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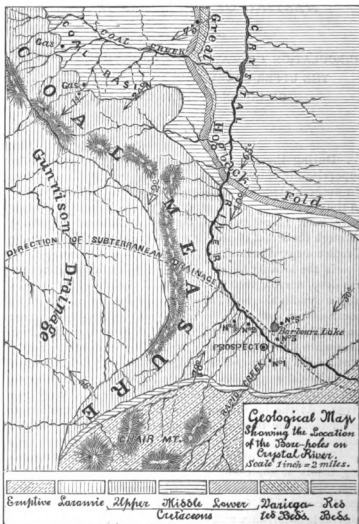
CIRCULATION OF WATER THROUGH THE STRATA OF
THE UPPER CRETACEOUS COAL MEASURE OF
GUNNISON COUNTY, COLORADO.

BY R. C. HILLS.

During the last year the writer has had occasion to supervise the operations of a diamond drill in prospecting for anthracite on Crystal River in Gunnison County, and in the course of these operations, some interesting facts have been noted bearing on the circulation of water through the strata of the Crystal River area of the Upper Cretaceous coal measure.

In the locality to which it is desired to call attention the deep, narrow valley of Crystal River traverses diagonally a synclinal trough, about 4 miles wide, formed by the southeastern extension of the Great Hogback fold on the one side and the North Ragged Mountain, or Chair Mountain upheaval on the other. The rocks of the upper part of the coal measure are exposed along the bottom of the valley, the upturned coal seams appearing on the opposite sides of the trough where the latter is cut by the river. At the lowest point in the trough the eighth coal seam from the base of the measure is 390 feet below the surface.

This 390 feet of overlying rocks consists of alternating bands of shale and sandstone, the latter predominating. The shale shows a decided tendency to crumble into small conchoidal fragments which are a source of considerable annoyance and delay in drilling. The main portion of the coal measure, or that which includes the workable seams, is made up of three well defined beds of grayish



massive sandstone, 60 feet to 100 feet thick respectively, separated from each other by beds of varying thickness consisting of thin bands of laminated or shaly sandstones and shales. At two places along the southern outcrop of the measure, or near its junction with the eruptive mass of the Ragged Mountains, a thin sheet of quartz-diorite intrudes itself conformably above the eighth coal seam. The beds are frequently distorted near this line of junction but along the bottom of the trough only a few slight contortions make their appearance.

The first bore-hole was located at a point about $\frac{1}{4}$ mile from the river and about 12 feet above the level of a small stream called Rapid Creek. The supply of casing being limited the hole was only cased to a depth of 80 feet. At a depth of 120 feet a band of very loose shale was encountered which absorbed water so rapidly that the hole had to be abandoned owing to the impossibility of pumping sufficient water through the hollow drill-rod to wash the borings up to the outflow at the top of the casing, which is one of the requirements of this method of exploration.

A second hole was commenced about 1 mile to the north and within 200 feet of the river, but the same difficulty was met with, and as the shale crumbled very badly, this hole also was abandoned. It was now thought probable that, owing to the mouth of the hole being in each case from 40 to 50 feet higher than the river, the water had found an outlet near by through joints and bedding-planes. Accordingly a third location was made, about 2,000 feet from the first, near to and on a level with the river, and nearly on the line of the synclinal axis. After considerable delay in passing through the upper part of the formation, this bore was extended to a depth of 600 feet.

Soon after the first hundred feet had been bored all the water pumped into the hole disappeared although casing was put in to a depth of 80 feet. Between 103

and 108 feet a band of loose shale was passed through, and this is supposed to be the point of outflow corresponding to that in the first hole. At a depth of 180 feet an artesian flow was struck which, when the pump was stopped, would rise through the drill-rod to the mouth of the hole, but would not rise to the surface on the outside of the rod, even when the pump was working to its full capacity. At a depth of 392 feet the eighth coal seam, overlaid by 7 feet of quartz-diorite, was passed through, and at the same time a strong flow of carbonated water was encountered that would rise in the drill-rod and flow over the top, 21 feet above the mouth of the hole. Even with this addition it was found impossible to force the water to the surface between the rod and casing. The first artesian flow came in at or near the ninth coal seam. Between this seam and the eighth, the point of strongest inflow, there is a stratum of massive sandstone about 30 feet thick.

No other flows were detected in boring the remaining 200 feet. All the water from the two flows, as well as that supplied by the pump, together with the borings and the material resulting from the grinding up of soft parts of of the core, passed off at the point of outflow between 103 and 108 feet below the level of Crystal River.

In raising and lowering the drill-rod it was noticed that when the cutting-bit reached the point of strongest inflow, the water would rise to the greatest height above the top of the hole. It was likewise observed that the water reached the top of the hole when the rod was down about 130 feet; consequently a pressure of about 45 pounds per square inch was required to overcome friction along the 25 feet of bore between the drill-bit and point of outflow and the resistance met with at the outflow.

It was not ascertained whether or not there was a pressure of water at 103 feet.

A fourth hole, 4,300 feet distant down the river, was bored to a depth of 446 feet. The location of this hole

was about 1,500 feet from the bottom of the trough, at the base of a high ridge on the west of the valley, 800 feet from the river, and approximately 75 feet above the level of the stream, or nearly on a level with the top of the third hole.

The dip of the strata is greater than the slope of the ground between the hole and the river. There is also a noticeable contraction of the shale beds as the formation curves upward from the bottom of the syncline towards the base of the Ragged Mountains; for these reasons the eighth seam was reached at a depth of 313 feet, or 81 feet less than in the third hole. At 14 feet below the surface of the exposed rock the drill passed through a layer of cross-fractured sandstone which, until it was "cased off," allowed all the water pumped into the hole to flow away at that depth. When the pump was stopped the noise of the water running in this channel was distinctly audible at the mouth of the hole.

The stream was supposed to discharge itself into the deep drift of the valley, as a strong flow at the same level in a neighboring gulley is evidently derived from the same bed of sandstone. After 50 feet of casing had been inserted, a part of the water supplied by the pump came back to the surface on the outside of the rod, although a large portion of it still flowed off through the rocks, and when a depth of 400 feet was attained the water again disappeared on or near the top of what is called the 3d sandstone, in allusion to its being the third layer of massive sandstone from the base of the measure. The points of outflow in the fourth hole do not correspond to those found in the holes previously bored; nor did the artesian flows met with at 180 and 392 feet in the third hole make their appearance in the fourth.

It is also to be observed that the lowest point of outflow in the fourth hole is geologically, as well as actually, lower than the points of inflow in the third hole.

The fifth bore-hole was located on the opposite side of the trough nearly 1 mile east from the fourth, about 410

feet above the river, 7 feet from a running spring and 6 feet above the level of a small body of water, 300 feet distant, known as Barbour's Lake. This bore was discontinued at a depth of 310 feet. Almost from the beginning the water from the pump flowed off into the surrounding rocks and as the hole was not cased the points of outflow could not be ascertained. At a depth of 290 feet the drill passed through 15 feet of loose shale, thought to be identical with that at the outflow in the third hole, and it was then noticed that there was a strong suction of air through the drill-rod, the draft being strong enough, when the rod was withdrawn, to extinguish the flame of a candle lowered into the hole.

This suction was supposed to be caused by the friction of running water, the noise of which could be heard distinctly when the ear was placed within a few inches of the top of the bore. At no point in this hole was an artesian flow detected, and it is worthy of notice that such were only encountered in the third hole, or at the bottom of the trough.

From the information obtained from the several borings, it would appear that there are, in the upper zone of this part of the measure, bands of material, either shale or sandstone, through which water circulates with greater or less facility according to the resistance met with in the direction of circulation or, as the case may be, giving rise to the conditions of an artesian flow, or to subterranean channels and water-courses.

In regard to the direction of subterranean flow, if the water circulating above the 8th coal seam is confined to the particular stratum in which it was found, as the conditions of an artesian flow existing at comparatively shallow depths would indicate, there are two directions in which it might be discharged, viz:—in the direction of the synclinal axis passing through the range of hills separating the drainage of Crystal River and the Muddy Fork of the Gunnison, or at the place, 4 miles down the valley, where

the river passes over the upturned edge of the coal measure. That the drainage is in the latter direction, however, seems doubtful owing to the entire absence of springs where the measure comes to the surface.

Neither is it probable that water circulating at a depth of 400 feet in the vicinity of the fourth hole, would discharge itself in that direction, for the reason that a point down the river at the same level would be somewhere in the Triassic sandstone and circulation in that direction would be retarded by the 5,000 feet of exposed intervening shale and sandstone strata. Water flowing in the direction of the trough would describe a semi-circle around the base of the northern end of the Ragged Mountains and would probably be discharged along the outcrop of the coal measure on the North Fork of the Gunnison. The nearest exposure of the measure in that direction is about 15 miles distant, and is 1,100 feet lower than the level of the 8th coal seam in the third bore.

It is to be regretted that economic considerations rendered it inadvisable to extend the explorations to a greater depth, by which means much interesting information bearing on the subterranean circulation of water might have been obtained.

Nevertheless since the coal measure rocks of the entire Grand River field present nearly the same lithological aspect the data furnished by the Crystal River borings may warrant the suggestion that where a valuable coal seam is thought to lie within working distance by shaft and the sinking of the latter is contemplated, considerable delay as well as expense might be avoided by first boring to the desired depth, in which manner an idea may be obtained of the kind and power of the machinery required, which will be governed largely by the presence or absence of strong flows of water, not to take into account the additional advantage which a thorough knowledge of the formation will give in the matter of preparatory work and general equipment.