SEISMIC INVESTIGATIONS ON HOLIDAY MESA, MONUMENT VALLEY AREA, SAN JUAN COUNTY, UTAH

By Robert M. Hazlewood

Trace Elements Memorandum Report 880

UNITED STATES DEPARTMENT OF THE INTERIOR

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Geology and Mineralogy

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Series A

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MONUMENT VALLEY AREA

SAN JUAN COUNTY, UTAH*

By

Robert M. Hazlewood

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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By Robert M. Hazlewood

ABSTRACT

A refraction seismic survey was made on Holiday Mesa, San Juan County, Utah, between May 21 and June 11, 1954, prior to an exploratory drilling program made by the U. S. Atomic Energy Commission to delineate channel trends in the area.

The seismic refraction method was successful in delineating the trend, shape, and depth of a large concealed channel on Holiday Mesa. The success of this investigation indicates that the seismic refraction method can be used in areas of similar lithology to delineate channel systems prior to exploratory drilling.

INTRODUCTION

D. E. Trimble (1952), U. S. Geological Survey, discovered a channel exposure on Holiday Mesa, San Juan County, Utah, in which there was higher-than-average anomalous radioactivity. The mineralized zone was in the Shinarump member of the Chinle formation near the base of a channel cut into the surface of the Moenkopi formation. In three other channel exposures on Holiday Mesa there was no anomalous radioactivity.

An electrical resistivity survey was made by Jackson (1953) in an attempt to establish the trends of the channel system on Holiday Mesa prior to exploratory drilling, but the results were inconclusive.

The Geological Survey, on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission, conducted a seismic refraction survey of Holiday Mesa between May 21 and June 11, 1954, prior to an exploratory drilling program on Holiday Mesa conducted by the Atomic Energy Commission. These investigations indicated that the seismic refraction method could be used successfully on Holiday Mesa to delineate channels.

LOCATION AND TOPOGRAPHY

Holiday Mesa is approximately 1 mile northwest of the Oljeto Trading Post in the Monument Valley area, San Juan County, Utah (fig. 1).

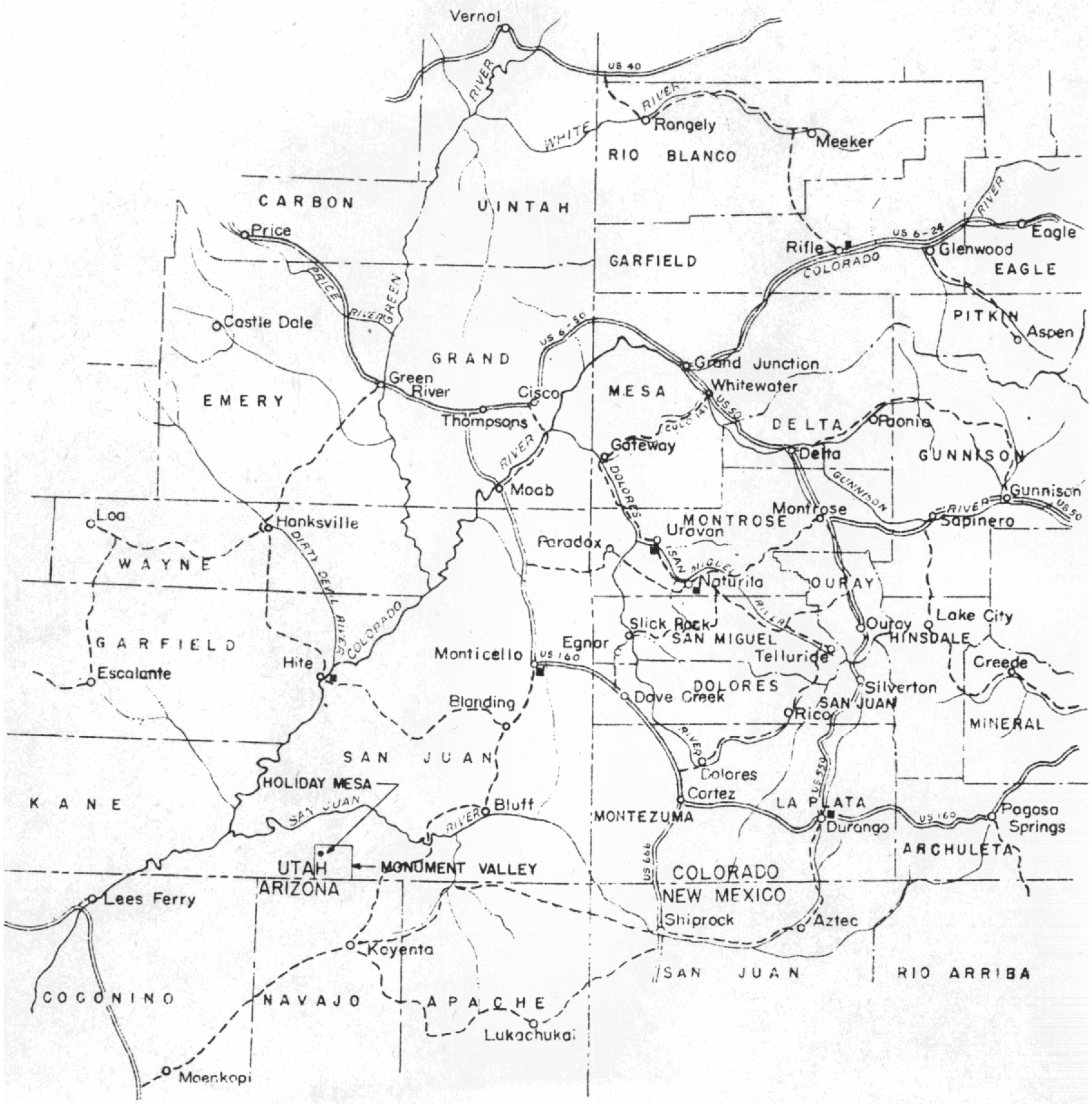

FIGURE 1. INDEX MAP OF PART OF THE COLORADO PLATEAU SHOWING LOCATION OF HOLIDAY MESA, MONUMENT VALLEY AREA, SAN JUAN COUNTY, UTAH

The Oljeto Trading Post is approximately 45 miles southwest of Bluff, Utah, on Utah State Highway No. 47 and approximately 8 miles west on an access road to the trading post. The top of Holiday Mesa is reached by a mine access road on the south side of the mesa.

Holiday Mesa is bounded by almost vertical cliffs which rise approximately 500 feet above the valley floor. The western rim of the Mesa has an elevation of 5,520 feet and at the eastern rim slightly more than a mile. The average elevation is about 5,400 feet. The topography of the mesa top is irregular and the Shinarump is exposed over much of the surface. Where alluvium is present it ranges in thickness from a few inches to 1 foot.

GEOLOGY

Sedimentary rocks of Permian and Triassic age are exposed at Holiday Mesa. The Permian rocks consist, in ascending order, of the Organ Rock tongue, the De Chelly sandstone member, and the Hoskinnini tongue of the Cutler formation. Shales, limestones, and sandstones of the Moenkopi formation rest on the Hoskinnini tongue, and are in turn overlain by the Shinarump member of the Chinle formation which caps the mesa.

The Shinarump is a thick-bedded sandstone with lenses of mudstone. On Holiday Mesa it ranges from 20 to more than 200 feet in thickness.

The contact of the Shinarump and Moenkopi is a marked unconformity. Large scours cut into the Moenkopi surface are filled with Shinarump.

The Moenkopi formation is approximately 200 feet thick and is composed of alternating beds of red sandstone and red shale or mudstone.

Underlying the Moenkopi formation is the Hoskinnini tongue of the Cutler formation. The tongue is approximately 70 feet thick and is composed of red, sandy siltstones. It rests on the De Chelly member which is a massive sandstone approximately 300 feet thick at Holiday Mesa (Lewis, 1954). The underlying Organ Rock tongue is exposed only at the extreme western end of the Mesa.

GEOPHYSICAL INVESTIGATIONS

Field techniques

The refraction seismic survey was made with a 12-trace portable refraction seismograph. The instrument was mounted in a jeep station wagon to permit more rapid coverage of the area. In areas inaccessible to a jeep the instrument could be removed for use as a portable unit in a matter of a few minutes.

Air shooting was used exclusively. A charge of five pounds of 60 percent dynamite was placed on a shooting pole 3 1/2 feet above the surface of the ground and detonated with a seismic electric blasting cap. This procedure provided sufficient energy for good record quality. Where it was not possible to bury the geophones to a depth of 4 to 8 inches, earth was placed over them to a depth of 4 to 6 inches to minimize excessive background noise.

The reversed profile method of shooting was used in making the seismic refraction field measurements. In this method the geophones are arranged in a straight line, and dynamite is detonated alternately at the ends of the line. In general the profiles were 650 feet long and the geophones placed at intervals of 50 feet along the line.

The locations of the seismic traverses on Holiday Mesa are shown in figure 2. Twelve traverses were shot in a northerly direction spaced approximately 300 feet apart to obtain maximum coverage of the mesa. Six east-west traverses were made to obtain more complete depth control.

Results

A subsurface contour map on the top of the Moenkopi formation was prepared from the seismic data (fig. 3), and clearly indicates a well-defined channel in a southeast direction. Exploratory drilling later confirmed the trend of the channel indicated by the seismic survey. The channel depths computed from the seismic results were approximately 10 percent shallower than the depths indicated by the drilling. In non-channel areas the computed depths checked the drilling depths quite closely.

The discrepancies between the computed depths to the Shinarump-Moenkopi contact and depths determined by drilling are probably a result of two factors: the presence of an irregular mudstone mass at the base of the Shinarump in the channel areas; and the effect of refraction in planes other than the vertical. The mudstone, which is found in many places at the base of the channel on Holiday Mesa, is generally 15 to 25 feet thick and constitutes a very resistant and high-velocity lens at the base. The mudstone acts as a refractor, and the depths computed from seismic data are the depths to the top of the mudstone and not to the top of the Moenkopi formation.

In non-channel areas the velocity in the Moenkopi formation is approximately 12,000 ft per sec, but in the channel areas the average velocity in the Moenkopi is about 14,000 ft per sec. The higher velocity in the channel areas may be due to the fact that the channel has been cut into more thoroughly indurated Moenkopi rocks (and hence, those with higher velocity).

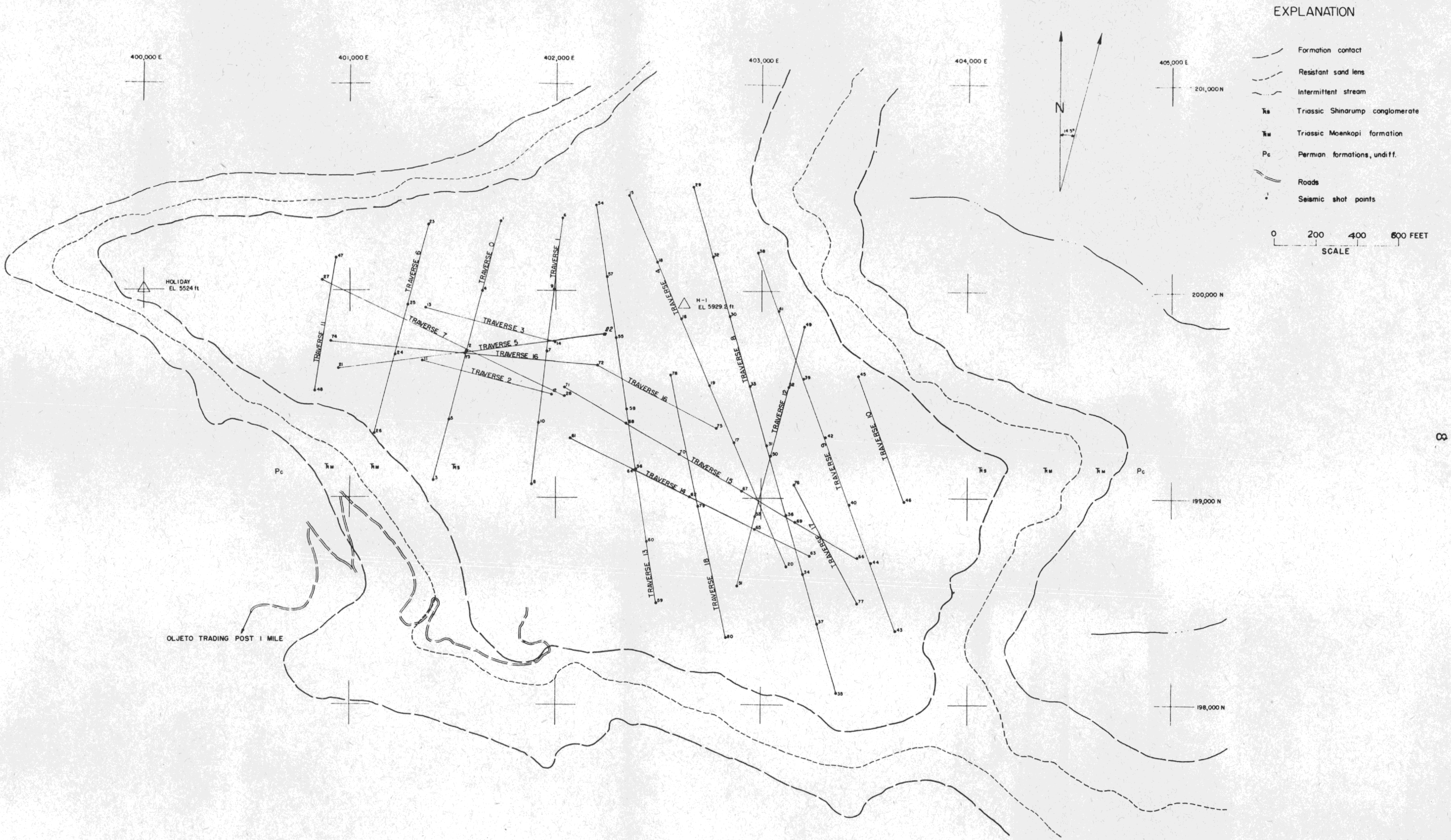

FIGURE 2. MAP SHOWING LOCATION OF SEISMIC TRAVERSES AND SHOT POINTS ON HOLIDAY MESA, SAN JUAN COUNTY, UTAH

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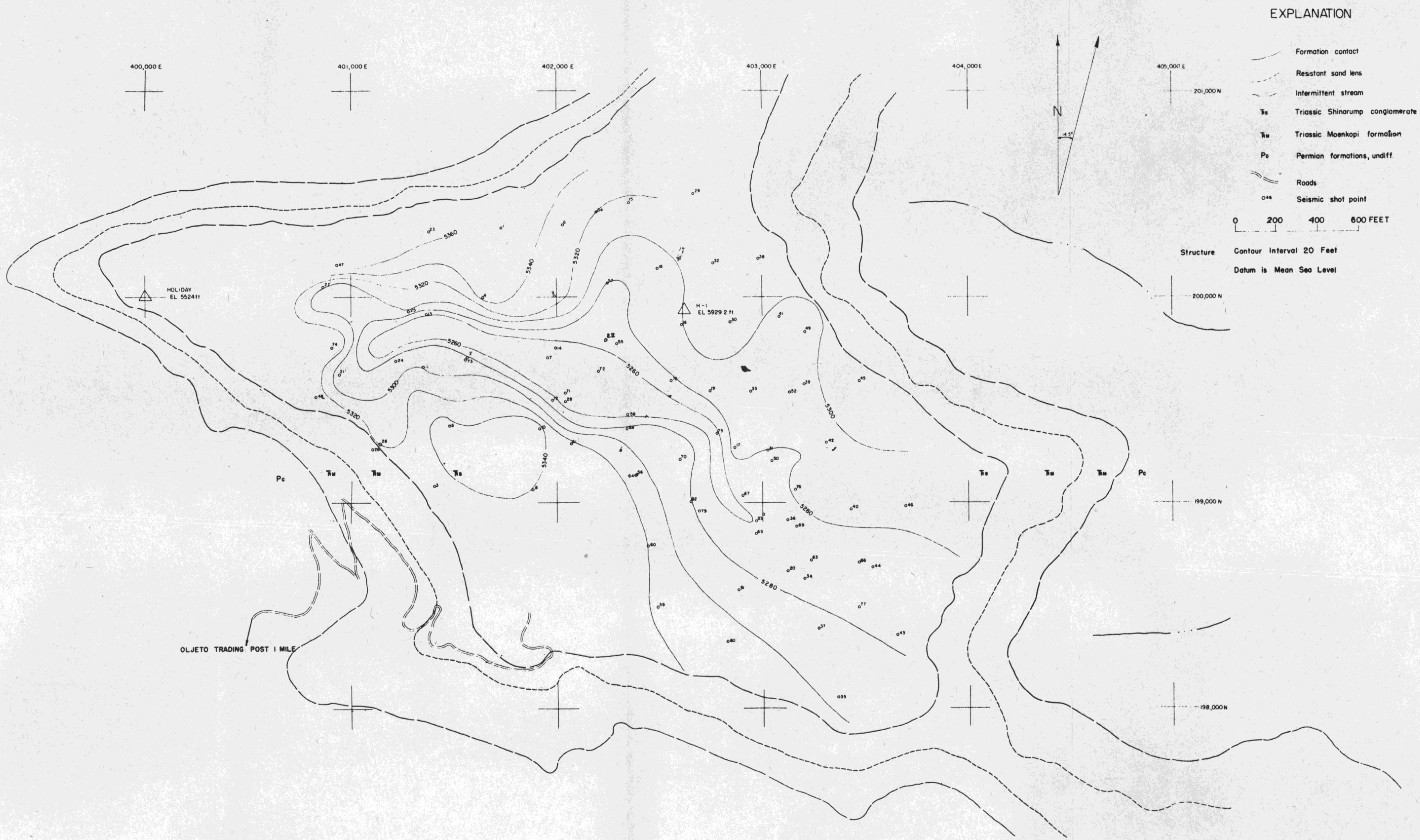

FIGURE 3. SUBSURFACE CONTOUR MAP OF TOP OF MOENKOPI FORMATION AS DETETERMINED FROM SEISMIC DATA

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The velocity in the Shinarump conglomerate ranged from 4,500 to 7,000 ft per sec. The higher velocities probably were due to mudstone lenses in the Shinarump.

Figures 4 through 6 illustrate typical traverses across and along the trend of the channel and include cross sections, traveltime graphs, ground profiles, and the subsurface profile on the top of the Moenkopi formation. The subsurface profile as shown on the traverses is taken from the subsurface contour map.

Standard computational procedures proved to be inadequate in the interpretation of many of the travel time curves from Holiday Mesa. A modification of a delay-time method originally suggested by A. J. Barthelmes (Pakiser and Black, 1956) was then used and the delay-time analysis made it possible to trace the refracting interface and determine the channel.

Traverse 0 (fig. 4) illustrates one of the problems in interpretation on Holiday Mesa: that of mapping a mudstone lens rather than the top of the Moenkopi.

The adjusted delay-time curve for traverse 0 shows that a high-velocity mudstone lens in the Shinarump conglomerate was the refractor being mapped rather than the top of the Moenkopi formation.

Delay-time analysis of the profile of traverse 5 (fig. 5) reveals the channel structure very clearly. The velocities on this profile of 15,500 ft per sec in the Moenkopi formation are higher than the average velocity in the Moenkopi and are probably apparent rather than true velocities. The refracting interface slopes downward from both ends of the spread.

Traverse 9 (fig. 6) illustrates the delay-time analysis of a traverse outside the channel area and the relatively flat surface of the top of the Moenkopi where no channel exists. The velocities in this profile are average velocities for the Shinarump conglomerate and the Moenkopi formation and are lower than the velocities obtained over the channel structure.

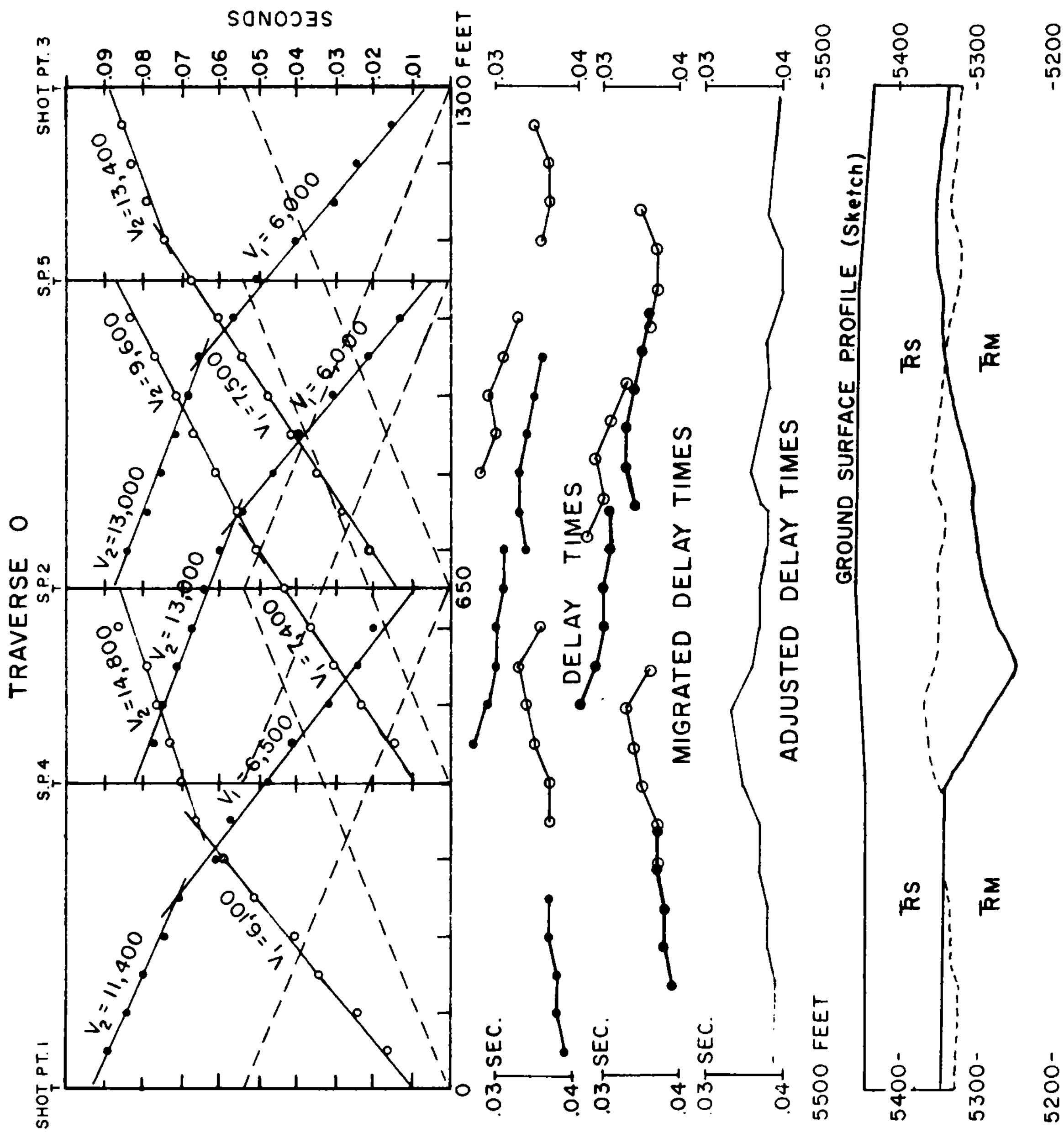

FIGURE 4. TRAVELTIME GRAPH FOR TRAVERSE O WITH ACCOMPANYING GEOLOGIC CROSS SECTION

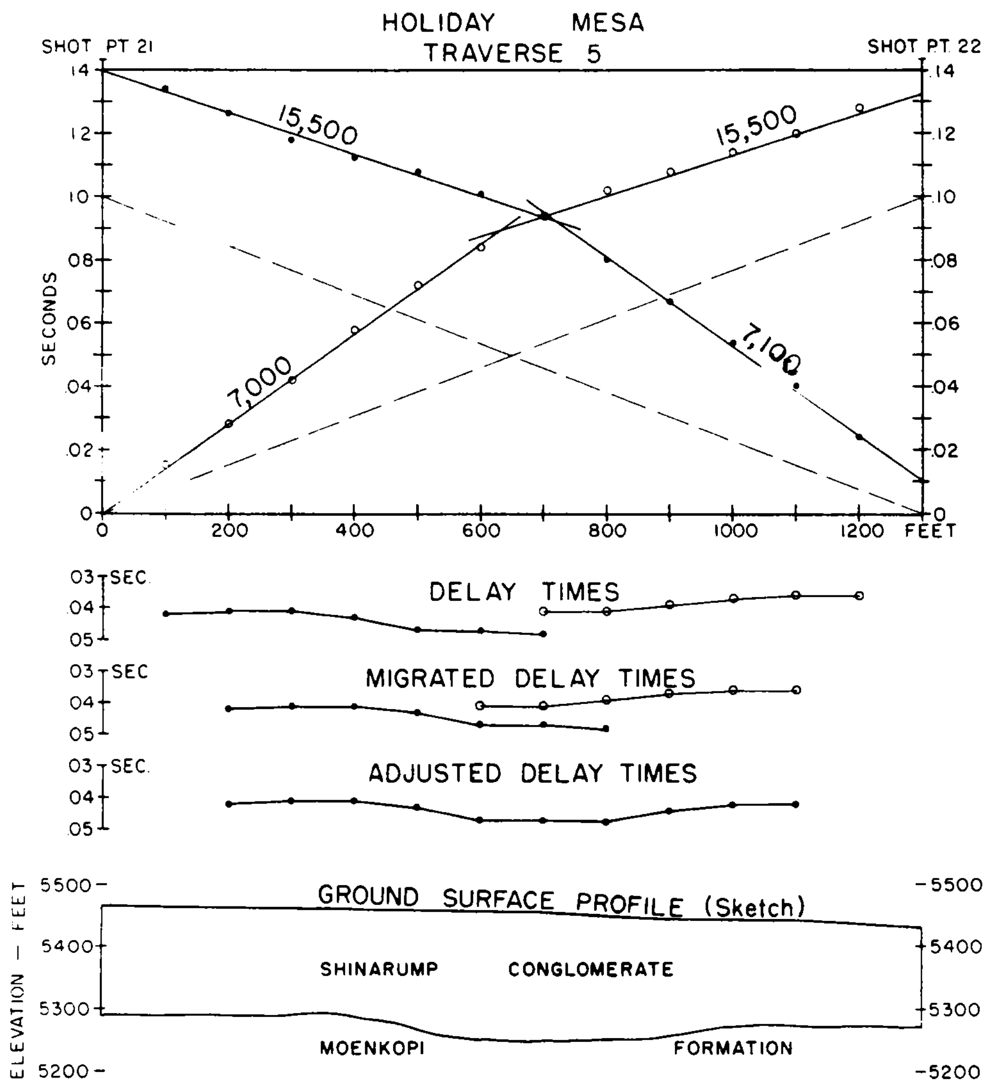

FIGURE 5. DELAY-TIME GRAPH AND GEOLOGIC CROSS-SECTION FROM SEISMIC REFRACTION DATA, HOLIDAY MESA, SAN JUAN COUNTY, UTAH

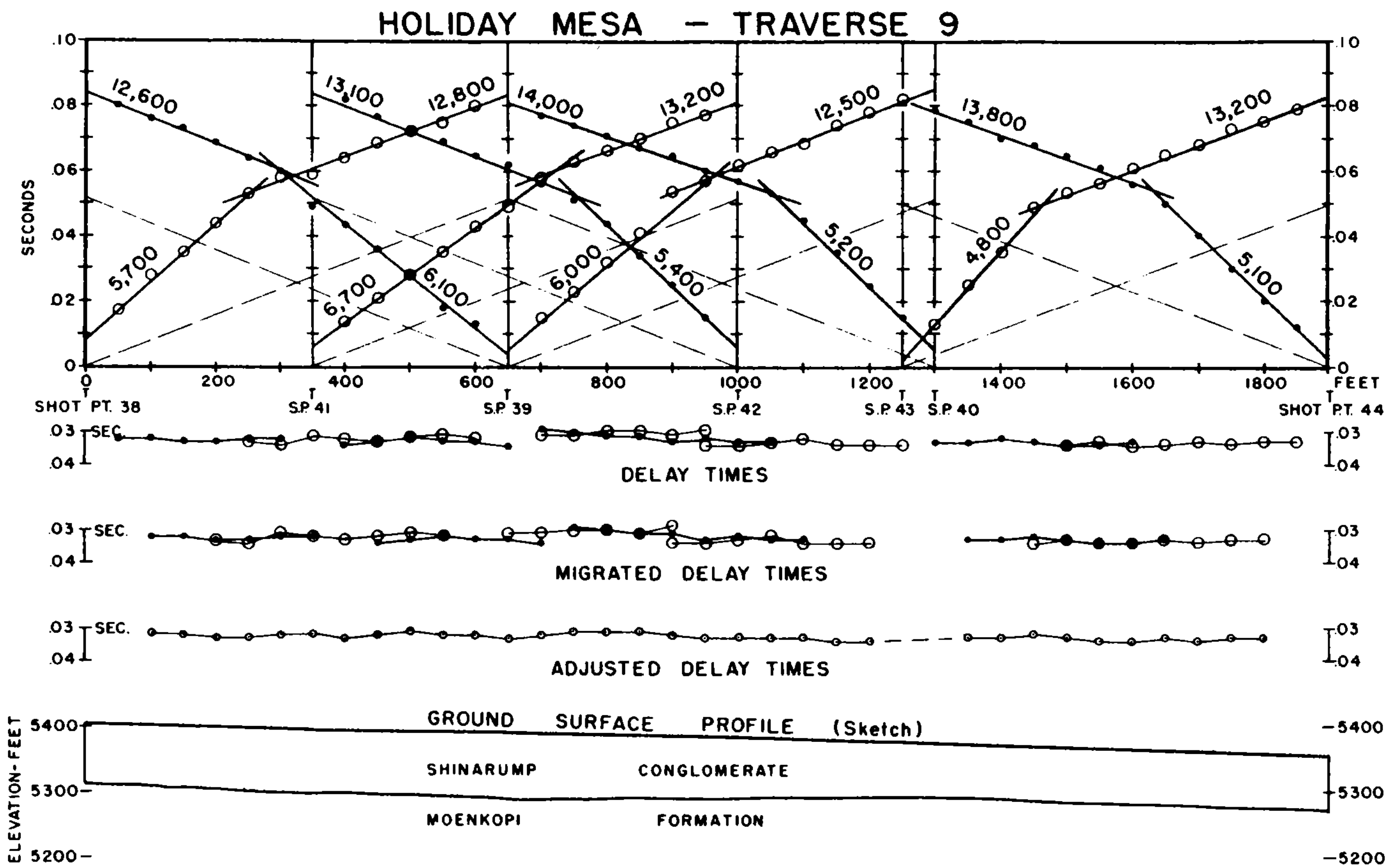

FIGURE 6. DELAY-TIME GRAPH AND GEOLOGIC CROSS SECTION FROM SEISMIC REFRACTION DATA, HOLIDAY MESA, SAN JUAN COUNTY, UTAH

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