red-bed outcrop further south, I refer with some reservation to the same epoch. As a description of this red-rock country, I will repeat some paragraphs written some years ago:

"The whole country is red. The soil, even where it contains much carbonaceous matter, is ruddy; the sedentary soil just forming on the steeper slopes is ruddier; flooded rivers glance in the sunlight like streams of blood; steep bluffs and the sides of narrow cañons pain the eye with their sanguine glare.

"Some buildings in the town of Harper are built of a brownish-red stone, which is obtained from quarries south and southeast of the city. Here and elsewhere the harder ledges are from two to 18 inches thick, and they are intercalated with arenaceous clays and clay shales and clays of richer color. The hard ledges are persistent for long distances, and give a definite contour to weathered bluffs and ridges. The clays are frequently of such toughness as to resist the weathering agencies as well as the harder ledges, which are sufficiently laminated and jointed to prevent their overhanging. Hence, there are red walls by the streams which are absolutely perpendicular. A specimen of one of the harder laminated layers from eastern Barber county and a specimen of sedentary soil formed from that and adjacent ledges have been submitted to G. H. Failyer, professor of chemistry at the Kansas State Agricultural College, who says: 'Both are strongly ferruginous, both rich in calcium carbonate. The stone is an impure limestone, containing ferric oxide, clay, and sand. Of course the soil contains the two latter in excess.' The ledges hard enough to supply building stone are comparatively rare. The thinner laminæ very frequently exhibit ripple marks, rain drops, and other signs of a littoral formation. Not unfrequently the upper surface of a lamina is brightly glazed, and at the foot of the bluff out of which a glazed specimen is taken may be found occasionally an illustration of the method of its formation in the glazed surface of dry red mud recently deposited from the overflow of a little stream, washing the material both of the deposit and the glaze from the cliffs where it has so long been solidified.

"The whole country increases in elevation westward and northward. There is an undulation of the dip which is not often perceptible, with an average inclination westward of very small amount, while in some parts of the western half of the area there are local depressions southward as well as eastward. The elevation of the country, combined with the average dip, gives increasing thickness to the Jura-Trias as we proceed westward.

"It will be seen from the map that the Medicine river, at Medicine Lodge, turns suddenly southward. The reach of the river above that place gives a section from the cretaceous formations above far down into the red rock. The lower reach of the river, to the State line and beyond, exhibits a section across the red rock. The eastern side is flanked by the Cedar mountains, or hills, whose sides are scored by cañons, not deep, but narrow, with sides perpendicular, and with ridges and amphitheaters carved and pinnacled like oriental temples. West and south of the river are the Gypsum Hills.

"The Gypsum Hills form the striking feature of the red-rock country. Throughout the entire region the laminated, arenaceous, ferruginous limestone has in it globose spots of greenish white. This is apparently a fine sand. The spots, in many places regularly distributed and like small peas in size, sometimes aggregate into streaks. Occasionally the streak becomes a layer. One of these layers, south and west of the Medicine river, becomes persistent over a considerable area. The erosion of the valley has left this layer nearly at the top of the area in which it appears, which shows as an irregular plateau, sloping east and north to the river.

The layer is, in its outcrop, bleached, and in many places has the consistency of stone. We therefore call this the white sandstone plateau. This plateau is cut by deep cañons, and its spurs occasionally terminate at the river as perpendicular red walls, from 20 to 30 feet high. The upper reach of the river valley narrows westerly, and the plateau narrows with it. The lower valley broadens southerly, and the plateau increases with it. In neither direction is the plateau very wide. In the lower valley, the western boundary of the white sandstone plateau is a solid wall of red rock, rising above it nearly 200 feet, surmounted by a great white coping of gypsum, from 12 to 15 feet thick. The wall runs southward for several miles, with some openings, and terminates abruptly, by a turn directly west. Northward, its termination is a bold promontory, and the neck, with gypsum absent from it in places, is only wide enough on the top for one person to walk. From this point the wall retreats, forming a huge amphitheater, with isolated buttes, and towers, and caps, and all up the western valley towers, pinnacles and buttresses are repeated, advancing towards or retreating from the river. Approached nearer, the lights and shadows on the gypsum have the appearance of quaint gables and mansard roofs. Where the gypsum has disappeared, single peaks are capped by projecting layers of the red rock. The butte I have called 'Mansard' is within the amphitheater, on its western side.

From Harper's Magazine.

Mansard Mound, Gypsum Hills, Barber county.

"In ascending to the gypsum, we find that the red rock gives way frequently to seams of selenite and laminated layers of greenish sandstone. Again are found harder layers of the red rock, and anon seams of nearly transparent satin spar (fibrous gypsum), one of which is persistent for a great distance, and two inches thick. These are in strata of clay or shale. Both the sandstone and satin-spar layers are ripple marked. The top reached, we find all these pinnacles and buttes are but the remains of another plateau, whose floor was this solid gypsum, which stretches away to the south and west, broken by broad valleys and profound cañons, reappearing beyond the Cimarron, on the Canadian and Red rivers, and on the edges of the Llano Estacado. Views in Marcy's report of the Red River expedition, in 1852, would serve to illustrate this region of southern Kansas. Over the gypsum, westward, are fragments of a hard gray limestone stratum, and again red rock. The gypsum has caves and underground channels, in which the sound echoes and reverberates when horse or vehicle passes over."

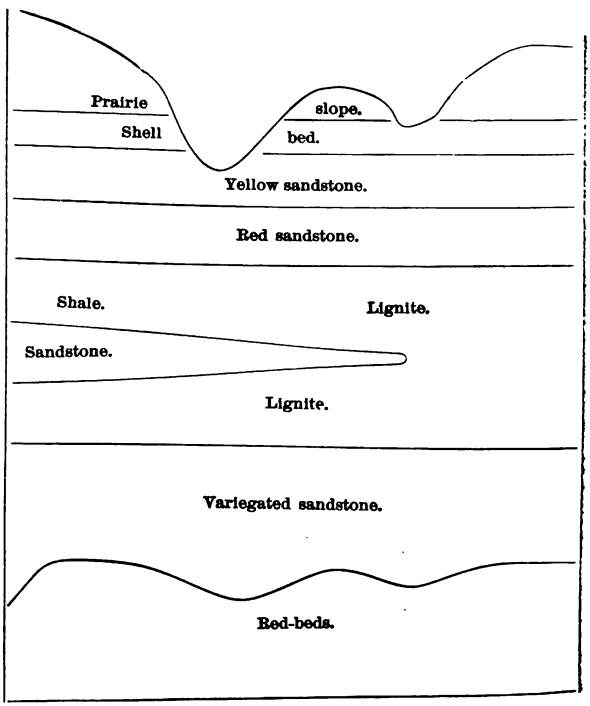
At the time the foregoing was written, though recognizing that the red-beds were a continuous series with the salt measures below them, I was inclined to consider them as belonging to mezozoic time. The absence of fossils was a strong negative feature. The Texas geologists have considered the similar beds there as of Permian age; and Professor Cope, of Philadelphia, has shown me undoubted Permian fossils obtained from the Texas beds. This has led me to place them in the geological scheme as Permian. Still, in the Kansas beds no fossils have yet been found. That the gypsum beds have proved useful, will appear further on, and other strata of the red-beds are being of service.

The salt borings, as far north as Ellsworth, all pass through the red-beds, and a re-study of the boring made years ago at Russell convinces me they are there also. They also appear in deep borings made in Haskell and Morton counties; apparently, also, in Decatur county; so that they probably underlie all the western part of the State. In the Kanopolis mine, and other northern tests, they are decidedly thinner than in the south and southwest. From 400 to 500 feet thick in the northeast, they are 800 to 1,000 in Barber and Comanche counties, and beyond the limits of the State they thicken still more.

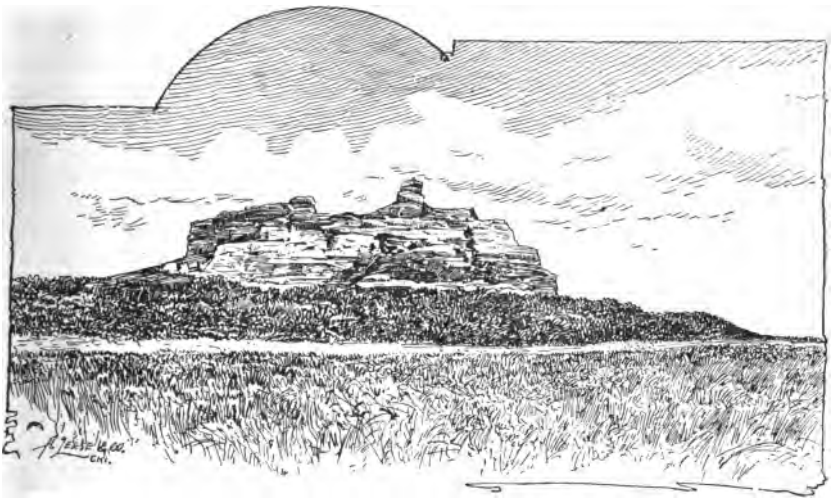
TRINITY SANDS AND COMANCHE PEAK BEDS.

In the northwest corner of Barber county, in a ravine on the south side of Medicine river, is an outcrop of beds, the bottoms of which rest on an eroded surface of red-beds something over 100 feet above the great gypsum horizon. The whole is not more than 25 or 30 feet of vertical exposure, as follows:

When I first saw these, I was inclined to synchronize them with the cretaceous beds (Dakota and Benton) which were known to exist on the south of the Arkansas river further west. Professor St. John, however, who saw the beds in the region further south, pointed out the resemblance of the fauna of the shell bed to Texas cretaceous forms, and afterwards others have worked out the stratigraphy of the beds up the valley of the Medicine and some of its tributaries, and made collections of the paleontological remains. Prof. R. T. Hill, of Texas, has also seen fossils belonging to these beds, and there seems now no doubt



but that they belong to lower horizons than the Kansas Dakota. There is no reason why the Texan names given to the beds—Trinity for the lower, fine-grained sandstones,



Bluffs of Trinity sands, near Belvidere, on Medicine river.

and Comanche Peak for the upper strata—should not be permanent, but some of the paleontologists still differ as to whether certain of the shells are lower cretaceous or of the Jurassic type. In the table I have placed them as lower cretaceous. They do not seem to have large areal development, but they thicken to the west. The rocks are well shown in the upper Medicine valley, on Thompson creek and in the Sand creek ravines to the southwest, but the "plains marl" and quaternary formations hide their extension under the body of the high prairie. There is a fine exposure of the Trinity sands at the Point of Rocks on the Cimarron, near the southwest corner of Morton county. I am also inclined to think that some fine sands brought up from drill holes in the salt region, *e. g.*, at Great Bend, also belong to the same horizon.

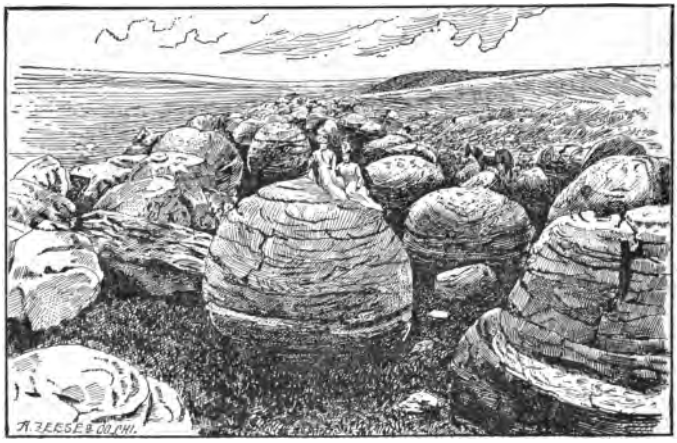
THE DAKOTA.

"Across central Kansas, from north to west of south, stretches a belt of country, marked in ravines by rugged sandstone rocks, and by long-rounded slopes on the prairie. This belt belongs geologically to the part of the cretaceous system known as the Dakota formation. To travelers on the Central Branch railroad, passing through Washington and Cloud counties, these sandstones are conspicuous objects. On the line of the Kansas Pacific, the same sandstones, underlain by colored shales, make the wild country from Bavaria by old Fort Harker to Ellsworth. On the Santa Fé railroad, a single hill standing out in the broad valley of the Arkansas, covered on its precipitous front with names of visitors—archdukes and naturalists—a hill of varied sandstone, capped with chalk, is a mark, left by the tremendous erosion of a million years, that here too the Dakota formation occupied its place. They are seen too from Larned up the Pawnee valley, and on the Saw Log, in Ford county. They have an outcrop on Bear creek, in Hamilton county, and are penetrated by the drill in Morton and Decatur.

"At our northern State line, the surface development of the Dakota is about 30 miles across, forming the bluffs of the ravines on the west side of the Little Blue,

and disappearing under the inoceramus limestones of the Benton series in the west of Washington county, north and south of Haddam. Further south, the belt is wider, in some places exceeding 50 miles. This is probably due to a greater slope of the surface in the south, in past ages, causing greater erosion of superincumbent deposits.

"The hill in the Arkansas valley is forever wedded to a tale of terror. It is the famous Pawnee Rock. But a little shred chipped from it tells another story. It is marked with the remains of an ancient flora. Further north, in Ellsworth county, are ravines with precipitous sides, on some of which a lost race has carved hieroglyphics of war and travel; and there are huge single rocks, like giant pulpits, standing out and alone. In Russell county are the worn pinnacles and crags of Rock City, and in Ottawa county the quaintly-rounded concretionary masses of another Rock



Rock City, Ottawa county.

City. In Washington county the bold sandstone cliffs are seen resting on Permian limestone, while their upper surfaces have been ground by the huge hard, bowlders of the glacial age. And in all these places are the relics of the old world flora, leaves —dicotyledonous leaves. Others of our counties have them—Clay, Cloud, Saline—and they are found away north and south far beyond our borders. The thickness is composed mainly of sandstones, those near the top, in most of the exposures we have seen, being light colored, and the lower ones dark brown or red. In some places it is blood red, streaked with yellow; and when the sun shines on it we have a gorgeous glory. The coloring matter is largely composed of some compound of iron, and in places this has oxidized in most curious forms, suggesting by their vitreous surfaces the action of fire. In many places we have picked up specimens with a botryoidal surface not to be distinguished from kidney hematite from Europe and elsewhere. Then there are nodules of all imaginable shapes and sizes, rough vases, large troughs, bunches of fruits, hollow stems.

"In several counties—Washington, Republic, Jewell, Lincoln, and Russell—seams of an inferior quality of coal have been found. It is lignite, having much pyrites and a large quantity of ash when burned. It is, however, of some use as a household fuel where the thickness of the seam is sufficient to pay for working it. Though the term lignite indicates the presence of wood fiber, yet we have no idea that any considerable part of this material was wood, for it has been shown conclu-

sively by experiments, the results of which are confirmed by our experience of modern forests, that wood fiber, especially of the higher kinds of trees, is not preserved in the conditions under which coal was formed, so well as material of the leaves, stems and seed vessels of the undergrowth of ferns and other plants of the lower vegetable orders. But the immense numbers of leaves in the Dakota sands indicate forests on the land, whose undergrowth through ages must have left a carbonaceous deposit which, entombing and preserving many trunks, may well be the lignite of to-day."

We have noted that the Dakota in the northeast rests on the eroded surface of the upper Permian beds of the Fort Riley section. This is so also as far south as Salina. In Kingman and Barber counties there are, however, small patches of it resting in the eroded hollows of the red-beds, and in Ellsworth county it lies over the main body of that formation, as it does also at Russell. At Kanopolis the Dakota is 175 feet thick; at Russell it is 360 feet, and that is probably the full thickness of the rocks of this epoch. The entire thickness is made up of sandstone and shales. There is no limestone. There are two main deposits of sandstone. One, 120 feet thick, near the bottom. Separated from this by only 10 or 15 feet of shales (bluish) is another, lying above, over 60 feet thick; and near the top is another, mostly lighter color, gray to white, 10 or 15 feet thick. Above this are shales in which is the lignite horizon described above, and the salt marshes, to be noticed further on. The rest of the thickness is composed of shales, mostly highly ferruginous, and some likely to yield ochreous paints and material for pottery. In Washington county and in Saline, the highest Permian beds have in their cavities crystals of celestite, which may have infiltered from the overlying waters from which were deposited the sands and shales of the Dakota.

FORT BENTON BEDS.

It has become common to class these strata with the superincumbent formations of the Niobrara, under the designation of the Colorado group. As they shade upward, both lithologically and paleontologically, without any great break, this grouping is reasonable. But the change of the Benton at the top is not more gradual than the change from the Dakota below; that is, stratagraphically. The strata of the Dakota—soft carbonaceous shales—may be seen (*e. g.*, in Russell county, on the south of the Smoky) passing gradually up into more calcareous shales, and, eventually, into hard, slaty shales, which then give place to layers of limestone. There are, however, differences in distant places. In Lincoln county the typical Benton outcrop consists of seven beds of limestone, none more than two feet thick, and separated by beds of calcareous shale varying from 15 to 25 feet in thickness. The shales below the lowest limestone vary in thickness, because the surface of the Dakota, though not eroded, was uneven. The beds of limestone are composed of layers of remarkably even thickness, from 6 to 12 inches; but sometimes the bed is of a single layer. These even layers can be cut easily. They are soft, and locally called magnesian limestone. In Russell county they are sawed into bricks. In several counties they are cut into long, narrow strips, for fence posts. They have some stain of iron in them, and this often is in a streak through the middle of the layer, which gives a warm tint and a pretty appearance to the buildings of Beloit, Lincoln, and other towns. To the northeast of Lincoln the beds of stone are not so numerous, and in Cloud county there is one massive layer three feet thick. On the Republican, in Republic county, and also at Glen Elder, there is an escarpment of between 20 and 30 feet, made of successive thin layers of limestone; and this is repeated on the Saw Log creek, in Ford county, and across the Arkansas, in Meade county. With these differences, then, the Benton consists of hard, limy shales and

soft limestones in thin layers. In Hamilton county, the outcrop of the Arkansas valley contains some clay shales in thin beds, and of bright colors (orange and yellow), that may yield materials for paint. The description of the Benton beds here given is totally different from what is correct in the Dakotas, or at Fort Benton, in Montana, whence they had their name. There they consist altogether of shales, and these are soft, soapy, dark, and carbonaceous. Occasionally, thin beds of chalky limestone, of small extent, and more rarely the shales are calcareous. The absence of lime is marked. Alum is frequently found in fine crystals, and also other salts. It is difficult to recognize as the same formation beds so different lithologically. Yet the paleontological evidence is conclusive. *Our* Benton limestones have abundance of shells, but not many species. *Inoceramus problematicus* and other *inocerami*, a few species of fish, a nautilus and belemnites are the principal. There are no large shell beds in the north, as we have in Cloud and Ellis counties, but they have the same forms. It is by this evidence, supplied by Dr. Hayden, that Professor Mudge gave up his provisional name of the Fort Hays group, and adopted for these beds the name by which we now call them.

THE NIOBRARA.

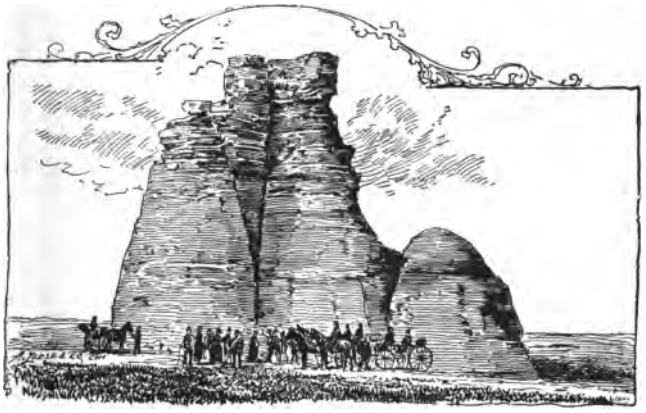
These, till comparatively recently, were thought to be the highest cretaceous strata in Kansas. Professor Mudge gave the thickness as 200 feet. My own observations in Trego, Rooks, Osborne and Norton counties led me to think they were somewhat thicker, but it is Professor Williston's estimates from recent observations which supply the figures (400 feet) which I have placed in the table of formations. A description written in 1883, of Niobrara strata in Norton county, is correct for other parts of the northwest, so we quote. The lower of two strata " . . . is in its best development, before weathering, a rather dark-bluish or lavender-colored shale. It is in some places very friable and brittle, in others tougher, and passes into a clay shale. Its color is much changed on exposure, becoming lighter, and in its upper layers inclines to buff. This stratum outcrops in each of the main valleys of the county, but in the Prairie Dog valley its layers lie low in the bed of the creek, and it is from wells that we have obtained its best appearance. In the Sappa valley it has a little more elevation, and in the Solomon valley it reaches from the river bed to a height of about 30 feet above it.

"This blue shale passes gradually (and conformably) into the stratum above, which is mostly a bright yellow chalk. The change from one to the other is so gradual in some places as to make it difficult to say where the line is. In other localities the line is so definite that some slight irregularities suggest unconformability, but further examination removes the idea. The greatest distinction we have observed is at two places widely separated. One, Miller's Spring, west of Lenora, where a fine stream of water comes from under the chalk off the top of the shale; the other, on the Sappa, where a depression in the shale of a few feet across is followed by all the streaks of the chalk, which is here beautifully banded. This little depression seemed to me just such a one as is often seen on the seaside sands, where a little stream, entering the ocean, makes its little furrow in the region between tide marks. As it is to-day, so it was in the old cretaceous sea.

"To the upper bed we very soon gave the name of the yellow chalk. It is chalk, and it is mostly yellow. We have seen since that Professor Cope has used the same designation for it, and this name will suit it well. It becomes white in places in the southeast of the county, and over in Rooks and other counties, white, but buff and yellow are the prevailing tints. There are patches and layers of a brick red and various shades of brown, and, in bright sunlight, a rich orange. The play of colors in some outcrops is perfectly gorgeous, particularly at Cedar Gulch and Ghost creek, on the

south side of the Solomon. At the latter place, the bold escarpments of the chalk lying over the shale, both in contour and color, suggested a sunset by Claude Lorraine. At Norton mill we were able to measure the thickness of the chalk. It is there about 55 feet. On the Sappa it is nearly as thick, but nowhere on the Solomon did we find it reach half that thickness, and in the southern valley it nowhere reaches so low as the line of the water in the river bed. It comes nearest to doing so at its most western outcrop, west of Lenora. This stratum presents abundant evidence of metamorphism by infiltration. It has had its upper surface extensively covered by materials containing much silica, and through the cracks and water holes, water charged with silicon has percolated, penetrated the porous chalk, and changed it into various silicates, jasper, agate, and other forms. We have seen a band of fine red chalk changed into a band of jasper, the yellow streak above still remaining chalky. In crevices, (as also in the shale below,) crystals of calcite and baryta are found, and sometimes small crystals of quartz. In many of the occurrences of the chalk the upper layers are altogether silicified. In one place, northwest from Norton, these hard layers contain many cavities which are large enough for wells, and, containing much water, are so used. Many of the apertures through which water has entered these wells are closed, and some nearly closed, by the deposit of the minerals in solution, of which silicon was among the chief—allowing us to trace the double action of water, first, in wearing out a channel, and then in closing it up."

On the Solomon, in Rooks and Osborne counties, also to the north, in Phillips and Smith, and south of the Smoky, in Trego county, the beds are less chalky. They are a soft, brownish, buffy limestone, less laminated in structure than the chalk beds. North of the Smoky, the chalk is in force, and white. There is an horizon in it which is decidedly harder. It is a phonolite, giving a sonorous ring to the stroke of the hammer. Locally abundant, it has been quarried as a building stone. Its hardness is due to infiltration from the chalk above, the pores being filled with semi-crystalline calcite. Westward, through Gove into Logan and Wallace counties, the upper member of the Niobrara keeps its chalky character, and a small area in Greeley county, known as Wild Horse Corral, shows it as the bright yellow chalk. This is in the valley of the White Woman, not many miles from the Colorado line. Lower down



Castle Rock, southeast part of Gove county.

this valley (*i. e.*, eastward) are some shales, of which I shall speak further on. Wherever the blue shale and chalk are found together, the former is always the

lower, but the line between them is not constant. Chalk is found at lower levels than neighboring blue shale; not by unconformity, but by change of structure in the same stratum. There is a notable example of this seen in the *Castle Rock*, 70 feet high, in southeast Gove county.

The Niobrara has its name from the river of Nebraska, otherwise called the Running Water. It is well developed on the Missouri river of South Dakota, above and below the mouth of the Running Water. The peope of South Dakota call it the *chalk*, but its texture is about that of the brownish limestone beds mentioned above, and its color approaching that of the lightest parts of the blue shale of Kansas. It weathers, and can be quarried, in huge blocks. It stands up in vertical cliffs, but the fallen masses break into splintery debris. Like the Dakota and Benton, the Niobrara is an extensive deposit, and lies under the whole mid-plains region, and turns up edgewise on the flanks of the front range of the Rocky Mountains.

MONTANA GROUP.

Doctor Hayden and the other geologists who fixed the nomenclature of Western geology gave names to two series of cretaceous rocks above the Niobrara, namely, the Fort Pierre and Fox Hills beds. Above these are also the Laramie or lignitic beds, which are mostly considered to be cretaceous, though they have some characteristics that foreshadow the tertiaries. Since Doctor Hayden's time, there has been a tendency to reduce the number of names, and the Pierre and Fox Hills beds are included in the term "Montana Group," as the Niobrara and Benton are included in the designation of "Colorado Group." In 1883, the present writer called attention to a *green sand* and a *green-clay shale* above the Niobrara chalk, in Norton county. Since then, I have seen shales somewhat calcareous and also carbonaceous in the valley of the Sappa, in the western part of Decatur county. Then there are numerous outcrops of similar shales in the ravines that slope to the Republican, in the northern part of Cheyenne county. It is also seen in several of the ravines south and southwest of Atwood, in Rawlins county. Going west, these shales become more carbonaceous. Coal has been suspected near Atwood, and at St. Francis a shaft was sunk that penetrated the shale more than a hundred feet. Over in Nebraska, in the Republican valley, the shale is more carbonaceous, but the hope of coal is not likely to be gratified, as, though some seams of lignitic coal have been found in the Montana shales, yet not of great extent or of workable value. The shales are found in all the rough valleys around the corner-stone that marks the limits of the three States, Colorado, Nebraska, and Kansas. Fossils have been found in this neighborhood, but they have not been studied for stratigraphic relations. Baculites found further south in Kansas probably belong to these beds, and I have suspected that the shales in the White Woman valley, referred to on a previous page, may belong to this group, though there are considerations which do not favor this supposition.

THE LOUP FORK.

The divisions of the tertiary formations, as originally made in Europe, into *eocene*, *miocene*, and *pliocene*, was based on the numbers of the kinds of fossils as related to modern species. This comparison was made of marine shells. In the region of the great plains the tertiary deposits were mostly if not entirely fresh-water formations. The fossil remains are mammals, not fish; fresh water, not marine mollusks. It is difficult, therefore, to correlate our plains tertiaries with European formations, or to use European nomenclature. It has become common to use the terms eocene and neocene for the entire age, the latter term covering miocene and pliocene. Professor Mudge called all our west Kansas beds pliocene, though he indicated several times that certain lower beds might hereafter be recognized as

miocene. We so class them here, under the designation of the *Loup Fork*, though some paleontologists regard them as pliocene. Beyond the limits of the State there is an older tertiary, known as the White River formation, lying beneath the Loup Fork, but, as we believe, shading up into it. In some of the northwestern counties we are inclined to think some strata that we have classed with the Loup Fork may properly belong to White River beds. But certainly there are no older tertiary deposits in the State. All are neocene. The greatest distinction is between the Loup Fork and the beds above. It was caused by the mid-neocene erosion.

To avoid the controversy as to age of the formation, I have called this earlier tertiary formation the

TERTIARY GRIT.

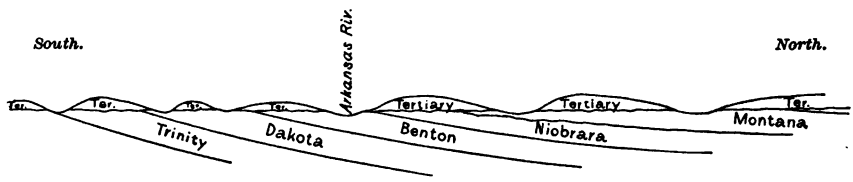
"The term grit is descriptive of this formation everywhere, yet it is of varying constitution. In places it incloses a fine powder, but the powder is largely siliceous, is useful as a polishing powder, and appears to be volcanic in its origin — wind-blown volcanic glass from the tertiary centers of eruption in the West. Elsewhere the grit is an aggregation of sand and lime, which we call its mortar-like form. Again, the lime exceeds the sand in quantity, and it is sufficiently fine to be used for inside plastering. Then we have the mortar form, inclosing abundant pebbles, quartz, feldspar, diorite, greenstone (hornblende), and more rarely granite with other igneous rocks. Then the limy matrix almost disappears, and we have a heavy conglomerate of water-worn pebbles of the rocks above mentioned, with jasper, quartzite, and agate, from the size of a nut to that of a large apple. Sometimes, also, there is a bone, or a piece of completely silicified wood. The mortar-like form often hardens into a building stone, and its softer beds contain hard, tough nodules, like indurated — not silicified — chalk. The conglomerate form changes at times into beds of a fair quality of sandstone. In some places it shows as a hardened bed of gravel, with well-marked cross-bedding. The mortar-like form is often a fossil bed, yielding bones of mastodon, *Aphelops*, and turtle. There are in many places root-like concretions penetrating the softer forms of the grit, and where these softer forms are of considerable thickness — they attain in places a depth of 15 to 20 feet — they are characterized by harder ledges at intervals of from two to three feet, which give very bold forms in weathering. The conglomerate is also manifested in abrupt breaks and rocky ledges.

"We find small patches of this in east-central Kansas. The increase of the area covered by the patches westward, and traces of remains of it in the form of thin gravel on slopes otherwise lacking signs of its presence, and its persistent occurrence as ledges a little below the highest prairie slopes, and, further still, its occurrence low in the river courses, indicated it as one of the most extensive deposits of the western part of the State. I have been enabled to define particularly two features of the grit: (*a*) In the Arkansas valley the conglomerate of the grit is mainly composed of pebbles of dark red feldspar. This is so marked a feature that its exposures, covered with the loose pebbles, can be recognized at long distances by their ruddy glow in the sun. In the valley of the Cimarron, and in counties farther east, the conglomerate is more often composed of quartz pebbles and pale feldspar, giving a whitish or grayish tint to the exposures. (*b*) In several well-marked instances I found the mortar form and the conglomerate together, indicating that they are not, as I had supposed, local variations of synchronous deposits. I found the mortar form below the conglomerate, the former having in those places its usual scant supply of pebbles. Rocky Point, a bold ledge of the conglomerate five miles west of Dodge City, gave this juxtaposition of the two forms, the mortar form showing only on the eastern or lower slope of the point, and disappearing under the conglomerate.

Elsewhere I found the mortar form embedding not only the pebbles of igneous rock, but also pebbles, both water worn and angular, of the cretaceous rocks of the region, these fragments being more or less silicified. A small patch of white sandstone, of which there were several near in Harper county, (section 5, township 32, range 5 west,) had similar relation to the underlying red rock. The red rock, a nodular clay, shades upward into the sandstone, the intermediate part being a conglomerate of quartz pebbles in a pasty matrix of the red-rock material. The sandstone itself has some pebbles of smaller size, and in the conglomerate the larger pebbles are below, and the least amount of the coloring matter — the pasty matrix — above."

The extent of the tertiary grit is enormous. It has covered all the mid-plains region from northern Nebraska to beyond the Red river of Texas. Erosion has since cut it away in most of the valleys, and sometimes it is missing on the upland plains. The greater erosion of the valley lands has caused its areas to be much diminished in Kansas east of the 100th meridian, and east of the 98th it still diminishes, and only a few patches testify its existence at the 97th. The most easterly occurrences that I know are: (*a*) At the west side of the Arkansas river, 1½ miles east of Geuda Springs. The west buttress of the bridge rests on a hard bed of the tertiary grit, which has here flung the stream to the east and narrowed its bed to 400 feet. The grit has been quarried a quarter of a mile to the southeast, and shows coarse ledges of sandstone and some conglomerate beds. (*b*) A small area by a railway cut in the northeast suburbs of Wichita, which has also been quarried, and *perhaps* the sandstone bed overlying the Permo-carboniferous limestone on the east bank of the Arkansas, just south of the enlarged bounds of that city. (*c*) A mere patch of conglomerate in the cut at Fogarty's mill, on the Smoky, at Junction City, 10 miles east of the 97th meridian.

If, in the western part of the State — the Cimarron valley or that of the Prairie Dog — the difference of elevation of occurrences of the grit in the larger valleys and those in the higher ravines near the high prairie be taken as the guide, the thickness of the grit might be taken as approaching 200 feet, and it is more than that in Nebraska. In Kansas, however, its thickness is much less than this appearance suggests. Before the grit was laid down there was a long period of uplift and erosion. The Rocky Mountains came up, and on their flanks the cretaceous strata were turned on edge, flexed, and folded. Throughout the great plains region they were above high-water mark, and, leaning to the east, the great and small valleys of the region were eroded by all weathering agencies of the long period of eocene time. Then there was depression, and the tertiary grit was deposited in fresh-water lakes, the rivers from the mountains bringing the pebbles for the conglomerate, which are smaller the further east they are found. The grit filled up the valleys and capped all but the highest land, so that its bottom varies with the eroded surface of the pre-tertiary rock, and its actual thickness, since it has been eroded in its turn, is probably, in Kansas, not anywhere more than 60 or 70 feet. As we shall see further



Section across western Kansas, showing the outcrop of successively lower cretaceous formations with the tertiary covering.

on, this tertiary grit plays an important part in the economic development of the West. It is the *water holder* of the plains.

THE PLAINS MARL.

After the grit there was another period of uplift and erosion. The grit was cut through nearly on the lines of the valleys of the pre-neocene erosion, and the cretaceous formations were laid bare over large areas. Then another submergence, and the plains marl was laid down.

"Superficially this marl is not unlike the loess of the Missouri valley, and in the middle of northern Kansas seems to shade into it, although in southern Kansas the loess is sufficiently distinct. The marl is arenaceous, argillaceous and calcareous in its texture. It is not at all like the mortar form of the tertiary grit, except in a very few localities, where, owing to each having a predominance of sand, there is some difficulty in distinguishing them. Its color is very uniform. It is a buff marl everywhere. We have seen no place where it was colored by the red rock. It is buff on the yellow chalk of the northwest, on the cretaceous limestones, on the Dakota sandstones, on the red-beds, and on the carboniferous strata. It contains chalky nodules, irregular in shape, some root-like, resembling those in the tertiary grit. Its texture is nearly the same everywhere. Where its bluffs are high its lateral exposures are wrought into rounded and symmetrical pillar-like forms, tapering to the top. Some views of it suggest the *mauvaises terres* of Nebraska.

"There is evidence in some places of a subdivision of the marl into two deposits, the lower one in each case being more arenaceous than the upper one. The lower arenaceous stratum seems also to be indicated in wells, where it yields water, after the marl has been pierced.

"We find the tertiary marl resting on eroded surfaces of Permian—buff limestone as well as the red-beds—cretaceous and tertiary grit formations. It is sometimes low down, buttressing the flanks of other formations, but its best development is at the greatest elevations. It forms the dead level of the high prairie between the great rivers, thinning off toward their valleys, but following the slope of the tributary dales. This thickening on the high prairie is manifest in almost every county—Barber, Pratt, Edwards, Meade, Ford, Hamilton, Seward, Scott, Graham, Norton, Morton, and Cheyenne—from Indian Territory to the Nebraska line. Wells pierce it in most of these counties over 100 feet, and in Meade county and in Graham from 140 to 180 feet, before the grit is reached. The grit has a supply of water; the marl seems quite dry except in its lower stratum. Walls of dug-outs and cisterns excavated in it may be plastered or cemented without the intervention of other material. The buffalo-grass is attached to the marl. It remains on it after wire-grass and others have taken possession of sedentary soils of the grit or other formations. Where the sod has been broken by the plow, it has been found that the marl in a few years ceases to be so dry. It can then be broken by the spade, where before a pick was necessary."

The modern erosion, which has made the present contour of the Western plains, has carried away this plains marl more than anything else—first, because it was on top; second, because of its soft, marly texture. The erosion is again on the old lines, and the valleys are mostly those that have been previously filled by grit and marl. The basin in Scott county has not yet had its drainage established on the surface, though the valley of the White Woman belongs to the pre-neocene age. This marl is the result of the breaking down, mainly, of the previous tertiary formations with some local admixture of cretaceous debris. It is mostly a lake or river silt. It is the fertile subsoil of the plains. Its most eastern occurrence known to the writer is at the second occurrence of the grit mentioned above, in the suburbs

of Wichita. On all high land west of the 98th meridian it is found, and further west it occurs as the second bottom of some river valleys.

There are few fossils in the marl. Horse, mastodon and bison remains have been found. Part of the formation Professor Cope has named Equus beds. We have classified the formation as pliocene, and it probably had its beginning in late tertiary time; but it is likely that the larger part of its deposit was contemporaneous with the great ice age, which prevailed to the northeast, and some of the lakes of which it was the silt were probably not dried up till very recent time. The buffalo-grass, which so much affects the marl, seems to have been its first vegetation, and over vast areas has had so short a hold as not to be able to make a black humus, but only to darken a little the surface.

DRIFT.

Northeastern Kansas is the southwestern corner of Iceland; *i. e.*, it is the southwestern part of the area which, in the times immediately succeeding the tertiary age, was covered with ice, and which is now largely covered with deposits which were brought by the ice, were formed under the ice, and left by the melting ice at its southern termination, or were laid down in cold waters that washed the margin of the ice.

Where the ice halted and its terminus remained stationary for a time, the melting being exactly met by the supply from the north, there was an accumulation of the solid matters it had carried along with it—bowlders, mostly angular, sand, and gravel. It is called the terminal moraine. Clay and limy matter made muddy the waters that ran from and bounded the glaciers. They deposited beds of clay, fine sand and marl for long distances around. The ice, by blocking up river valleys, affected the drainage of regions far distant from its actual presence, and caused floods and lakes far removed from the ice margin. These waters deposited material all over southeast Kansas, and as far west as the Medicine river valley.

The ice itself crossed the Kaw river valley, not for its whole length perhaps, but for most of the distance east of the mouth of the Blue river. The southwest corner of this ice region is characterized by an immense moraine. East of St. George, the tops of the bluffs overlooking the Kaw valley are paved with large bowlders, and on the south side of the valley, a little to the east, the moraine is simply immense. At the western extremity two hill-tops—flat mounds—are paved with the bowlders to a depth of eight or ten feet, and to the northeast, east and southeast the moraine extends for miles. In places it looks like surging waves of stone. They stand up in great heaps; they show smooth surfaces through the grass; they are angular, but glassy, and some are covered by the lichens of centuries; some are as small as a head or a fist; many weigh several thousand pounds each; not a few weigh scores of tons. One, nearly square, is eleven feet long by nine feet six inches in width, and its highest part is two feet above ground, and its average height is fifteen inches. It is imbedded firmly, apparently in the underlying shale, and has been scored by other stones in the ice passing over it. The striæ on it have a direction about south 25 degrees east. It is of the red quartzite that comes from South Dakota and Minnesota, and fully 95 per cent of the bowlders of this moraine are of this material. The rest are mainly hornblendic greenstone and granite. I found a few fragments of a hard limestone that is very common in the drift of North Dakota. A tongue of the glacier was pushed across a low divide here, and continued down to Mill creek, while the main body of the moraine trends east, still on the south side of the Kaw. At Topeka the river valley was also crossed, a tongue of moraine stretching down to Tevis, 10 miles southeast. At Law-

rence, and a few miles south and west, there are again immense morainic deposits. In Missouri they are found further south than the mouth of the Kaw. The largest bowlder known to the writer is of the red quartzite, with streaks of conglomerate in it. It is in the northwest corner of Shawnee county. It lies nearly square with the points of the compass. It is 17 feet 6 inches from north to south, and is one foot shorter from east to west. Its highest part is seven feet above ground. It is probably as deep in the ground. It weighs several hundred tons. In its present position its stratification dips to the east. Its sides are nearly vertical. The frosts of many milleniums have opened some of its natural lines of cleavage and bedding, the former being nearly vertical. Some masses beside it on the east probably once were part of it, having slid off it, as some others are being slowly loosened by the weathering of the ages. Bowlders are found in all counties from the Missouri to the Blue. In Washington county they are found west of the Blue, and there also are found mounds of gravel and small bowlders which, if they were not so weathered, would be recognized as *osars* and *kames*, which probably were first melted out on the top of the glacier, and at last were left in position by the final disappearance of the ice resting on bed rock of the country. The true

HARD-PAN,

Or *till*, is a stiff, pasty, dark brown clay, with pebbles and small bowlders. It seems to have been formed under the ice by the grinding of the material over which the glacier passed—clay shales, soft limestones, and sand. It is not as extensively found in the glacial area of Kansas as in some other States. I have seen it in thin beds in Washington, Pottawatomie and Nemaha counties, and without doubt it exists elsewhere under other deposits. Fortunately it is not often at the surface, as it forms an intractable soil. Where it exists as a subsoil, drainage will be required. A modified hard-pan, joint clay, or

GUMBO,

Is more often found near the surface in the glacial area, and is post-glacial in its origin. And far away from the glaciated region there is a similar formation. Some of these beds of gumbo are of quite recent origin, being results of floods and weathering by agencies still at work. So that these beds, all strictly local, come down from immediately after the ice to the present day.

LOESS.

This deposit, otherwise called *bluff*, because the bluffs of the Missouri river are formed of it or capped with it from Kansas City to Yankton, is a buffy or yellowish marl. Over immense areas it is substantially the same material as that which gives color and muddiness to the water of the present river. In some regions it takes color from local surroundings, and has streaks of coarse sand or gravel, and becomes of orange brightness. It is generally agreed that the loess is the material deposited in the broad lakes and streams that fronted the ice sheet, and which followed its retreat to the north. In some States there is believed to have been an interglacial epoch of milder climate; that is, there was for a time a retreat of the ice sheet and a second advance and repetition of the various phenomena. In Kansas, the whole of the direct glacial phenomena belong to the oldest ice epoch, and the second ice sheet did not come here. This, however, is not so with regard to the loess. The loess of the second advance overlapped the more ancient loess, but the limits of the overlap have not been worked out. Loess is found as far west as Dickinson county and Medicine Lodge, and down the Arkansas and Neosho valleys into the Indian Territory. It is found low down in river valleys and in ridges at great elevations. It is found as high as 1,200 feet above sea level in Geary county, and up to 1,500 in

Morris, and to 1,000 feet in Bourbon. We have already noted that the plains marl shades into it.

When the Kaw river valley was dammed by ice in Wabaunsee county, the Platte valley of Nebraska must have been closed also, and the Missouri was stopped at Fort Randall, and its waters must have been thrown over Nebraska and northwestern Kansas. The height of the wall of ice must have been sufficient to throw the waters over the high divides to the west and south. Perhaps some Missouri river water, after being spread out into wide lakes, was thrown into the valleys of the Neosho and the Arkansas. Across these waters floated icebergs large or small, which carried angular bowlders far beyond the ice border, and which are found in the loess that was deposited on the glaciated area during the recession of the ice to the north. Probably at this time the deep trough of the Blue river was cut by the strong current along the west front of the ice, and the pass cut across Wabaunsee county round the southwest terminal moraine to Mill creek, whose wide valley below McFarland with deep alluvia shows a large stream once worked there. The pass we refer to is now used by the Santa Fé and the Rock Island railways for their tracks from Manhattan to Mill creek. The tracks at the highest point are little over 100 feet above Manhattan or McFarland, but the neighboring hills are from 200 to 300 feet above the two valleys. The *loess* has done much to smooth the contour of a region that before this age was very rugged. That it is otherwise of economic value, will be seen further on.

GRAVELS.

In Bulletin 57 of the United States Geological Survey, I have distinguished an *earlier* and a *later* gravel in southwest Kansas. The material of both is from the tertiary grit. The *earlier* I have defined as that which began to be formed as soon as the grit became dry land, from the breaking up of its conglomerates, and has remained near — in some cases actually at the side of — its original deposit as grit. But such gravel is still forming. The *later* gravel I defined as that which was removed by post-tertiary, perhaps post-glacial, floods, which by strong currents reassorted the material and deposited it in hollows of the older formations. A fine example of this is seen in the railway cuts on the west and south of Wellington. Such gravels are found under the loess in other places than at Wellington, and gravels made of paleozoic material, in the eastern counties, were deposited both before and after the loess. There are river gravels, more recent still, that belong to the epoch of the present

ALLUVIA.

By this term we designate the valley formations which owe their existence to the action of rivers and floods since the present general system of drainage was established. These include the present *bottom* lands and many of the second bottoms of the river valleys, the gravelly and sandy stretches of the flood plains, and the sub-angular gravels and finer deposits of the upper parts of smaller valleys and ravines all over the State. Of the same age are various regions of sand dunes in the Arkansas, Solomon, Cimarron, Kaw, Medicine, Republican and other valleys. The sands left dry after river floods are caught by the wind and piled up in hills. The debris of the tertiary grit, the plains marl, and the loess is treated in the same way before it is carried to the larger streams, and there are stretches of sandy land now wholly or partially covered with vegetation, that have had this recent origin, in different parts of the State.

Thus we have briefly described the various rock formations of the State, in their geologic order. In nearly the same order, we shall now treat of some of various materials they yield to the use of man. This is

ECONOMIC GEOLOGY,

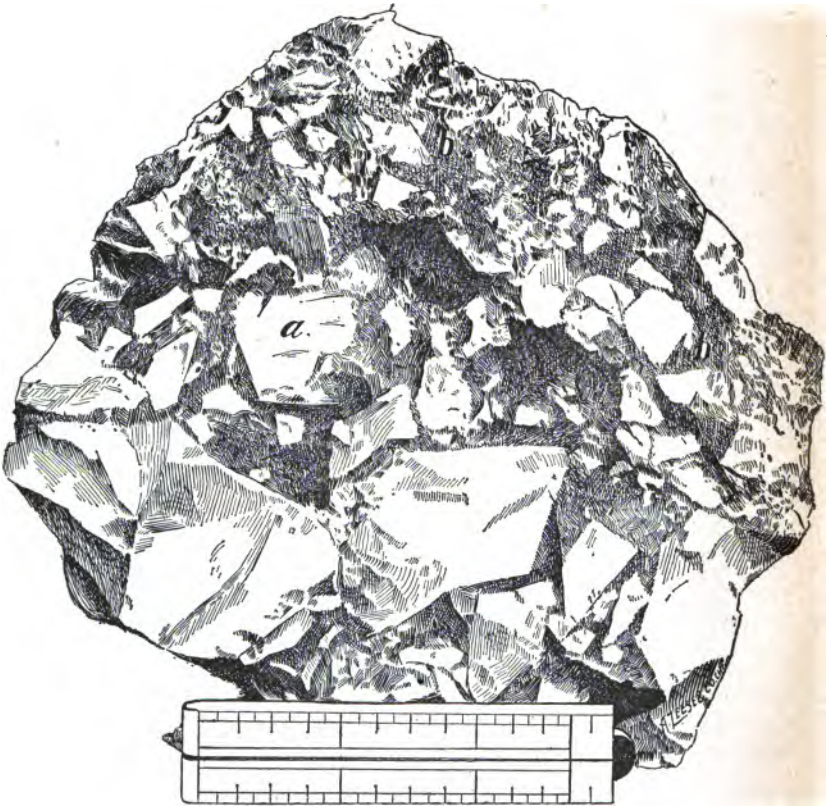
Or, in other words, the MINERAL RESOURCES OF THE STATE, beginning with those found in the *sub-carboniferous* formations, the lowest in the geologic scale that are found on the surface of the State.

LEAD AND ZINC.

Lead and zinc mining in Kansas is confined to the southeast corner of the State —to the southeast corner of the most southeastern county, Cherokee. Small quantities of lead have been obtained at great cost in Miami and Linn counties as far back as the end of last century, and signs of zinc have sometimes caused excitement in Bourbon county. But it is in the limited area east of Spring river, in Cherokee county, that these metals have become, comparatively recently, the source of remunerative employment for labor, of paying investment for capital. Within this area, at Standley — only two miles from the Missouri line, and slightly more from the Indian Territory — in 1872, lead was discovered and worked, but it does not appear to have been profitable in the long run. In April, 1877, mines both rich and profitable were sunk to the northeast, and the rival towns of Galena and Empire City sprang into existence in a few months, having 3,000 inhabitants. Galena remains the leading mining town. The site of the city is now on a labyrinth of vast caves formed by the getting of millions of tons of ore. A curious incident of this successful industry is, that the lot on which the school-house of the early mining camp of Galena was built has been honeycombed with mines, and from the royalties paid for the ore extracted the school directors have bought another site, and built a larger brick school-house where it was supposed no mineral was, but which is now surrounded by mines, and the officials are besieged with applications to lease the ores beneath the surface of the new school lot. In 1890, other areas were proved to contain paying ores, and an immense development has since then been made southwest and west of the "Short Creek diggings" of Galena, and reaching close to the old Standley diggings. Professor Mudge, 14 years ago, gave a pretty full account of the industry as it then existed at Short Creek. His account of the manner of the occurrence of the ores in the mines is as correct for to-day as it was then, as the writer has verified by many descents into the shafts in the present year and years ago, both in Kansas and over the border in Missouri. Professor Mudge, referring to the lottery character of the mining industry, says, that "of the shafts sunk, not one-third have produced any ore, and not one in ten has been profitable." It is now claimed that the recent developments are much more favorable; that fully one-fourth of the shafts sunk in 1892 are profitable. This is a much more favorable ratio than exists in the mining districts of Webb City and Joplin, in Missouri. With improved methods of handling, low-grade ores now yield some profit, and dump piles are culled by feeble men or children at reasonable wages.

The geologic formation in which the zinc and lead ores are found is that part of the sub-carboniferous group known as the Keokuk limestone. This outcrops on Short creek and Spring river, down into the Indian Territory. The limestone is in thick, massive ledges, and, though mostly porous, in places it yields good building stone. It contains numerous nodules of chert or almost pure flint, and has besides some seams of chert or cherty limestone intercalated between the heavier beds of limestone. The general position of these beds, especially near Spring river, and as seen at the quarries near the Memphis railway station at Galena, is nearly horizontal. Where the beds thus show little or no disturbance, lead and zinc ores are scarce. Occasionally a little has been seen, to stimulate the digging of prospect holes, which have proved unremunerative. Across the town-site of Galena and for two miles

towards Standley, and also in the region of Missouri to the east and northeast, this condition of the strata does not exist. On the lands of the South Side Mining Company, and again, a mile to the southwest, in the neighborhood of the newest diggings, there are outcrops of the limestone which appear to be the beds turned up to a nearly vertical position, constituting "walls." As seen in the shaft of an old mine, the real position is not vertical, but at an angle of 60° to the horizon. On the South Side Company's estate the direction of the "wall" is north of west to south of east. On the other side of the town the direction was south of west to north of east. Where we saw any appearance of these walls below ground, the direction was again different, trending to the northwest. This on the South Side land. In all the mines the chert is much broken and the ores mingled with the broken chert. Where the limestone is encountered in position, or even as a wall, it is only on its surfaces or in cracks that the ores are found. The upturning of the limestone and the breaking up of the chert are apparently the necessary prerequisites to finding ore. The limestone is not so much broken because it is not so brittle as the chert, and this has been well illustrated in an article by Prof. E. Haworth. The mining region, then, has sometime been subjected to powerful seismic influences, which, in limited areas, upset the beds of limestone and fractured the chert into sharp-edged splinters and blocks. When this "bouleversement," as the French say, was accomplished,



Brecciated zinc ore: (*a*) Fragments of chert; (*b*) zinc blende.

we cannot positively tell, but it appears certainly to have been after the lower coal measures were laid down above the lower carboniferous beds—perhaps after the former were partially eroded away—because in several of the mines, both east and southwest of Galena, masses of coal-measure shale are encountered, some of which contain crystals of zinc blende, which, being somewhat rounded, are called pebble ore, and chunks of coal-measure sandstone with impressions of fossil vegetation are found impregnated with lead, which shows as minute cubes of galena. The lead and zinc ores are among the broken limestone and chert. They have been deposited from waters in which they were held in solution, and they have through immense masses filled up all cavities and formed with the angular chert fragments a beautiful breccia. Where cavities have not been entirely filled, the metallic ores have formed large masses of crystals—the blackish brown or amber-colored zinc blende and the bright cubic crystals of galena. The zinc blende is the sulphuret of zinc, yielding from 30 to 40 per cent. of metallic zinc. Galena is sulphuret of lead, yielding when pure 85 per cent. of the metal, and at Short Creek running anywhere above 60. Occasionally carbonate of lead is obtained, which is not bright like the sulphuret. It is the miners' "dry bone." Silicate of zinc (calamine) is also obtained, and in Missouri it is found in larger quantities. Oxide of zinc is sometimes obtained suitable for paint, but not in great quantity. Iron and copper pyrites are found in abundance, the form marcasite giving fine specimens. Calcite is found in abundance in places, sometimes as Iceland spar, and dolomite in sharp crystals is not infrequent.

The water coming over these various minerals is more or less charged with them and silicic and sulphuric acid, and as a result the breccia or limestone is again locally porous and the pores sometimes refilled with another of the minerals. When this has occurred with crystals, we have fine pseudomorphs.

The mining of this region has in past time been carried on at hap-hazard. The lead of the ore has been followed in all directions. There are no regular drifts or tunnels, but huge, irregular caves. We may stand on an underground ridge with a profound chasm on one side, to the bottom of which the miner's light does not shine, and on the other hand a vaulted roof dimly discernible. Some of these caves, representing immense bodies of rich ore carried away, are 60 feet high, and may be entered from various sides, as different mining claims have come to their common boundaries. The way that land for mining purposes is let and sublet on mining leases, and the royalties charged, are to some extent responsible for this irregularity of work, though the irregularity of the deposits is the main reason. The Carterville (Mo.) *Republican* supplies the following as explanatory of the methods of leasing there, and it has been reprinted in the Galena *Republican* as correctly giving "the situation" in Kansas:

"MINING COMPANIES AND HOW THEY OPERATE.

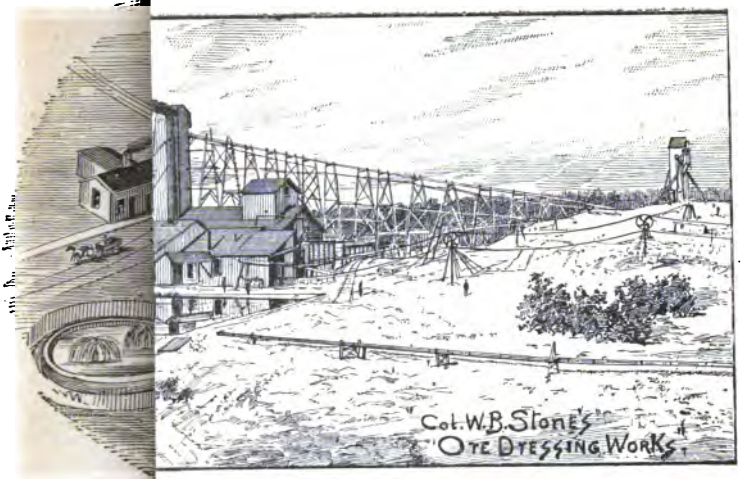
"In response to numerous inquiries from Eastern men who are not familiar with lead and zinc mining, leasing of mining lands, etc., we here give the *modus operandi* pursued by most of the companies at work in this district. An individual, or company of men, will lease a tract of land—40, 80 or 160 acres—that they wish to mine for a term of 10, 15 or 20 years, binding themselves to pay to the land-owner 5, 8, 10 or 12 per cent., or any other per cent. agreed upon, of the gross product from said land as royalty. The company then, generally speaking, plat the ground that they have leased; that is, they lay it off into lots 200 feet square, which they sublease to miners, at a royalty of 20 to 25 per cent. of the gross product of zinc ore that is mined off of said lots by the miner, and a royalty ranging from 25 to 55 per cent. of the lead mined.

"The companies generally develop the ground either by sinking a shaft or shafts, or by finding ore with drill holes, before they attempt to sublease any lots. When a company starts in to develop or prospect their ground with a shaft, they generally sink it 6x9 feet, or large enough to put in a pump and also hoist out of. The miner generally sinks his shaft, which is only used for hoisting purposes, 5x5 feet in the clear. Most companies, in subleasing lots to miners, agree to drain the ground and furnish water to miners to wash or clean their ore with, which necessitates the sinking of their pump shaft to the water level, and the putting in of pumps. In some ground the water is stronger than in others, and it is frequently the case that a shaft can be sunk 80 to 100 feet without putting in a pump, while in other cases strong water is encountered nearer the surface.

"Some companies reserve a number of lots to work themselves, while others sublease all their lots to miners, and rely solely on the royalty they receive for their profits. All ore is weighed over the company's scales when sold, and the company receives all moneys paid for ore, and, after deducting the royalty coming to them, pay the remainder over to the mine operators, generally on Saturday evening of the week in which the ore is sold; they also settle with all the hands they may work on Saturday evening. Wages range in this section, for practical miners, from $1.75 to $2.25 per day.

"While we have thousands of acres of mineral land in this section yet undeveloped, we do not wish to be understood as advocating that all a company has to do is to sink a hole, strike ore, and become immensely wealthy, but we do say, that with common judgment used in the selection of the land, location, etc., there is no other business a capitalist can go into with such surety of large returns for the money invested as in developing mining lands in Jasper, Mo., and adjoining counties."

Under this system the lead and zinc mining of this region has developed to its present large proportions. Before stating what those proportions are, we will briefly state the processes the ore is subjected to after mining before it is ready for smelting. Much of the lead comes up the shaft in large crystals, or crystalline masses of galena in the brecciated rock, and is removed by the hand when the rock is broken by the hammer. Some, however, goes through the crushers, of which there are 15 in the district, driven by steam, 12 of which were in operation in October, 1892. All the zinc goes through the crushers, and is afterwards "jigged." All these operations require water — water in abundance — which the pumps keep constantly lifting from the mines, to which the drainage from the surface is continuous, owing to the upturning of the strata and the fractured condition of the chert. The steam crusher is similar to those used by road makers for macadam, but the constant stream of water washes out the lighter parts — chert and limestone — and the finer pieces are then crushed between two pairs of rollers, water still accompanying the process and carrying off a cherty gravel. The crushed zinc ore, still accompanied by some chert, goes to the "jigger." This is an oblong sieve immersed in a square trough of water, and suspended at the end of a long lever. A man at the other end of the lever raises and lowers, by gentle jerks, the sieve in the trough. This is the process of jigging. The lighter chert is thus assorted to the top, and the heavier ore sinks through the sieve into the trough. The sieve itself, raised out of the water, has its upper surface of fine chert scraped off and shoveled away as tailings, of which there are immense piles outside all the crushing plants. A lower stratum in the jig sieve, that formerly went with the tailings, is now shoveled to a bin and is sold to persons who rewash it for the ore it contains. The ore that has passed through the sieve is scooped out of the trough and thrown into bins, where it drains, and is carried away to be shipped to the smelters, where it is worth from $17 to $25 per ton. It resembles a coarse brown



alena Kas

sand or fine gravel, and is not at all attractive in appearance. The water running from the crushers and jiggers is muddy, and in different parts of its course before leaving the works it is passed through wide, shallow tanks, where, its velocity being abated, it deposits some of its mud. The mud, locally called *sludge*, is collected, as its brown color shows it contains some zinc. It is sold for $1.50 per ton, to the *sludge mill*, where it goes through processes which wash away most of the foreign matter, and it can be sent to the smelter as a somewhat inferior ore. All this was formerly wasted. There is one crushing mill that also does the jigging by steam. In this place, which is the property of Col. W. B. Stone, (who is also president of the South Side Mining Company,) there are four sets of steam jiggers, in which the material, always accompanied by water, is passed through many sieves, the finest being of brass wire with a mesh of one-sixteenth of an inch. The gravel from the crushers is now being shipped for ballast on railways and roads. The railways pay 25 cents per car load above the cost of loading. The finer *tailings* are beginning to be used in making coarse mortar. It is very even in size, and should become extensively useful. Silicate of zinc does not go through these processes of crushing and washing, nor does carbonate of lead. The occasional chunks—from the size of the fist to that of a nut—are separated by hand at the mouth of the mine, and are shipped to the smelters when there is enough for a load.

Professor Mudge, in the first biennial report, states that the annual output of lead ore reached 6,000,000 pounds, but gives no estimate of the amount of zinc. He, however, noted that two zinc smelters had then been established in the State. Let us see what this mining industry amounts to now. Mr. Chas. T. Dana, of the Galena *Times*, has now for nearly three years personally collected the data for a weekly statement of the output of the mines of the Galena district. He goes to two sources for the *rough ore*, which show slight discrepancy, but the statements for smelting ore are sufficiently accurate. We give one week's statement, which shows the number of companies operating, as well as the amounts of the products:

STATEMENT OF OUTPUT OF ORE (IN POUNDS), FOR WEEK ENDING OCTOBER 29, 1892.

CRUSHERS.	ROUGH ORE.		*Zinc ore sold.*	*Lead ore sold.*
	Crushed.	*Sold.*		
Stone's crusher No. 1	284,060	.....	111,810	.....
Stone's crusher No. 2	197,770	.....	.....	.....
Robert Crowe	516,170	.....	93,470	.....
Murphy No. 1	528,220	.....	146,480	.....
Murphy No. 2	294,980	.....	60,840	1,470
Galena Lead and Zinc Company	320,410	.....	145,430	.....
Wyandotte	.....	.....	.....	.....
Emmons & Miller	.....	.....	.....	.....
Murphy & Murphy	250,000	.....	24,000	.....
B. Cooley	345,490	.....	72,340	9,220
COMPANIES.				
South Side Mining and Manufacturing Company	.....	353,740	120,580	.....
Galena Lead and Zinc Company	.....	352,540	75,980	.....
Windsor	.....	.....	.....	.....
Cornwall Mining and Smelting Company	.....	.....	.....	.....
Empire Mining Company	.....	85,610	.....	.....
Ohio Lead and Zinc Mining Company	.....	212,390	25,280	26,000
Illinois Lead and Zinc Company	.....	69,830	6,660	.....
Gracie Clark Mining Company	.....	.....	.....	8,000
Stone Mining Company	.....	.....	.....	.....
Maggie Taylor Mining Company	.....	.....	.....	.....
O. Sparks Mining Company	.....	20,000	31,650	6,000
Annie Laurie Mining Company	.....	.....	.....	.....
Templar Mining Company	.....	69,000	21,340	6,000
Central Mining Company	.....	264,000	59,760	27,340
State Line Mining Company, From Euclid Company,	.....	.....	.....	.....
Crystal Mining Company	.....	213,480	27,740	50,190

STATEMENT OF OUTPUT OF ORE—*Concluded.*

CRUSHERS.	ROUGH ORE.		*Zinc ore sold.*	*Lead ore sold.*
	Crushed.	*Sold.*		
Fahlenback & Co.	.....	.....	.....	.....
Sonneberg Mining Company	.....	136,000	66,000	2,400
Queen Bee Mining Company	.....	17,000	7,600	.....
Harrelson Lead and Zinc Company	.....	.....	.....	.....
Battlefield Mining Company	.....	423,845	41,270	52,000
J. M. Cooper Mining Company	.....	120,000	.....	.....
B. Cooley	.....	.....	.....	.....
Neutral lots	.....	.....	123,380	.....
Log Cabin Mining Company	.....	.....	.....	.....
Totals	2,737,100	2,335,580	1,261,770	188,560

Sales aggregated, total value, $16,244.

SHIPMENTS.

"Gulf" railroad: Zinc, cars, 2; gravel, cars, 43.
"Frisco" railroad: Lead, cars, 3; zinc, cars, 27; gravel, cars, 14.

LEAD ORE TURN-IN.

"This week was one of the biggest in Galena this year in the production and sale of zinc ore. The price was the same as the week before, viz.: $18 for crushed ore and $20 for free ore. Lead is not any higher, but there is a very ready market. The sale of manufactured lead never was bigger than it has been this season, and, on this account, the price of lead is likely to rise in the near future."

An examination of these weekly returns shows great variations in the amounts of ore raised. These are illustrated by the figures for three weeks, including the greatest and the least, in 1892:

Week ending—	*Zinc ore, pounds.*	*Lead ore, pounds.*
January 16	540,000	29,330
January 23	80,080	12,890
November 5	1,495,780	268,580

One cause of the variation shown is the fact that the returns are made from sales, which vary somewhat with the market price, some owners holding their stocks occasionally for better prices. Another cause is actual variation of output, which is usually diminished when the spring rains flood many of the mines, or severe winter weather interferes with the outdoor work. The ratio of lead and zinc is also fluctuating, lead sometimes being more than half the zinc; at others, less than one-eighteenth.

The totals for the years last past will show how this mining industry has grown, and something of its fluctuations:

Year.	*Authority.*	*Zinc ore, pounds.*	*Lead ore, pounds.*
1878	Professor Mudge's estimate	.....	6,000,000
1890	C. T. Dana	43,350,888	8,347,927
1891	C. T. Dana	41,283,551	7,204,420
1892	C. T. Dana	47,623,778	14,376,340

Total values for 1892: Zinc ore, $437,236; lead ore, $301,908; gravel, $13,000.

While individual ventures are often made at a loss, the operations of a company, covering five or ten acres or more, are almost always remunerative. The South Side Mining and Manufacturing Company owns 80 acres of the old lands and some

more in the new. Originally established in 1877, with a name only slightly differing from its present designation, it had a capital of $4,000. The change of name was made in 1881, and the capital made up to $500,000, on which it pays good dividends. One of the newer companies, only two years old, is making regular dividends of over $2,500 per month on a capital invested probably not exceeding three months' dividends. The following extract from a Missouri paper refers to some of the newer Kansas mining camps, though the word "district" means the Kansas-Missouri mining region: " . . . Central and Crystal lands present the liveliest appearance of any camp in the district. New prospects are starting up and new strikes being made almost every day."

Present indications are that the more extensive Missouri mining region will begin to be considered an adjunct to the more fruitful Galena district.

SMELTING.

From 1879 to May, 1891, the South Side Mining Company smelted its own lead ore; but it pays best to send the lead ore to the lead-smelting centers — Galena, Ill., St. Louis, etc.— and since the latter date all lead ore is sent out of the State for that purpose. This is not the case with zinc. The proximity of coal, at Scammonville, Weir City, and Pittsburg, has led to the establishment of zinc smelters at those places. It takes between two and three tons of coal to smelt one ton of zinc ore; therefore, the ore is taken to the coal. The first zinc smelter was established at Weir City in 1873. The company is now known as the Weir City Zinc Company. For smelting, the furnaces are built in pairs. Each pair is called a *block*. The progress of the zinc-smelting industry has more than kept pace with the progress of zinc mining in Kansas. Much of the zinc ore of Missouri comes to Kansas to be made into metallic zinc. The progress of one or two smelting companies and the dates of the establishment of others will show the large and steady increase of the zinc-smelting industry.

The Weir City Company had four furnaces in 1873; added four in 1883; two in 1889; and two in 1891.

This company has, also, works of the same size at Pittsburg, having added the last two furnaces in October, 1892. Robert Lanyon & Co. were the first to establish at Pittsburg. Their furnaces began as follows: Two furnaces in 1878; two in 1879; four in 1881; and two in 1889.

The zinc smelters now in Kansas are as follows:

1. Weir City Zinc Company, at Weir City, 12 furnaces; established 1873.
2. Weir City Zinc Company, at Pittsburg, 12 furnaces; established 1885.
3. Robert Lanyon & Co., Pittsburg, 10 furnaces; established 1877.
4. W. & J. Lanyon, Pittsburg, six furnaces; established 1882.
5. S. H. Lanyon & Bro., Pittsburg, six furnaces; established 1880.
6. Pittsburg and St. Louis Zinc and Land Company, Pittsburg, eight furnaces; established 1891.
7. Granby Mining and Smelting Company, Pittsburg, eight furnaces; established 1881.
8. Girard Zinc Company, Girard, four furnaces; established 1890.
9. Scammon Zinc Company, Scammon, four furnaces; established 1890.
10. American Spelter Company, Galena, six furnaces; established 1892.

Total, 76 furnaces.

It will be noted that seven of these zinc works are in the coal region of southeast Crawford county, the Girard works being some miles east by south of that city. The others are in Cherokee county. The one last named in the list is an exception to the rule that the ore is brought to the coal. The reason is that the American Spelter

Company have built their furnaces on a more compact plan, and the heat is supplied by coal gas. It is claimed that this method saves 50 per cent. of the coal used, and that there is a further saving of 30 per cent. in the labor required to produce a given

Zinc furnaces, Pittsburg.

quantity of *spelter*, which is the word used in the market to designate the metallic output of the furnaces. The spelter works at Galena, under these conditions, are not therefore worse situate than those on the coal-field to the north. The use of gas in zinc smelting is, however, not yet fully established, though it is in use at La Salle and Peru, in Illinois, and at Carondelet, in Missouri. At Marion, Ind., natural gas is used for the purpose. The Granby works, at Pittsburg (No. 7 in the list), have been shut down since the beginning of September, while experiments are made on modified furnaces, in which gas is to be used.

The processes that extract the bright metal from the ore may be briefly described. The brown, gravel-looking ore which left the jiggers, as previously described, is dried, and then subjected to "*roasting*" or *calcining* in a furnace of a peculiar construction, which eliminates from it a large proportion of the sulphur, which escapes up the smoke-stack in fumes of sulphuric acid, which is not friendly to the vegetation to leeward. The roasted ore is then mixed with a certain proportion of coke, which is previously broken to a fineness nearly the same as that of the ore. It then goes to the smelting furnace. This consists of several rows of cylindrical *retorts*, about 4 feet long and 11 inches external diameter, made of fire-clay, which lie in horizontal rows, one above another, and resting in the walls of fire-brick, and so arranged that the supplied heat gets all around them. The open ends of the retorts are outward, and fitting into each is a hollow truncated cone of smaller dimensions, called a *condenser*, also made of fire-clay. The narrow ends of the cones are outward, and present to view glowing rows of greenish flames. The closed ends of the retorts at the back of the furnace are separated only by a wall of fire-brick from the back of the next furnace, which faces in the opposite direction, the two forming a *block*. The retorts, charged with the mixture of ore and coke, are subjected to furnace heat so intense that the *charge* is *vaporized*. The vapors passing into the condensers, where a lower temperature prevails, the vapor of zinc condenses into the molten metal; which being drawn off, with some ashes which float on its surface and are readily skimmed off, the white metal is poured into iron molds not more than an inch deep, and, when cold, plates of spelter are removed weighing from 42 to 50 pounds each, and bearing from the impression at the bottom of the mold the brand of the company. The Weir City Company's brand is the word "Cherokee"; the Granby

Company has the single word "Granby," and the Scammon Company the word "Scammon." All the other companies have for brand the full name of the firm. Besides this, the American Company has the device of an *eagle*.

Every company makes its own coke, and the retorts and condensers are all made on the premises. The fire-clay comes from the neighborhood of St. Louis, though some experiments on Kansas clays are in progress, and, for condensers, so far with some degree of success, but smelters are chary of using untried material in retorts, as the bursting of one of them involves considerable expense. The wages of the head man at a furnace are about $2.40 per day, while his assistant gets $1.75. These men get a small premium, graded on the amount of spelter produced, which acts as a hindrance to waste. Other men about the works have wages ranging down to $1.25 per day for the least skilled labor.

There is ever some improvement taking place in the smelting business, the newer furnaces producing a little larger amount of spelter with the same or less expenditure of labor and fuel. But the general average of the daily production is not greatly different in any of the works when all the *blocks* are taken together. The larger works have a little advantage in the matter of unskilled labor, as it does not take more than five times as much of such labor to run six blocks of furnaces as to run one block. In 1891, one of the Lanyon firms produced, from six furnaces 5,026,000 pounds of spelter, from 12,060,000 pounds of ore, by using 19,000 tons of coal. This gives an average of about 2,100 pounds of spelter for each furnace per day, and though some furnaces produce at times as high as 2,700 pounds per day for weeks together, as I saw by records shown me of the daily runs at some of the works, yet, taking into account fluctuations in the quality of ore, and occasional stoppages for repairs, it is probable that the amount does not greatly exceed the average given above. Taking into account some improvements in all works, and calling the average 2,250 pounds, and deducting for the temporary shut down at the Granby, and for the time new furnaces have not been at work this year, we may reckon that 65 furnaces have been in full blast all the 366 days of 1892 — for these furnaces never stop but for repairs — which have produced an aggregate for the year of *54,000,000 pounds of spelter* or metallic zinc. The value of this product is not less than $2,000,000. This is 27,000 tons, which represents fully 65,000 tons of washed ore, of which a little less than one-half is raised in Kansas, the rest coming from Missouri. About one-third of the Kansas ore is used by the Weir City Company. The rest is distributed among other firms, but the St. Louis and one or two other companies use no Kansas ore. Silicate of zinc requires a special form of furnace for calcining (roasting) it. Robert Lanyon & Co. use about five tons of this ore daily, and the Weir City and the St. Louis companies are also provided with the special furnace. As, however, the silicate is more useful in the manufacture of the oxide for paint, it is not likely that its use for making spelter will increase. The average number of men employed to a block of furnaces is about 30, so that the zinc-smelting industry employs in Kansas nearly 1,200 people directly, besides the indirect employment of colliers, railway employés, and the army employed in Kansas and Missouri digging, crushing and washing the ore.

The finished product, spelter — metallic zinc — is found, on analysis, as might be expected from the association of the ores, to contain a very small per centum of lead and a still smaller trace of silver. It is probably as pure a product as any of the non-precious metals ever gets to be. It is sent to Philadelphia, Pittsburg, New York and other places, to take a very important part in the arts of life. What we see as sheet zinc — the spelter plates rolled thin — used under and about our stoves, shows but a small part of its utility. It is used as an alloy of other metals. It

forms one-third of the weight of ordinary brass, and is one per cent. in composition of the bronze used in coinage. Salts of zinc have been used in medicine, and it is frequently used as a substitute for lead, both as a metal and as a paint. Probably, however, its most extensive use is to coat iron ware—buckets, pipes, wire, pans, tanks, etc.—to preserve it from rust. The coating is done by electricity, and we know the product as galvanized iron. To all these uses the ores and smelters of Kansas contribute a large share.

SILVER SMELTING.

We have noted that much zinc ore from Missouri is brought to Kansas to be smelted. We will briefly note here that this is true to some extent of silver ores. Though all excitements about the discovery of silver ore in the State have been without foundation, it pays to bring ores from Colorado to eastern Kansas where coal is cheaper. Pittsburg, in Crawford county, besides being the headquarters of zinc smelting, has the works of the "*Chick Short-Method Gold and Silver Refining Company*," which, established in 1891, is dealing by a new process with the ores of the precious metals. Argentine, in Wyandotte county, has two plants engaged in similar work, of which one has already produced from the ores reduced 9,600,000 ounces of silver. The people of Kansas City speak of this as the silver suburb.

COAL.

There has been some coal mined in Kansas from the early days of settlement. Seams outcrop in Cherokee, Crawford, Bourbon, Linn, Neosho and Labette counties, and these outcrops have been worked by drifts into the hillside and in places by "stripping" off superincumbent earths, and even limestone, when the thickness has not exceeded a few feet. We have already noted that the coal in the counties above named is near the bottom of the coal measures. At Leavenworth three shafts have been sunk to a depth of 720 feet, which get coal 22 inches thick, also near the bottom of the coal measures. More recently a shaft has been sunk 2½ miles west of the State shaft, at Lansing, which reaches the coal at a depth of 811 feet.

In the report of 14 years ago, Professor Mudge mentioned one shaft at Leavenworth—all there was then—and he gives statistics of the quantities of coal shipped on the railway from Leavenworth, and also the quantities shipped on the Fort Scott & Gulf road from the coal districts of the eastern tier of counties, from Linn south. Of the beds in the upper coal measures—Osage county—the Professor gives no statistics, though he describes the coal area and its proximity to the railway.

Professor Mudge says: "The thickest and best seam of coal in Kansas is the Cherokee bed, found in Cherokee, Crawford and Labette counties. It extends from the Indian Territory, entering the state near Chetopa, and runs across the southeast part of Labette county, the west and northwest parts of Cherokee, and southeast part of Crawford, and enters Missouri." This description of position is practically correct to-day, though on *part* of this area it was another seam that was probably known at that time. On the eastern edge of this line there is, however, only the one seam that is worked. Its workable area has largely been increased within the limits formerly known. At a few miles north of Columbus the coal mining region begins, and we have a series of mining towns—Scammon, Weir City, Cherokee, Fleming, Frontenac, Pittsburg, Arcadia, Minden—around which the coal seam, whose average thickness is over 40 inches, is worked. In the northeastern part it is worked in "strip" banks and drifts; in the southern part by shafts, the deepest of which is 140 feet. In part of the district there is a workable seam above this. The widest part of this area is said to be eight miles, but it is not more than about four on the average. Recently Mr. John Marchant reports having made a

"*prospect*" drill hole 1¼ miles east of the railway station at Scammon, and found coal 33 inches thick. This would extend the width of the field at that place more than a mile, as Scammon has been considered on the east edge of the field. W. E. Turkington, Esq., manager of the Western Prospecting Company, supplies the following drill record, which, some little distance west from Cherokee, gives the succession of strata, which may be considered about an average statement for the middle of this coal region:

STRATA.	*Thickness of strata.*	*Depth.*	STRATA.	*Thickness of strata.*	*Depth.*
	FT. IN.	FT. IN.		FT. IN.	FT. IN.
1. Soil and clay	.....	16 6	17. Fire-clay, soft	1 4	74 10
2. Coal	1 4	17 10	18. Gray shale	14 8	89 6
3. Fire-clay	8	18 6	19. Drab shale	3 8	93 2
4. Gray shale	3 6	22 0	20. Coal	1 0	94 2
5. Conglomerate limestone	4 0	26 0	21. Fire-clay	1 6	95 8
6. Gray shale	2 6	28 6	22. Gray shale	20 4	116 0
7. Black shale	10 1	38 7	23. Drab shale	12 0	128 0
8. Coal	1 1	39 8	24. Black shale	4 6	132 6
9. Fire-clay	1 4	41 0	25. Coal	9	133 3
10. Gray shale, soft	6 0	47 0	26. Gray shale, hard (good roof)	20 3	153 6
11. Drab shale	4 9	51 9	27. Coal (the *main*)	3 4	156 10
12. Limestone	4 3	56 0	28. Soft, bituminous clay	1 8	158 6
13. Fire-clay	1 4	57 4	29. Coal	4	158 10
14. Gray shale	6 0	63 4	30. Fire-clay	2 0	160 10
15. Black shale (good roof)	8 0	71 4	Drill stopped in the clay.		
16. Coal	2 2	73 6			

The foregoing, which is a prospect hole made with a diamond drill, may be compared with the following, which is the record of the *shaft* of Cherokee Coal Mining Company, *at* Cherokee, but over the line in Cherokee county:

STRATA PASSED THROUGH.	*Thickness of strata.*	*Depth.*	STRATA PASSED THROUGH.	*Thickness of strata.*	*Depth.*
	FT. IN.	FT. IN.		FT. IN.	FT. IN.
1. Soil and clay	12 0	12 0	11. Soapstone	10 0	57 5
2. Soapstone	5 0	17 0	12. Black slate	6 0	63 5
3. Coal	1 3	18 3	13. Coal	10	64 3
4. Black shale	10 0	28 3	14. Fire-clay	4 0	68 3
5. Black sulphur rock	1 0	29 3	15. Sandstone rock	9 0	77 3
6. Coal	2 2	31 5	16. Black slate, bowlders near bottom	15 0	92 3
7. Fire-clay	3 0	34 5	17. Coal	8	92 11
8. Fire-clay and bowlders (concretions)	6 0	40 5	18. Bastard sandstone	20 0	112 11
9. Soapstone	6 0	46 5	19. Sandstone	15 0	127 11
10. Marble	1 0	47 5	20. Coal	3 0	130 11

No. 6 of this corresponds with No. 16 of the prospect record, and No. 20 to No. 29. The differences in depth are due mainly to the dip, but a little also to difference of surface levels. After allowing for the uncertainty of miners' terms, there is here also evidence of the change in the character of formations of the same horizons. Sandstones become hard shales (probably arenaceous), and *vice versa*, in a few miles. This change is less often seen in limestones which persist over large areas, but it is also common with the coal seams, which never persist in Kansas more than a few miles east and west, and though continuing further in the direction of south by west, which is the Spring river trend before mentioned, yet they also run out in that direction also. In the series of coal beds above the Cherokee-Crawford field—that of Fort Scott—we have an example in point. The coal at Fort Scott and neighborhood is known as Mound coal, for it crops near the top of the promontories and mounds that overlook the lower levels of the land towards Dry Wood creek and as far south as the northeast of Crawford county. The following is a typical section in the city of Fort Scott:

1. Fragment of the hard, rough layer, limestone, 2 to 10 feet. (This is the Pawnee limestone, which further west runs up to 60 feet thick.)
2. Black laminated slate (almost coal), 5 feet.
3. Yellowish and greenish clay shale, 4 feet.
4. The hydraulic limestone (the cement rock), 4 feet.
5. Clay with nodules, 6 inches to 1 foot.
6. Laminated coaly shale, 2 feet.
7. Coal, 18 inches to 2 feet.
8. Laminated yellow shale, 20 feet.

The black slate, No. 2 of this section, frequently gives about a foot of usable coal. The "cement rock," No. 4 of the section, is very persistent, and is a characteristic of the district topography. It thickens in places to six or seven feet. No. 7 is the Fort Scott coal. It is probably the coal worked just east of Girard, in Crawford county; but to the southwest, near McCune, and further still, in the bank of the Neosho above Oswego, while the cement is there, the coal is represented by a hard, black shale—slate, as the miners term it.

Coal is mined at La Cygne, Boicourt, and Pleasanton, in Linn county, which is probably about the horizon of the coal above the sandstone plateau of Bourbon county. It is 110 feet deep at La Cygne, 93 feet at Boicourt, and 90 feet at Pleasanton. There are differences in the coal and the accompanying shales that make it difficult exactly to correlate these beds.

As previously mentioned, the Osage county coal is in the upper coal measures, and the coal of Lyon, Shawnee and Coffey may be considered as of the same horizon, and that also in the Verdigris valley, further south. State Inspector Stewart says of this field: "The vein dips to the north and west, as usual throughout the coal measures of the state. It ranges from 12 inches thick, west of Topeka, until it reaches 22 inches at Scranton, gradually getting thinner, when it again gets to 11 or 12 inches thick at Lebo, in Coffey county. At Burlingame, where it is mined furthest to the northwest, the deepest shafts are situated, some of them being over 100 feet deep. It is mined from strippings, drifts, and shafts." It is probable that the coal in the north of Nemaha county is of this horizon.

The coal in Leavenworth county is, however, of the lowest coal measures. It is reached by the deepest coal shafts in the state. There are now five of these mines. In 1881, Mr. Oscar Lamm, manager of the shaft at the State Penitentiary, published the record of the strata passed through. We reprint it, in an abridged form. It is as follows:

STRATA PASSED THROUGH.	*Thickness of strata.*	*Depth.*	STRATA PASSED THROUGH.	*Thickness of strata.*	*Depth.*
	FT. IN.	FT. IN.		FT. IN.	FT. IN.
1. Surface clay, bowlders, etc....	35 5	35 5	22. Shale, gray, etc.....	18 4	268 4
2. Limestone, gray.....	12 0	47 5	23. Limestone, gray.....	2 6	270 10
3. Shale, black.....	3 11	51 4	24. Shale, gray, etc.....	4 3	275 1
4. Limestone, blue.....	2 5	53 9	25. Limestone, dark gray.....	1 11	277 0
5. Soapstone, light drab.....	23 6	77 3	26. Shale, black, etc.....	5 10	282 10
6. Limestone, gray-dark.....	15 8	92 11	27. Limestone, light gray.....	1 7	284 5
7. Shale, green-gray, etc.....	23 0	115 11	28. Shale, gray, etc.....	1 6	285 11
8. Limestone, brown, etc.....	6 8	122 7	29. Limestone, gray, etc.....	21 0	306 11
9. Limestone, gray, etc.....	7 10	130 5	30. Limestone, black, etc.....	4 0	310 11
10. Soapstone, light drab.....	37 0	167 5	31. Shale, black, etc.....	10 1	321 0
11. Limestone, brown, etc.....	17 10	185 3	32. Limestone, gray.....	18 8	339 8
12. Shale, black, etc.....	11 8	196 11	33. Shale and limestone, drab, etc.	9 0	348 8
13. Limestone, gray-dark.....	4 10	201 9	34. Limestone, light gray, etc.....	12 3	360 11
14. Shale, gray-black.....	3 2	204 11	35. Shale, gray, etc.....	142 8	503 7
15. Limestone, brown.....	1 1	206 0	36. Limestone, brown.....	6	504 1
16. Shale, gray-purple.....	8 0	214 0	37. Shale, drab.....	7 10	511 11
17. Limestone, gray.....	6 5	220 5	38. Coal, black.....	2	512 1
18. Shale, green.....	1 6	221 11	39. Shale, drab.....	9 2	521 3
19. Limestone, gray.....	2 5	224 4	40. Limestone, light brown.....	5 0	526 3
20. Shale, gray, etc.....	15 6	239 10	41. Shale, black, etc.....	3 9	530 0
21. Limestone, drab.....	10 2	250 0	42. Limestone, gray.....	1 0	531 0

	STRATA PASSED THROUGH.	Thickness of strata.	Depth.		STRATA PASSED THROUGH.	Thickness of strata.	Depth.
		FT. IN.	FT. IN.			FT. IN.	FT. IN.
43.	Shale, black	1 0	532 0	64.	Fire-clay, drab	5 1	611 4
44.	Limestone, gray	3 2	535 2	65.	Limestone, light gray	3 3	614 7
45.	Shale, black, etc	7 5	542 7	66.	Shale, drab	2 3	616 10
46.	Limestone, light gray	3 5	546 0	67.	Limestone, light gray	1 10	618 8
47.	Shale, black	6	546 6	68.	Shale, drab	4	619 0
48.	Limestone, light gray	2 0	548 6	69.	Limestone, light gray	2 7	621 7
49.	Sandstone, brown-gray	8 3	556 9	70.	Shale, black	2 4	623 11
50.	Shale, black	12 0	568 9	71.	Fire-clay, dark	3 7	627 6
51.	Limestone, brown	3 3	572 0	72.	Shale, light, sandy	24 0	651 6
52.	Shale, black	2 6	574 6	73.	Shale, dark drab	8 0	659 6
53.	Coal	8	575 2	74.	Limestone, dark gray	6	660 0
54.	Fire-clay	6	575 8	75.	Shale, drab, etc	10 1	670 1
55.	Sandstone, gray	4 0	579 8	76.	Coal	10	670 11
56.	Shale, drab	2 2	581 10	77.	Fire-clay, drab	2	671 1
57.	Shale, bituminous	1 8	583 6	78.	Sandstone, black	6 0	677 1
58.	Shale, buff	1 9	585 3	79.	Slate, drab, etc	7 1	684 2
59.	Limestone, light gray	4 0	589 3	80.	Coal	2	684 4
60.	Shale, drab-purple	9 6	598 9	81.	Fire-clay and shale	1 4	685 8
61.	Limestone, light gray	2 2	600 11	82.	Shale, dark	3 0	688 8
62.	Shale, black	4 9	605 8	83.	Slate, drab and black	23 4	712 0
63.	Coal, black	7	606 3	84.	Coal	1 9	713 9

There has been a deep boring made at Leavenworth since the date of Mr. Lamm's record. It was a city *prospect well*. The drill reached the depth of 2,116 feet. Two seams of coal were penetrated below the horizon of the seam previously worked. One is only 25 feet below, but the other is nearly 270 lower. It is said to be two feet thick, and its bottom is 990 feet deep. There is black shale 200 feet below, and possibly that is the bottom of the coal measures.

One of the indications of the growth of the coal industry and the great extension of the known areas of workable coal is found in the fact that there has been now for six years a state inspector of coal mines. We have already quoted from reports of the present inspector, John T. Stewart, and we are indebted to him for the statistics we shall now use, those for 1891 being kindly furnished in advance of publication. Comparing with some information given by Professor Mudge, it will be seen how large now is the coal industry of the state.

Professor Mudge gave a total of 9,612 car-loads shipped on various lines of railway, but apparently including none from the Osage county field. If that field then raised its present proportion to the whole, the number would be raised to 11,500 cars. This is fully equal to 120,000 tons, or 3,000,000 bushels. As this, however, was only the railway shipment, it may be assumed, perhaps, that the product of Kansas coal reached 5,000,000 bushels in 1877. Let us see what it is more recently. The following statement by counties will show that several counties have each far exceeded the whole output of the earlier date:

COAL OUTPUT FOR 1891.

COUNTY.	Mines and drifts.	Strip banks.	Bushels of mined coal.	Bushels of stripped coal.	Total bushels.	Value.	No. of employés.
Bourbon	2d	70	.....	.....	500,000	$32,500	175
Cherokee	20	14	21,918,463	509,814	22,428,277	1,098,629	1,990
Crawford	18	30	23,184,785	1,261,779	24,446,564	1,155,912	2,230
Chautauqua	1d	.....	36,600	.....	36,600	3,294	6
Coffey	.....	29	.....	427,114	427,114	38,000	117
Franklin	14	20	554,500	283,500	838,000	71,907	196
Labette	.....	6	.....	61,000	61,000	5,500	26
Leavenworth	5	.....	7,479,406	.....	7,479,406	448,762	887
Linn	7	15	878,500	347,000	1,225,500	61,000	165
Lyon*	5	.....	85,200	.....	85,200	8,520	36
Osage	106	53	10,202,633	1,422,882	11,625,515	974,227	2,917
Shawnee*	5	2	159,692	44,119	203,811	24,400	60
Nemaha*	2	.....	54,300	.....	54,300	5,970	24
Totals	185	239	64,544,079	4,317,208	69,411,287	3,928,621	8,829

*Figures for 1890.

The number of mines varies as the areas of coal are worked out and new mines opened, and this is particularly true of the strip banks. These are almost invariably on the lower edge of a slope, and as they work into the hill the amount of earth or rock to be stripped becomes greater and passes the limit of economic work. Then the bank must be abandoned or work by drifts take its place. The thickness of superincumbent earth that can be economically "stripped" does not exceed 10 feet, and it is only in exceptionally favorable circumstances that stripping exceeds six feet.

The figures given above show the magnitude of the industry at the close of 1891. The increase is from year to year. The following will show the increase on the previous year for the counties named, and they are representative of the whole:

COUNTIES.	BUSHELS OF COAL.		*Increase.*	*Decrease.*
	1890.	*1891.*		
Cherokee	19,338,189	22,428,277	3,090,088	.....
Crawford	21,606,377	24,446,564	2,840,187	.....
Franklin	779,350	838,000	58,650	.....
Osage	11,715,550	11,625,515	.....	90,035
Leavenworth	6,676,070	7,479,406	803,336	.....
Totals	60,115,536	66,817,762	*6,702,226	.....

*Net increase.

The net increase on these counties is probably in the same proportion as in the other coal-fields, and it is highly probable that the output for 1892 will show a similar increase. It is therefore likely that the total output of coal for 1892, including the lignite, of which which we shall treat further on, will be not less than seventy-eight millions of bushels, or over THIRTY-ONE HUNDRED THOUSAND TONS.

The quality of Kansas coal has yet to be spoken of. Most of it is well up, for all the purposes for which bituminous coal is used. There is no anthracite, and there is no cannel coal. The coal of most of the fields makes good coke and some is good gas coal. The last fact is particularly true of that part of the southeastern field lying between Pittsburg and Weir City. Pittsburg and other places are being supplied from it with a good illuminant. Professor Mudge caused some experiments to be made at Girard, the result of which was to show that the coal used had only 7 per cent. of ash. More recently Professor Bailey has made a series of analyses of Kansas coals which were published in the transactions of the Kansas Academy of Science. Many samples were examined from most of the districts, and the following is a summary of the averages, with some from other States for comparison:

ANALYSES OF KANSAS COALS.

Name.	*Water.*	*Volatile.*	*Fixed carbon.*	*Ash.*
Cherokee	1.94	36.77	52.45	8.84
Cherokee (upper vein)	2.08	35.32	48.64	13.96
Fort Scott	2.94	41.76	47.55	7.75
Leavenworth county	2.69	39.21	47.41	10.69
Linn county	2.07	39.42	46.89	11.62
Osage county	6.76	41.59	40.86	10.79
Franklin county	7.55	44.40	37.68	10.37
Cloud county	13.70	46.14	28.52	11.64
Pittsburg, Pa.	1.31	36.61	54.17	7.91
Nebraska	4.93	38.17	49.44	7.46
Warren county, Mo.	6.75	36.40	45.75	11.10

LIGNITE.

The foregoing takes no account of the coal of north-central Kansas, except that the table of analyses has a line for Cloud county. It will be seen that that coal has a large percentage both of water and ash. We have already remarked that it is not coal of the coal-measures epoch. It is found in that series of cretaceous formations which we call the Dakota group. As a fuel, it is mostly an inferior material, but as it is more than 200 miles from the carboniferous coal-fields, and a still greater distance from the lignites of superior quality found in still higher horizons in Colorado and Wyoming, it is used locally to a considerable extent, and has a higher money value at the pit mouth than the better fuels of the more distant fields. There is a constant, through scarcely an increasing, supply of this lignite, as it is called, because of its more woody structure compared with the coal of the coal measures. The following table shows the output for 1890:

Counties.	*Bushels.*
Cloud	162,825
Ellsworth	125,970
Jewell	20,000
Lincoln	162,470
Mitchell	24,000
Republic	24,650
Russell	150,135
Total	670,040

There are some shafts, but most of the coal is obtained by drifts into hillsides, and these are worked mostly in the fall and winter months by the farmers of the vicinity. For about 40 per cent. of the working days of the year, the above output gives employment to over 300 men, who can earn 7 cents per bushel, which is a higher price than the selling value of the coal in the most of coal-measure districts. It may be that a new use will be found for this lignite as the sugar industry develops, as it can be made of service in some of the processes of puifying the cane syrup.

We have seen, then, that the getting of coal, including the lignite, in Kansas, employs over 9,000 persons, besides the army of those in other trades more or less directly dependent on the coal business, and also without reckoning the industries, such as smelting and iron founding, which consume coal in their various operations.

ROCK GAS.

Earlier writers had mentioned the small flows of natural gas at the drilled mineral wells of Iola, Independence, and Girard, as well as at one or two other places in the State, but the first general report on the subject of Kansas rock gas was made in 1886, in the Fifth Biennial Agricultural Report, after the towns of Paola and Fort Scott had become especially famous for its use. The gas at that time was in use in the following counties, though there were only two or three places where it was systematically managed. Not counting the small flows from the wells above mentioned, gas, in usable quantities, was obtained in Wyandotte, Miami, Linn, Bourbon and Labette counties. In the "Mineral Resources of the United States," for 1890, Dr. D. T. Day gives the production of rock gas in Kansas as the equivalent of 6,000 tons of coal. What it is worth now will appear as we proceed.

There have been fluctuations in the supply of gas in the places where it was first

used, and new localities have been added to the list of places using the new fuel. At Fort Scott, the wells have gradually diminished their yield and that city is no longer using natural gas. The wells formerly described as supplying the city of Paola were situated 7½ miles east of that city, and all of them have so diminished their supply as to become practically worthless, and the pipe lines conveying the gas to the city have been taken up. But Paola has not given up the use of gas. Upwards of 60 borings have been made in and about the city, and six wells are now supplying gas at a higher pressure and with more volume than the old wells to the east. The highest pressure is 125 pounds to the square inch, and the average of the six wells reaches 110 pounds. There are also a few wells used by private parties at a similar pressure. One of these, at the water-works, has a rock pressure of 145 pounds; supplies gas jets under the boilers of the pumping engines. Doing this work, it is the equivalent of coal to the value of $800 per annum. The temperature of the gas at the mouth of one of the city wells (No. 2) was 63 degrees Fahrenheit. This well has the principal supply of gas, in a fine white sand, at from 275 to 286 feet deep. This is practically the same in the other wells. Some of the wells are dry, but most of them give some salt water at various depths. The firm having the city franchise is the Paola Oil, Gas and Mining Company, and it supplies most of the heating and many of the kitchen stoves in the city.

The Paola city wells are better than those formerly used, mainly because, being further west, they are further from the outcrop of the gas sands.

Osawatomie, still further west, though also south, as might be expected, has still stronger flows of gas. W. M. Mills, who practically constitutes the company which has drilled the wells at this place, under the firm-name of the Pennsylvania Gas and Mining Company, has eight wells from which gas is taken, and one or two not productive. The first was bored in 1886. Now 300 stoves in this thriving railway town are being supplied, and the Welshbaugh incandescent lamp is making the gas into a powerful illuminant. I was present at the testing of one well (No. 10), which showed a rock pressure of 180 pounds. Its temperature was 57½ degrees Fahrenheit. The highest pressure is 250 pounds, and that of the lightest well 160 pounds to the square inch. The State Insane Asylum is supplied with the gas, and so saves the cost of freight on its otherwise large supply of coal. The variableness of coal-measure strata is illustrated by the different depths at which gas is obtained at Osawatomie. The principal flows in well No. 1 are at 324 and 424 feet. In well No. 8 the main gas is 685 feet, and in well No. 9 it is 686 feet deep. This is the well of highest pressure.

Iola is now one of the gas towns. There are now five wells supplying gas to this city, and the pressure of No. 4—the strongest—is said to be 280 pounds.

Humboldt also has a successful gas well. For a time it supplied one of the two boilers of the steam flour mill which manufactured 700 barrels per day. In this case, the gas was the equivalent of about 2,000 tons of coal per annum. The mill has unfortunately not been rebuilt since a disastrous fire, and the gas is used in the restaurants, banks and houses of the town. A second well at Humboldt had an uncontrollable flow of brine which rendered the gas useless.

Chanute and Independence have recently made borings for gas, and at the latter place the result only partially reached, yet it seems likely to be an important success. The old flow at Mound Valley is also now being utilized, and that at Kansas City is still of service.

The largest developments of gas, however, are at the two important railway towns of Montgomery county—Cherry Vale and Coffeyville.

At Cherry Vale the management of the gas is very systematic, and I was able to see the testing of several of the wells, with the following results:

Well.	*Volume in cubic feet per minute by anemometer.*	*Rock pressure.*	*Temperature, Fah.*	*Depth.*
No. 1.....	990 cubic feet per minute	213	60°	609 feet.
No. 2.....	2,350 cubic feet per minute...	175	58°	610 "
No. 4.....	2,500 cubic feet per minute....	.....	58°	.....
No. 6.....	3,780 cubic feet per minute....	225	55°	593 feet.

No. 2 had gas sands at 200 and 300 feet deep.

The *flowing* pressure at No. 2 was 150 pounds, but the pressure at the receiver, where all the wells are brought together, was 185 pounds. A return made by Mr. J. H. Butler, the secretary of the gas company, gives 4¾ millions as the highest number of cubic feet per day from the strongest well—No. 6.—which is somewhat less than that indicated in the figures above. There are nine wells now available for use, and the average pressure is given at 240 pounds. The amount being used in the fall of 1892 did not exceed 3½ millions of cubic feet per day, which indicates a great reserve for winter use and future expansion of the business, without the boring of additional wells. It is estimated that over 2,500 tons of coal per annum are displaced by the rock gas of Cherry Vale.

When I visited Coffeyville in August last, the laying of pipe lines was in full progress, and the work at the wells was in an unfinished state, so that it was not possible to test rock pressure without endangering the stability of casings, etc. It was manifest, however, and was freely admitted by persons interested in the gas of Cherry Vale and Osawatomie, that the flow of several of the Coffeyville wells was stronger than anywhere else in Kansas. The force of the escape reminds one of the heavy gas wells in Ohio, and the pressure cannot be less than 300 pounds. W. P. Brown, the secretary of the gas company, at a late date, reports the arrangements still incomplete, but that five wells are already yielding gas, and that it is contemplated to have 10 wells for the purpose, and gas will be used in quantity before this is published.

Borings are being made at Fredonia and Neodesha, and it is quite probable they may find gas, and, as has already been mentioned, it is not impossible that it should be found in usable quantities in Wilson, Greenwood and Chautauqua counties.

We estimate that the coal displaced in the towns now using gas, viz., Cherry Vale, Osawatomie, Paola, Iola, and Humboldt, is not less than 10,000 tons per annum, and Coffeyville will increase this by fully 3,000, which, with the smaller flows at Mound Valley, Kansas City, and Louisburg, will raise the total to nearly the equivalent of 15,000 tons. The value of this varies with the distance of the city using gas from the coal fields, but the cleanliness of its use gives it a hold on the user which coal does not obtain.

The rock gas is used for all domestic purposes, including illumination, for the heating of steam boilers of various kinds of manufactories, and at Coffeyville, Osawatomie and in Wyandotte county it has been successfully used for burning brick.

SALT.

Two years ago and four years ago, in the sixth and seventh biennial reports of this Board, the present writer gave full accounts of the discovery of rock salt and the development of the salt industry of the State. This account will be briefer. Professor Mudge, in 1866, and again in 1878, called attention to the salt marshes,

salt springs and salt lands of the State, describing, in detail, the Tuthill marsh, in Republic county, and the method of making salt there used at that time. This method was singularly like that described by Marco Polo as in use in Cathay six centuries ago, though it is highly improbable that Marco Polo and Mr. Tuthill had ever heard of each other. In 1882, Prof. O. St. John referred to the same things, and spoke of brines to be obtained in wells in the eastern part of the State. Both these writers expressed the view, which was then a common expectation in the State, that the salt springs, marshes and wells described by them would be an important source of wealth to the State as population increased and the Western demand for salt was augmented. Professor St. John gave an analysis of the salt obtained by the National Solar Salt Company, by solar evaporation, near Solomon City. It is noteworthy that that company, established in 1867, is the only one which has, from brines comparatively near the surface and far removed from being saturated solutions, kept on manufacturing salt. In the years preceding 1888 it was the sole reason that Kansas was placed in the list of the salt-producing States of the Union. Probably the stronger brines of Michigan, with its denser population and more abundant capital, were the main reasons why the surface salines of Kansas failed to be developed to an industry. In my report of 1890, I. quoted Professor Mudge's first description of the Tuthill marsh, and I described the "Big Marsh," which stretches from near the northwest corner of Cloud county into Republic and Jewell. Other marshes were also noted, but a large one south of the great bend of the Arkansas river, in Stafford county, though referred to both by Mudge and St. John, has so far received no adequate description.

I will briefly state the main points noted in a recent visit made to it, and to a smaller one to the south of it. This large marsh is in town 21, range 11 west of the sixth principal meridian, and occupies parts of sections 21, 22, 27, 28, 29, 32, and 33; so that Professor Mudge's statement that it occupied 2,000 acres is well within bounds, though the actual marsh *now* is probably under a thousand acres, as the encroachments of sand from neighboring dunes, of soil from ploughed land, and of humus made by marsh plants, have largely restricted the saline area. This marsh is unlike those in the northern counties: no creek runs through it. It is an inclosed basin without outlet. The rim of the basin is almost entirely sand hills. Some but recently have been bare dunes, but now have thin vegetation, and most are covered by herbage whose roots have now matted into a sod. There is a timber claim on the south side of the marsh, and good farms in the sand hills further away. A circumstance worth noting is, that in the fall this marsh becomes a large shallow lake, where water fowl do congregate. The water rises out of the marsh slowly. It is clear and brackish. It is not the result of *recent* rains. It is there in the dryest year. It is probably the result of underground percolation of the rainfall of the previous spring, and it is not impossible that it may be connected with the *underflow* of the Arkansas valley. At the time of my visit, in September last, several hundred acres were covered with water, and it was still rising. The general direction of the marsh is from northwest to southeast, and its widest parts are about a mile across. The efflorescence, covering scores of acres, was not decidedly white, but was sufficiently saline. Digging a hole over a foot in depth near the edge of the water, the salometer showed the brine, which had a temperature of 76 degrees Fahrenheit, to have a strength of 20 degrees, which of course is less than would be indicated by reducing the temperature to the standard of 60 degrees Fahrenheit. The rising water would also certainly render the brine weaker than if a hole were digged in the dry marsh. Professor Mudge gave the brine strength as 8.8 Baume, equivalent to 34 of the usual salometer, with the temperature at 60 degrees Fahrenheit.

There is another small marsh in this district, south by east from the one above described. It is on both sides of the line separating townships 22 and 23, in range 11 west. It occupies parts of sections 35 and 36 of township 22, and of 1 and 2 of township 23. It had a greater proportional part of its area covered by water, and it always has some water, though at this season it rises as in the larger marsh. It is an inclosed, undrained basin, but the sand-hill topography on all its borders is much modified. As I saw it, there was very slight efflorescence, and the water was scarcely to be recognized as brackish. Rattlesnake creek, coming from Edwards county across Stafford to Reno, passes between these marshes. Its waters absorb salt, and its taste becomes brackish, but it does not drain either of the marshes.

These two marshes we have thus noticed because of their difference from all the others as to drainage. We, however, note of all the 12 marshes of the State—and we have visited all—that they are, since settlement, greatly reduced in area, principally by the dust driven from ploughed lands and from the aid of grasses and marsh plants. It appears, too, that the brine of these marshes is decreasing in strength, though this is less certain, as the tests made at distant times have not been made under the same circumstances.

It is likely that the salt marshes of Kansas will, in the years to come, be of less importance than now. We will, therefore, give them a final enumeration.

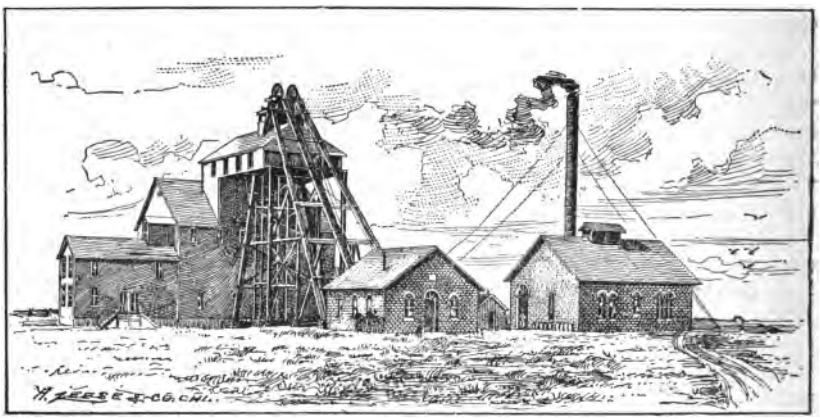
1. Geuda Springs, on the line of Cowley and Sumner counties.
2. Some miles northwest from No. 1, Sumner county.
3. Great marsh in northeast of Stafford county.
4. Little marsh, south by east from No. 3, Stafford county.
5. On Rattlesnake creek, Lincoln county.
6. Some miles southeast of No. 5, Lincoln county.
7. Great marsh on Salt creek, Mitchell county.
8. Smaller marsh on Salt creek, north by west of No. 7, Mitchell county.
9. On Plum creek, four miles northeast of Beloit.
10. On Big Marsh creek, in Cloud, Republic and Jewell counties.
11. On Little Marsh creek, in northwest Cloud county.
12. The Tuthill marsh, in southeast Republic county.

To these 12 marshes should be added, as surface sources of natural brines, the salt pool in Meade county, 130 feet across, opened by a falling in of the prairie in 1878; the Waconda, or Great Spirit spring, near Cawker City, which is a natural artesian pool of saline water 60 feet across; and there is a saline area in Wilson county. Some salt licks in Leavenworth county give name to Salt creek.

Wells in Miami county have yielded brine, and borings in every eastern county, from Geary and Wabaunsee to Wyandotte, and from Brown to Labette, have given strong salt water. Brine from a gas well at Coffeyville had a strength of 28° in the salometer, and that from a well at Paola had a strength of 36°, while some tested at Iola only showed 20°. Deep borings (1,000 feet) at St. Mary's and Wamego seem to have pierced three or four feet of *rock salt*, and recently the drill at La Cygne appears to have perforated 80 feet of that mineral, which, from its propinquity to the coal fields, may probably be worked to advantage.

It is, however, near the 98th meridian that the rock salt has been discovered in such masses that an important industry has been created since 1887, which employs many hundreds of persons and produces now over a million barrels per annum. Not marshes or surface pools, but thick beds of solid rock, from 450 feet to 1,300 feet below the surface, are the sources from which Kansas is to supply the salt demand of western America. Hutchinson, in the Arkansas valley, where the salt is reached at least depth from the surface, is the leader of the salt industry in Kansas.

Its product goes all over the West. We have seen Hutchinson salt in Mexico. Other salt towns are Anthony, Wellington, Nickerson, Sterling, Great Bend, and Kingman. These all have holes bored down to the bottom of the belts of salt, into which water is poured, and pumped up almost immediately a saturated solution — marking on the salometer from 95° to 100°. By the usual processes of boiling and evaporation the salt is obtained, of a high degree of purity — 97 to 99 per cent. on analysis.



Kanopolis Salt Works.

But, besides this, the rock salt has been reached by shafts and is mined in its solid state at Kingman, Kanopolis, and Lyons. There are two mines at Kingman, two at Lyons, and one at Kanopolis. All the mines, except the first at Kingman, have their shafts to the bottom of the salt, a little over 1,000 feet, and are working thick veins there and will operate upwards. The exceptional mine at Kingman went to the middle of the salt measures and began operations on a vein eight feet thick at a depth of 800 feet. Veins in other mines being worked are 8, 10 and 18 feet thick. The salt is practically much thicker than this. The division into veins is by thin layers of shale, from one or two feet or a few inches to the fraction of an inch in thickness. These seams of shale divide the salt conveniently into workable beds, giving an even floor or roof to the mine. The salt measures have an average thickness of 300 feet, and in no place yet tested is the workable solid salt less than half the thickness of the measures, except at Wellington, where, being near the outcrop, most of the salt is leached away.

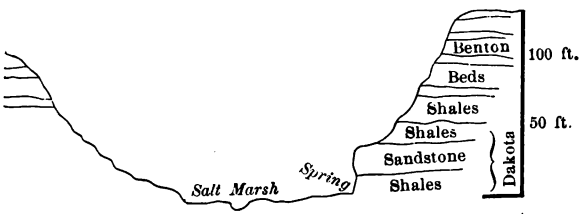
Borings have proved the existence of the salt at Caldwell, Rago, Pratt, and Wilson. A re-study of the drill record of the hole bored 10 years ago at Russell leads to the belief that it is highly probable the salt would have been found there at a little greater depth than was reached. But it is not necessary to try to extend the area of the known salt deposits, especially as the depth at which they will be reached will be deeper as we go west and south. The area from the south line of the State to north of the Smoky river, from 20 to 50 miles wide, under half of which it is safe to assume that salt exists from 50 to 150 feet thick, suggests a supply so enormous that there is no need for extension. A single acre of salt 100 feet thick would yield 2,178,000 barrels. Six acres would supply the whole consumption in the *United*

States for a year. There are fully 1,000,000 acres in Kansas. This would supply the entire world for centuries to come.

The development of the salt manufacture in Kansas has already caught up with the demand. The production for 1891 was 1,100,000 barrels. In 1892 it will exceed that amount. There is a lull in the operations now, and the price is low. The works and the salt are there, ever ready to keep pace with the growing demands of the West.

In the mine, Kanopolis.

The geology of Kansas salt is interesting. We will state it briefly. The brines of the wells and borings in eastern Kansas are from porous rocks—both sandstones and limestones—of the coal measures, and, as already mentioned, one or two beds of rock salt are believed to be there. The two salt marshes at and near Geuda Springs have their salt apparently from the old leachings of the salt measures which, near there, have their outcrop, the marshes themselves being in the highest beds of the Permo-carboniferous and near deposits of gypsum, in exactly the same horizon as the brines of Solomon City. The great beds of salt rock are in a series of gray beds we have called the salt measures, that lie conformably upon the top of the lighter Permian. The "*red-beds*" which cover these, and which are pierced at every salt town except Wellington, which is on the outcrop of the salt measures, contain beds and seams of gypsum with little salt. The salt marshes of Stafford county are in the highest horizon of these "red-beds," which some years ago we inclined to rank as triassic, but now think are probably of Permian age. It may be, however, that the salt of these marshes is derived from the debris of the succeeding Dakota formations, which probably once covered the region, and show now in strong force in the north of Barton county. The rest of the marshes (5 to 12 in the list) have their salt from the shales of the upper part of the Dakota, nearly coincident with the lignitic horizon of Cloud, Lincoln and Russell counties. This is some 50 or 60 feet below the lower Benton limestones. The salt pool in Meade county is probably in the same horizon, and this is also true of the Great Spirit spring, in Mitchell county. The guide to this is the fact that limestones of the lower Benton, and at greater elevations than the pools, are in neither case far away. In Nebraska there are salt marshes about the middle of the Dakota formations. The upper cretaceous and tertiary beds of the West have no salt. The saline mineral waters at Oberlin and Richfield are artesian flows that come from the Dakotas or the red-



Section on a branch of Salt creek, Mitchell county, Kansas.

beds. The artesian flows at Great Bend and Larned are from the bottom of the red-beds or in the salt measures.

GYPSUM.

It has already been shown that there are beds of massive, saccharoidal gypsum in the Permo-carboniferous formations, and also at the top of the Fort Riley section. Again, there is the heavy deposit of the Gypsum Hills, in Barber county, near the top of the red-beds. Manufactories of various kinds of plasters of which gypsum is the base have been begun in each of these gypsum fields. The oldest of these industries is that at Blue Rapids, near where the gypsum crops out on the banks of both the Big and Little Blue rivers. This outcrop is in what we have called the Manhattan beds. The gypsum is about nine feet thick. It is handled by the Blue Rapids Plaster Company, established in 1877, which, however, was the successor of a much older company. The product of this company is gradually increasing in quantity, and it is believed that it is now of a high, stable quality. The following figures show the increase: 1889, 20,000 barrels of plaster of Paris; 1891, 25,000 barrels; 1892, 30,000 barrels. These works can produce 275 barrels per day of 24 hours.

The gypsum has recently been proven to exist within the city limits of Blue Rapids, and a shaft has been sunk to obtain it by mining. Before this is through the press, it is probable that the manufactured product will be on the market from this mine. There is an outcrop of gypsum about the same horizon and about the same thickness, extending for 10 or 15 rods, on the west bank of Soldier creek, in the northwest of Jackson county. It is too far, however, from railroad facilities to be utilized just yet. There are indications in the debris of a valley in northern Brown county that massive gypsum exists there also. It will be at an horizon well within the coal measures, but its exact position not being known, it cannot be said whether it has economic value or not. The horizon at the top of the Fort Riley section is utilized for the manufacture of plaster in Saline and Dickinson counties, on the first high land south of the Smoky Hill bottom, and on the east side of Gypsum creek. At Hope, which is at the eastern extremity of the gypsum belt, the Hope Stucco Works are making several varieties of plaster product, at the rate of 20 tons in a day of 10 hours. They make a brown stucco, which they name "Granite Wall Plaster," and they have a white plaster of Paris, for finish work, which is known as the "Hope Challenge Plaster." These products are shipped to Chicago, St. Louis and other points of Missouri. There is some disadvantage in the position of the rock gypsum here, as its surface has been largely and irregularly eroded, and again covered up and the irregularities filled with a loess-like deposit. It has, however, failed to stain the gypsum, which is practically the pure mineral. This condition is the same as at the neighboring quarries of the plaster factory at Swayne or Dillon, which produces a finish plaster of about the same quality as the Hope works, and can produce about the same quantity.

One of the important things of late years in the gypsum industries is the discovery of the ACME cement. It is a *native plaster*, of which over 60 per cent. is gypsum. It is an alluvial deposit in a small valley on the east of Gypsum creek, and is a mixture of the wash of the adjacent deposits of gypsum, clay, limestone, and sandstone. It forms one of the best brown plasters ever made. It needs no grinding. It is calcined in kettles that hold five tons each, at a temperature of 390 degrees Fahrenheit, and, as soon as cold, it is packed in bags holding 100 pounds each. The railway agent informed me that shipments had been made in car-load lots to Boston, New York, New Orleans, Chicago, North and South Carolina, Georgia, Texas, Colo

rado, Oregon, Washington, Canada, and British Columbia. It would seem, therefore, that its commercial value is definitely established. Capt. Geo. E. Pond, late quartermaster in charge of the extensions at Fort Riley, said of it: " . . . It makes a remarkably hard and durable wall, that does not crack, resists moisture, and is vermin proof." The deposit is from 8 to 12 feet thick, and occurs only in two limited areas. The scientific interest lies in the fact that it is of such an equable mixture of diverse materials, in alluvial deposits sufficiently extensive to promise an increasing supply for an indefinite number of years. The headquarters of the *Acme* Company is at Salina, where another corporation, the Salina Plaster Company, has recently been formed to work some other deposits said to resemble the Acme.

The saccharoidal gypsum of the upper red-beds is utilized at Medicine Lodge, in Barber county. An article published in *Harper's Magazine*, in June, 1888, giving some written and pictorial descriptions of southern Kansas, referred to the deposits of the Gypsum Hills. This attracted the notice of capitalists in England engaged in making the finest kinds of finish plasters. They came and examined the Barber county deposit, and, seeing the quality of the raw material, its extent and accessibility, they began, at Medicine Lodge, the manufacture of products that before were supposed impossible out of England or France.

The following is the chemical analysis of the Barber county gypsum:

Water of combination	19.50
Oxide of alumina	.09
Silica	.14
Magnesia	.67
Lime	32.52
Sulphuric acid (18 parts solid sulphur)	45.02
Alkalies—carbonic acetate	2.06
	100.00

Messrs. Best Bros., the manufacturers, have had some of their products tested in Washington. The following is the report of these tests:

WASHINGTON, D. C., July 12, 1891.

Mr. McCracken, Agent Best's Keene's Cement:

MY DEAR SIR—Inclosed please find report of tests made at the Washington & Georgetown railroad shops of the Medicine Lodge Keene's cement, which you forwarded me some time ago. You will, or should be, both surprised and gratified at the result, as it is extremely rare that material of this character will make such a showing. I have the bricketts here, which I will forward you to-morrow.

Yours very truly, JOHN J. CLARKE,
Washington & Georgetown Railroad Company.

To Whomever it may Concern: GEORGETOWN, D. C., June 17, 1891.

We have tested the cement furnished us by Mr. J. J. Clarke, said to be Medicine Lodge cement, with the following results:

No. 1 broke at 374 pounds after 24 hours, and 630 pounds after 7 days.
No. 2 broke at 325 pounds after 24 hours, and 698 pounds after 7 days.
No. 3 broke at 402 pounds after 24 hours, and 678 pounds after 7 days.

This was all mixed neat, with water enough to make stiff plaster.

D. J. CABLL,
Assistant Engineer W. R. & J. N. Co.

They make, at Medicine Lodge, several of the ordinary products of gypsum, but the chief is the fine white plaster known as Keene's cement. It has long been used by the builders of England and France for the best kinds of work, and it is now produced in Kansas. It has gone into large buildings in many of the great cities—Chicago, Denver, St. Louis, New York, and Washington—and the amount made is steadily increasing, as will be seen by the following figures.

Production in 1891	Keene's cement, 203 tons. Other products, 147 tons.
First six months, 1892	Keene's, . . 345 tons.
Second six months, 1892	Keene's, . . 490 tons.
First six months, 1892	Other products, 225 tons.
Second six months, 1892	Other products, 340 tons.

The small area of gypsum in Sumner county, northwest of Geuda Springs, is at the same horizon as the Saline county gypsum. It is hard, and has been quarried as a marble. Some business blocks in the city of Wellington were built of it. The stone is both handsome and durable. I have seen an outcrop of the gypsum in western Barber county that is hard and marble-like. It is not as accessible as that now being used for plaster, but in time, probably, other beds will be found that will be useful in buildings.

CEMENT.

There are several beds of limestone and limy shales in the State that make cement that will set under water. The concretionary, massive limestone already mentioned, and known at Fort Scott as "the cement rock," has been used for many years for the manufacture of a good hydraulic cement. There are two firms engaged in producing this material, which has an established place in the market. There is an hydraulic limestone in Wyandotte county, and one at Milford, in Geary county, and these two were combined at the works in Kansas City, Kas., and for several years a useful product was made; but competition of other articles made with less cost has eventually caused the stoppage, at least temporarily, of these works. At Manhattan, in Riley county, and near Alma, in Wabaunsee, there are beds of shale that, while worked, produced a good quality of cement. There was also for a time cement made in Douglas county. It is not unlikely that some of the beds of the Niobrara, in the western part of the State, may have a value in this direction; but so far, only the strata of the carboniferous period have been proved useful for hydraulic cements, and the manufactories at Fort Scott are the only ones that have withstood competition of older cements, and are now permanently established.

LIME.

The making of lime in Kansas has scarcely attained to the dignity of an industry. The rough limestones of the coal measures have served for local supply in the eastern fourth of the State. Hundreds of farms have their old lime-kilns. As the railways developed, lime was brought from Missouri and elsewhere, where the quality of the stone allowed it to be made more economically. The sub-carboniferous limestones of the zinc-producing area have also supplied some lime, and there is permanent lime making at Fort Scott. There is a native lime in several western counties — Dickinson, Gove, Hamilton, Kearny, Rawlins, Rooks, Sedgwick, Saline, Seward, Meade, Marion, and Logan — but for making mortar it does not appear to answer very well.

There is, however, a limestone in the Permo-carboniferous formations that has been shown to have commercial value for making lime. It is the lower flint beds, the No. 5 of the Fort Riley section. For a number of years lime has been made from it at Wreford, in Geary county, and I have elsewhere called it the Wreford limestone. It outcrops on the Fort Riley reservation, and further to the northeast in Riley county. It has also been utilized for lime rather extensively near Council Grove, in Morris county. Both from there and at Wreford the lime has been shipped in large quantities. The upper flint beds will also yield good lime in localities.

Some of the chalky limestones of the Niobrara and Benton will probably yield some lime.

BUILDING STONE.

The *building stones* of Kansas, to be exhaustively treated, would require much more space than can be given to them here. It must be sufficient to indicate their locality and their geological position with such incidental addenda as will help to show their importance. We will notice the prominent

LIMESTONES AND MARBLE

First. The sub-carboniferous limestones of Cherokee county have been much exploited for foundations, and recently more compact beds have been found that yield a fair quality of dimension stone. The rough Pawnee limestone, from north of Fort Scott to western Crawford county, though usually too much in broken layers, has in some places massive beds which have been more or less infiltrated with silica, and can be had in large, hard blocks which take a high polish. The next heavy limestone to the west, forming the floor of the sloping prairie of Allen and Neosho counties, though often soft and frequently rendered porous by decomposed fossils, has many areas of excellent stone of great thickness. The dark crinoidal MARBLE of the Verdigris valley, near Independence, belongs to this horizon. It takes a high polish, and will sometime take high rank as material for the best buildings. The lighter colored IOLA marble belongs to this formation. It exists in a massive bed without cracks or flaws, 30 feet thick, going below the level of a small creek, on the side of which it outcrops. It is already being quarried with the aid of the most approved machinery, and is cut by saws into slabs of any size, up to 20 or 25 feet long, 6 or 8 wide, and any thickness. It can be polished, but it makes a very handsome material for public erections without, and will serve well for the floors of such buildings as the capitol and large hotels. It is almost entirely a carbonate of lime, and of the requisite degree of hardness and crystallization to be called a marble, and these characteristics are vouched for in the following reports:

DEPARTMENT OF THE INTERIOR, U. S. GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY, WASHINGTON, D. C.

Report of analysis No. 1161. Stone from Iola, Kansas:

Carbonate of lime	97.94
Carbonate of magnesia	1.07
Oxide of iron	.29
Sand and clay	.86
Water	.04

Examined by H. H. Stokes, and reported March 19, 1891.

F. W. CLARKE, *Chief Chemist.*

Microscopical analysis, by Prof. E. Haworth, Penn College, Iowa:

"1. The rock is perfectly sound throughout. No signs of rottenness or decay could be found.

"2. There seems to be a total absence of small portions of impurities which would decompose by weathering and cause the rock to crumble. Different compounds of iron, such as the sulphide or carbonate of iron, if present, would easily change on exposure to the atmosphere, and thereby destroy the value of the rock. But no trace of either could be found.

"3. The value of such a rock as this depends largely on the degree to which crystallization has developed within it. A most careful microscopic examination shows that no less than nine-tenths of the rock is composed of crystals and consequently it is adapted for use the same as other marble."

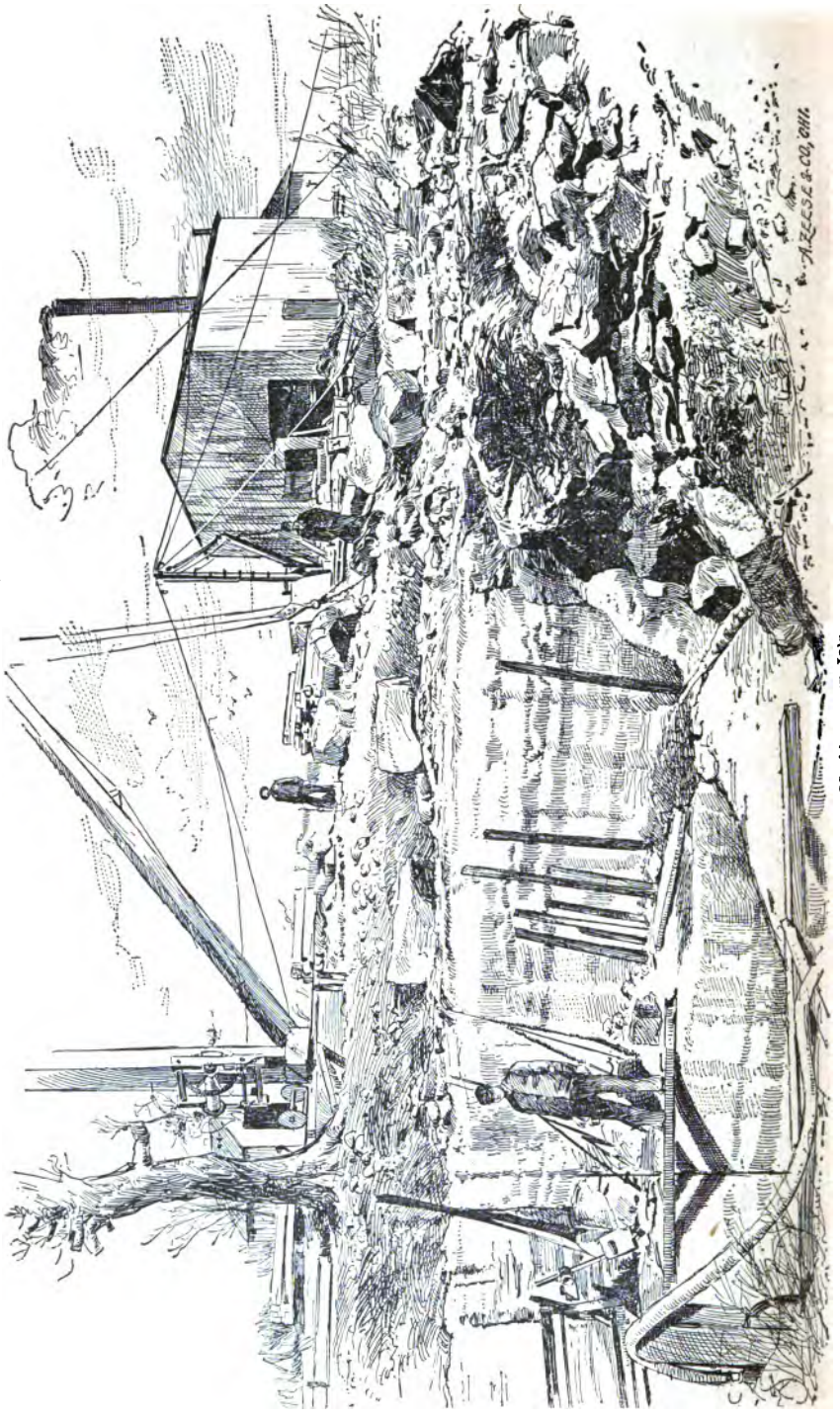
The crushing strain of this stone has also been tested by the supervising architect of the Treasury Department, at Washington. Four two-inch cubes were treated in the usual manner, with the following results:

No. 1 cracked at 43,450 pounds; crushed at 53,200 pounds.

No. 2 cracked at —— pounds; crushed at 41,000 pounds.

No. 3 cracked at 42,000 pounds; crushed at 47,840 pounds.

No. 4. cracked at —— pounds; crushed at 35,415 pounds.



Marble quarry, Iola.

Of this stone the quantity is simply inexhaustible. Other limestones of the coal measures are useful for building in all the northeastern counties, some in Brown county and Nemaha having an approximation in texture to the better known Permo-carboniferous limestones further west. Wyandotte county has, however, probably done more than any other eastern county in developing its building material, and there are five quarries where limestone of fine quality is sawed and shipped for building purposes. There is also an excellent dimension limestone at Leavenworth. There has for many years been a quarrying industry in Marshall county, at Beattie, Bigelow, and one or two other points. The stone is a buffy white, but in places becomes a lavender blue, which is very handsome. The horizon of this stone is near the top of the Manhattan beds, and so is practically the same as the very handsome white stone which is quarried southwest of Manhattan, which is hard and durable. The Marshall county stone is softer but hardens to the weather. There are other outcrops of this stone in Pottawatomie county, and on the Blue in Riley, and the supply will meet all the demands of the future.

The east wing of the Capitol at Topeka is built of stone from Geary county. It is No. 11 of the Fort Riley section. It is a buffy, soft, magnesian limestone, with very little magnesia. It works easily, and the surface hardens on exposure. Where first opened, this ledge unfortunately had many defects—small cavities, probably from decomposed fossils—but the other parts of the State House have been constructed from the same horizon in the southern part of the State, where the stone has not the same defect. This is a very persistent horizon of good stone. It is worked at Junction City, Strong City, Florence, Augusta, Winfield, and Arkansas City, and is sent by the various lines of railway that cross it to all other parts of the State, and also beyond its boundaries. The Government building at Topeka, and the court-house at Wellington, with several buildings at Wichita, are fair examples of what can be done with this extensive deposit.

Prof. F. W. Clarke, chemist of the United States Geological Survey, has given the following analysis of the Cowley county stone, which is not very different from the analysis that would be made of samples obtained at any of the other places where this stone is worked:

ANALYSIS OF COWLEY COUNTY STONE.

Silica	5.27 per cent.
Water	.78 "
Ferric oxide	.71 "
Ferrous oxide	.32 "
Alumina	1.07 "
Carbonic acid	40.34 "
Lime	50.36 "
Magnesia	.56 "
Sulphuric acid	.07 "
Phosphoric acid	.06 "
Soda	.20 "
Potassa	.10 "
Total	99.84 per cent.

Matter dried at 100°.

The stone was also tested for strength in Washington, and the two-inch cube crushed at 29,490 pounds.

The gypsum marble of Sumner county and similar material in Barber county have already been referred to. A similar material, possibly hardened by siliceous infiltration, exists in Clark and Meade counties.

The Benton limestones, from Cloud and Republic to Russell county and Meade, yield soft layers that are good building material. Many of them have an iron stain

that gives a warm tint to the stone, and some of them have this stain in a broad streak in the middle of the layer. This gives a very handsome appearance to some buildings in Beloit, Lincoln, and other towns. A residence in the west part of Abilene, seen from the Union Pacific railway, is a good example of this stone. In Lincoln county, in a very limited area, one of these Benton strata is a marble. It takes a high polish. Its hardness seems due to an infiltration of silica. As the tertiary siliceous formations overlie the cretaceous more as we go west, and have caused much infiltration, it is not improbable that in the region where they are removed by erosion that other hardened limestones may be found.

The Niobrara chalks and chalky limestones yield some material for building. This is true in Osborne, Rooks, Ness and Trego counties, and will probably be also true in Smith, and Phillips, and Graham. Most of these stones are, however, too soft. On the other hand, some chalk that can be easily whittled with a knife, sawed into blocks is a useful building stone, when laid in the usual manner with the grain of the stone horizontal. The depot at Wa Keeney is a good example. The same stone in fence walls also is durable, but when it is laid edgewise it weathers into thin laminæ, and the frosts of a few winters destroy it. The more compact stone in Osborne and Ness counties is sufficiently durable for all ordinary buildings. Some, as may be seen in buildings in Osborne City, takes a beautiful satin finish. The infiltrated "bell rock" of Trego county is so far known only in limited areas.

SANDSTONE.

In Doctor Day's "Mineral Statistics of the United States for 1889," the total value of sandstone quarried is put at $10,816,057, which is the product of forty States and Territories. Kansas stands thirteenth in the list, with a product of $149,289. The counties returning that output were: Bourbon ($90,000), Phillips ($35,086), Rawlins ($18,000), Crawford, Woodson, Clark, Wilson, Kingman, Harper, and Comanche.

In this statement it is seen that the counties of the coal-measure area — Bourbon, Crawford, Woodson, and Wilson — are most prominent in the production of sandstone, and this is more prominently true now than 1889. In Cherokee county, the sandstone quarries are yielding some good flags for sidewalks, and quite an industry of this kind has recently been developed in Woodson county, near Yates Center. But the best quality of flagging, probably as good as any in the country, is that obtained on the sandstone plateau of Bourbon county, and stretching southward into Crawford county. The sandstone is in beautiful even layers. Each layer maintains its own thickness through a considerable area, but the series embraces beds varying from 2½ to 8 inches thick. Gilfillan and Pawnee have produced fine material, but the best known product is that of the Bandera Company, whose quarries are west of Redfield. There are over 40 layers in these quarries, and flags 15 feet by 10 feet are a common occurrence. This material is known as Fort Scott flagging, and has been extensively used at Topeka, Wichita, Kansas City, Fort Riley, and more distant places.

Sandstone has been little used for building, but there are massive beds in Greenwood, Woodson, Wilson, Elk, Chautauqua and Montgomery counties, which will, without doubt, be so used some time. Many railway bridge abutments in the southwestern counties are built of this material. The material in the *red-bed* counties, Harper, Kingman, Barber, and Comanche, is not so good, but in the last named and in Clark there are the *Trinity* and possibly some other beds that will be useful. Much of the Trinity is, however, soft and not very coherent.

In north-central Kansas we have the Dakota sandstones. Some of these are gray, some dark iron-brown. They have been only locally used, but there are valuable beds in Washington, Cloud, Lincoln, Saline and Russell counties, and when

sandstones are in demand, they will be found in other counties. The traveler on the Union Pacific railway may note examples of the dark sandstones in the schoolhouse at Brookville, in Saline county, and in the depot at Wilson, in Ellsworth county. There are Dakota sandstones in Ford county and Hamilton.

The sandstones of Phillips and Rawlins are of the tertiary grit, and are metamorphosed by infiltrations so as to become a quartzite. It is as hard as granite, and has been shipped to the Missouri river towns, outside the State, in the form of paving sets. The tertiary grit has hard beds of sandstone, all more or less infiltrated. This is the case in southwest portion of Norton county, and more decidedly in Seward county, on the Cimarron river.

ORNAMENTAL STONES.

In northwestern Gove county, and in other parts west of the 100th meridian, the tertiary grit contains in its softer beds hard, flinty nodules which suggest concretions, but they have no concrentric structure. They seem sometimes to be a pure flint, but less translucent. Some have a faint pink tint. All have the dendritic delineations known in moss agates. They have a more or less flinty fracture and take a high polish. The dendritic forms are distributed from the surface inward. The late Joseph Savage, of Lawrence, introduced them to dealers in gems in Denver, and they have now for several years been using the Gove county agates in their sales of polished stones as Colorado specimens. They are found all over the plains, but these in Gove county are about the best. They can be used for inlaid work. They appear to be the hard, nodular masses referred to in the tertiary geology, further indurated and metamorphosed by infiltration of siliceous matter.

The flint beds of the Fort Riley section, both upper and lower, yield round nodular flints in layers. These flints have concentric stains, not layers, and, as they take a good polish, they can be used for paper weights. I have had good specimens from the quarries both at Blue Rapids and Wreford.

It has already been noticed (geology of the Niobrara, *ante*) that the chalk of Norton county has in many places suffered metamorphism by siliceous infiltration and has become jasper. Some of the specimens take a high polish, and where the chalk was banded it has become a banded jasper, some of it suitable for cameos. The place where this infiltration of the Niobrara beds has been most extensive is in the valley of the Saline, near the southwest corner of Graham county and the adjoining parts of Trego and Gove. There the entire mass of the chalk bed is silicified, has a clear ring under the hammer, and breaks into splintery fragments with sharp edges. It is the weathered portions that are most jasperized and take the best polish. Of this Graham county stone, Mr. Savage, some years ago, sent specimens East, and some were used for ornamental work by the firm of Tiffany, of New York. In an article on *precious stones*, in 1883, in the report of Albert Williams, jr., on the mineral resources of the United States, George F. Kunz, the celebrated gem expert, writes of this Kansas stone as follows:

" . . . Near Collyer, Graham county, Kansas, is a bed of banded jasper. The colors are mainly red and yellow, with bands of white, and these bands are so remarkably even that the stone would furnish an excellent material for cameo work. Should this style of jewelry come into vogue again, this may prove of considerable value; as it is, the beautiful red and yellow are so strikingly relieved by the white that it makes fine ornamental stone."

It may be noted that Collyer is not in Graham county, but it is the nearest railway station to the locality which is described above.

In sinking the salt shafts at Kingman, seams of alabaster were passed through. They were highly colored, were semi-translucent, and as hard as the specimens from

Derbyshire, England. This material is susceptible of high polish, and many paper weights and larger slabs were made of the polished specimens. The supply was soon exhausted, as it was only within the area of the shafts that it was taken. It may, however, be some time found in other parts of the gypsiferous red-bed area.

Notice has already been taken of the *marbles* of the gypsum and limestone regions.

The immense quantities of large bowlders of quartzite and other hard stones in the moraines of Wabaunsee, Shawnee, Douglas, Jackson and other counties of the glaciated area will some time possibly be used for buildings as well as for ornamental purposes, as is the case in Dakota.

CLAY.

There are several products of clay now made in Kansas. The principal are—

Common bricks,
Pressed bricks,
Vitrified bricks,
Draining tiles,
Pottery.

The existence of brick clay is reported in 61 counties of the State, and pottery clay in 14 counties. The quality of the material is various, and the use of it has been fluctuating, but the occurrences of deposits of the best material are not decreasing, but are being constantly found in new localities. Clay for bricks has been used of an inferior quality, to meet a local demand for chimneys, etc., in frame buildings, but better material is constantly being found, and more care in the manipulation has resulted in a product of higher value. Time was when all bricks of the best quality had to be brought from St. Louis or other outside places for the better buildings in our cities and towns; now the finest of brick buildings can be made of Kansas bricks.

Most of the clays used in brick making are surface deposits of the quaternary geologic period, and as these are found plentifully in every county east of the 97th meridian, all the eastern counties have abundance of excellent material for bricks. The quaternary clays are less plentiful further west; but even in the most western valleys there are alluvial clays of a sufficiently good quality for common bricks. In the eastern counties, it is sometimes the *loess* that is the brick clay; more often it is a washed-over loess or a modified hard-pan. There are many beds of so-called "*joint clay*" that have not yet been tested, though likely to yield good material. In the west the *plains marl* has occasional areas where its argillaceous ingredients preponderate, but mostly its limy parts so prevail as to make a poor brick. Where the lime has been reduced by the growth of vegetation, bricks have been made of the slightly-darkened marl just beneath the surface sod. The result, however, has not been encouraging. The carbonaceous material is no better than the calcareous—the outcome is a light, porous brick.

The eastern half of the State and some southern counties further west have abundance of material for excellent bricks of all kinds. Fluctuations in the business of brick making are due to fluctuations in settlement of the country, which is still young. Common bricks of very good quality are being made at Girard, Atchison, Paola, Leavenworth, Osawatomie, Coffeyville, Osage City, Wichita, Medicine Lodge, and nearly all the eastern counties. Johnson, Jackson, Brown, Nemaha, Doniphan, Cherokee, Elk, Labette and the rest make them from time to time, to supply local demand.

Pressed brick has been made at Fort Scott, Leavenworth, Junction City, Wichita, and it seems to be established as a permanent industry at Kansas City, Kas.

At Marion Centre brick has been made of a clay shale, of the highest Permian formation below the salt measures. In 1884, Professor St. John wrote: "Some of the fine shale deposits occurring in the coal measures will probably be found serviceable for the manufacture of a superior article of bricks and moulded blocks." The occurrence at Marion may be taken as a verification of that prediction; but it is better illustrated by the recent development of the manufacture of

VITRIFIED BRICK.

Atchison was the place and Thomas Beattie was the man by whom, and at which, glazed bricks for paving were first made in Kansas. This was in 1887. They are now made at Atchison, Leavenworth, Topeka, Osage City, and Pittsburg.

If it is too much to say that these bricks are the best of all material for street paving, yet it is quite true that they stand in the very front rank. They are durable, smooth, and not more noisy than asphalt or cedar blocks. The clay is a shale of the coal measures, more or less ferruginous and siliceous, and the glaze that comes on them in burning, which gives them their name, is probably silicate of iron. The iron existed in the first deposits at Atchison as limonite concretions; but these are not found in the shales at all the places. The standard size of these bricks is 8x4x2 inches, but I have measured some that are 2⅛ inches thick, and some 4¼ wide. Their weight is from 5½ to 6 pounds, and Atchison bricks have been tested and have borne a crushing strain of 12,000 pounds to the square inch. There are streets in Atchison paved with these bricks that after five years show scarce a sign of wear. The clay bed at Pittsburg is underlain by the main vein of coal, the clay changing gradually to black shale immediately above the coal, and that cannot be used for the bricks. The clay there is 10 feet thick. At Atchison it reaches 25 feet, and Topeka, Osage City and Leavenworth have intermediate thicknesses. The supply is practicably inexhaustible. The method of using these bricks in paving is: (*a*) Prepare the bed in the most approved method for foundation. (*b*) Place on the bed an even cushion of sand three inches thick. (*c*) Place bricks close together on the sand, resting on their broadest surface, so as to form a layer two inches thick, and put sand on to fill up the interstices. (*d*) Put on the brick a cushion of sand one inch thick, perfectly even. (*e*) Place another layer of brick *edgeways*, so as to be four inches deep, and brush sand over till the interstices are filled.

There is here a thickness of 10 inches, of which six inches is this hard but smooth brick. If the work is done properly, so as to keep the sand cushions in place, it is seen that this is a very stable pavement. One hundred and ten bricks go to a square yard.

The method of making these bricks involves the use of the most-improved machinery—grinding the clay on millstones and through rollers, wetting it in a closed mixer, passing it to the cutter as a long parallelopipedon, and cutting into lengths with a wire revolving at the same rate as the movement of the clay block, drying in sheds of regulated temperature (180° F.), and burning in kilns (down draft or other) of the best construction. With these methods the quantity of bricks already made is enormous. For 1892 the return is: Atchison, 4,000,000 bricks; Leavenworth, over 1,000,000; Topeka, 2,500,000; Osage City, 200,000; Pittsburg, 2,000,000.

At Pittsburg there are nine blocks of streets, 76 feet wide, already paved. As the manufactory here only began in 1891, its export trade has scarcely begun. Topeka has 34 blocks paved with these bricks, and the works have shipped to places as far away as Goodland, Sterling, and Kansas City, Mo. Atchison has 3½ miles of brick-

paved streets, and has shipped to Denver, Omaha, Sedalia, Chillicothe, and Kansas City.

At Leavenworth an improvement on the common brick has been made, by mixing the clay shale with the loess which is so abundant in the neighborhood.

Brick shale over coal drift, Pittsburg, Kas.

Clays for vitrified bricks are not confined to the localities mentioned, and as the bricks become more used the industry will become more widely extended. In Franklin county clay has been found of which the following is the analysis, and a company formed to work it:

ANALYSIS OF CLAY FROM SOUTHEASTERN FRANKLIN COUNTY.

Silica	59.60	per cent.
Alumina	17.86	"
Oxide of iron	14.94	"
Lime	.79	"
Magnesia	.81	"
Water, etc., undetermined	6.00	"
	100	per cent.

The clay suitable for

POTTERY

Is not so widely diffused, and attempts at pottery manufacture have in several places been abandoned, not so much, however, because of failure of material, as failure of

getting into a market against the competition of established potteries. The counties in which clay is reported are Barber, Bourbon, Chautauqua, Cherokee, Kingman, Leavenworth, Linn, Neosho, Osage, Ottawa, Pawnee, Reno, Rice, Saline, Franklin, but the principal manufactories are those of Fort Scott, in Bourbon county, and Geneseo, in Rice county, where a good quality of brown earthenware is made and extensively sold. Clay for finer qualities of ware is believed to exist, and is one of the future developments confidently expected, and terra cotta is one of the possibilities.

Drainage tiles are made at Burlingame and Paola, and it seems reasonable to expect that roofing tiles might be made, as roofing slate does not exist nearer than the Eastern or Western mountains, and even shingles have to be brought from the distant pineries.

There is fire-clay in connection with the coal seams, but as yet no fire-bricks have been made. There seems no reason, however, why good bricks of this class should not be made, and also retorts for the silver and zinc smelters. It is a question of who will be the first by actual experiment *to demonstrate* the value of the fire clays that are near the surface in the coal counties, and so establish another valuable industry. At present fire-clays and fire-bricks are brought from Illinois and St. Louis, and the Kansas producer would have the advantage of no freight on the raw material.

MINERAL WATERS.

That waters having medicinal properties exist in Kansas, has long been known. That they are numerous and valuable, is less known. As a source of wealth they have been little developed, and this must of necessity depend on the growth of population in the West and on the surroundings of the particular waters. The reports of the United States survey on this subject, made by Dr. A. C. Peale, only deal with those waters which have a commercial value by being shipped for sale. In 1885 Dr. Peale reports 7 localities in Kansas of mineral springs or wells; 32 individual springs; 6 springs that had been subjected to chemical analysis; 3 spring localities used as places of resort; but only 2 of these had reported directly to him. He gives no names. In 1888 he gives the names of five springs or wells as all of commercial value: "Blasing's Artesian Mineral Wells, near Manhattan; Conway Springs, at Conway Springs, Sumner county; Geuda Springs, Cowley county; Iola mineral well, Allen county; Topeka mineral wells, Shawnee county."

Waconda, or Great Spirit spring.

In 1886 Dr. Peale, in a special bulletin of the United States Geological Survey (No. 32), gave the following list of Kansas wells, classifying them as saline, chalybeate, etc., as in the fourth column:

MINERAL SPRINGS OF KANSAS.

Name and location.	No. of springs.	Flow, in gallons per hour.	Temperature, Fahr., deg.	Character of the water.	Remarks.
Alma salt well, Alma, Wabaunsee Co.	.....	.....	48		
Arrington mineral springs,* Arrington, Atchison county	3	420	60	Carbonated, saline, chalybeate,	Used commercially and as a resort.
Baxter medical springs, Baxter Springs, Cherokee county	2	450	50	Chalybeate	do.
Bonner's Springs,* Tiblow, Wyandotte county	20+	.....	.....	Calcic, carbonated	Resort.
Brom-magnesian mineral well,* Independence, Montgomery county,	1	.....	62		
Cranmer Springs, Conway Springs, Sumner county	8	3,000	43½ to 50		
Flowing spring,* two miles southwest of Junction City, Davis Co.					
Fort Scott artesian well, Fort Scott, Bourbon county	1	416	67½	Sulpho-saline.	
Geuda Springs, Geuda Springs, Sumner county	7	1,500	55 to 61	Saline	Used commercially and as a resort.
Girard mineral well,* Girard, Crawford county	.....	.....	.....	Saline	Local resort.
Great Spirit spring,* Cawker City, Mitchell county	1	.....	.....	Saline	Resort.
Haddon mineral well,* Moss Sp'gs, Davis county	.....	.....	.....	Saline (?)	
Henek's Mineral Springs,* Arrington, Atchison county. (See Arrington Springs.)					
Iola mineral well, Iola, Allen Co.	1	120	61	Saline	Used as a sanitarium and resort, and commercially.
Jordan's Springs, Jordan Springs, Reno county	24	1,800+	56 to 57	Saline	Unimproved.
Lee's Springs, six miles east of Peabody, Marion county	4	350			
Louisburg gas wells, Louisburg, Miami county	3				
Louisville springs, Louisville, Pottawatomie county	3	.....	64	Chalybeate	Resort.
Manhattan or Kansas artesian mineral wells, 10 miles from Manhattan, Riley county	2	800+	56	Saline	Used commercially and as a resort.
Mineral spring, Atchison, Atchison county	.....	.....	.....	.....	Has local reputation.
Moodyville mineral springs, four miles south of Blaine, Pottawatomie county	.....	.....	.....	Alkaline, etc	Resort.
Mound Valley spring, Mound Valley, Labette county	1				
Murphy's Seven Sp'gs, seven miles from Junction City, Davis county	7	.....	.....	Alkaline, calcic.	
Pfister's Mineral Spring,* six miles from Junction City, Davis county.					
Piqua mineral wells,* Piqua, Woodson county	3				
Salt Springs:					
In northeast part of Stafford Co.					
In sections 14 and 15, township 8, range 7 west, Mitchell county	10+	100			
Sulphur Springs:					
In section 35, township 7, range 2 west,* Cloud county	8	360+	47	Calcic	Unimproved.
In Allen county.					
Tar springs, near Somerset, Miami county	6+	.....	.....	.....	Used to limited extent as resort.
Wyandotte gas wells,* Wyandotte, Wyandotte county	6				

Of those marked (*) in the above list, the chemical analysis is given by chemists in and out of the State. With regard to the first of those called salt springs, it probably means the waters of the salt marshes, which rise from the basin as described under salt. Some large springs in the neighborhood are not saline. The Mitchell county marshes have salt springs.

Doctor Peale's list includes a few that are scarcely to be reckoned as mineral waters, only as all waters from underground carry some trace of the minerals over which or through which they flow, and these had been analyzed to see what they contain. But besides those in this list, there are many other springs and wells in Kansas that actually have medicinal value. In answer to recent inquiries, I have statements of the location of mineral waters in 32 Kansas counties. These include all of the above list, the more noted of which are, Fort Scott artesian well, Geuda Springs, the Great Spirit spring, the Iola well, Bonner Springs, and Arrington Springs. There are others that are likely to become as noted, and many of them I have personally visited. The counties making these returns are:

County.	*Locality of mineral water.*	*County.*	*Locality of mineral water.*
Allen	Iola.	Logan	South part of county.
Barton	Northeast of Great Bend.	Marion	Chingawassa, Marion, and east of Peabody.
Bourbon	Fort Scott.	Morton	Richfield.
Butler	Southwest from Douglass.	Mitchell	Near Cawker (Great Spirit Spg.)
Chautauqua	Chautauqua and S. of Sedan.	Nemaha	4 miles north of Sabetha.
Cherokee	Baxter Springs.	Osage	Carbondale.
Cowley	Southeast of Arkansas City, and Geuda.	Pawnee	Larned.
Crawford	Girard.	Pottawatomie	Moodyville and Onaga.
Doniphan	Eagle Springs, northwest part of county.	Riley	12 miles S. E. of Manhattan.
Franklin	Williamsburg, Ottawa, and Lane.	Sedgwick	11 miles S. by E. of Wichita.
Geary	Southwest of Junction City.	Shawnee	Topeka.
Hamilton	Coolidge artesian wells.	Sumner	Geuda Springs and Conway.
Jewell	Eight miles east of Mankato.	Wabaunsee	10 miles northwest of Alma.
Labette	Mound Valley.	Wallace	Sharon Springs.
Leavenworth	Near Lansing.	Woodson	9 miles west of Yates Center.
Linn	Mound City.	Wyandotte	Bonner Springs.

The fact most important about the wells is, that most of the best are bored wells, with artesian flow. This is true at Fort Scott, Topeka, Mound Valley, Great Bend, Larned, Richfield, Coolidge, Girard; and to these might be added Lawrence, Oberlin, St. Mary's, and Wamego, where there is a small artesian flow of saline water. The waters at Mound Valley, Oberlin, Lawrence and Fort Scott probably all flow by gas pressure, while those at Wamego, St. Mary's and Richfield are most likely raised to the surface by rock pressure.

The Coolidge wells are not highly mineralized, and they are mostly used for domestic purposes and irrigation, but they have some mineral qualities. They come from the Dakota sandstones, about 300 feet deep. The Richfield water is from about 600 feet deep, and is more highly mineralized. This is true of the Oberlin water, which is a very small flow, but might be larger if the wells were cleared out. The well at Great Bend is strongly saline, and has other properties, but it has not yet been utilized.

The well at Larned is the strongest artesian flow in the State. When measured by the writer three years ago, it gave not less than 300 gallons per minute. A large swimming bath has been constructed and a series of private baths erected, which are much used, and the water is used internally, being reported valuable in rheumatic and other affections. It is strongly saline, and also has other properties.

The mineral waters of the places in whose names the word *springs* appears, are, of course, natural flows; Geuda and Baxter have long been known. Arrington spring, which is in Dr. Peale's list, but of which no return has recently been made, is an *iron water*, which owes its mineral qualities to a gravel which is manifestly a débris of the Dakota sandstone, which was probably put there in pre- or early pleistocene time, and covered up by quaternary deposits. Other springs in the glaciated area are chalybeate in character. The following is the analysis of the spring near Onaga, called Hoover's. The analysis is by Dr. Nunelly.

Sulphate of calcium	1.41	grains.
Chloride of calcium	.39	"
Chloride of magnesia	1.29	"
Chloride of sodium	2.46	"
Arsenic	.60	"
Oxide of iron	2.22	"

Sulphate of magnesia, not estimated.

The water is soft, and has a temperature of 60 degrees Fahrenheit. The flow from the main spring is about three gallons per minute.

There can be no question but that the salubrious air, the medium altitude and dry winters of western Kansas offer a good basis for health resorts for invalids for whom the greater elevation of Colorado is injurious. If these advantages were combined with means of bathing in or otherwise using mineral waters, a sanitarium, properly advertised and fitted with the necessary accompaniments, would certainly be a hygienic success, and in time would recompense the investors. Hutchinson, Larned, Great Bend, and Coolidge, in the Arkansas valley, Richfield and Meade Centre, to the south, Oberlin, Ellsworth, and Cawker City, in the north, all have advantages that might be developed in this direction, while the mineral waters of eastern Kansas will be of medicinal value to those who need not the additional advantages of altitude.

GRAVEL.

In the sixth biennial report attention was called to the existence of large quantities of gravel in western Kansas, arising from the breaking up of the tertiary conglomerate of that region. The pebbles are of feldspar and quartz and other granitic materials, and it was suggested that this was valuable material for concrete and asphalt pavements. In the Neosho valley, in the region around Fort Riley, in Greenwood and other southern counties, there is another gravel of very different structure, but which promises to be of similar value for road ballast. It is not composed of *rounded* pebbles, but though way-worn they are angular and sub-angular in form. They are fragments of chert, cherty limestone, and other impure limestones, which have resisted by their physical structure the abrasive forces to which they have been subjected, and have acquired a *vitreous* luster, and a smooth surface that seems to have prevented their further decrease in magnitude. On some slopes the chert, or as it is in some districts a real flint, is seen just broken out of the parent beds, and so with the limestones; and at lower levels the way-worn, vitrified gravels. Near Burlington the deposits are large, and from near Neosho Falls this material has been shipped to Kansas City. It has been used there for filling the interstices in block paving to the extent of 150,000 square yards. It has a value of $2.50 per cubic yard.

This material has been extensively used by the railway companies for ballast. This may be seen at Arkansas City and Iola. It not only is used on the railways, but has been applied on the county roads with fine effect.

Another gravel is now on the market. It has already been described in treating of the zinc and lead mining region of Cherokee county. It is the débris from the crushers and jiggers that extract the ore from the cherty material thus left behind. Its value as road metal is undoubted, the shipments from Galena reaching as much as *60 car-loads* in a single week. There are immense quantities of uncrushed material in the dump piles of the lead district that probably will in time be worth crushing and using as macadam on county roads or ballast on the railways.

OTHER MINERALS.

What other minerals will yet supply the basis of special industries in Kansas we know not, but there are several things that have had partial success in the trial.

Mineral paints have been obtained from red-bed clays at Kingman, and from ocherous clays at Quenemo, Leavenworth, and elsewhere, but the demand for improved values being small, they have not been persistently manufactured. It is said that a large furniture manufactory at Leavenworth is using one of the ochers very successfully as a stain for wood. Oxide of zinc is also obtained in the zinc region and used in a manner similar to white lead. The silicate of zinc is being also employed as the base for the manufacture of zinc white, but it is sent out of the State for that purpose.

Chalk of a very pure white is found on the Smoky and Solomon, in several of the northwestern counties. It was once manufactured into whiting at WaKeeney, and both whiting and school chalk will probably yet be made in abundance. Chalk will possibly also go to the formation of some plasters and cements.

If ever iron pyrites — sulphuret of iron — becomes of value as an iron ore, or as a source of sulphur, there is abundance of it in Cherokee county, and it occurs less plentifully in nearly every other county in the State. IRON ORE of the more useful kinds — hematite and magnetite — will certainly be found in quantity. The writer found a bed of soft hematite on Cavalry creek, northwest from Coldwater, several years ago, and lately Miss Best, of Medicine Lodge, has found that the sands of the Medicine river, and of its tributary, Elm creek, contain black grains of iron ore in considerable quantity. They are readily separable by the magnet, and under the glass resemble well-known iron ores from other regions. It will be interesting to trace this black iron sand to its parent bed in the lower cretaceous or red-bed formations of the Medicine river drainage basin.

Meteoric iron has been found in several counties. In Kiowa county, three years ago, were found over 2,000 pounds of the variety known as Pallasite; 75 pounds of meteoric iron were obtained at Tonganoxie, 160 pounds of the stony iron in Washington county, and 1,000 pounds in Phillips county. Years ago there was one in Mitchell county, known as the Waconda meteorite.

In Norton county and McPherson, and elsewhere, there are beds of very fine powder, some many acres in extent and several feet in thickness, which are useful as polishing powders, not even scratching silver. The material is *volcanic ash* or *glass* that has been wind blown from the eruptive centers in the West and deposited in the tertiary lakes. In Nebraska it is found in the latest tertiary beds, and as far east as Omaha in the loess. Some beds in Kansas are very pure, and will some time have a place in the useful arts.

Forms of *strontium* (celestite and strontianite) have been found in Saline, Riley, Brown and Jefferson counties; the last probably in quantities used in crystallizing refractory sugar syrups.

WATER.

Though all water may be said to be of meteoric origin, yet there is an important sense in which it is a geologic product. The supply of it is directly dependent on the physical texture of the rocks on which it falls or through which it percolates. If the surface is compact, the rainfall runs off, instead of into the earth, and causes floods in the rivers. On the other hand, porous material — sand, gravel, loose soil — receiving the rains, passes the water readily downwards, and allows it to accumulate in fissures, cavities, and the pores of the lower terranes, whence it may issue as springs, at low levels, or become the supply of artificial wells.

Nearly all river and creek valleys have some alluvial deposits of sand and gravel below the surface soil, and these are water holders, which are everywhere useful as reservoir supplies for the use of farm wells, and which are also available for the

larger demands of villages and urban communities. In these subterrene waters there is often a movement—a flow in the general direction of the valley—slow compared with the currents of surface streams, but sufficiently perceptible. This may be called the UNDERFLOW. It is found in the valleys of the Neosho and Smoky Hill rivers, as well as in those of the Prairie Dog, the Cimarron, the Stranger, and the Marais des Cygnes, and even of smaller streams. In places this underflow is very restricted in its area, especially in the eastern parts of the State, where alluvia are often clays, while the gravels and sands are shut in by the more impervious strata. Yet towns in some eastern counties are well supplied with water from such sources.

In western Kansas, where the sandy and gravelly alluvia are deeper in all the valleys as well as more continuous, the underflow is valuable not only as a source of supply for the domestic and manufacturing purposes of cities, but it is sufficiently plentiful and available to be useful for the irrigation of the land. Where the slope is sufficient, it may be led out to the surface by gravity through an open ditch, called variously a "sub-canal" or "fountain," or, in other circumstance, it must be raised by the power of wind or horse or steam.

Besides these valley alluvia, there is in the West a porous water holder underlying the higher levels of the plains, almost everywhere present in great abundance. It is the tertiary grit. Wells sunk through the superincumbent *plains marl* to the water of the grit find an unfailing supply. Single wells have, by the aid of a wind pump, supplied the wants of hundreds of cattle or thousands of sheep. An additional pump would make many of these wells available for irrigation, and so render fertile 10 to 25 acres of land on many farms in the dryest years.

There are many springs of great force in the eastern part of the State, but the most noticeable, as related to geologic structure, are a series found across the east-central part of the State. They come out of the limestones of the upper and lower flint beds of the Fort Riley section, mainly the upper beds. They have worn out channels both in the limestone and accompanying shales, and some rush out with great volume. They are found in Riley, Geary, Morris, Marion, Chase, and counties further south. The Seven Springs, of Geary county, have been famous for their perennial flow of hundreds of thousands of gallons daily from the old California days, for they marked a noted camping place on the Smoky Hill route. The Chingawassa Springs, in Marion county, are of this series, and others in Morris and Geary are very large.

In the west, the springs come from the top of the shales or limestones beneath the tertiary grit, and the streams (excepting only the Cimarron and Arkansas, which come from the mountains) have no permanent water in their channels till they have cut to or near the bottom of the grit; and where the water is invisible at the surface it is usually found as underflow.

There are comparatively few areas in the State where the conditions are favorable to the ARTESIAN flow of wells. Some such flows in the eastern part of the State, we have already stated, are due to gas pressure and rock pressure, and the westerly dip of the strata, combined with the increment of elevation in the same direction, is unfavorable to the expectation of artesian flows from the waters of the sandstones or other porous strata of the region.

In the west, the easterly dip makes a favorable condition, but other circumstances are such as not to warrant sanguine expectations; yet the Larned flow, and some considerations connected with the Scott county closed basin, might lead to prognostics for parts of the Pawnee valley for results as favorable as those at Coolidge, in the Arkansas valley, or at Richfield, in Morton county. The Meade county area, on upper Crooked creek, which has upwards of 100 artesian wells yielding from 10

to 60 or 70 gallons per minute, has its supply from the gravel and sand of the tertiary grit, which is locally covered with a stiff, light-colored, soapy clay, which holds the water down till the drill taps it. These wells are all shallow—from 50 to 150 feet deep—but their flow is undiminished after years of running, and notwithstanding that the grit a few miles away is supplying permanent water to Spring creek. Both the artesian wells and the waters of Spring creek are used for irrigation, and there are valuable farms now on lands that would have been abandoned in the drouth of a few years ago but for this supply. These waters also supply several carp ponds.

SOIL.

"Wherever the surface of the earth is not covered with water, and is not naked rock, there is a layer of earth more or less mixed with the remains of animal and vegetable substances in a state of decomposition, which is commonly called the *soil*." So say the dictionaries, and the condition of having the decayed vegetable matter is accepted usually as the first quality of a soil. The more *humus* it contains and blacker it is, the more generally it is believed to be a good soil. And yet, in their origin, soils are a geologic product. Being on the surface, they are the latest geologic product; and before any vegetable matter was in them they were capable of holding the roots and sustaining the life of vegetation. As soon as they were born from the waters that deposited them or were loosened from the rock of which they formed a part, they began to be soils, and by being soils—the home of growing plants—they became better soils. Bulletin No. 10 of the chemical division of the United States Department of Agriculture, by Edgar Richards, puts the facts of the origin of soils so concisely, that we quote:

ON THE DERIVATION AND THE FORMATION OF SOIL.

"All soils are the result of the natural disintegration of the rocks by atmospheric agencies, mingled with decayed vegetable and animal matter in greater or less proportion. If natural agencies, such as glaciers, rain, frost, wind, etc., did not come into play and wash and transport the materials of soil to a greater or less distance from their sources, the soil of every locality would be simply the decayed upper surface of the underlying rocks. But in proportion to the slope of the ground and the activity of the agents above mentioned, the soil is transported from higher to lower levels, and in many cases a good soil may be found covering rocks which of themselves would only yield a poor soil.

COMPOSITION OF THE SOIL.

"Soil is a mixture of sand, either quartzose or feldspathic, clay, carbonate of lime, and humus or organic matter, and on the preponderance of one or more of these constituents the usual classifications of soils are based.

GENERAL CLASSIFICATION OF SOILS.

"Soils are usually classified as sandy, sandy or light loams, loams, clayey loams, heavy or retentive clays, marls, calcareous loams, and peaty soils. This classification has reference chiefly to composition and texture, a special chemical composition, siliceous, calcareous, etc., being necessary for the profitable growth of particular crops, and a certain mechanical texture, friable, porous, etc., suiting best for the permeation of rain and air, and the spreading of the roots of the plant.

"Loams, which may be considered as typical soils, are a mixture of sand, clay, and humus, which are spoken of as *light* when the sand predominates and as *heavy* when the clay is in excess. These terms, *light* and *heavy*, do not refer to the actual weight of the soil, but to its tenacity and degree of resistance it offers to the imple-

ments used in cultivation. Sandy soils are, in the farmer's sense of the word, the lightest of all soils, because they are the easiest to work, whilst in actual weight they are the heaviest soils known. Clay, though hard to work on account of its tenacity, is comparatively a light soil in weight. Peaty soils are light in both senses of the word, being loose or porous, and having little actual weight.

GEOLOGICAL CLASSIFICATION OF SOILS.

"Whatever their composition and texture, soils are, from a geological stand-point, mainly of two sorts: *soils of disintegration* and *soils of transport*. Under the former are comprehended such as arise from the waste and decay of the immediately underlying rocks, the limestones, traps, granites, and the like, together with a certain admixture of vegetable and animal débris; and which are directly influenced in their composition, texture and drainage by the nature of the subjacent rocks from which they are derived. Under the latter are embraced all drift and alluvial materials, such as sand, shingly débris, miscellaneous silt, and clay, which have been worn from other rocks by atmospheric agencies and transported to their existing positions by winds, waters, or ancient glacial action.

DIFFERENCE BETWEEN THE SOIL AND THE SUBSOIL.

"Besides the *soils* proper, which come immediately under cultivation, there are in most places a set of *subsoils*, differing from the true soils, and which cannot be ignored. The true soils are usually of a darker color, form the larger admixture of humus, whilst the subsoils are lighter in hue, yellow, red, or bluish, from the greater preponderance of the iron oxides. The soils are more or less friable in their texture, whilst the subsoils are tougher, more compact, and more largely commingled with rubbly and stony débris. The soils are usually a little more than mere surface covering, whilst the subsoils may be many feet in thickness.

WEATHERING OF THE ROCKS AND FORMATION OF THE SOIL.

"All exposed rocks break up in course of time under the continued action of atmospheric agencies, however hard and refractory they may be. These agencies act both chemically and mechanically. The rain, owing to the absorption of carbonic acid from the atmosphere, acts chemically on the rocks by its solvent action, and also from its oxygen combining with substances not yet fully oxidized. Its mechanical action appears in its washing away the finer portions of the disintegrated rock or soil from higher to lower ground. The changes in temperature have a loosening influence, by causing alternate expansion and contraction. The atmosphere itself acts chemically upon the rocks by the slow oxidization of those minerals which can absorb more oxygen, and the production of carbonates and bicarbonates whose solubility still further aids disintegration. These disintegrating agencies are still further aided by the root growths of plants, by the burrowing of worms and other earth-dwelling creatures, and in no small degree by the generation of organic acids, humic, crenic, etc., by organic decay.

"From the hardest granites, basalts, and lavas, to the softest limestones and marls, all are undergoing this disintegration; and the soils to which they give rise will vary in depth, composition, and texture, according to the softness and mineral character of the rocks and the length of time they have been subjected to these agencies.

"According to Darwin, the solid rocks disintegrate even in countries where it seldom rains, and where there is no frost. De Koninick, a Belgian geologist, is of opinion that such disintegration may be attributed to the carbonic and nitric acids, together with the nitrates of ammonia, which are dissolved in the dew.

"The rocks which weather most easily and rapidly do not always exhibit most

soil; very often the reverse. A pure limestone would exhibit hardly any weathered band or soil, because the carbonic acid of the rain would almost at once dissolve and remove the particles it acts upon. Even in the case of igneous rocks, their composition may be such that those which weather the most rapidly would, likewise, show little of a weathered band, owing to the same solvent action.

THE SOILS FORMED BY THE DIFFERENT GEOLOGICAL FORMATIONS.

"The rocks of which feldspar is one of the constituents are the origins of the clays and potash which are met with in all arable soils; feldspar is a silicate of aluminium and potassium, which on disintegration forms clay, a silicate of aluminium and a silicate of potassium.

"The primitive and igneous rocks yield soils rich in potash, and the fossiliferous rocks those rich in phosphoric acid.

THE DENUDATION OF THE SOIL.

"The same agencies which form the soils are also wasting and carrying them away. During every rain storm transportation of soil goes on, as the brooks and rivers show, after heavy, long-continued rains, by the yellow, muddy color of their waters, that they are carrying a vast quantity of sediment towards the sea. The running streams bear along the transported matter, and gradually deposit it as the current diminishes in velocity, the very finest particles being carried as long as the stream remains in motion. When a river reaches a flat or level tract, and over which its waters can flow in flood with a slow motion, the suspended matter, consisting principally of sand and mud, is deposited, and constitutes the *alluvium*, or new land, formed by such deposits at the river's mouth or along its banks."

Soil varies from the structure of coarse gravels to that of the most tenacious clays. It may be loose sand or obdurate rock, for even on granite such vegetation as lichens will find a home. The authority previously quoted says: "Those soils are best adapted to agriculture which consist of a mixture of sand with a moderate quantity of clay and a little vegetable matter." It should be noted, besides, that soda, lime, magnesia, potash and iron are desirable ingredients in most soils, and it is a fortunate fact that they are mostly present in greater or smaller quantities in all soils. The mechanical condition, in which the materials which the roots of plants absorb are found, is much more important in a soil than the actual quantity contained. This is obvious from the fact that the amount of matter absorbed from the soil is very small as compared with the weight of the mature plant, whose principal bulk is obtained from air and water. One of the desirable physical conditions of a soil is certainly that of having the right ingredients of plant food finely comminuted. Another is that the soil shall be easily penetrable by water. This last is so important, that in the great West, where aridity or semi-aridity must be removed by irrigation, it scarcely matters what other characteristics a soil has. Gravelly soils under irrigation give as fine crops as the black humus of moister regions.

The soils of Kansas are the mineral resource most widely distributed. They are everywhere. The plains marl of the west and the loess of the east are deposits covering high lands and slopes, in which all plants will grow. The latter is affected by oak trees, and the vine thrives upon it. The former gives immense areas for wheat and all other grain. These formations are the direct product of the last great geologic agencies—the waters that flooded the plains previous to and during the great ice age. Since then the alluvia of all river valleys have been formed—sandy or argillaceous, and made of the ingredients of the former and the admixture of the newer débris of limestones, shales and sandstones from near or far. In many valleys—the Kaw, Neosho, Marais des Cygnes, Marmaton, Stranger, Blue, and Verdi-

gris—the possession of the newer soils by vegetation has been so long and under such favorable conditions, that a deep, black mould has been formed, sometimes three and four feet deep. Further west the black humus is not so deep, but the subsoils are true soils to their very bottom—lake silt, with all ingredients finely comminuted. In some of the eastern counties, the red loess has, under the influence of vegetation, become a blackish brown, known as a mulatto soil. Sandy bottoms have also acquired the vegetal characteristics. There is in some valleys, from the Solomon to the Marmaton, a transported soil, which at first is very intractable, but which is finely comminuted, and under right weather conditions is very fertile. It is the soil of bottom lands or slopes which have been formed from the breaking up of neighboring blue shales. It is a stiff clay soil, which retains water on the surface. Under right conditions it produces large crops. It is often called gumbo.

There are mounds and promontories with flat tops in eastern and central Kansas which have a *thin*, sedentary soil (soil of disintegration) formed from the decay of limy shales and limestones, which is not a rich soil, but it is only the thinness that is the fault, and this pertains to the edge of the flat tops. Further on the sedentary soil is deeper, and the results are not to be distinguished from the product of adjacent high land which may be covered with a thin deposit of loess. There is a red soil in the red-bed region that is sedentary, also, though thin on the slopes of the "ferruginous, arenaceous, argillaceous red limestones" and shales, is scarcely less productive than the red alluvial deposits of the valleys, which are as fertile as any soil in the country.

We have not space here to classify all the soils of Kansas, but we have perhaps indicated how the various kinds may be known as to their geologic relations, which relations are the reasons why they occupy so important a place in the MINERAL RESOURCES OF KANSAS.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