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PRELIMINARY REPORT

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Underground Waters of a Part of Southeastern Colorado

BY
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AND
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GROUND WATERS OF PARTS OF ELBERT, EL PASO, AND LINCOLN COUNTIES

By R. C. Coffin

INTRODUCTION

The area examined by the Colorado Geological Survey in eastern Colorado during the summer of 1919 included parts of El Paso, Lincoln, and Elbert counties. The center of this area, which is discussed in this preliminary report, lies 38 miles east, and 5 miles south of Colorado Springs. V. J. Hendrickson and D. R. Knowlton assisted the writer during the examination, which covered approximately 225 square miles. The object of the investigation was to obtain data which would be of help in directing the search for well water in the area.

In as much as sand and gravel cover practically the entire area, information as to possible water-carrying beds was limited, for the most part, to questionable data obtained from water wells. For this reason the boundaries which appear on the accompanying map are generalized.

The area is a part of the Great Plains of eastern Colorado, being an undulating surface covered with a sandy soil. Farming, stock-raising, and dairying in limited amounts constitute the industries of the region. Water for irrigation is not present in the area, and in many places as yet no well water has been found. Aside from small areas adjacent to streams, the ground water of the region comes from local rains and snows.

GENERAL GEOLOGY

Tertiary and Quaternary deposits.—The surface material over practically the entire area is a sandy soil covering sand and gravel. In places the basal part of these materials has been consolidated into a conglomerate. The materials are considered Eocene in age and constitute the Nussbaum formation as it has been described in reports that deal with areas farther south. In many places soil and sand have been shifted by winds and deposited in dunes. These dunes represent the youngest deposits of the region. The thickness of these Tertiary sands and gravels is 200 feet in places, but is less than 100 feet over the larger part of the area examined.

Laramie formation.—In the northwestern part of the area mapped the Tertiary gravels are underlain by beds of the Laramie formation. Exposures of these beds occur along Horse Creek near the Forder ranch and at Signal Rock. The exact boundary between this formation and the Fox Hills formation was not determined in these exposures. The basal part of the Laramie includes sandstones similar to the upper ones in the Fox Hills formation. Coal, which occurs locally within 50 feet of the base of the Laramie formation, is mined at one point. Beds above the coal were not exposed and need not be considered, as the areas wherein the Laramie beds are present seem to have no well-water problem. During the examination no well was found which had been drilled a reasonable depth within these areas which failed to encounter water.

Fox Hills formation.—Sandstones make up approximately 125 feet of the beds immediately below the coal horizon of the Laramie formation. The upper part of this interval includes beds of the Laramie group, but the presence of fossils in the lower sandstones proves that the greater part of the interval is a part of the Fox Hills formation. Beds of the Fox Hills formation are exposed along Horse Creek between the Forder ranch and the east boundary of section 29, T. 13 S., R. 58 W. In this distance the truncated edges of approximately 400 feet of beds are exposed below the sandstones already mentioned. These 400 feet of beds include from the top downward the following units.

Partial section of the Fox Hills formation measured along Horse Creek

1. Shale and sandy shale 50 feet. This unit probably includes locally water-carrying beds.

2. Shale 200 feet. The unit includes no water-bearing bed.

3. Sandy shales and sandstones 150 feet. Two distinct sandstones occur near the base of the unit which are sufficiently porous to allow for the free circulation of ground water. These beds are the lowest ones in the region which could act as a reservoir for well water.

Data from wells south of Truckton indicate that in this region beds equivalent to the 400-foot section given are much more sandy than in their exposures on Horse Creek. Beds which apparently come in the stratigraphic position of No. 2 of the Horse Creek section include sandstones which, in places, are water bearing. It is probable that the exposures of shale which come within the area examined along the lower part of Horse Creek include beds of the Pierre formation.

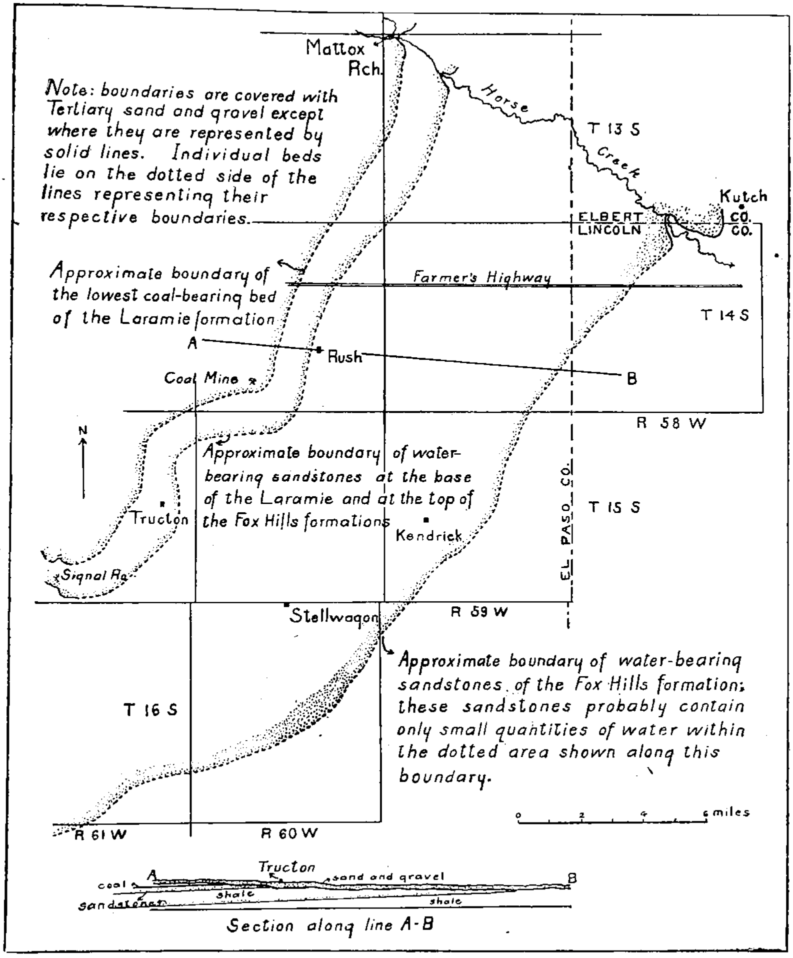

Fig. 1. Sketch map showing approximate positions of important geologic horizons.

Geologic history.—Only a few points which have to do with the geologic history of the region need be considered. After the deposition of the Laramie and older formations, the area was affected by processes of folding which tilted these beds toward the northwest. Erosion which followed carved from these beds an undulating surface whose general slope was toward Arkansas River. This undulating surface probably possessed differences of elevation comparable to the present surface. Stream courses and flat-bottomed depressions existed in this ancient plain. The beds of the Laramie formation were at that time exposed in the northwestern part of the area under consideration, and beds of the Fox Hills and Pierre formations were exposed in the south and southeastern parts.

Sand and gravel were eventually scattered over this area by streams which flowed generally east and southeast from the present mountains. These sands and gravels filled the depressions and obliterated the ancient stream courses. Since the deposition of these materials in late Tertiary times they have been partially consolidated and in some places have been removed by the present streams.

WATER-BEARING BEDS

The water-bearing beds of the region are as follows:

1. Basal part of the Tertiary sands and gravels.
2. Sandstones at the top of the Fox Hills formation and at the base of the Laramie formation.
3. Sandstones within the Fox Hills formation.

Basal part of the Tertiary sands and gravels.—There is no uniformity as to presence of water in these materials. In the northern part of the area mapped the Tertiary sands and gravels contain water in most regions, except those adjacent to Horse Creek. In the southern part of the area many wells did not encounter water in these surface gravels, but had to be drilled to the sandstones of the lower formations. The depth of wells which supply water from these sands and gravels ranges from 10 feet to 200 feet. The water from these wells is uniformly of good quality.

Sandstones at the base of the Laramie formation and at the top of the Fox Hills formation.—These beds constitute a single water-bearing unit and can be considered under one head. The accompanying map shows approximately the limits within which these sandstones would be encountered by drilling. Aside from an area southwest of Truckton, all wells drilled to these sandstones contain an abundance of good water. The small quantities of water in this area can be explained by the present topography and the structure of the underground beds. It is probable that these sandstones are not 300 feet deep within any of the area examined.

Sandstones within the Fox Hills formation.—The approximate limits within which these sandstones would be encountered by drilling are shown on the reconnaissance map of this region. With the exception of areas near the edge of these sandstones, all wells which have been drilled to these lower beds have supplied enough water for the domestic use and stock of the average farmer. In a few wells which have been drilled to these sandstones the water is hard, but at no place is it unusable.

The experience gained by drilling south and east of the limits mapped for the Fox Hills sandstone has established a rule which is followed by many drillers. The prevailing notion is that no water is found in or below "blue shale." Drillers are reluctant to continue operations after striking shale. Many wells drilled within the limits of the lower Fox Hills sandstones encountered no water in the Tertiary gravels, and they continued into the lower beds, but were abandoned when they encountered shale, which, in many places, overlies the lower Fox Hills sandstones. Although the rule would appear to be applicable to areas which do not involve the Fox Hills sandstones, it should not apply to areas within the limits of these sandstones. No well was found by the Survey party which had been drilled to these beds without encountering water. It is to be noted that wells near the edge of these sandstones may encounter only small quantities of water.

STRUCTURE AND DEPTH TO DIFFERENT WATER-BEARING BEDS

All beds below the Tertiary dip to the north and west at angles which average approximately 1°. It follows that any bed becomes deeper toward the north and west, owing to its dip and a rise in the present surface in that direction. To understand the ground-water conditions it is necessary to keep in mind that the beds below the Tertiary gravels dip to the northwest, and that the present surface and the surface upon which the gravel rests are inclined to the southeast. Where the Tertiary deposits rest upon shale which is relatively impervious, the ground water entering from the surface passes down to the base of the gravels and follows near the contact between the Tertiary and older formations. The tendency in such areas is for the water to accumulate in and follow the depressions in the shale which lead, in general, in a southeasterly direction. Where the Tertiary deposits rest upon the sandstones already described, water which passed down through the surface gravels enters the sandstones and is carried toward the northwest with a constant increase in its depth. The depth to water which is found in the basal part of the Tertiary materials seldom exceeds 150 feet, and the average is less than 100 feet. Wells which are drilled within the limits of the basal beds of the Laramie formation are seldom over 200 feet deep, but many such wells encounter water in beds above the basal sandstone of the formation.

In areas immediately south and east of the line representing the limit of the upper Fox Hills sandstones, should wells fail to find water in the Tertiary gravels, known conditions would justify that drilling be continued to the lower sandstones of the Fox Hills formation. These sandstones should be encountered at depths which range from 350 to 525 feet immediately south or east of the line mentioned above. In areas nearer the line which represents the limit of the lower Fox Hills sandstones this depth is less.

GROUND WATER CONDITIONS BEYOND THE LIMITS OF THE FOX HILLS SANDSTONE

Several deep wells and an examination of beds which outcrop along Horse Creek, below the ones already described, would suggest that the lower Fox Hills sandstones, as outlined, constitute the lowest persistent water-bearing beds of the region. No data have come to the Survey thus far in this examination which would justify drilling below the Tertiary sands and gravels in areas beyond the limits of the lower Fox Hills sandstones. Small quantities of water have been encountered in sandy streaks in wells drilled below these sandstones, but the water has been too salty for the use of stock,

The principles which determine the distribution of water in the Tertiary gravels cannot be expanded in this short paper.

ARTESIAN-WATER POSSIBILITIES AND DEPTH TO OTHER SANDSTONES

The structural conditions would make it impossible for water to flow at any point from wells which might encounter the different sands within the area examined. No water-bearing sandstones are known to exist between those described and the Carlile and Dakota sandstones of lower formations. In as much as these sandstones are more than 2,500 feet deep in the area discussed they cannot be considered possible sources of ground water under present conditions.

UNDERGROUND WATERS OF PARTS OF LINCOLN AND CROWLEY COUNTIES

By A. J. Tieje

INTRODUCTION

During the summer of 1920 the writer examined an area in southeastern Colorado, which is mainly comprised in Townships 13, 14, 15, 16, 17 S., Ranges 56, 55, 54 W., and in T. 18 S., R. 57 W. He was assisted by A. N. Murray. The aim of the examination was to aid residents of this area in their search for well water.

The area is a portion of the Great Plains of eastern Colorado, a region predominantly of almost level divides between occasional intermittent streams. Farming and stock raising are the industries. Karval, with 50 inhabitants, is the only town.

GENERAL GEOLOGY

In this area only three formations are of practical importance to the water seeker. The lowest of these is:

The Pierre shale.—These shales, of Cretaceous age, underlie the entire area mapped, and extend beyond it in all directions. In the vicinity of the Arkansas River below Pueblo the lowest 500 feet consist of medium-gray unfossiliferous shale, and the uppermost zone of sandy yellowish-green shale, with fossils suggesting those of the Fox Hills formation. In the area mapped, only the middle zone of the Pierre is present. An understanding of the nature of this shale would save the water seeker from many "dry holes."

Extended beds of shale are essentially hardened mud, deposited in a sea; in the case of the Pierre shale, this sea lapped the shore of mountains somewhere to the west. The hardening was caused by the pressure of overlying sediments. Much later, the shale was uplifted and became land.

The middle zone of the Pierre shale, as now visible in the creek valleys, consists of a thin-bedded rock, almost black, except where long exposed to the air; then it is whitish. It contains many 2-foot oval masses of iron-stained sandstone and limestone. Of importance to the water seeker is the presence of crystals of gypsum, often mistaken for mica or "isinglass." It is this gypsum which renders much of the water in wells bitter. Mica is flexible and elastic. Gypsum is not. Moreover, gypsum is easily soluble in hot water.

Of importance to the water seeker, also, is the occurrence of the "tepee buttes," which rise as rudely conical hills above the softer and more easily eroded shale. These buttes are conspicuous along Adobe Creek, Stanley Gulch, and farther to the southeast. They consist, not of shale, as is commonly supposed, but of a dark-gray, coarse-grained limestone, which may be a water carrier. Probably these "buttes" were limy banks in the ancient sea.

The shale is further distinguished by its fossils. The most common are *Scaphites nodosus*, a small, coiled form; *Lucina occidentalis*, the so-called "peachstones"; and *Baculites compressus* and *Inoceramus sagensis*, the "petrified fish" and the "clam shells" of the well digger.

The Nussbaum formation.—Other formations, such as the Fox Hills and the Laramie, may once have overlain the Pierre shale. If so, they were eroded after the uplift. On all the divides the Pierre shale is now overlain by the clays, sands, and gravels of the Nussbaum formation, supposed to be of Pliocene age. These clays, sands, and gravels were laid down by streams flowing from the western mountains. The thickness of the Nussbaum formation ranges from 10 to 20 feet on the stream bluffs, to 200 feet on some divides. The understanding of the nature and history of this formation should greatly aid the water seeker.

The lowest 3 to 5 feet of the Nussbaum formation is not everywhere present; it consists of moist, coarse gravel or fine sand. The next 2 to 15 feet is best exposed at Stony Point on the Karval-Limon road or at the springs of Adobe Creek on J. F. Lockwood's ranch. This material is to all appearances a conglomerate; that is, a cemented mass of water-rounded pebbles. Even where disintegrated into small masses, the conglomerate has a whitish-gray color, and a limy cement binds together pebbles of granite, quartz, feldspar, bits of Pierre iron concretions, and fragments of petrified wood. Extended exposures of the massive rock show cross bedding.

Well logs best explain the character of the sediments overlying this conglomerate.

Well at Karval

	Ft.	In.
Loam, blackish	1	6
Sand, massive, yellow, medium-grained, slightly clayey	6	..
Clay, bluish to reddish, hard, greasy, gritty, limy; lumps of "magnesia"	8	..
Sand, loose, white, coarse; suggestions of conglomerate	16–20	..
Clay, whitish, sandy, somewhat plastic	10	..
"Soapstone"—really a ferruginous clay, giving fire test for ordinary brick; smooth, even talc-like, fine grained, very plastic, barely gritty to teeth	4	..
Sand and clay, moist	2	..
	46–51	6
Shale		

Miller well, south half section 26, T. 15 S., R. 56 W.

	Ft.	In
Soil and subsoil	6	..
Gravel and sand, coarse	3	..
Gravel, fine	10	..
Sand, fine	8	..
Gravel, coarse, wet, suggestions of conglomerate	35	..
Sand, fine, moist	10	..
Gravel, coarse, wet, mixed with clay	20	..
Gravel, medium	3	..
Conglomerate	2	..
Conglomerate, much coarser; water rose slowly to four feet below this	24	..
	121	..
Shale		

The Pleistocene alluvium.—Alluvium is a term applied to unconsolidated deposits in river beds or at the sides of rivers where the waters reach only in flood times (flood plains), or where, as the streams slowly cut deeper, they no longer reach at all (terraces). Such deposits, of a comparatively recent period, are of considerable width southward along Horse Creek from the point where it enters the area mapped. Along Adobe Creek, there is little alluvium, except in the beds of small tributaries. In these the alluvium may be 8 feet deep; in Horse Creek Valley it may be 12 to 15 feet deep. The alluvium is mainly sand or fine gravel, chiefly due to side wash from the disintegrating Nussbaum on the divides. In this case it often carries water of good quality. If the alluvium consists of shale decomposed in place, any water it may carry will be bitter.

THE MOVEMENT OF UNDERGROUND WATER

To sink a well intelligently, the water seeker should understand the nature and movements of ground water. When rain falls, the water either stands upon the surface, runs off, evaporates or sinks. Certain rocks with large pore spaces, like sandstone, allow considerable downward flow; other rocks with minute pore spaces, like shale, tend to stop downward movement. Thus, when water moving downward through sandstone encounters shale, the water can more easily move sideways than downward. This fact tends to saturation of the beds above the shale, the depth of the so-called ground-water zone then depending chiefly on the supply from above. The upper level of the saturated zone is called the ground-water table.

The ground-water table, however, is not flat. Under elevations, the water, though farther from the surface, is constantly domed up by fresh supplies. Thus, it stands higher than under valleys. Flow lines are established toward any point of escape at a lower level.

The ground water, also, moves very slowly, its rate depending on the shape and diameter of the pore spaces, and, hence, upon the sizing and packing of the rock grains. Shale is not impervious to water; it may even be saturated. *But it will not yield water readily.* On the other hand, water moves with enough practical rapidity in saturated sandstones and gravels to make them, not only water carrying, but *water yielding.* If, now, a well penetrates the saturated sandstones or gravel, and water is removed by pumping, the ground-water table is lowered in the immediate vicinity. Artificial flow lines toward the well are established. A new supply enters the well. When water rises rapidly in a so-called artesian well, the situation is not really different. The "artesian" bed carrying the water must be inclined. It must be exposed at the surface at some fairly distant point, and at an elevation above the highest level to which it is hoped the water will rise. Finally, the bed must be capped above by a so-called impervious layer, such as shale. Under such conditions, the pressure under which the water is flowing down the incline will cause it to rise in the well. For rough calculations as to height of rise, only the difference in elevation between the locality where the bed is exposed at the surface, and the point where the bed is pierced, need be known. Ability to rise is lessened because of (1) friction; (2) loss of water upward or even downward through leaky beds; (3) change in diameter of pore spaces; (4) change of temperature of the water; (5) improper sizing and casing of the well. Roughly, a decrease of 1 foot per mile must always be allowed for.

The water seeker should further remember two facts. Water seldom or never moves underground from streams. Streams are always below the ground-water table and movement is toward them. Secondly, the doming of the ground-water table is much less marked than would be suggested by surface elevations. In the area here considered, the relative size of elevations and depressions in the surface of the Pierre shale, far below the ground, is of prime importance. Given the light rainfall of southeastern Colorado, any considerable depression in the surface of the Pierre shale would tend to become a small local reservoir of water-yielding gravel.

GROUND-WATER POSSIBILITIES

The beds below the Pierre shale.—Water-bearing beds below the Pierre shale are: (1) the Timpas limestone; (2) the sandstones of the Carlile shale; (3) the Dakota sandstone. The laws governing the rise of water in artesian wells prohibit expectation of securing water from the Dakota sandstone in this area. It is at least 2,000 feet below the surface. The Timpas limestone is about 1,250 feet below the surface, the Carlile sandstones about 1,500 feet.

The Pierre shale.—Water is very rarely found in the Pierre shale, because of conditions previously explained. Hendrix's spring, section 1, T. 17 S., R. 55 W., is the only exception known to the writer. This spring, however, is in a fissured "tepee butte," which, very possibly, is here a portion of a continuous limestone lens of some thickness. Surface water has sunk downward to this limestone because erosion of the Pierre had removed all overlying shale before the deposition of the Nussbaum gravels. The water seeker who advances this spring as proof that "water is in the shale" should consider these special conditions.

The Nussbaum formation.—The topography of the surface of the divides is such that the ground-water supply is governed by *local, scanty* rainfall. Much water, furthermore, seeps away at creek bluffs. Well logs indicate, also, that the ground water is seldom or never found in adequate quantity except between the conglomerate and the shale. Accordingly, the conditions under which the Nussbaum formation was laid down must be understood by one who seeks water on the divides.

When the Cretaceous sediments were tilted up so as to slope away from the rising western mountains, the deposits made by the mountain streams were dependent upon the climate. At first, it seems to have been moderately wet. The streams cut deep east-west valleys, and from these valleys northwest-southeast tributaries worked back. The climate then probably became drier. But at intervals, just as now, violent floods burst from the fountain canyons. The streams, overloaded with sediment, were forced to deposit it because of (1) lessened gradient; (2) lessened velocity; (3) evaporation and the sinking of water into the thirsty soil. Thus the streams gradually filled in former valleys; as they dwindled in volume, they spread out into numerous "branchlets," meeting branchlets from neighboring canyons and forming an intricate interlacing network not unlike the small-scale one of the Big Sandy near Limon; and the result was the probable formation of a vast "apron" of sand, clay and gravel, sloping gently southeastward from the mountains. On this apron, any given stream might at one time dig a shallow temporarily persistent channel, its bed covered with coarse material. Later, another temporary stream in a different channel might, by overflow, deposit clays and finer sands above this coarse material. Thus, would arise such sediments as make up the Nussbaum, mainly: (1) irregularly alternating courses of gravel, sands and clays in east-west lines, or (2) discontinuous stretches of gravel bounded on all sides by finer, less pervious sediments. Through all of these the surface water slowly sinks, being finally held in between the irregular belts of the conglomerate and the underlying shale.

This discontinuity of both the water-yielding gravels and the conglomerate "cap" is probably the chief reason for "dry holes." But, furthermore, water does not always underlie the conglomerate. The Pierre shale has been spoken of as probably cut into slight depressions and elevations, with a general southeast slope, before the deposition of the Nussbaum sands and gravels. Ordinarily, such shallow depressions would not greatly affect the lateral movements of the ground water. The position of many springs shows that the ground water does not constantly move southeast. But the depth of the ground water above the Pierre shale is so slight that very frequently the water may not have the power to flow over even low divides, and is impounded in longitudinal depressions. It may even flow from all directions into four-sided basins. Naturally, wells piercing the conglomerate on one of the gentle under-surface divides will get no water.

The following suggestions may prove of value to those seeking water in the Nussbaum formation. (1) Outcrops of the conglomerate may show the direction in which ground water is moving, and their width may indicate the width of water-bearing gravels in the vicinity. Buried conglomerate may be suggested by a line of successful wells. Conglomerate, even if disintegrated, is indicated by the presence of bluff-side springs. (2) The direction of source of flow from springs indicates probable water-yielding gravels. (3) In the absence of all such aids, the water seeker may select the lowest point on his land. If he fails to secure water, he should note the presence or absence of conglomerate, the depth to shale on both sides of the well, etc. He should dig his second well in a remote corner of his land. If he now makes allowance for the slope of the surface topography from well (a) to well (b), he can roughly figure the slope of the shale and locate a third well with better chances of success. (4) A well which shows feeble seepage may be improved as follows: Drain tunnels should be dug, sloping slightly upward and at right angles to the direction whence the seepage comes. In general, the flow should increase. (5) If the diameter of a large shallow well is doubled, the flow will increase. (6) Tubular wells set in the bottom of a large dug well sometimes increase the flow. (7) With caution, a well may be torpedoed to increase flow. The water seeker, finally, should always remember that too many wells exhaust a limited quantity of ground water.

The Pleistocene alluvium.—The water seeker will usually find water very near the surface. It may, however, be bitter, because of the well entering decomposed shale. He should avoid "enlarging the basin" if the presence of gypsum is suspected.

REQUEST

Ranchers who are digging wells on their land will greatly aid the work of the Survey by tabulating the beds passed through, after the fashion of the section given for the Karval well. Such data and specimens of rocks should be sent to the State Geological Survey office at Boulder when requests for information are made.