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SOME OBSERVATIONS ON THE THERMAL SPRINGS OF THE SOUTHEASTERN BLACK HILLS OF SOUTH DAKOTA

P. MURRAY WORK

LOCATION

The thermal springs to be discussed occur in the southeastern portion of the Black Hills in the east-central part of T. 7. S., R. 5 E. in and near the city of Hot Springs, and in Sec. 20, T. 8 S., R. 5 E. near the town of Cascade Springs, Fall River County, South Dakota.

GEOLOGY

The entire region is underlain by pre-Cambrian metamorphics. The Deadwood (Cambrian) sandstone, and the Englewood and Pahasapa (Mississippian) limestone underlie, but do not outcrop, this area. The oldest rock which is exposed at the surface, and with which the thermal springs are associated, is the Minnelusa (Pennsylvanian) limestone and sandstone which is overlain in order by the Opeche (Permian?) red shale, the Minnekahta (Permian?) limestone, and the Spearfish (Triassic?) red shale. Pleistocene conglomerates occur in the valley of Fall River.

STRUCTURE

Although lying on the southeastern edge of the general Black Hills uplift, the dominant structural feature of the area is an asymmetric anticline just west of the city of Hot Springs. This anticline, which is plunging to the south, is first observed in the northern part of the area and extends in a southerly direction down the western side of T. 7 S. and T. 8 S., R. 5 E. The west flank of the anticline is more steeply dipping than the east. Having a length of more than 15 miles, and average width of 3 miles, and a closure of more than 800 feet the Hot Springs anticline, as this structure is designated, is one of the largest secondary structures of the Black Hills anticlinorium.

DESCRIPTION OF THE SPRINGS

GENERAL

In the vicinity of Hot Springs, on the east side of the Hot Springs anticline, there are a large number of springs issuing along the valley of Fall River. However, there are only six that have been distinguished by separate names. On the west side of the Hot Springs anticline there are two large thermal springs known.

The springs in this area are not hot springs, but their average temperature of about 87° F. would place them in the classification of warm springs. However, their temperatures of 82° F. to 92° F. undoubtedly indicates their thermal nature. Their average temperature is 42° F. above the mean regional temperature.

Due to the existing conditions no actual measurement of the volume has been made. Apparently there is little or no seasonal variation in either the volume or the temperature. The total volume of flow of the springs in the vicinity of Hot Springs is 11,400 gallons per minute or 1500 cubic feet per minute. The flow of the Cascade Springs has also been measured at about 1500 cubic feet per minute. Even during the extremely dry summers of 1929 and 1930 the flow of these springs had not diminished.

Springers Ranch Spring

This large spring, from which the city of Hot Springs secures its water supply, is located in Hot Brook Canyon about 2½ miles west of Hot Springs. There is no single spring, but for a distance of 200 feet the water issues along the bed of the canyon. Below this spring Hot Brook is a permanent stream, above it only intermittant. The temperature of the water is 92° F. The flow was approximated as being about 2100 gallons per minute. This spring emerges on the axis of the Hot Springs anticline, ½ mile north of the crest, and 100 feet above the base of the Minnelusa formation. The elevation of the spring is 3650 feet above sea level.

Mammouth Spring

This spring is located at the junction of Hot Brook and Cold Brook, and like the Springers Ranch Spring, the water issues through several orifices along the stream bed. The temperature is 91° F. It is not possible to even estimate the flow of this spring due to the commercial use of its waters, but the writer believes that Mammouth Spring has a larger flow than all the rest of the springs in the vicinity of Hot Springs put together. This spring issues about two-thirds of the way down the east limb of the Hot Springs anticline. Stratigraphically it issues from the top of the Minnekahta limestone formation. Its elevation is 3500 feet above sea level.

Other Springs in Fall River Valley

Within the Pleistocene valley of Fall River there occur several other warm springs, the most important of which are the Minnekahta Spring, Hygeia or Kidney Spring, Lakatah Spring, a spring near the railway station, and the Hiawatha Spring.

With the exception of the Hiawatha Spring the others all issue within a radius of ¼ mile of the railway station. The waters are largely used in bath houses or are piped away from the original orifice making it impossible to secure the volume of flow. These springs also issue about two-thirds of the way down the east limb of the Hot Springs anticline, but at a slightly lower elevation. They issue at the top of the Minnekahta limestone. The temperature of this group of springs varies from 92° F. for the Minnekahata Spring to 83° F. for the Hygeia Spring.

Hiawatha Spring is situated about one mile southeast of those already described on the east side of the Fall River Valley. This spring is structurally located further down the east limb of the Hot Springs anticline than any of the others and at a higher stratigraphic position, namely, near the top of the Spearfish formation. The volume of this spring is not known although the temperature has been measured at 82° F.

Cascade Springs

Seven miles in a straight line southwest of Hot Springs there are two thermal springs with a flow of over 10,000 gallons per minute. These springs are located in the S.E. ¼ of Sec. 20, T. 8 S., R. 5 E. at the southern end of Albaugh Canyon and at the head of permanent water of Cascade Creek. Cascade Springs issue from the top of the Minnekahta limestone and are structurally located on the steeply-dipping west limb of the Hot Springs anticline at a place where the trend of the axis of the anticline makes a 45° bend to the southeast. The elevation of the springs is 3400 feet above sea level.

Relation of Cold Springs to the Thermal Springs

There are several cold springs within the area with a temperature of about 45° F. that are associated as to location with the thermal springs. The most outstanding example is a cold spring ½ mile north by northwest of the Springers Ranch Spring. This cold spring issues about 200 feet above the base of the Minnelusa formation just west of the axis of the anticline. Its stratigraphic and structural position is almost identical with the nearby warm spring, yet, this spring, as the other cold springs of the region, ceased flowing in the dry summer of 1930 whereas there was no decrease in the flow of the Springers Ranch Spring.

SOURCE OF THE WATER

METEORIC

Obviously these thermal springs are not hillside or gravity springs but should be classified as fissure springs. If the water is of meteoric origin it would be derived from some water-bearing formation that is involved in an artesian structure. Upon inspection of the conditions necessary for artesian water it is found that there is a poor artesian structure, the gathering ground is too close to the place of issuance to assure no seasonal variation of flow, and an acquifer, although present, has been found by wells sunk into it to contain only a moderate supply of water. Also, the Minnelusa formation, one of the most important water-bearing sands, has been breached above most of the springs by the valley of Hot Brook. A well within the city limits of Hot Springs was sunk to the Minnelusa formation but yielded only a small amount of water and was non-flowing. The Deadwood formation, wherever penetrated by wells in this region, yields only small amounts of water. A point of interest is that water secured from wells which penetrated either the Minnelusa or Deadwood or both has a normal temperature and is not of a thermal character.

JUVENILE

The major uplift of the present Black Hills, which took place in Tertiary time, was accompanied by the intrusion of large masses of igneous rock. In the Northern Black Hills there are many domes and anticlines formed by Tertiary igneous intrusion, some of which are covered while some have been uncovered by subsequent erosion. Although no Tertiary igneous rocks are exposed in the Southern Black Hills, it does not seem too broad an assumption to assume that intrusions took place here the same as in the Northern Black Hills, but the intrusive masses are still covered.

The assumption is that the Hot Springs anticline is the result of Tertiary igneous intrusion. The water of the warm springs, although partially of meteoric source, is largely derived from a cooling magma, the water rising through fissures which occur on the axis and flanks of the anticline. The almost constant flow and temperature of these springs seems evidence of the magmatic source of the water. Kirk Bryan [1] states in a paper on the thermal springs of Arkansas that, "Springs with steady flow and without great variations in temperature or quantity, especially if they are

[1] Bryan, Kirk. The Hot Water Supply of the Hot Springs, Arkansas. Jour. Geol., Vol. XXX, pp. 425-449, 1922.

hot, must arise from some deep artesian circulation or be of juvenile origin." If this is true the springs in this region could only be of magmatic origin because the necessary conditions for a deep artesian circulation are lacking as the greatest depth to the water-bearing formations does not exceed 1100 feet.

Source of the Heat

Radioactivity

Although the springs underdiscussion have never been examined for radioactivity, it is doubtful that radioactivity plays any part in their thermal condition. Investigations of the hot springs of both Iceland and Yellowstone Park by experienced geologists indicate that there is no connection between the amount of radioactivity and the temperature of the waters. In some instances the waters of cold springs in Yellowstone were found to be slightly more radioactive than the hot waters.

Chemical Processes

There are no indications that chemical processes near to or far from the surface are in operation to furnish the heat supply. There is no rock decomposition near the springs, nor are large amounts of chemically precipitated material deposited by the waters. The waters of the springs are not acidic, but in fact are alkaline.

Forced Flow

Adams [2] in 1924 presented a hypothesis that some warm springs might be due to forced flow through a porous plug which would tend to raise the temperature of the water. The relation of the springs to the regional structure precludes this hypothesis.

Sosman [3] in a discussion of Adam's hypothesis believes that the reverse of forced flow is more likely. He writes, "The transfer of a mass of water from a high level to a low level involves the loss by the water of a certain amount of potential energy. This must be either distributed along the route or appear in the water itself at its final location, either as kinetic energy or as heat." Although the above is true, there is not a sudden enough change in level of any acquifer in this area to produce a rise in temperature of 45° F. above the mean regional temperature.

Thermal Gradient

Assuming that the thermal gradient for this region is one degree

2 Adams, Leason H. A Physical Source of Heat in Springs. Jour. Geol., Vol. XXXII, pp. 191-194, 1924.

3 Sosman, Robert B. Notes on the Discussion of the Papers presented in the Symposium on Hot Springs. Jour. Geol., Vol. XXXII, pp. 464-468, 1924.

of Farenheit for every 60 feet of depth it is found that meteoric water would have to descend at least 2700 feet in order to reach a temperature of 90° F. The depth just given does not take into consideration any loss of heat by the water on its return to the surface. Unless Tertiary igneous rocks are present, this area is underlain at a depth of not more than 1100 feet by pre-Cambrian metamorphics. Therefore, water could not follow any artesian structure to a depth sufficient to raise its temperature to that of the water in the springs.

MAGMATIC OR VOLCANIC HEAT

After considering the other possible sources for the heat we are led to the conception that the heat is probably derived from a cooling magma which was intruded in the Tertiary at the time of the general Black Hills uplift and forming the Hot Springs anticline. Fissures were formed along the northern part of the east limb, along the axis, and at a flexure near Cascade Springs of the anticline which extend down to this magma. Due to the gradual cooling and crystallization of the magma highly heated water and steam is expelled which rises through the fissures, is cooled and condensed as it nears the surface and mingles with some meteoric water, loses any contained volcanic gasses by dissipation through the rock on its upward journey, and issues at the surface as warm springs.

The fact that the thermal spring waters contain a much higher percentage of mineral matter, particularly silica, than do waters from wells in the vicinity, would indicate that their source was different and perhaps the temperature inherent.

DES MOINES, IOWA.