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NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

SEISMIC SURVEY FOR DETERMINING GEOLOGIC CONTROL OF GROUND
WATER OF THE NORTHWESTERN JORNADA DEL MUERTO
T.4S., R.3E., SOCORRO COUNTY, NEW MEXICO

by

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ABSTRACT

A seismic refraction survey, consisting of two lines with a combined length of ten miles, was run on the northwestern Jornada del Muerto in order to determine geologic structure, that might control the flow of ground water. Two synclinal troughs were found, and they are considered to be the best locations for cattle wells. The field equipment and techniques used were satisfactory in most cases.

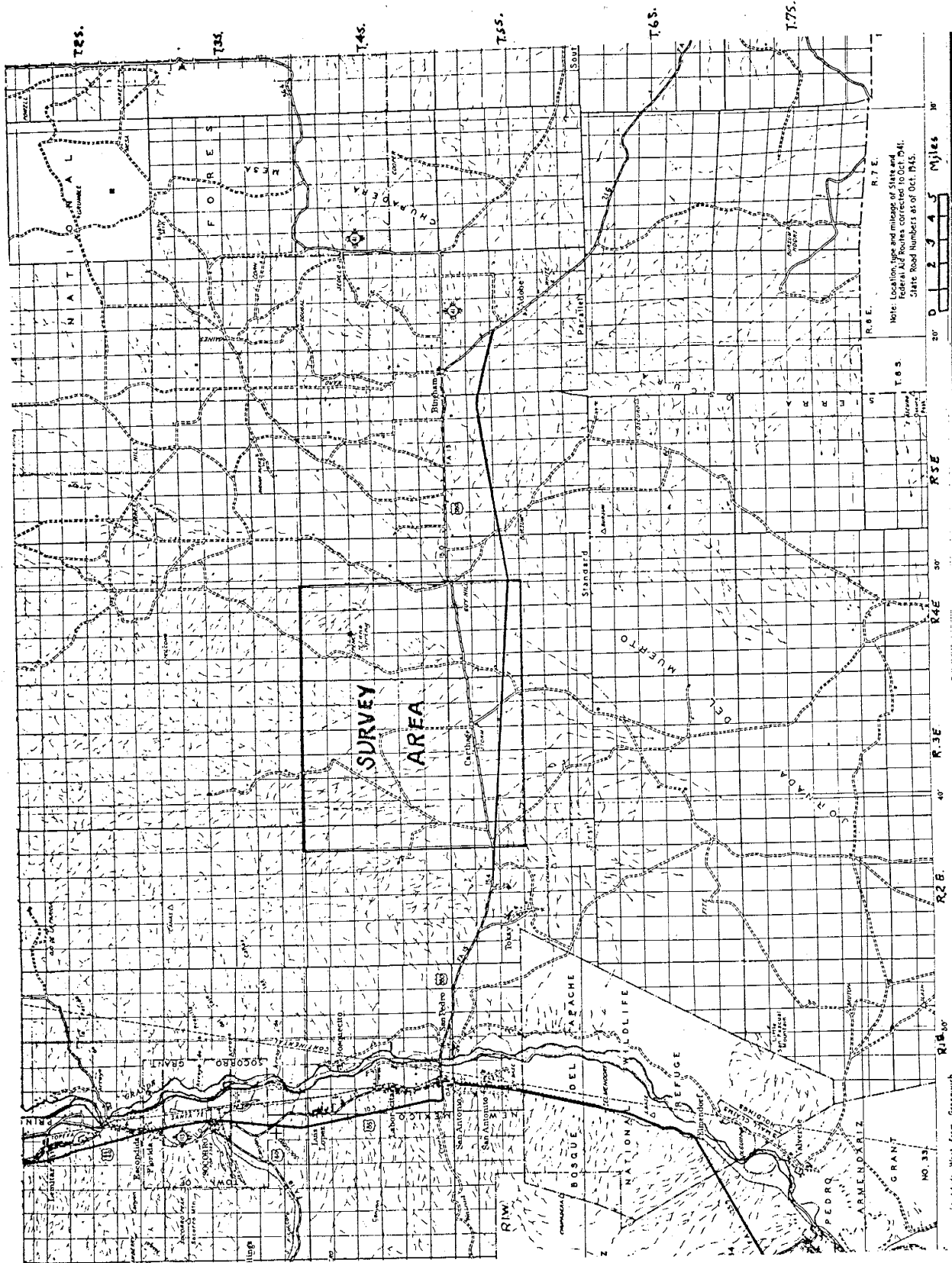
INTRODUCTION

The seismic refraction survey, with which this study is concerned, was run on the northwestern Jornada del Muerto for two purposes. One of these was to determine the geologic structure of the area, with respect to its influence on the flow of ground water, and the possibility of developing the water resources of the area. The second purpose was to determine the limitations of the present seismic field equipment and techniques in areas covered by several hundred feet of alluvium.

The field area is located about 15 miles east of San Antonio, New Mexico (see Fig. 1). It may be reached by driving east on U. S. Highway 380 from San Antonio. Access into the area is by means of several graded ranch roads.

The area is composed mainly of a flat plain that slopes gently towards the south. In the northwestern section the sediments have been faulted up so as to form a line of small hills. Along the western edge of the area is a small ridge that divides the drainage in the area. The drainage west of the ridge enters the field area, and proceeds through it and down through the Jornada del Muerto. Northward, the plain narrows into several small valleys between tilted blocks of uplifted sediments. Through these valleys passes the surface runoff of 50 square miles. Most of this runoff flows through a fairly large wash near the center of the area and is lost to the area.

Two refraction seismic lines were run; one north-south, and the other east-west, with a combined length of about 10 miles. The two lines were surveyed, and "weathering spreads" were run on mile intervals on both lines.



INDEX MAP

From: New Mexico State Highway Dept.
 General Highway Map
 Socorro County

EQUIPMENT

The seismic equipment used consisted of a twelve channel PSU-11 amplifier, a PRO-11 oscillograph, a FCB-11 blaster, a PPS-11 power supply, a PIC-11 input checking unit, and 22 S-15 seismometers all manufactured by Southwestern Industrial Electronics Company of Houston, Texas. In addition there are two sets of cables, one supplied with the above equipment having seismometer connections every 90 feet and having a total length of 1080 feet, and the other set of cables prepared by Roger Torres with connections every 240 feet and having a total length of 2880 feet.

The field equipment consisted of the above seismic equipment mounted in the back end of a Dodge "Power Wagon", and an "Earth Borer". The "Earth Borer" is a G.I. C. 4 by 4 truck with a post hole digger, capable of drilling an 18 inch diameter hole seven feet deep, mounted on the rear end.

FIELD PROBLEMS

Three problems were encountered while doing the seismic field work; the spread length necessary to receive refracted seismic waves from beds at depths of 500 to 600 feet, the method for putting sufficient seismic energy into the ground to obtain good records, and the reduction of seismic noise resulting from the vibration of the seismometers by the wind.

It was determined, by shooting spreads of various lengths, that the spread length should be at least 2000 feet. The original set of cables had a spread length of only 1050 feet; therefore, a new set of cables 2380 feet long were prepared.

The problem of putting the seismic energy into the ground was never completely solved. The solution of the problem was prevented by the shallowness of the drill holes, seven feet maximum, and the limitation, for safety, of the charge to two-thirds of a case of 40 percent dynamite.

The seismic noise, which resulted from the vibration of the seismometers by the wind, was slightly reduced by covering all of the seismometers with dirt. Two seismometers were connected in parallel 30 feet apart to each of the six connections most distant from the shot hole; this reduced the amplitude of the wind noise by a factor of at least two on the six channels so affected.

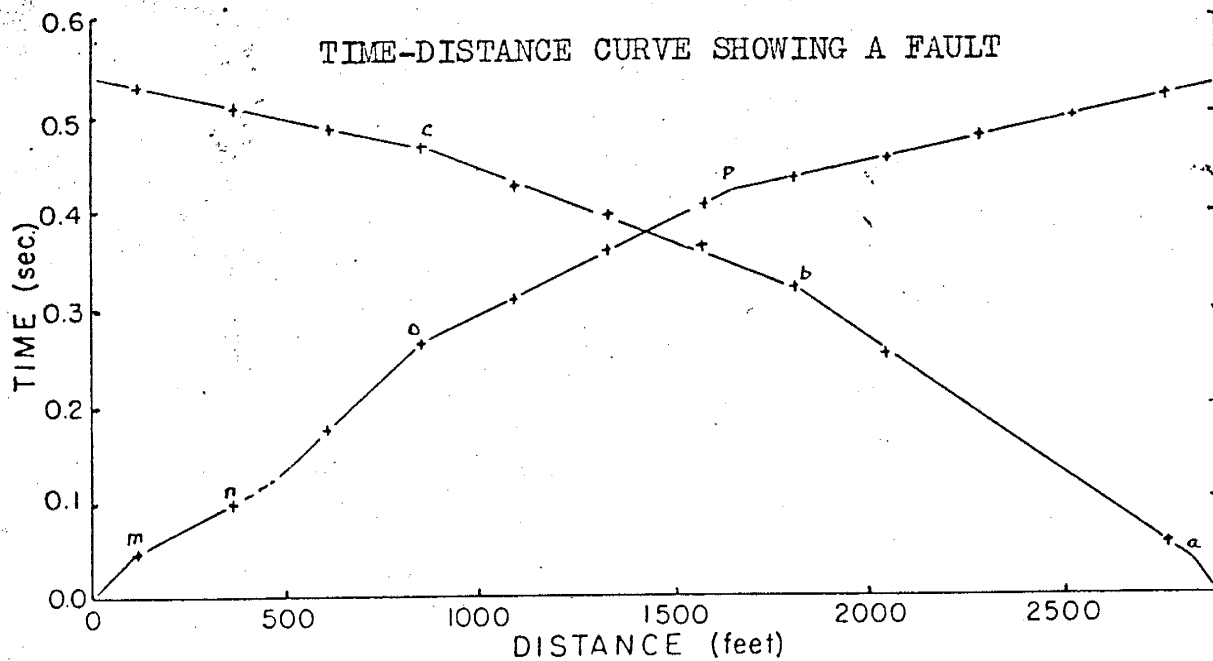


FIGURE 2

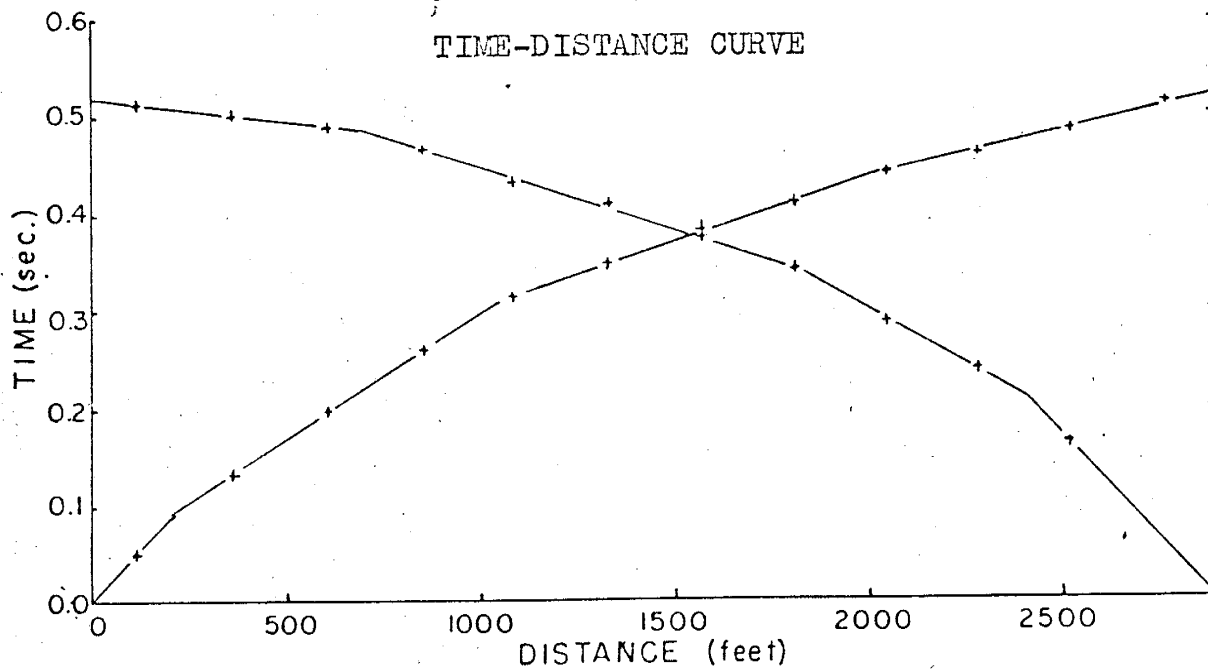


FIGURE 3

INTERPRETATION

The interpretation employed standard techniques. The time of the first seismic wave to reach the seismometer was plotted against the distance of the seismometer from the shot hole. All interpretations were then made from these time-distance curves. Figures 2 and 3 are sample time-distance curves taken from the field records. By obtaining the reciprocal of the slope of the curves, the velocities of the seismic waves in the layers are determined. In figure 2 the reciprocal of the slope of the segment of curve between a and b would be the velocity of the seismic wave in the first layer; while the reciprocal of the slope between b and c would be the velocity of the seismic wave in the second layer. The velocity obtained in the case of the second layer would be the true velocity only if the top of the layer were horizontal; if the layer were dipping, the velocity obtained would be the relative velocity. For this reason the spreads are shot from both ends giving pairs of time-distance curves (i.e. both curves in either figure 2 or 3) from which the true velocities may be determined. Figure 2 is of special interest as there are indications of a fault on the time-distance curve. Examination of the slopes of the segments mn and op of the curve shows that the segments are parallel, but displaced from each other. This indicates a fault with the downthrust side farthest from the shot hole. From these and other time-distance curves, the so-called

"weathered layer", or low velocity surface layer, was found to be from 8 to 25 feet thick, and transmits seismic waves with velocities of about 1,000 feet per second. Below this is the Quaternary alluvium, which is up to several hundred feet thick, and transmits seismic waves with velocities of about 3,500 feet per second. Next comes the Mancos shale and/or the Mesa-verde formation, several hundred feet thick, which transmits seismic waves with velocities between 5,500 and 6,000 feet per second. Below this is the Dakota sandstone, which transmits seismic waves at velocities of 10,000 feet per second or greater.

The quality of the time-distance curves is fair; occasionally one or two traces on the record could not be picked. Dip and depth determinations were made on the time-distance curves in accordance with the method outlined on page 530 of Heiland's "Geophysical Explorations".

GEOLOGY

The formations of interest to this survey, in order of their deposition, are the Dockum formation of the Triassic; the Dakota sandstone, the Mancos shale, and the Mesaverde formation of the Cretaceous; and the Quaternary alluvium.

The Dockum formation has a maximum thickness of 500 feet, and consists of maroon and light-gray sandstone, siltstone, and shale.¹ The upper members are nearly impervious.

The Dakota sandstone crops out at the eastern end of line A, not a quarter of a mile west as shown in figure 4; where about seven feet of light-gray, medium-bedded, medium-grained sandstone is exposed in a wash. These beds strike approximately N65W and dip 21° southwest at this outcrop. In the Carthage coal field, about 9 miles west, the Dakota sandstone is 71 feet thick, and consists of light-gray to buff, thick-bedded, medium-grained sandstone, with some interbedded gray shale near the base. The sandstone is a conspicuous ridge former.²

The Mancos shale is not exposed in the field area. In the Carthage coal field the Mancos shale consists of three members. The lowest member is a dark-gray to dove-gray, friable, calcareous

¹ Wilpolt, R. H., and A. A. Wanek, Geology of the region from Socorro and San Antonio east to Chupadera Mesa, Socorro County, New Mexico: U. S. Geolo. Survey Oil and Gas Investigations, Map OM 121, sheet 2, 1951

² Idem.

shale 295 to 340 feet thick, with several thin beds of flaggy limestone just above the middle. The middle member is a medium to fine-grained, medium-bedded, light-buff sandstone 240 feet thick, interbedded with light-gray, red, and lavender beds of shale. The upper member is dove-gray to blue-gray, calcareous shale 225 to 290 feet thick.³

The Mesaverde formation crops out near the Law coal mine (see Fig. 4). There are few outcrops, and it is difficult to determine the sequence of beds. In the Carthage coal field the Mesaverde formation consists of yellow and buff sandstone and shale 200 to 900 feet thick, with two thin coal beds just above the basal sandstone.⁴

The Tertiary Baca formation is exposed in one small outcrop along the western edge of the field area. The Baca formation, having a maximum thickness of 1023 feet, consists of coarse conglomerate, red and white sandstone, and red clay.⁵

The tertiary Datil formation is exposed in the northwestern corner of the field area. The formation, which has a maximum thickness of 2000 feet, consists of latite, rhyolite, and andesite flows, volcanic agglomerate, conglomerate, tuff and sandstone.

3 Wilpolt, R. H., op. cit.

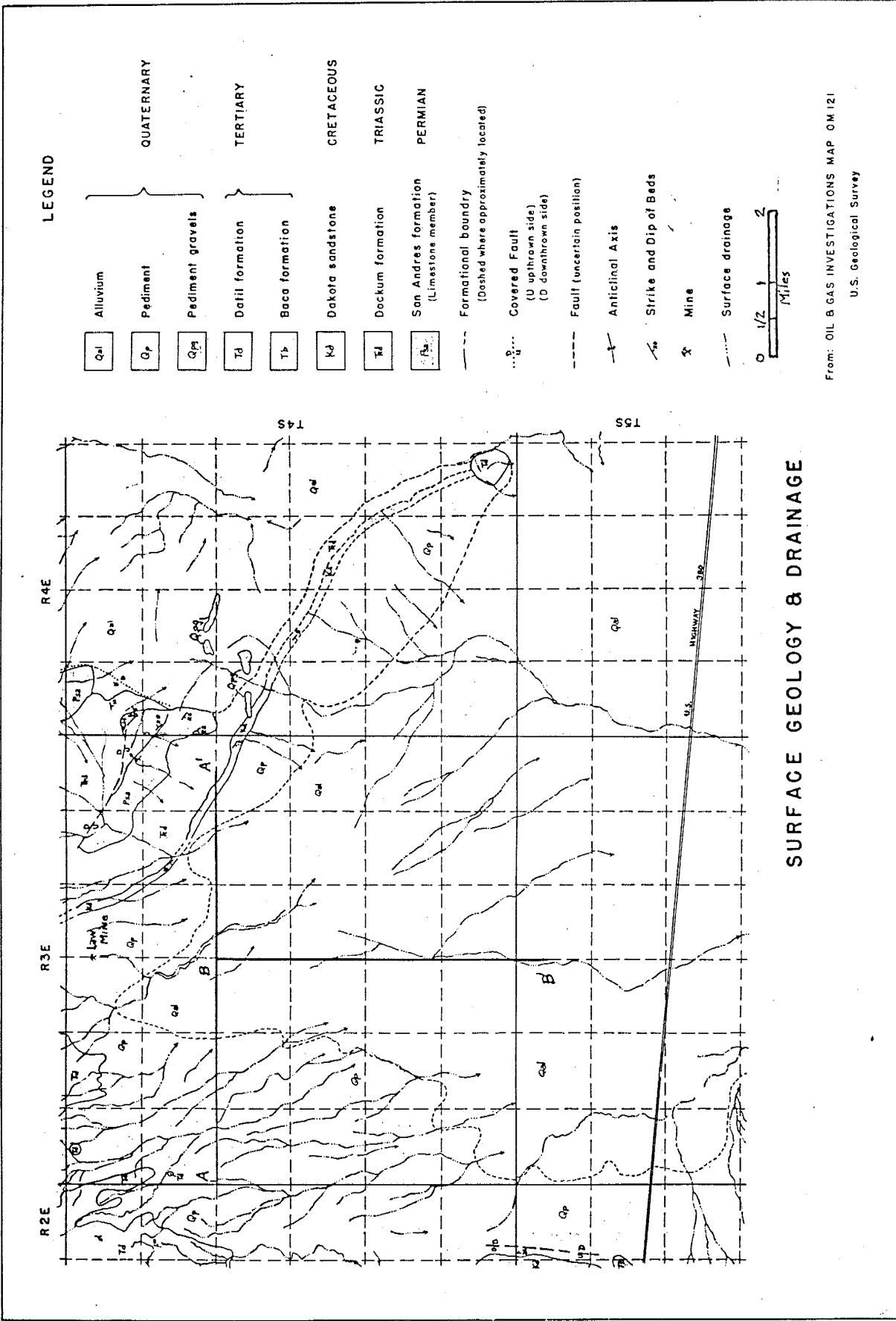
4 Idem.

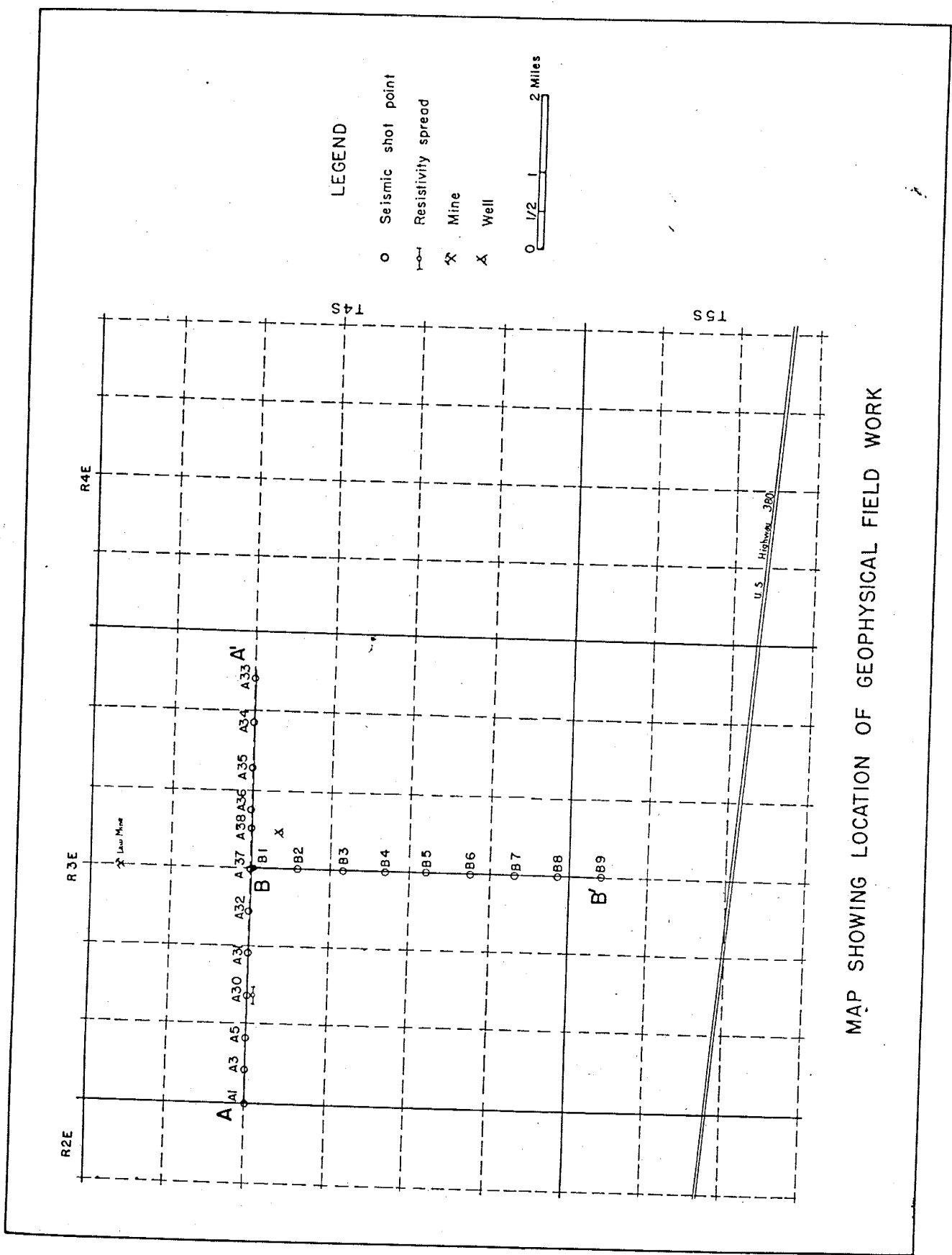
5 Idem.

6 Idem.

The central part of the area is covered by Quaternary
bolson deposits that attain a thickness of several hundred
feet. According to Wilpolt and Wanek "The Jornada del Muerto
is bordered by a relatively young undissected pediment surface
that is veneered with sands and gravel."

Sometime after the deposition of the Mesaverde formation,
all formations deposited by that time underwent a period of
faulting and folding, followed by a period of uplift in which
erosion took place. The Quaternary alluvium was afterwards
deposited, and there is some surface evidence, in the form of
what appear to be small fault scarps, of a second period of
faulting, during or after the deposition of the Quaternary
alluvium. The present surface of the Quaternary alluvium is
relatively undissected, with the exception of one wash near
the center of the area.





MAP SHOWING LOCATION OF GEOPHYSICAL FIELD WORK

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GROUND WATER

The ground water in the area, ^aexcept for a few cattle wells and tanks, has not been developed. The mineral content of the water from these wells is high; therefore, the ranchers use cisterns to store their drinking water. Cattle will drink the well water only after they have been on the range about a week.

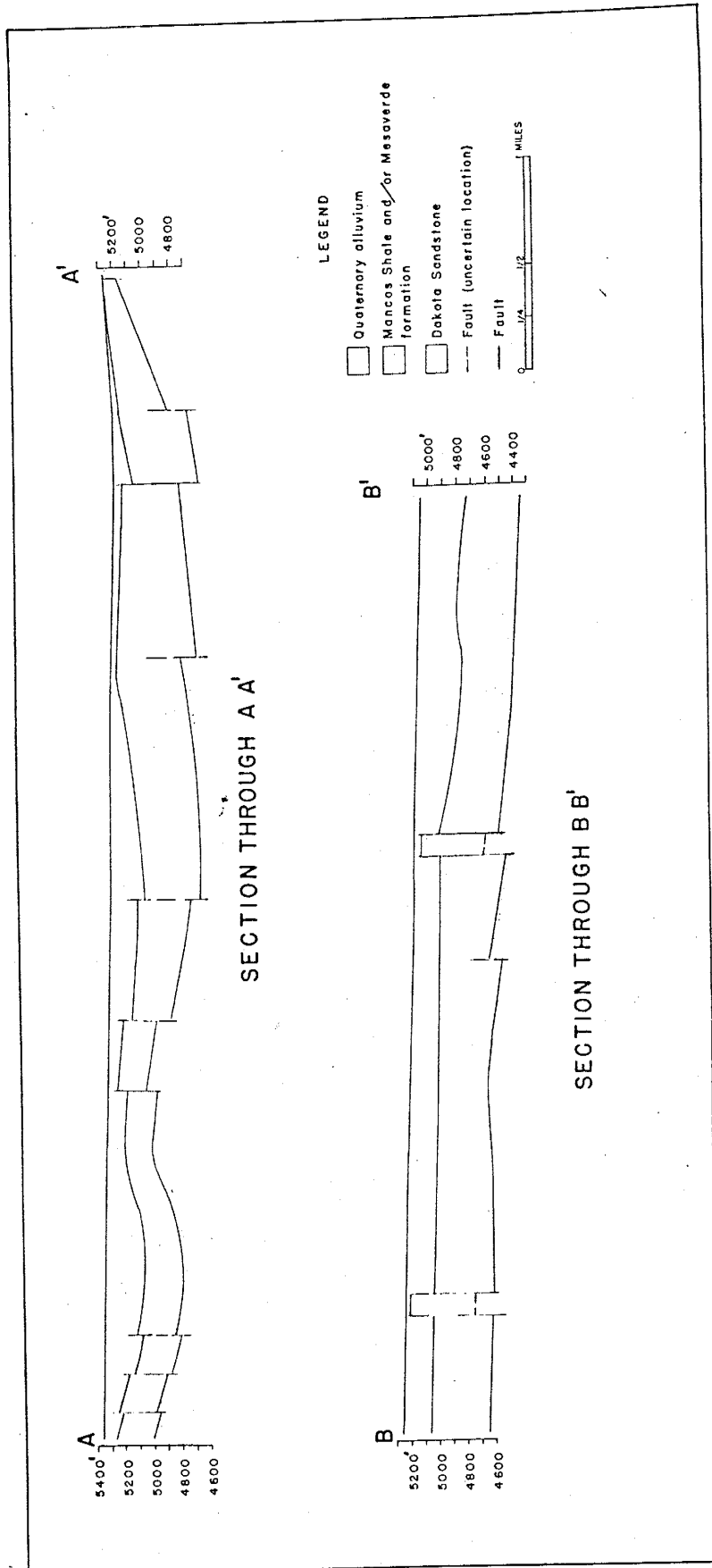
There appear to be at least two water horizons, the Quaternary alluvium and the Dakota sandstone. A cattle well drilled near both profiles (see Fig. 5) passed through the two water horizons, one between 200 and 300 feet and the other around 540 feet; however, the supply of water from the Quaternary alluvium was insufficient for stock purposes.

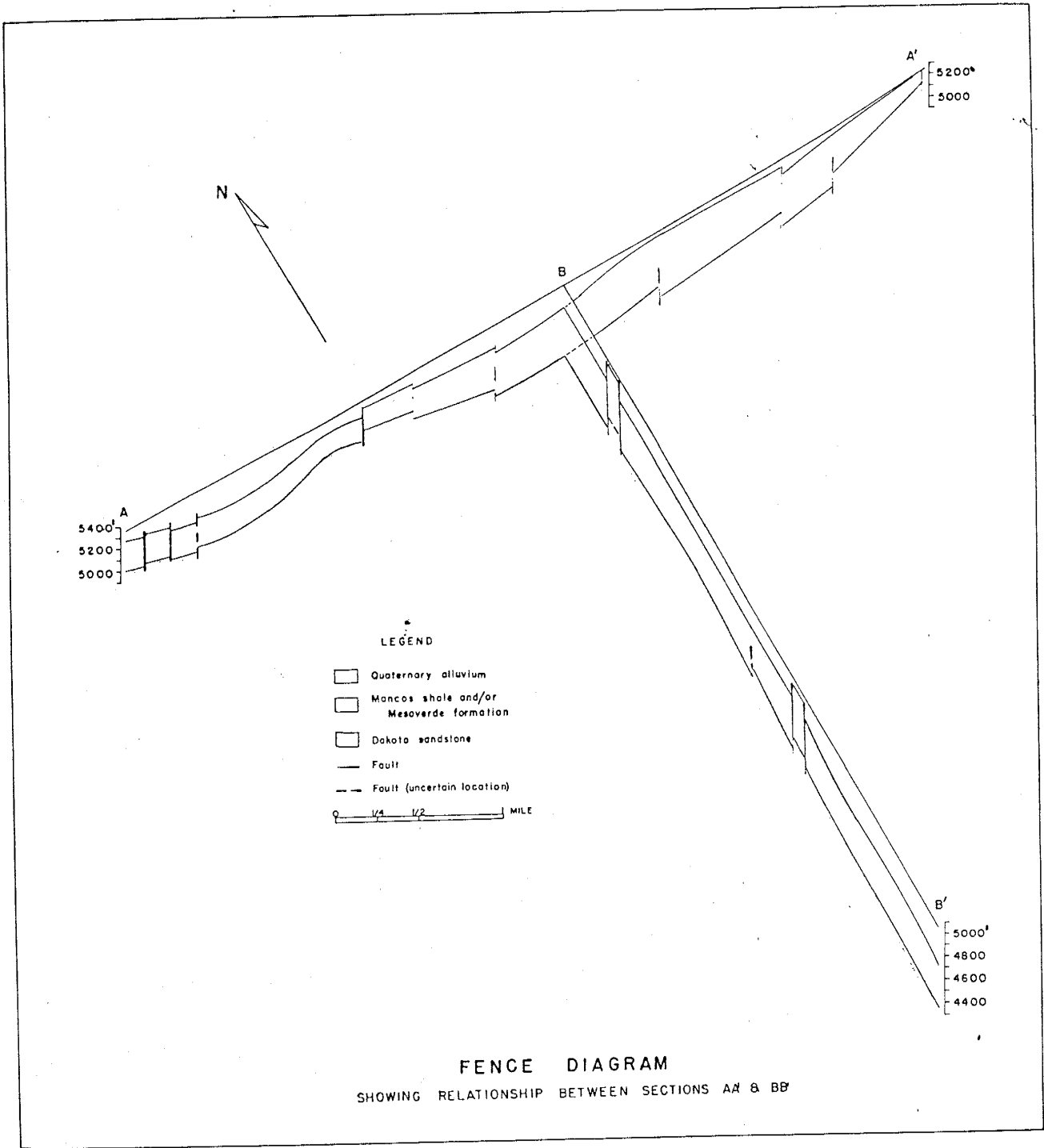
Figure 4 shows the location of both profiles, and the general surface geology and drainage. Section AA' (Fig. 6) shows two synclinal troughs, along with several faults. The best well locations would probably be along the axis of these synclinal troughs. In times of continued drought, such as the present time, these troughs would hold most of the available water. The Dakota sandstone is a confined aquifer, between the shales of the Dockum formation below and the Kansas shale above.

There are several possible interpretations of the field data for the north-south profile. Section BB' (Fig. 6) shows one possibility; another possibility would be to consider the horsts in section BB' as ridges of more resistant material along

the top of the Mancos shale and/or Mesa verde formation. In either case the horsts or ridges, as the case might be, may form dams in the Quaternary alluvium. In the Dakota sandstone the faulting shown with the horst interpretation might form dams, but the ridge interpretation, not formed by faulting, would not indicate dams at those locations. A perspective of the two sections in relation to each other may be obtained from the fence diagram (Fig. 7).

The possibility of developing the ground water in the area, except for stock purposes, does not seem very favorable. The depth to the Dakota sandstone, 600 to 700 feet in the synclinal troughs, would make pumping expensive, and the pumping rate of a large well might be much greater than the rate of recharge.





CONCLUSIONS

From the geologic structure shown in the two sections several good locations for cattle wells may be found. These wells would have the possibility of obtaining water from either the Dakota sandstone or the Quaternary alluvium, with the best supply being from the Dakota sandstone.

The present seismic field equipments and techniques are adequate, with the exception of the limitation of seven feet as the maximum depth of shot holes, to obtain satisfactory refraction records in this type of area.

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