Uranium deposits at the Jomac mine, White Canyon area, San Juan County, Utah

By A. F. Trites, Jr. and G. A. Hadd

Trace Elements Investigations Report 561

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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November 23, 1955

Mr. Robert D. Nininger, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-561, "Uranium deposits at the Jomac mine, White Canyon area, San Juan County, Utah," by Albert F. Trites, Jr., and George A. Hadd, August 1955.

We are asking Mr. Hosted to approve our plan to publish Part I of this report as a Geological Survey Bulletin.

Sincerely yours,

John H. Eric
for W. H. Bradley
Chief Geologist

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Geology and Mineralogy

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Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

URANIUM DEPOSITS AT THE JOMAC MINE, WHITE CANYON AREA, SAN JUAN COUNTY, UTAH*

By

Albert F. Trites, Jr., and George A. Hadd

August 1955

Trace Elements Investigations Report 561

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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 Albert F. Trites, Jr., and George A. Hadd

ABSTRACT

The Jomac mine is in the White Canyon area, San Juan County, Utah, about 13 miles northeast of the town of White Canyon, Utah. The mine is owned by the Ellihill Mining Company, White Canyon, Utah.

Mine workings consist of two adits connected by a crosscut. Two hundred feet of exploratory drifting and 2,983.5 feet of exploratory core drilling were completed during 1953 by the owners with Defense Minerals Exploration Administration assistance.

Sedimentary rocks exposed in the area of the Jomac mine are of Permian to Late Triassic age, having a combined thickness of more than 1,700 feet. An ancient channel, from 200 to 400 feet wide and about 4 feet deep, enters the mine area from the southwest, swinging abruptly northwest near the mine workings and continuing to the northern tip of the Jomac Hill. This channel was cut into the upper beds of the Moenkopi formation and filled in part by Chinle and in part by Shinarump sediments. This channel is marked by depressions that apparently were scoured into its floor; a tributary channel may have joined it from the southeast at a point near the mine workings. Chinle beds intertongue with Shinarump beds along the southwestern part of the channel. After the main channel was partly filled by siltstone of the Chinle formation, the stream was apparently diverted into the tributary channel, and scours were cut into the Chinle siltstone and filled by Shinarump sandstone, conglomerate,

and siltstone. Statistical study of wood orientation in the beds of the Shinarump conglomerate further indicates a channel trend of about N. 23° W. Basal siltstone-pebble conglomerates appear to mark the edge of channels and scours.

Jomac Hill is on the crest of a southwest-plunging fold that is on the west flank of a larger syncline. The area surrounding the hill is broken by intense faulting, but no faults were noted in the vicinity of the mine. The major fractures in the mine workings strike N. 70° to 80° E. and are steeply dipping. Secondary steeply dipping fractures strike N. 40° to 60° E., and N. 10° E. to N. 10° W. The fractures are believed to be related to the anticlinal structure rather than the faults.

Most of the uranium is contained in coal, associated with jarosite and gypsum in sandstone, conglomerate, or sandy siltstone near the base of the Shinarump conglomerate. Uranium occurs in a fibrous green secondary mineral, metazeunerite, an unknown fibrous yellow mineral, and an unknown massive yellow mineral. Secondary copper minerals, including malachite, azurite, and chalcanthite occur locally with the uranium minerals.

Principal ore guides at the Jomac mine are channels, and scours at the bottom of these channels, coal-bearing sandstone or conglomerate at the base of the Shinarump conglomerate, coal, and jarosite.

INTRODUCTION

Location and accessibility

The Jomac mine is on the east side of the Colorado River about 13 miles northeast of the town of White Canyon, San Juan County, Utah (fig. 1). The town of White Canyon, Utah is across the river from Hite, Utah. The property is reached from the town of White Canyon by traveling about 3 miles east along Utah Highway 95 and then turning to the northeast on a bulldozer road that leads to the mine. An airstrip, suitable for light planes, is available on the flats above the Colorado River 2 miles northeast of the Jomac mine. The nearest point for receiving uranium ore is 22 miles by road from the Jomac mine. The mine workings are on the southeast side of the Jomac Hill at an altitude of about 5,200 feet.

History

The Jomac mine is on an unpatented claim located by J. B. Plosser and A. M. McLeod in November 1950. The property is owned by the Ellihill Mining Company, White Canyon, Utah, a corporation recently formed to explore for and to develop uranium deposits. The property owned by the Company consists of three contiguous lode claims known as the Jomac I, Jomac II, and Jomac III, in unsurveyed T. 34 S., R. 14 E. Salt Lake principal meridian.

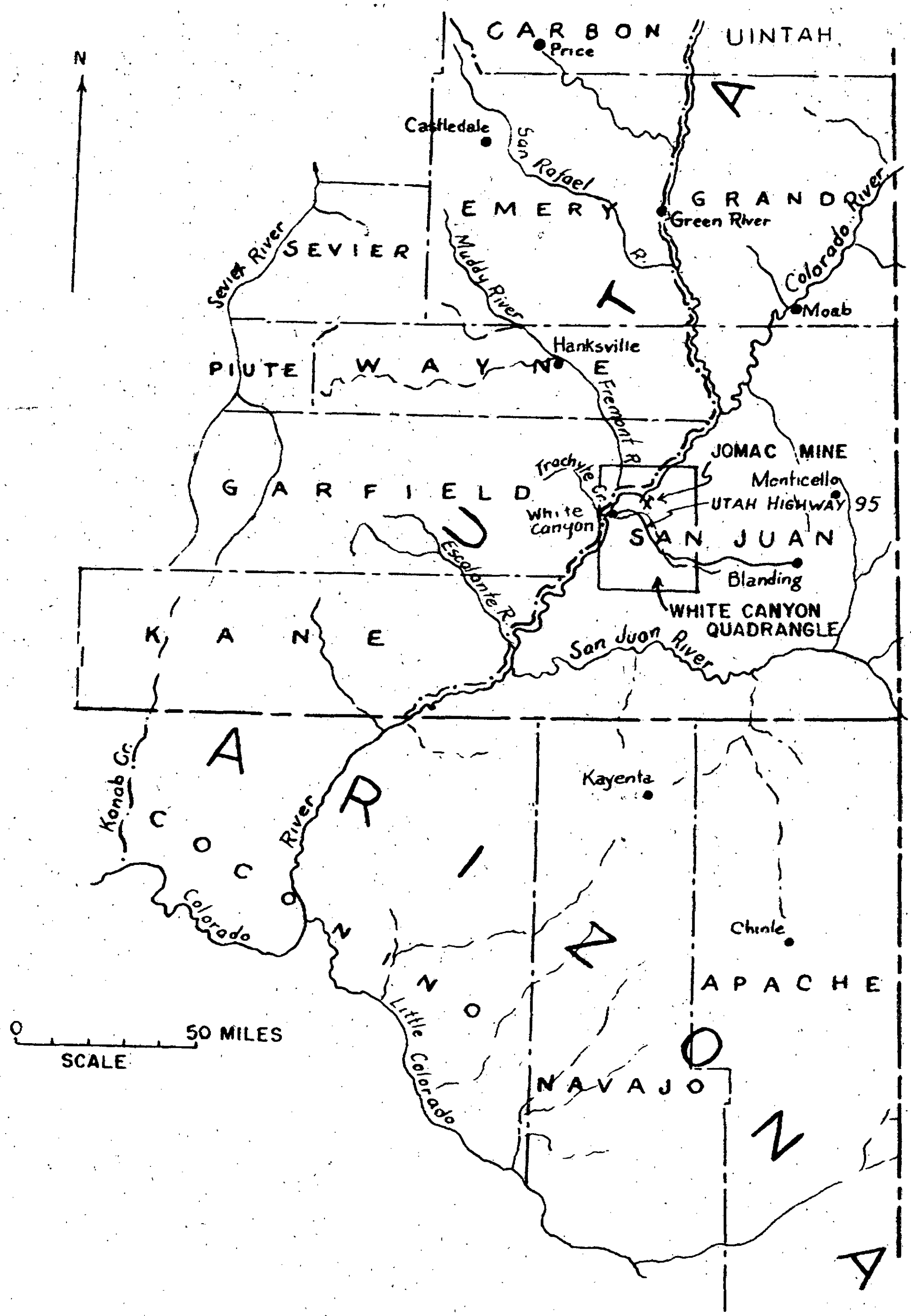


FIGURE I. INDEX MAP OF PARTS OF UTAH AND ARIZONA SHOWING LOCATION OF JOMAC MINE, WHITE CANYON AREA SAN JUAN COUNTY, UTAH.

Mine workings

Two adits, 315 and 130 feet long, had been driven into the uraniferous deposit by August 1953. These adits have been connected by a 75-foot crosscut. Another crosscut was being driven from adit no. 2 to intersect the extension of adit no. 1 at a point approximately 140 feet behind the rim. A short drift, 25 feet long, has been driven northward from adit no. 1.

Diamond drilling

Between December 1952 and June 1953, 2,983.5 feet of exploratory diamond drilling was completed at the Jomac mine by the owners with financial assistance from the Defense Minerals Exploration Administration, contract Idm-E397. These holes tested the eastern part of Jomac Hill where beds of Shinarump conglomerate are exposed at the rim. The drill holes ranged from 33.8 to 159.0 feet deep; all of the holes were collared in beds of the Chinle formation, above the Shinarump rim and all except four of the holes were bottomed in beds of the Moenkopi formation. Core was recovered in both the Chinle and Shinarump beds and was logged in detail in the Shinarump section.

Field methods

The Jomac mine was studied in detail by the writers during May 1953. A surface map was prepared on a scale of 1 inch equals 100 feet using plane table methods. Structural contours were drawn of the bottom of a basal sandstone of of the Shinarump conglomerate, of the top of the Moenkopi formation, and of an upper resistant siltstone bed of the Moenkopi formation, to determine what effect channels and the regional dip of the strata may have had on the localization of the uranium deposits. Structural contours drawn of the bottom of a basal sandstone of the Shinarump conglomerate and the top of the Moenkopi were corrected for regional dip by using the contours of the siltstone bed of the Moenkopi formation.

The Shinarump conglomerate was logged in detail in each of the 32 holes, and these data were used in interpreting the mode of uranium occurrence and in determining the grade and reserves of the uraniferous rock.

A transit survey was made of part of the mine workings, and wall maps were prepared of the workings on a scale of 1 inch equals 5 feet. More than 40 samples of the Shinarump beds were collected in the mine workings. Analyses for equivalent uranium have been made on 28 of these samples and for copper on 10 of the samples.

Acknowledgments

The Jomac area was mapped by T. L. Finnell, J. D. Sears, Lyman Huff, and Roger Morrison of the U. S. Geological Survey in the course of the areal mapping in the White Canyon district during the 1952 field season. This mapping was on a scale of 1 inch equals half a mile and is shown in figure 2. Charles Lough of the Geological Survey assisted with the underground geologic mapping.

The writers wish to thank Mr. J. B. Plosser, president, and Miss Margaret Jordan, secretary, of the Ellihill Mining Company for many favors and much helpful information furnished during the investigation.

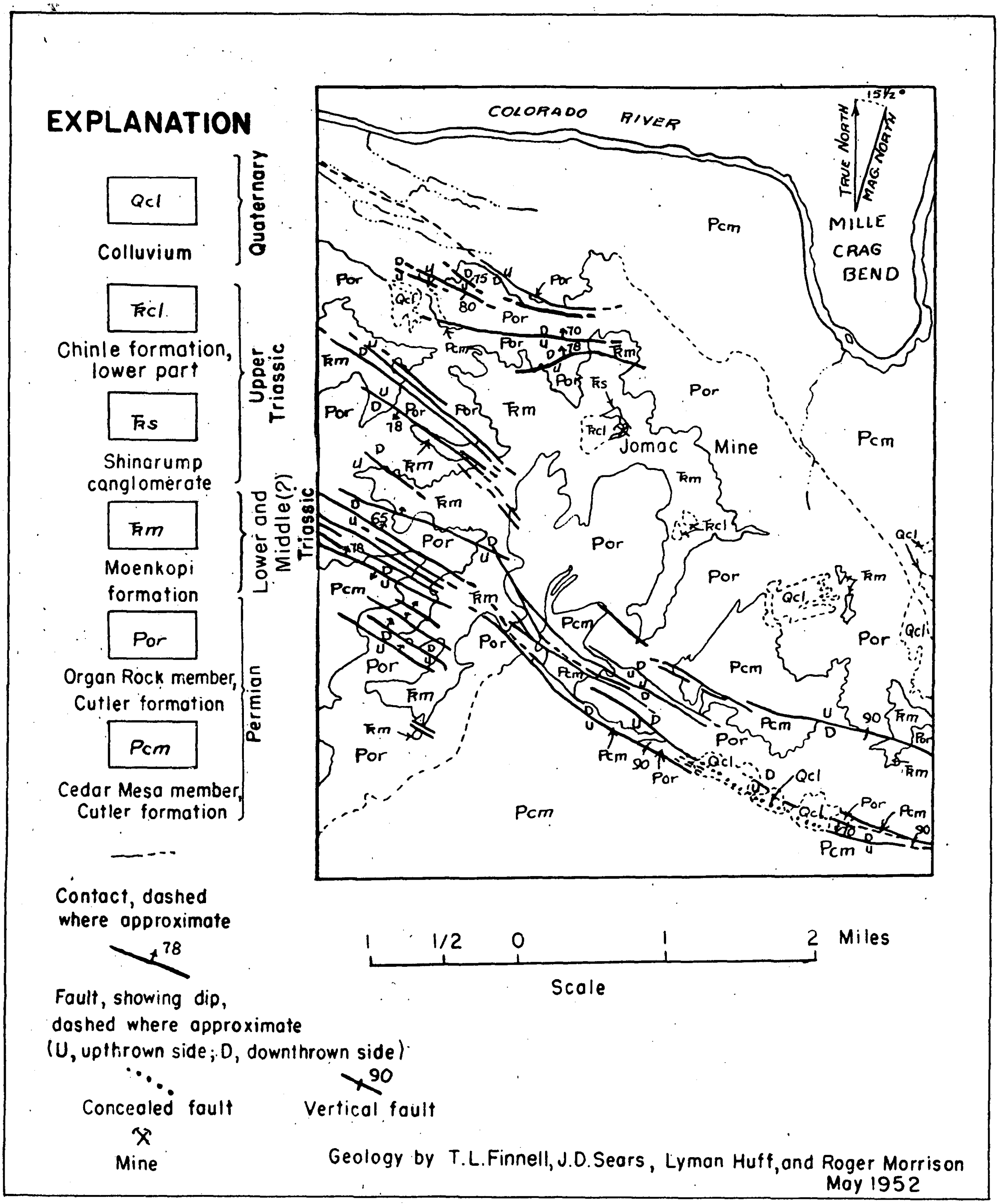


FIGURE 2. GEOLOGIC MAP OF THE JOMAC AREA, SAN JUAN COUNTY, UTAH.

This work was done by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

GEOLOGY

Stratigraphy

Jomac Hill is composed of sedimentary rocks of Permian to Upper Triassic age. These rocks are on the west flank of the Monument upwarp; the beds in general strike N. 2° W. and dip 2° SW. The Monument upwarp is a large north-trending anticlinal structure more than 60 miles long, extending for 30 miles on each side of the San Juan River (Gregory, 1938, p. 85-88). The upwarp has a gentle west slope with dips ranging from 0.5° to 2°, and a steeper east slope with dips locally exceeding 50°. The exposed sedimentary rocks in the vicinity of the Jomac Hill have a combined thickness of more than 1,700 feet.

In places reddish-brown siltstone of the Moenkopi formation underlies sandstone and conglomerate of the Shinarump conglomerate, and in places the Moenkopi siltstone underlies siltstone that can be traced into beds of a lower member of the Chinle formation (fig. 2). The Shinarump conglomerate, the uranium-bearing formation, intertongues with the lower member of the Chinle formation and is present only on the east side of the hill where it crops out as a ledge beneath the Chinle formation. A sandstone bed of the lower member of the Chinle formation caps the hill; the Chinle formation is composed of carbonaceous siltstone and claystone and three prominent beds of sandstone or conglomerate.

Cutler formation

The Cutler formation of Permian age exposed in the area of Jomac Hill includes the Cedar Mesa sandstone member, the Organ Rock member and the White Rim sandstone member. The Cedar Mesa sandstone member forms the base above which the hill rises. This member is about 1,000 feet thick and consists of cream-colored, crossbedded sandstone with local red shale beds near the top. Reddish-brown siltstone and very fine-grained sandstone of the Organ Rock member forms the lower slopes of the hill and part of the nearly vertical wall above the lower slopes. The Organ Rock member is about 300 feet thick in the area. The White Rim sandstone (not shown on fig. 2) ranging from 10 to 20 feet in thickness, forms a light-colored ledge beneath the Moenkopi formation. The White Rim sandstone member is composed of cream-colored, fine-grained sandstone.

Moenkopi formation

The Moenkopi formation of Early and Middle (?) Triassic age is about 300 feet thick in the area of the Jomac mine and consists of thinly laminated dark reddish-brown siltstone and fine-grained sandstone in beds ranging from a few inches to 4 feet in thickness. The upper Moenkopi beds have been altered to light olive-gray for a thickness of as much as 7 feet and for an average thickness of 3 feet beneath the Shinarump conglomerate and the lower member of the Chinle formation. These altered Moenkopi beds are distinguished from Shinarump and Chinle siltstones by the fact that they are devoid of carbonaceous plant material whereas the Shinarump and Chinle siltstones commonly contain carbonaceous matter; also many of the Moenkopi siltstones split along micaceous cleavage planes whereas the Chinle and Shinarump siltstones are not readily split.

The alteration zone at the top of the Moenkopi formation attains its greatest thickness in drill hole no. 19, where a low hill of Moenkopi siltstone is partly encircled by a bend in the channel cut into the Moenkopi formation. This long narrow projection of red Moenkopi siltstone would have been in a very favorable position for chemical attack by waters passing through the Shinarump- and Chinle-filled channel either when the sediments were being deposited or at a later time. The degree of alteration appears to be independent of the type of sediment above the Moenkopi formation, suggesting that the alteration was caused by solutions associated with the original stream rather than by later solutions which would be mostly restricted to the more permeable rock.

Shinarump conglomerate

The Shinarump conglomerate beds of Late Triassic age at the Jomac mine fill a channel that has been cut into the Moenkopi formation on the east side of the hill and into siltstone of the Chinle formation west of the mine workings. The Shinarump conglomerate ranges from slightly more than 10 to 30 feet in thickness in the area of the Jomac mine and consists of very fine- to coarse-grained sandstone, conglomerate, siltstone, and claystone. Geologic sections of the Shinarump beds cut by the diamond drilling and exploratory drafting are shown in figure 3. The sandstone beds of the Shinarump conglomerate are cross-laminated and range from slightly less than 1 foot to 7.6 feet in thickness. The basal sandstone beds are coarser grained than those higher in the section. Most of the sandstones are very pale orange, freckled with limonite. The rock is composed of subangular quartz grains and minor pale-yellow microcline grains set in a matrix of claystone or siltstone. Some of the sandstone beds contain both wood fragments that have been altered to coal, and wood that has been replaced by limonite and hematite. Many of the beds contain limonite and jarosite impregnations.

Occasional conglomerate beds, from 0.5 to 5.0 feet thick, occur at various horizons in the Shinarump conglomerate, although the conglomerates are most commonly at either the base or top of the Shinarump. Where conglomerate occurs at the base of the Shinarump, beds of the lower member of the Chinle formation are not present beneath the Shinarump, and the conglomerate rests upon the Moenkopi formation. In general, these basal conglomerates occur along the upper edges of channels or at edges of depressions on the floor of the channel as shown in figure 3, part d in drill hole no. 1. The conglomerate beds at the top of the Shinarump appear to intertongue with siltstone beds of the lower member of the Chinle formation and are believed to have filled scours cut into underlying beds of sandstone and claystone.

The basal conglomerate beds of the Shinarump conglomerate are medium gray to grayish-yellow and contain an average of about 20 percent Moenkopi siltstone pebbles in a matrix of siltstone or fine- to coarse-grained sandstone. Pieces of coal are abundant in most of this conglomerate and are associated with jarosite, gypsum, limonite, and local pyrite. Wood replaced by hematite and limonite is present in minor quantities.

The conglomerate beds near the top of the Shinarump conglomerate range from very pale orange to grayish-orange and consist of as much as 50 percent carbonaceous siltstone pebbles set in a very fine- to fine-grained sandstone matrix. Hematite- and limonite-replaced wood is abundant, and carbonized wood (coal) is present in chunks up to 1 foot in length. Impressions of limonitized wood more than 9 feet long and 1-1/2 feet across have been found; the larger pieces apparently dammed pebble beds behind them.

Thin beds of gray carbonaceous siltstone are common throughout the Shinarump conglomerate and are abundant in the upper part of the formation. Most of these siltstone beds are less than 1 foot thick. A bed of gray claystone 2.9 feet thick was cut in the upper part of the Shinarump conglomerate by drill hole no. 13 (fig. 3, secs. a and b); a seam of light-gray siltstone, less than 0.5 feet thick, occurs at the base of the ore-bearing carbonaceous sandstone in the outer parts of the mine workings. This basal siltstone bed has been included with the Shinarump conglomerate because locally it contains quartz grains similar in appearance to the sandstone beds above it.

The name Shinarump conglomerate is restricted by the writers at the Jomac mine to the sandstone, conglomerate, and interbedded siltstone and claystone. The variegated and carbonaceous siltstones that intertongue with and underlie the sandstone beds of the Shinarump conglomerate west of the mine workings are continuous with beds of the lower member of the Chinle formation and are believed to be a part of this member. Intertonguing between the Shinarump and the lower member of the Chinle formation may be of two types: 1) upper beds of sandstone of the Shinarump conglomerate extend as fingers into siltstone or claystone of the lower member of the Chinle formation, or 2) a lateral lens of Shinarump conglomerate extends upward from the top of the Moenkopi formation into the Chinle formation.

Gradational contacts between the Shinarump conglomerate and the lower member of the Chinle formation have been observed at the Jomac mine. In general, the Shinarump is finer in grain size near the top, and the contact between the Shinarump conglomerate and the lower member of the Chinle formation would not be placed at the same horizon by every observer.

Lower member of the Chinle formation

The lower member of the Chinle formation of Late Triassic age forms the upper 170 feet of the Jomac Hill. This member is composed of gray carbonaceous siltstone and claystone and three prominent beds of sandstone and conglomerate.

The upper conglomerate sandstone, ranging from 4 to 6 feet in thickness, forms the crest of the hill. This sandstone is equivalent to the prominent conglomeratic sandstone capping many buttes and benches in the White Canyon area.

A less prominent sandstone crops out approximately 65 feet above the top of the Moenkopi formation and forms a discontinuous narrow bench around the hill. This sandstone ranges from 5 to 14 feet in thickness; it is a thinly laminated, very fine-grained, very pale orange, freckled sandstone consisting of subrounded quartz grains cemented by limonite-impregnated clay. In some places a thinner bed of limonite conglomerate underlies this sandstone, and the sandstone grades laterally into conglomerate.

A third sandstone, ranging from 7 to 14 feet in thickness, is from 40 feet to 50 feet above the top of the Moenkopi formation. It is a thinly laminated, poorly sorted, medium- to coarse-grained, white, very pale-orange, and grayish-orange sandstone composed of clay pebbles and quartz grains in limonitic clay cement. Limonitized wood as much as 9 inches across is concentrated in this sandstone and in places a 1-foot bed of conglomerate underlies this sandstone. This conglomerate ranges from pinkish gray to light olive gray, and consists of siltstone and clay pebbles and quartz grains in a matrix of clay and limonite. Gypsum and limonitized wood are abundant in local accumulations; one fragment of limonitized gypsiferous wood was abnormally radioactive to a slight degree.

Sedimentary structures

Channels

The top of the Moenkopi formation (fig. 4), forms a surface that strikes approximately N. 25° W. and dips 2° SW because of the regional dip. This surface has a 4-foot rise near the north end of the hill, a 3-foot rise centered on drill hole no. 19, and a valley that trends N. 70° W. and separates these highs. Superimposing the structural contours of the regional dip of figure 5 upon the structural contour of the top of the Moenkopi formation in figure 4, the Moenkopi surface was restored to a horizontal position (fig. 6).

A channel was scoured into the upper beds of the original Moenkopi surface (fig. 5). This ancient stream course entered the area of the mine workings from the southwest, turned abruptly in the vicinity of drill hole no. 13, and continued N. 23° W. to the north tip of the Jomac hill. This channel is about 400 feet wide where it enters the mapped area, narrowing to less than 200 feet at the north end of the hill. The channel has an average depth of about 4 feet and is marked by a 4-foot basin-like

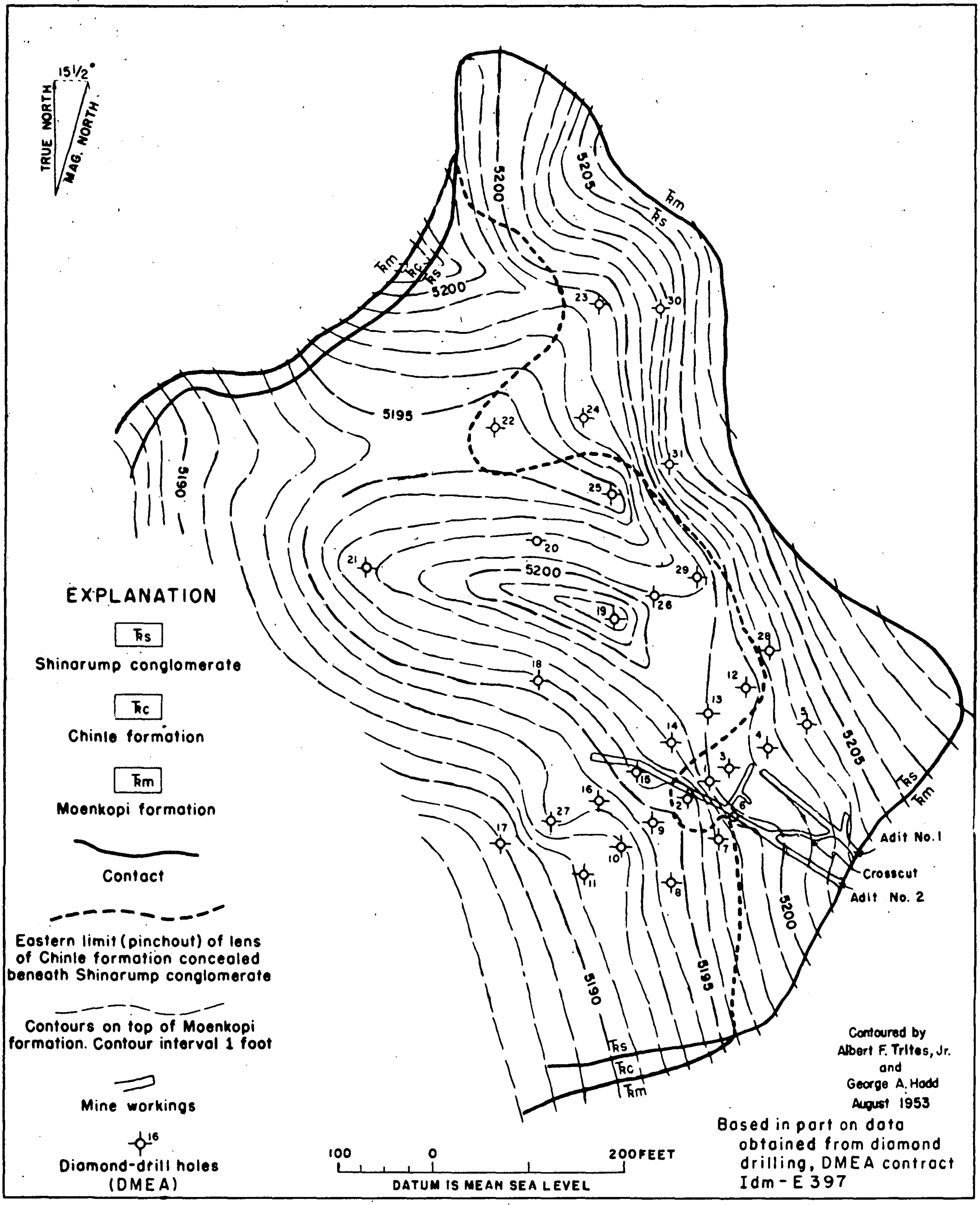


FIGURE 4. STRUCTURAL CONTOUR MAP ON THE TOP OF THE MOENKOPI FORMATION, JOMAC HILL, WHITE CANYON AREA, SAN JUAN COUNTY, UTAH.

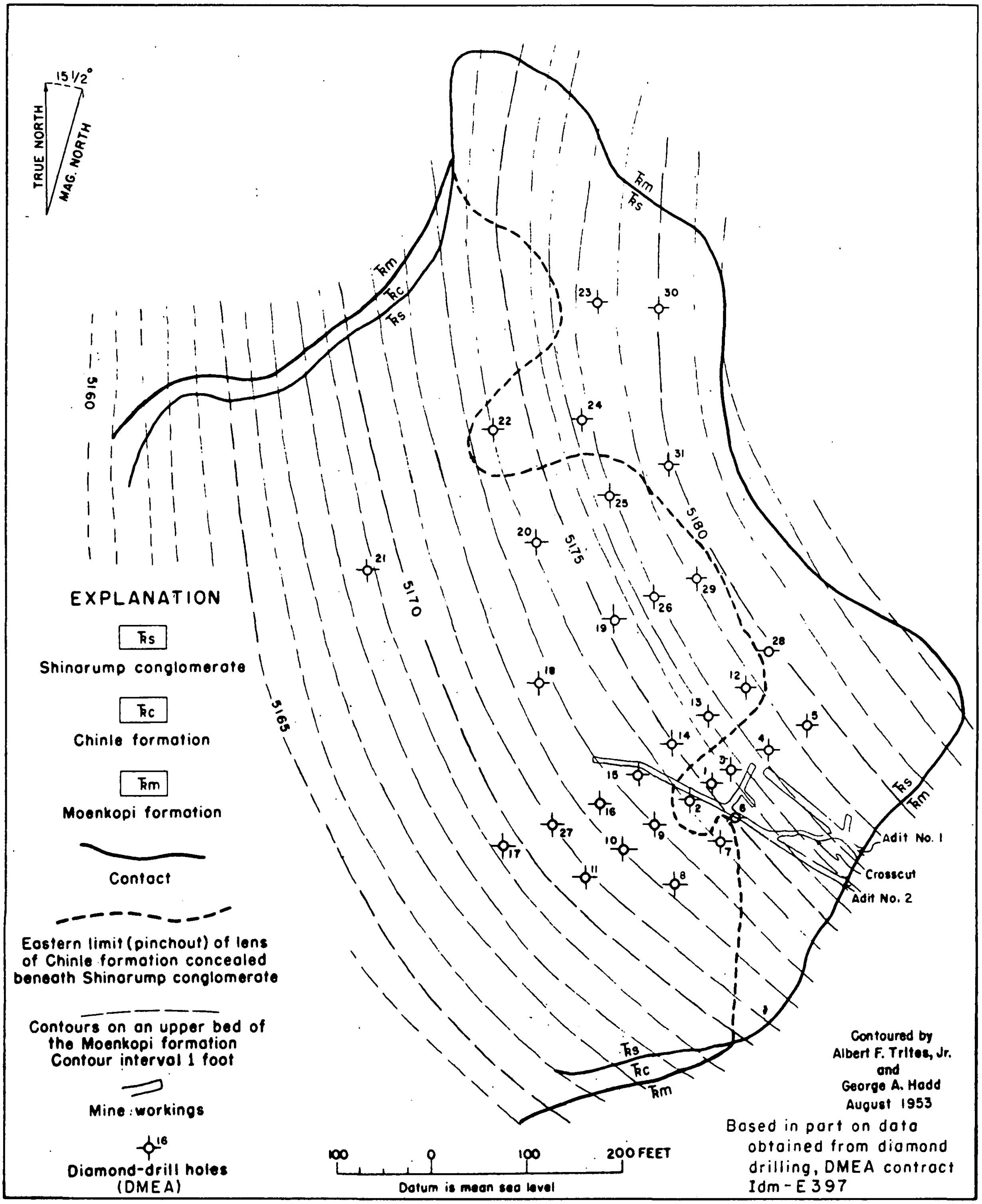


FIGURE 5. STRUCTURAL CONTOUR MAP ON AN UPPER BED OF THE MOENKOPI FORMATION, JOMAC HILL, WHITE CANYON AREA, SAN JUAN COUNTY, UTAH.

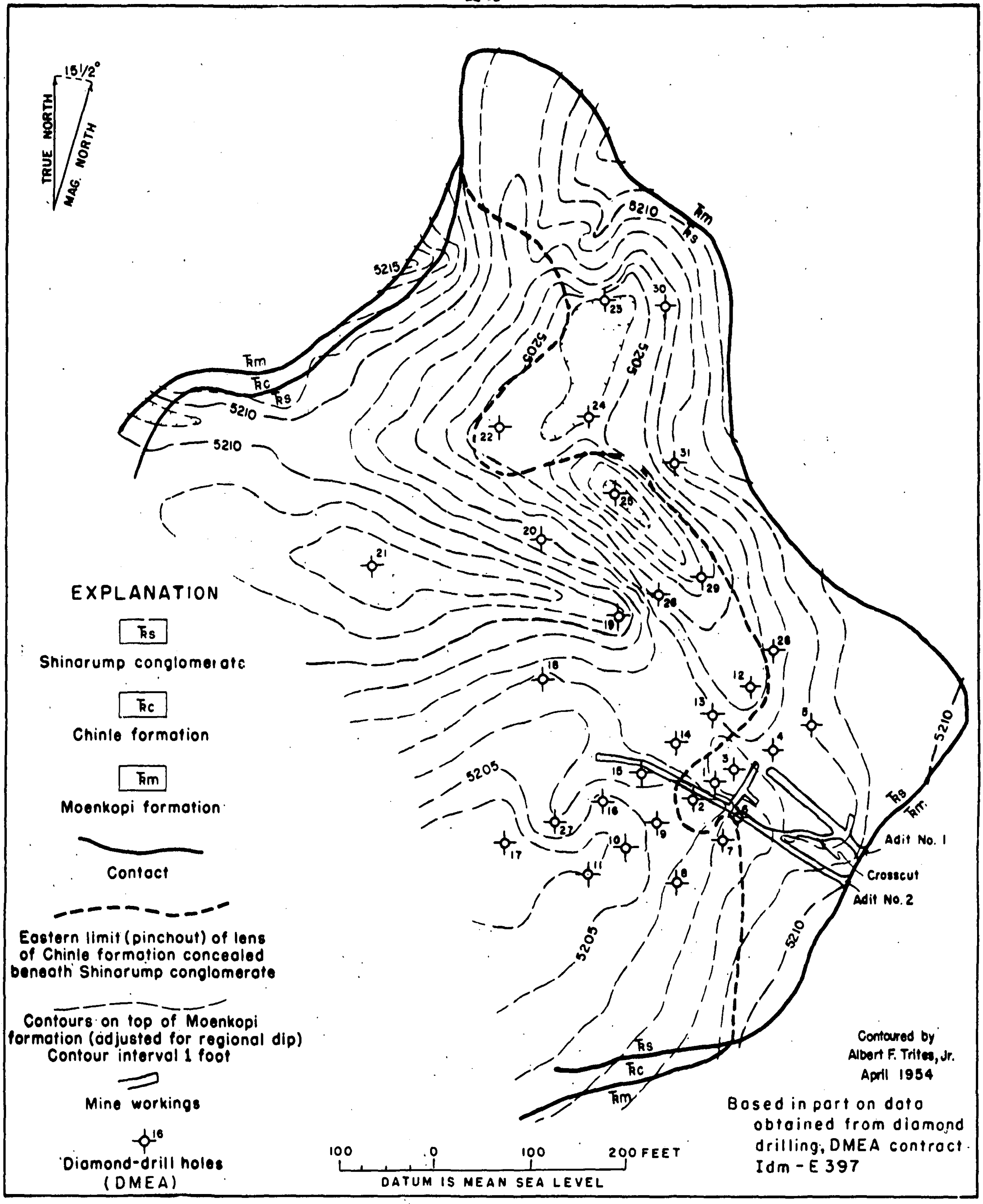


FIGURE 6. STRUCTURAL CONTOUR MAP (ADJUSTED FOR REGIONAL DIP) ON TOP OF THE MOENKOPI FORMATION, JOMAC HILL, WHITE CANYON AREA, SAN JUAN COUNTY, UTAH.

depression scoured into its bottom at drill hole no. 25. The channel has been filled mainly with siltstone beds of the Chinle formation west of the line representing the base of the Chinle formation in figure 6, and by sandstone, conglomerate and siltstone beds of the Shinarump conglomerate east of this line.

Contours drawn on the bottom of the basal sandstone of the Shinarump conglomerate (fig. 7) indicate a channel, approximately 150 feet wide and 4 feet deep, that trends N. 24° W. from a point about 100 feet southwest of the portal of adit no. 2 to a point about 150 feet southwest of the north tip of the Jomac Hill. This channel corresponds with the channel in the top of the Moenkopi formation (adjusted for regional dip, fig. 6), including the channel from the bend at drill hole no. 13 to the north end of the hill. This Shinarump-filled channel is marked by three basin-like scours in its bottom at drill holes nos. 2, 24, and 29. These scours range from 2 to 4 feet deeper than the channel. Another scour to the southwest of the main channel is 5 feet deep and is centered in drill hole no. 27. A somewhat similar channel at the bottom of the basal sandstone of the Shinarump conglomerate, after adjustment for regional dip, is shown in figure 8. The northwest dip of the cross-stratification in the sandstones of the Shinarump conglomerate suggests that water flowed toward the northwest.

The edge of channels seems to be marked in places by siltstone-pebble conglomerates. These conglomerates are believed to represent material that slumped from the upper banks of the streams and was incorporated into the stream sediments. The presence of such conglomerates may prove to be a guide in exploratory drilling for channels.

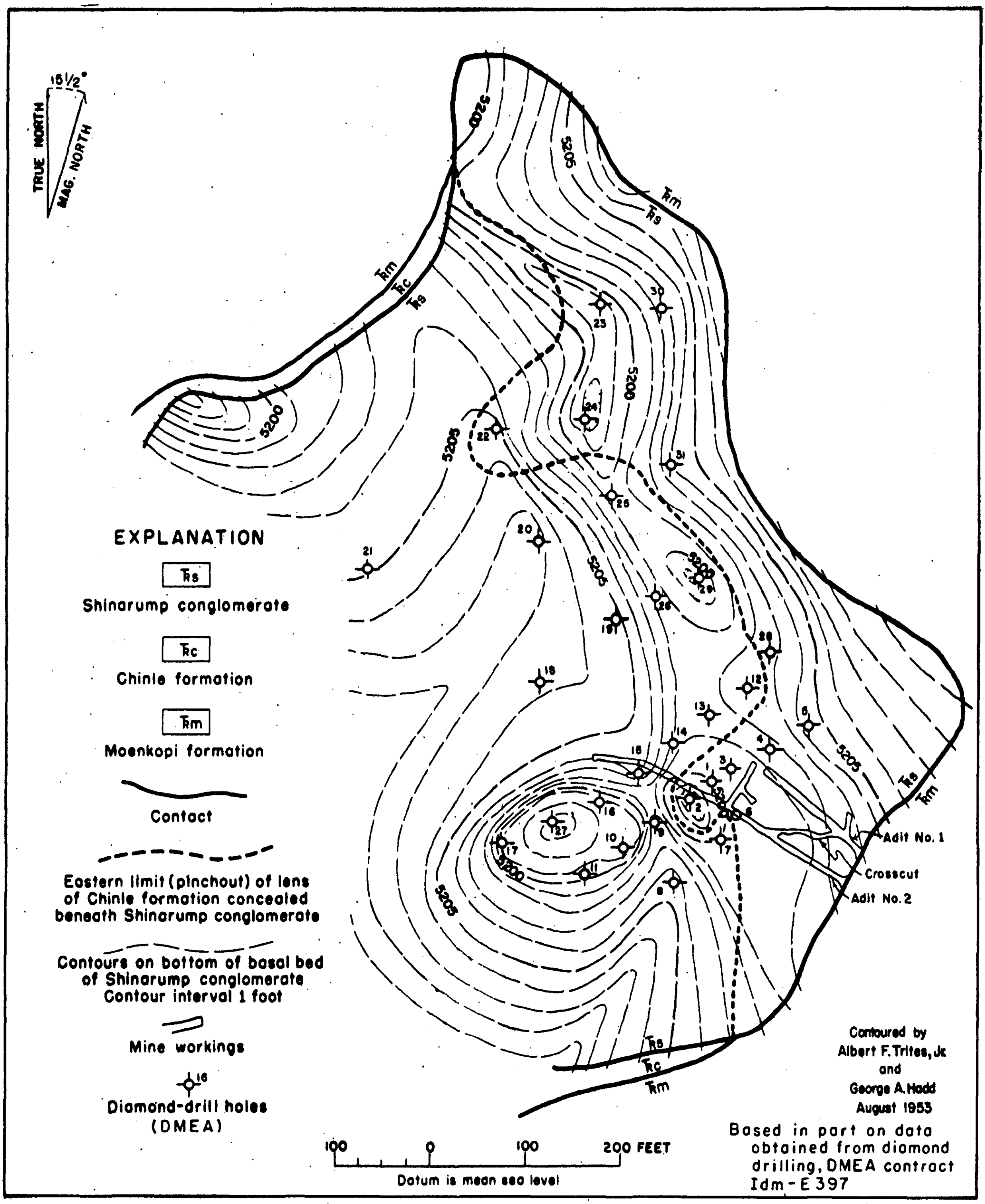


FIGURE 7. STRUCTURAL CONTOUR MAP ON THE BOTTOM OF THE BASAL SANDSTONE OF THE SHINARUMP CONGLOMERATE, JOMAC HILL, WHITE CANYON AREA, SAN JUAN COUNTY, UTAH.

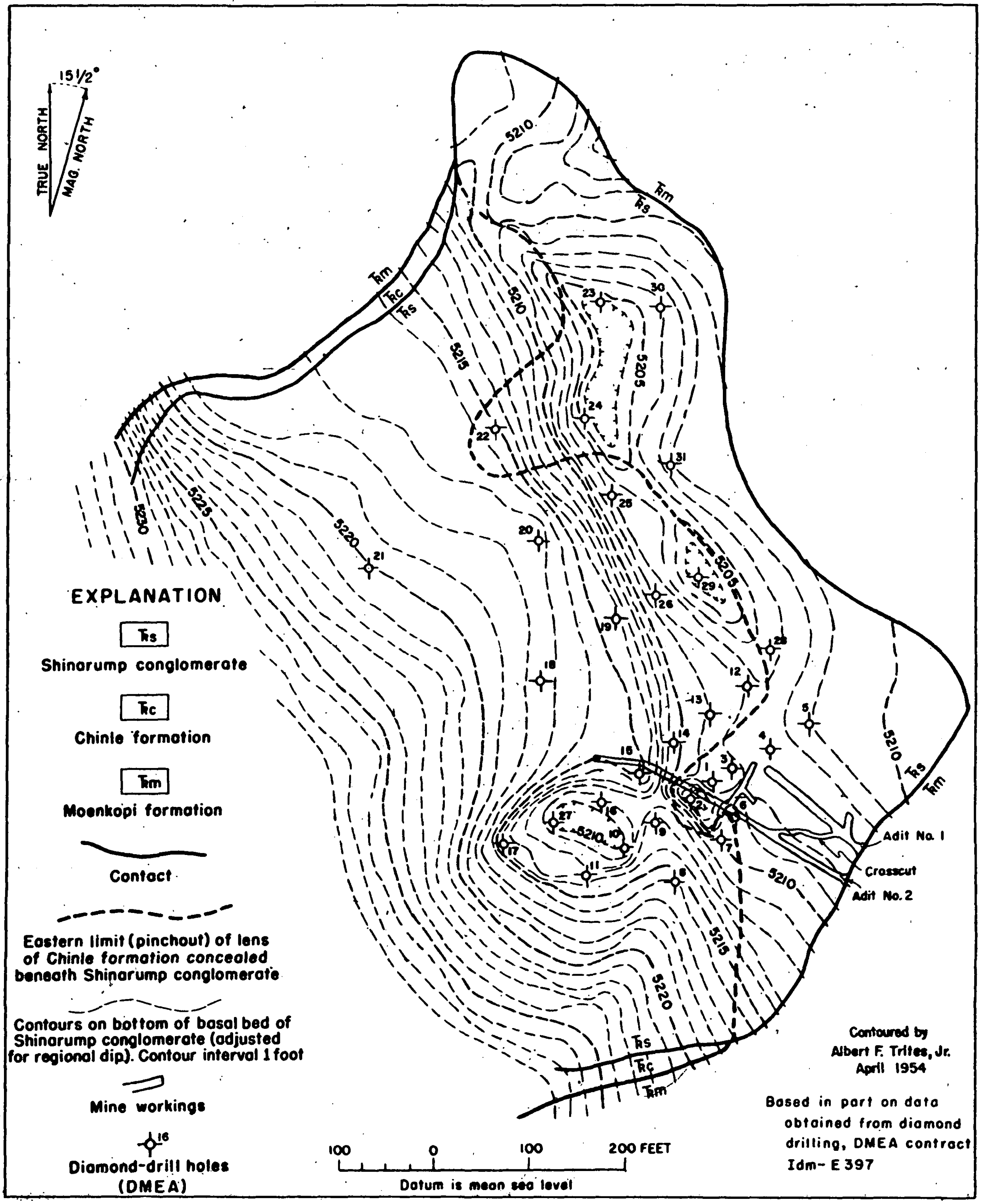
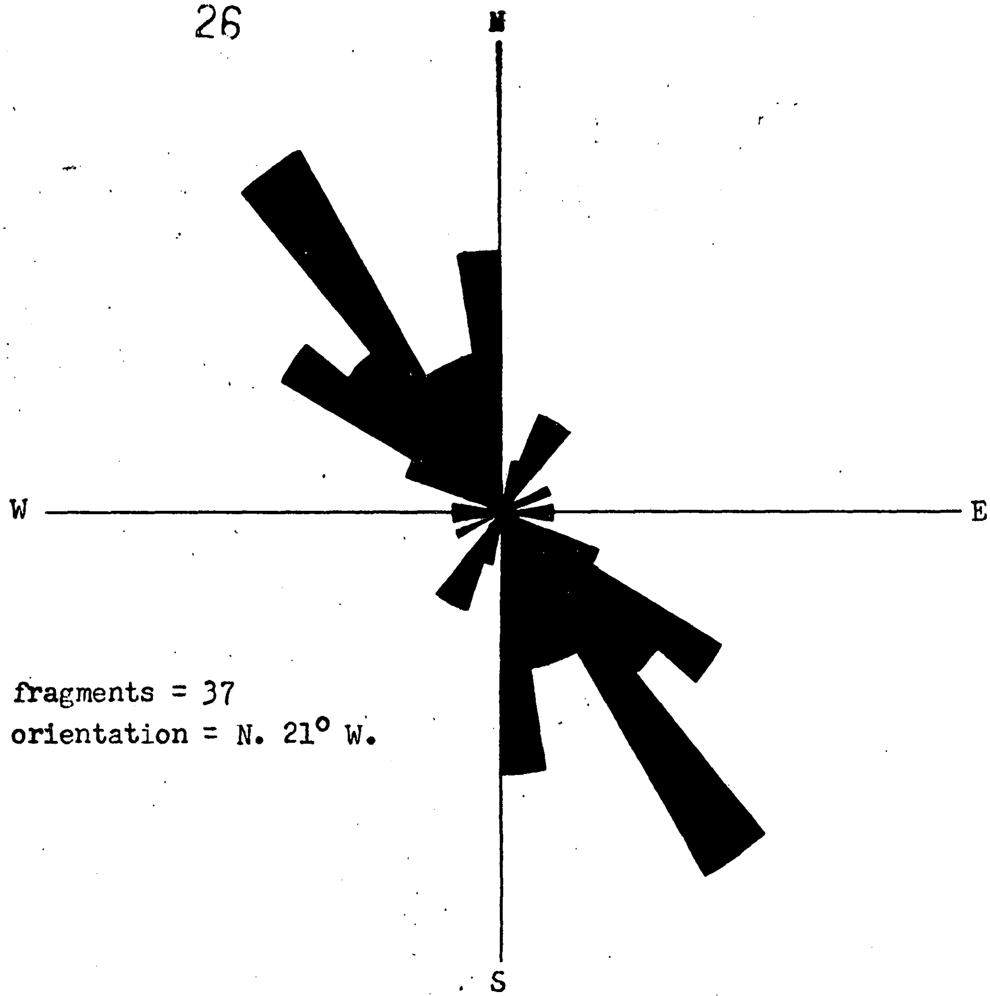


FIGURE 8. STRUCTURAL CONTOUR MAP (ADJUSTED FOR REGIONAL DIP) ON THE BOTTOM OF THE BASAL BED OF THE SHINARUMP CONGLOMERATE, JOMAC HILL, WHITE CANYON AREA, SAN JUAN COUNTY, UTAH.

Wood orientation

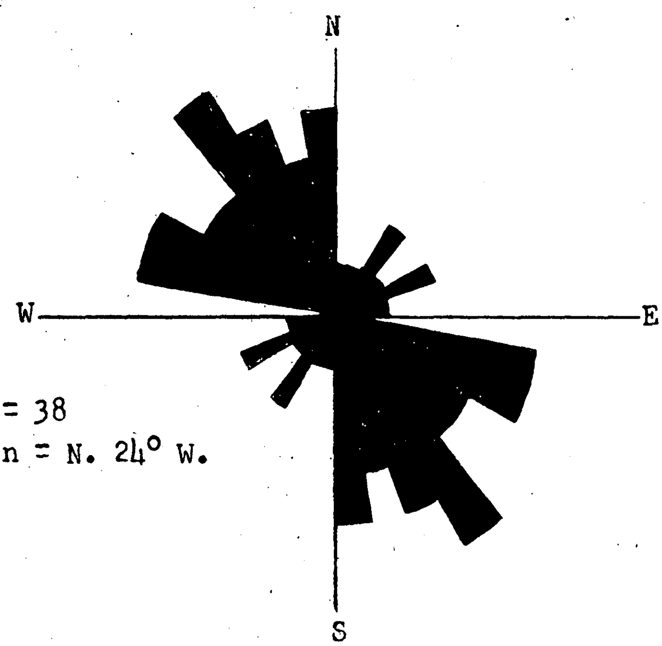
Wood replaced by limonite and hematite occurs above the basal carbonaceous sandstone beds of the Shinarump conglomerate and is especially abundant in conglomerate beds exposed in the upper parts of the mine workings. The orientation of 37 pieces of wood less than 12 inches long and of 38 pieces of wood more than 12 inches long is shown in figure 9.

These diagrams suggest that, in general, the wood fragments, regardless of size, have a resultant orientation of N. 21° to 24° W. (or S. 21° to 24° E.). These pieces of wood were deposited at the bend of a channel; the part of the channel north of the mine workings trends about N. 23° W. (or S. 23° E.) and the part south of the mine workings trends about N. 45° E. (or S. 45° W.). The resultant direction is nearly parallel to the part of the channel north of the mine workings and only a few pieces of wood measured were alined parallel to the part of the channel south of the workings. As previously stated, the general northwest dip of the cross-stratification in the Shinarump conglomerate in the mine workings suggests that the stream flow was from south to north in the channel. If this flow direction is correct, the wood at the bend has been deposited in a general orientation nearly parallel to the new direction of flow. This high consistency in direction of wood orientation suggests that orientation studies elsewhere in Shinarump-filled channels may be of considerable assistance in planning exploration. A relatively small number of pieces of wood, perhaps less than 40, may be necessary to determine the trend of a channel.



Number of fragments = 37
Resultant orientation = N. 21° W.

a. Fragments shorter than 12 inches



Number of fragments = 38
Resultant orientation = N. 24° W.

b. Fragments longer than 12 inches

Figure 9 . Diagrams showing the orientation of wood fragments at the Jomac mine, San Juan County, Utah.

Structure

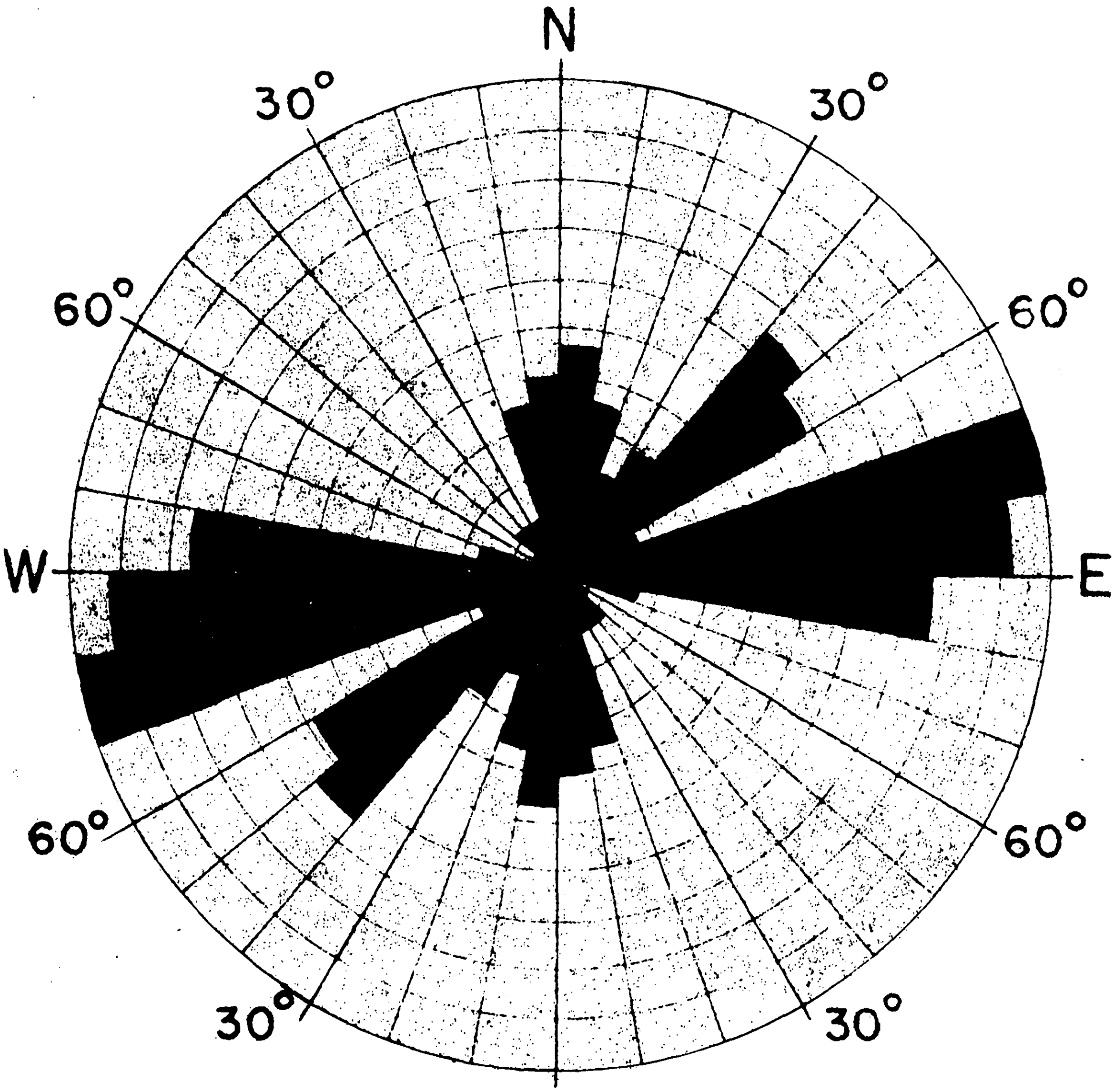
Folds

The structural contours on an upper bed of the Moenkopi formation (fig. 5) indicate that Jomac Hill is along the crest of a southwest-trending flexure. This flexure is on the west flank of a northeast-trending syncline which extends from a few hundred yards east of Jomac Hill to the south side of White Canyon.

Faults, fractures and joints

Jomac Hill is in an area of intense faulting as shown in figure 2. Most of the faults are steeply dipping, strike N. 50° to 75° W., and have vertical displacements from a few feet to more than 80 feet. The nearest fault to the Jomac mine is about half a mile north of the workings, and may be seen from the mine road below the hill. This fault strikes N. 65° W. and dips from 75° NE to vertical. The stratigraphic throw measured by T. L. Finnell is 10 feet with the north side of the fault downthrown.

No displacement was noted in the fractures at the Jomac mine. A study was made of 154 fractures in the mine workings to determine the major systems and the amount of fracture filling for each system. Most of the fractures are steeply dipping, and relatively few of them cut all of the Shinarump beds exposed in the wall at the points of observation. Instead, the fractures tend to end at contacts between lithologic units. The strikes of three prominent sets of fractures are shown on figures 10 and 11: 1) N. 70° E. to S. 80° E., 2) N. 40° to 60° E., and 3) N. 10° E. to N. 10° W. All strikes were recorded in the northern hemisphere but

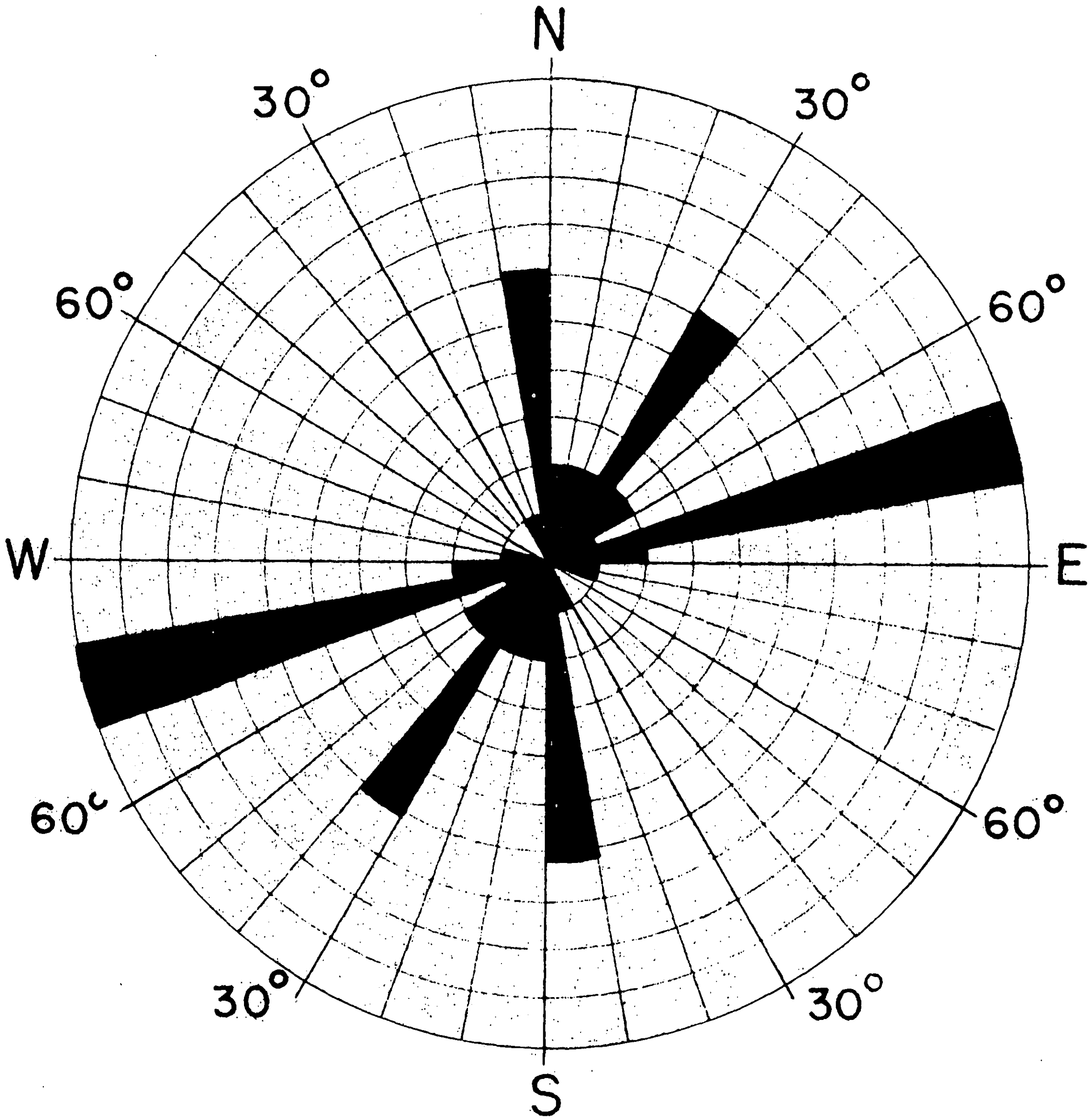


Circular graph showing percentage of fractures with strikes within 10° of arc.

115 fractures

Each division equals 1.5 percent.

Figure 10. Diagram showing the strike of unfilled steeply dipping fractures, Jomac mine, San Juan County, Utah



Circular graph showing percentage of fractures with strikes within 10° of arc.

39 fractures

Each division equals 2.5 percent.

Figure 11. Diagram showing the strike of steeply dipping fractures that have been filled with iron oxide and gypsum, Jomac mine, San Juan County, Utah

were plotted on both the northern and southern hemispheres. The major trend (N. 70° E. to S. 80° E.) is roughly parallel to the axis of the flexure and may represent the longitudinal set of crestal fractures. None of these fractures appear to be related to the faults in the area.

A diagram showing the strikes of 39 fractures that have been filled with iron oxide and gypsum is shown in figure 11. It will be noted that three major sets of fractures have been filled by these secondary minerals; these sets strike N. 70° to 80° E., N. to 10° W., and N. 30° to 40° E. In general, these sets are similar to the sets of fractures that contain no secondary minerals, and apparently each of the three principal sets was favorable for secondary mineral deposition. This also suggests that all of the fracture systems pre-dated the movement of at least some of the secondary solutions containing iron and sulfates. If some of the unfilled fractures were caused by the underground mining operations, the fractures were formed along pre-existing planes of weakness parallel to the filled-fracture planes. For this reason, it appears to make very little difference whether filled or unfilled fractures are chosen for study to determine prominent fracture directions.

URANIUM DEPOSITS

Localization

Most of the uranium at the Jomac mine is believed to be contained in carbonized wood, associated with jarosite and gypsum in sandstone, conglomerate, or sandy siltstone near the base of the Shinarump conglomerate. Abnormal radioactivity has been found in carbonized wood fragments in the sandstone above the basal sandstone, but this carbonized wood is insufficiently concentrated to constitute ore bodies. A more detailed distribution of individual pieces of uraniferous carbonized wood in the mine wall is shown in figure 12. This carbonized wood is believed to be low-rank coal; it is dark gray to black, is light weight, and has a silky sheen. It may be a vitrain and can be burned over a gas flame to give off volatiles. The area in which the carbonized wood and uranium is concentrated in the lower Shinarump beds is shown in figure 13.

Mineralogy

Uranium minerals

Uranium minerals at the Jomac mine include metazeunerite, an unknown fibrous yellow mineral, and an unknown massive yellow mineral; no pitchblende nor uraninite has been found.

The metazeunerite ($Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$) occurs as pale green plates as much as 2 mm across, coating pieces of coal and associated with plates of gypsum and coatings of jarosite. Some of the metazeunerite plates are in clusters radiating about a center. The results of semiquantitative spectrographic analyses of the metazeunerite are shown in table 1.

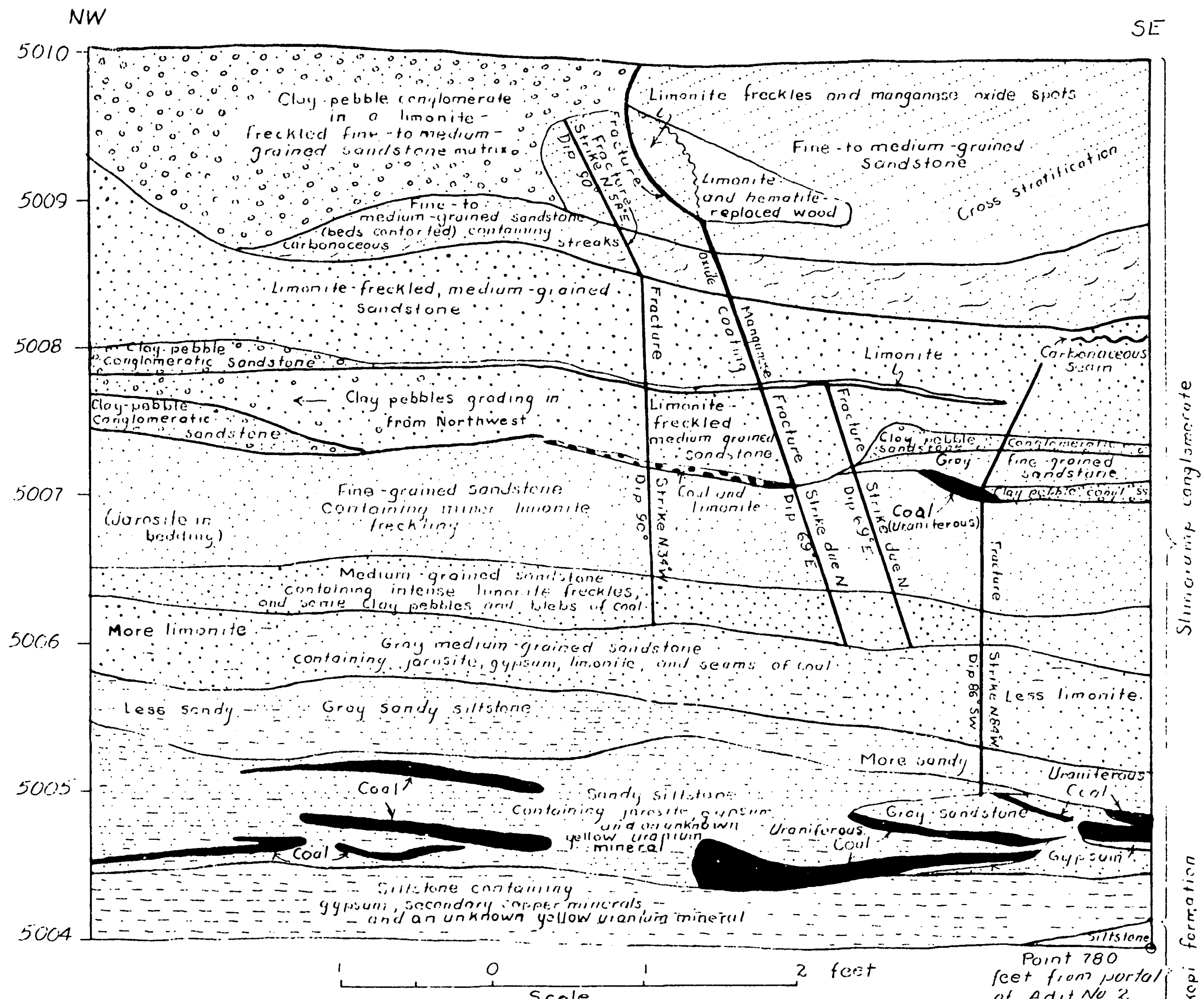


FIGURE 12. GEOLOGIC SECTION OF A SEGMENT OF THE NORTH WALL OF ADIT NO. 2, JOMAC MINE, SAN JUAN COUNTY, UTAH.

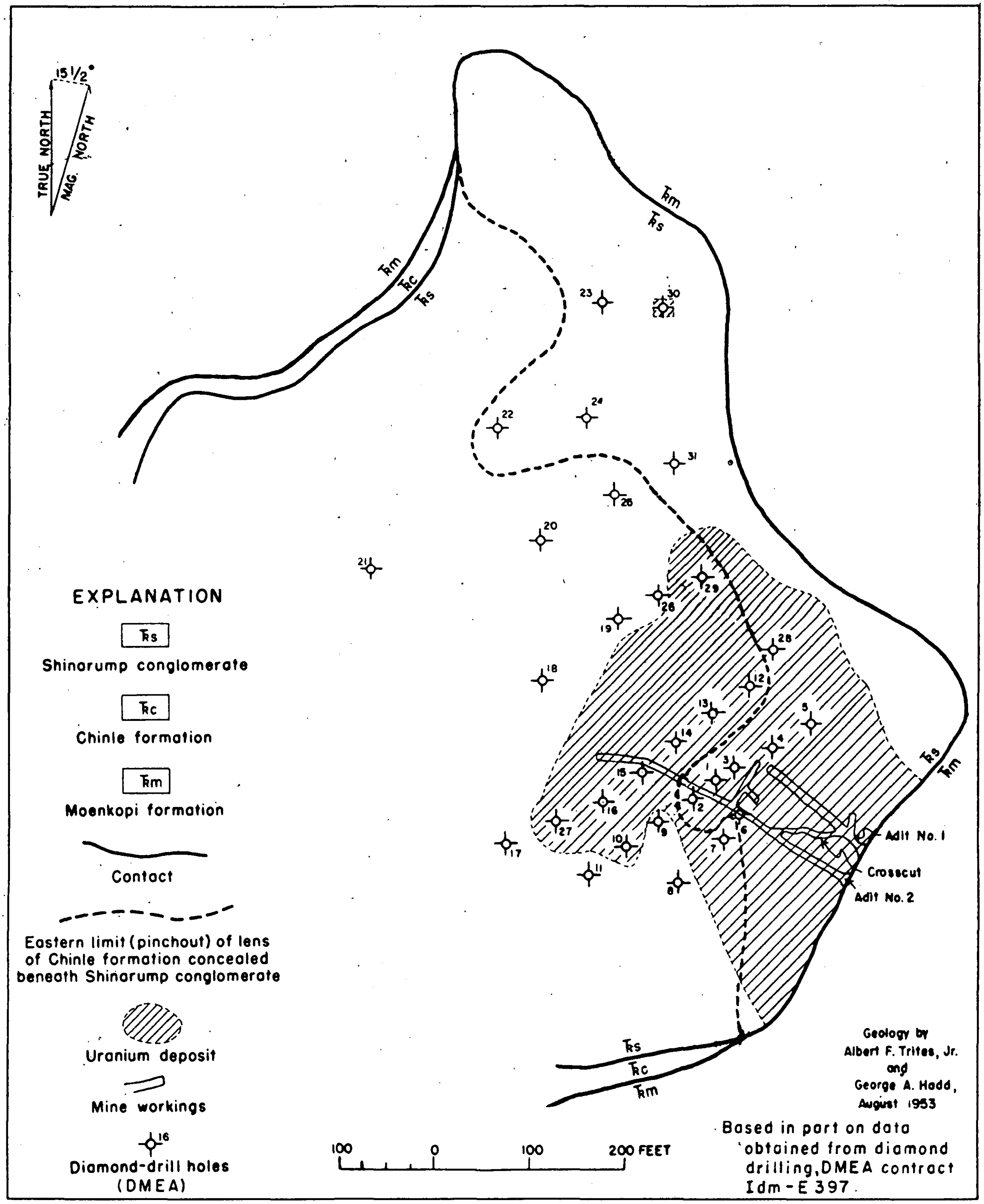


FIGURE 13. MAP SHOWING THE URANIUM DEPOSIT, JOMAC MINE, SAN JUAN COUNTY, UTAH.

Table 1.--Semiquantitative spectrographic analyses of secondary uranium minerals, Jomac mine, White Canyon area, San Juan County, Utah, in percent 1/

Mineral	Over 10	5-10	1-5	0.5-1	0.1-0.5
Metazeunerite	U	Cu	Ca, As, Si, Al, P	Fe	None
Unknown fibrous yellow uranium mineral	Si, U	Al	Ba, P, K, Fe, Ca, Mg	Na	Ti
Unknown massive yellow uranium mineral	U, P	Al, Fe	Ca	None	Si

1/ Analyst, Katherine E. Valentine of the Geological Survey Washington Laboratory.

The unknown fibrous yellow mineral occurs as impregnations in the upper sandstone beds of the Shinarump conglomerate a few feet north of adit no. 1. The mineral fluoresces an intense yellowish green. Semiquantitative spectrographic analysis suggests that the mineral is a silicate as shown in table 1.

The unknown massive yellow uranium mineral is in nodular porcellainous masses as much as half an inch across, associated with carbonized wood and gypsum in sandstone beds near the base of the Shinarump conglomerate. The X-ray powder pattern of the mineral matches none of the standard uranium minerals in the files of the Geological Survey. The results of semiquantitative spectrographic analyses are shown in table 1.

Sulfide minerals

Minor amounts of chalcopyrite impregnate a sandstone lens in the basal coal-bearing sandstone near the end of adit no. 2, in the coal-bearing sandstone in the cross cut, and in basal Shinarump siltstone in drill hole no. 17. Pyrite occurs in some of the sandstones and siltstones of both the Shinarump conglomerate and the lower member of the Chinle formation. In general, the pyrite replaces pieces of carbonized wood in these rocks, but in places it also impregnates the sandstone. The 0.5-foot coal-bearing sandstone cut by drill hole no. 1 contains approximately 4 percent pyrite, impregnating the rock and replacing the woody cells of the coal. Nodular concretions of pyrite have been found in core from drill holes that have cut Chinle clays about 100 feet above the Shinarump beds.

Secondary copper minerals

Secondary copper minerals found at the Jomac claim include malachite, azurite, and chalcanthite, in addition to the metazeunerite previously described. Small amounts of malachite and azurite occur at the Shinarump-Moenkopi contact, associated with gypsum. Chalcanthite locally impregnates the basal coal-bearing Shinarump sandstone bed exposed in adit no. 2.

Gangue minerals

The gangue minerals at the Jomac mine include quartz, feldspar, clay minerals, hydrous iron oxides, hematite, jarosite, gypsum, and manganese oxides. Quartz is the most abundant of the gangue minerals, occurring as grains in the sandstone, siltstone, and conglomerate. These quartz grains consist of coarsely crystalline quartz and quartzite; secondary quartz overgrowths are present on many of the quartz grains in the poorly cemented medium- to coarse-grained sandstones.

A few grains of pale-yellow microcline are scattered throughout the sandstones of the Shinarump conglomerate. Some of the feldspar grains appear to have been altered partly to a clay mineral.

Clay minerals form the cement of some of the sandstone, are abundant constituents of some of the siltstone beds and pebbles, and have replaced some of the feldspar grains.

A mixture of unidentified hydrated ferric oxides, referred to as limonite, but probably principally goethite, has replaced some of the fragments of wood and has impregnated many of the sandstones and conglomerates. The limonite is believed to be of supergene origin and probably has been derived from pyrite. The limonite freckles in some of the sandstone may have resulted from the alternation of pyrite crystals that impregnated the sandstone.

Hematite has replaced some of the fragments of wood and has locally impregnated the sandstone. The hematite is nearly everywhere associated with limonite.

Jarosite is abundant in the lowermost sandstone, conglomerate, and siltstone beds of the Shinarump conglomerate. It forms part of the cementing material of some of the sedimentary rocks which contain abundant pieces of carbonized wood. The close association between jarosite and uranium-bearing carbonized wood makes jarosite a guide in determining beds that may be favorable for finding ore.

Abundant gypsum occurs in the basal coal-bearing Shinarump sandstone, in the upper 1 foot of the bleached Moenkopi beds, and along fractures. The gypsum is most commonly associated with the coal in the Shinarump conglomerate; many pieces of coal are partly surrounded by a layer of gypsum as much as one-fourth inch thick. Gypsum along the fracture surfaces is commonly associated with limonite.

Manganese oxide forms a widespread coating on many bedding surfaces and fracture planes in the bleached Moenkopi siltstone, and forms irregular coatings of the quartz grains and clay cement of many of the Shinarump conglomerate beds exposed in the underground workings and in the diamond-drill cores. The secondary copper minerals are commonly associated with manganese oxide.

Ore guides

The principal guides believed to be useful in the underground exploration are the Shinarump-filled channel, the included basins, carbonaceous sandstone or conglomerate at the base of the Shinarump beds, coal, and jarosite. Jarosite appears to be of the greatest value for exploratory drilling, especially in holes in which pieces of uranium-bearing carbonized wood may not have been penetrated; the Jomac mine is the only deposit in the White Canyon area in which jarosite is considered a guide to ore.

CONCLUSIONS

The detailed study at the Jomac mine has helped to clarify several questions pertaining to the nature of channels and their contained sedimentary features in the White Canyon area.

Geologists working in the White Canyon area for the Atomic Energy Commission have maintained the belief that a better understanding of channels cut into the Moenkopi formation and filled by Shinarump conglomerate may be obtained by adjusting the structural contour maps of the surface of the Moenkopi formation for regional dip. It has been shown in the previous discussion that such adjustment for regional dip is necessary at the Jomac mine to produce a logical channel picture. It is believed that such adjustment may define more distinctly many of the channels in the area.

This study has also suggested that structural contour maps on the bottom of the basal sandstone or conglomerate bed of the Shinarump conglomerate may indicate depressions and channels imperfectly defined or not defined at all by the contours on top of the Moenkopi formation where siltstone or claystone overlies the Moenkopi beds. Such channels above the Moenkopi surface may change somewhat in trend from those cut into the Moenkopi beds and may be the major localizing structures of many of the deposits. Shinarump and Chinle rims should be examined thoroughly with the possibility in mind of channels from a few feet to perhaps tens of feet above the Moenkopi surface.

The significance of wood-orientation studies is believed to be important in determining the trend of channels, and as few as 40 observations may be sufficient. Apparently the size of the wood fragments is not important in such studies.

Edges of channels may be determined by the presence of siltstone-pebble conglomerates and conglomeratic sandstones that contain pebbles of the underlying siltstone beds. These conglomerates require considerably more study at other localities in the White Canyon area before they can be established as a guide to channels.

Jarosite may be useful as an ore guide in the White Canyon area in deposits in which the uranium is concentrated in carbonaceous material, but it must be used carefully in connection with favorable lithology and other criteria.

LITERATURE CITED

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