Geology, Ore Deposits, and Exploratory Drilling in the Deer Flat Area White Canyon District San Juan County, Utah

GEOLOGICAL SURVEY BULLETIN 1132

Prepared on behalf of the U.S. Atomic Energy Commission

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By TOMMY L. FINNELL, PAUL C. FRANKS, *and* HAROLD A. HUBBARD

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By Tommy L. Finnell, Paul C. Franks, and Harold A. Hubbard

ABSTRACT

The Deer Flat area is about 28 miles west of Blanding, in southeastern Utah, and includes an area of about 50 square miles.

The exposed rocks of the area range in age from Permian to Recent. From oldest to youngest they are the Cedar Mesa sandstone member, and the Organ Rock tongue of the Cutler formation of Permian age; the Hoskinnini member of the Moenkopi formation of Triassic(?) age, and the upper member of the Moenkopi formation of Early and Middle(?) Triassic age; and the Shinarump member, the mudstone-sandstone unit, the Moss Back member, and the limy unit of the Chinle formation of Late Triassic age. Quaternary deposits include alluvium, sand, soil, talus, cemented talus, and landslides.

The area is on the west flank of the Monument upwarp, and the beds strike N. 12°–45° W., and dip 1°–3° SW., except in monoclines where they dip as much as 7° SW. A few normal faults cut the rocks in the area; they trend northwestward and have as much as 32 feet of throw.

Uranium-copper deposits in the Deer Flat area are mainly confined to the basal 10 feet of the Shinarump member of the Chinle formation where the Shinarump fills channels in the Moenkopi formation. Several low-grade uranium deposits are in chalcedony lenses in the mudstone-sandstone unit of the Chinle formation, and there are even two ore-grade deposits in the mudstone-sandstone unit where it rests on the Moenkopi formation north of the regional pinchout of the Shinarump member.

Ore deposits range from tapering bodies as much as 2.5 feet thick, 10 feet wide, and 30 feet long, to irregular tabular bodies as much as 14 feet thick, 150 feet wide, and 220 feet long. Ore grades average 0.56 percent U_3O_8 and 1.9 percent copper.

The principal uranium ore minerals in the area are uraninite, uranophane, bayleyite, schroeckingerite, zippeite, autunite, and metatorbernite; copper minerals are chalcopyrite, bornite, chalcocite, covellite, malachite, azurite, brochantite. boothite, and native copper. Gangue minerals are authigenic quartz, calcite, dolomite, manganosiderite, gypsum, pyrite, jarosite, black manganese oxides, hematite, barite, galena, sphalerite, limonite, alunite, alunogen, kaolinite, and montmorillonite. The ore minerals preserve plant-cell structure, replace quartz and feldspar, fill fractures, and impregnate sandstone.

Four channels filled with the Shinarump member of the Chinle formation were partly explored by diamond drilling; these channels trend from N. 50° W., through west to S. 70° W., and range from 150 to 1,000 feet in width, from 12 to 19 feet in depth, and from 1,500 to more than 2,000 feet in length. In general the Shinarump in the channels is thicker than that on the banks, but no lithologic differences are known between the rocks in the two positions. Pre-Shinarump monoclinal folds may have increased local stream gradients and perhaps altered the course of the streams that cut the channels.

Guides for exploration are channels, scours, gray to yellowish-gray medium- to coarse-grained sandstone filling channels, mudstone or muddy sandstone above the basal sandstone, copper minerals, fossil plant material, and anomalous radioactivity. Structural terraces and local monoclines may be guides either to channels or to mineralized parts of channels. Sedimentary structures in the lower part of the Shinarump can be used to determine the trend of outcropping channels.

Uranium was probably introduced into the Shinarump member during Late Cretaceous or early Tertiary time. The source of the uranium and its mode of introduction are not known, but the ore deposits were formed by replacement in medium- to coarse-grained sandstone that fills erosional depressions in relatively impermeable shale, and that was also overlain by relatively impermeable rock. Local monoclines may overlie buried faults that tapped a deep source of uranium. The uranium may have risen along the faults and found its way into the Shinarump member by traveling along joints in the Moenkopi. The channels would tend to confine and guide solutions moving through the Shinarump.

INTRODUCTION

In the Deer Flat area, which is in the east-central part of the White Canyon uranium mining district, in southeastern Utah (fig. 1), mines in the Shinarump member of the Chinle formation of Triassic age have produced several thousand tons of uranium ore from deposits that are mineralogically similar to those previously studied elsewhere in the White Canyon area. Therefore, in June 1951, the U.S. Geological Survey began a mapping program in the Deer Flat area to compare the geologic setting of its uranium deposits with that of the better known deposits to the west. The purpose of the work was to map and study the ore-bearing Shinarump and adjacent strata, and to outline favorable areas for exploratory diamond drilling. During the summer of 1952 the Hideout No. 1 claim was mapped and was recommended for exploratory drilling to trace and delimit the Hideout No. 1 channel, which had been partly explored underground by drifts. An integrated program of geologic mapping and exploratory drilling was begun in June 1953 and continued until October 1954. The work was done on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission.

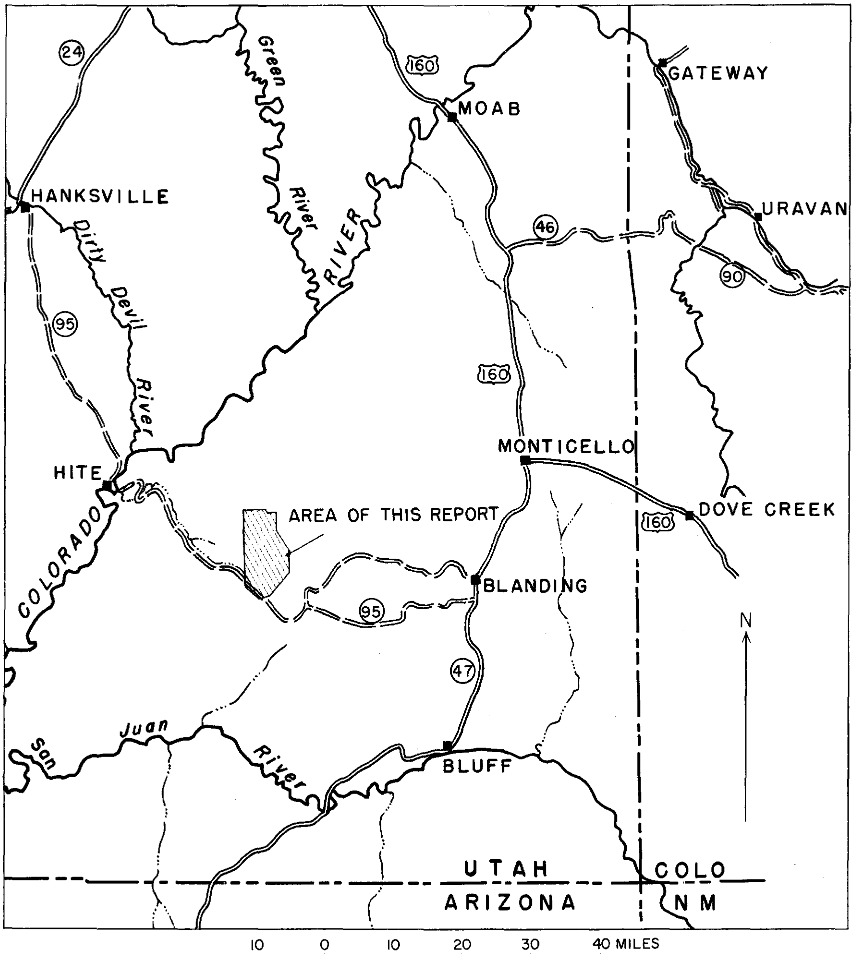

FIGURE 1.—Index map of part of the Colorado Plateau showing the location of the Deer Flat area.

The fieldwork was begun under the supervision of A. F. Trites, Jr., of the U.S. Geological Survey. Other Survey geologists who worked on the project at various times are E. P. Beroni, D. A. Brew, R. W. Schnabel, B. L. Renzetti, R. L. McDonald, O. T. Marsh, R. A. Ready, and T. G. Fails.

The fieldwork comprised examination and sampling of all outcrops of the Shinarump member to determine the distribution of uranium in that unit, geologic mapping on aerial photographs (scale 1:31,680), compilation of geology on topographic base maps (scale 1:24,000), plane-table mapping of selected mineralized areas on scales of 1:2,400 or 1:240 (scale depending on amount of detail required), and mapping of mine workings and bulldozer cuts with Brunton compass and tape on a scale of 1:240. Some valuable information was obtained from drill holes put down during 1954 by mining companies on Deer Flat and Upper Lost Parks. These holes were probed by the U.S. Geological Survey with a gamma-ray logging unit. Four channels filled with rocks of the Shinarump member were explored by drilling by private companies under contract to the U.S. Geological Survey. The primary objectives of this work were to delimit the channels and determine the size and spacing of any ore bodies found in them; others were to test the known guides to ore and to develop new ones.

Generous cooperation and help were given by local residents and prospectors, particularly by Messrs. Robert Hancock and Raymond Starr, representatives of the White Canyon Mining Co. of Cortez, Colo., who facilitated the mine mapping and also provided useful data regarding claim location. Mr. L. J. Miller, of the U.S. Atomic Energy Commission, made available to us the results of diamond-drilling in channels on Frey Point, about 1½ miles west of Deer Flat; this information proved very useful during the early stages of the drilling on the Hideout No. 1 claim.

EXPLORATION BY THE U.S. GEOLOGICAL SURVEY

Diamond-drilling was done for the U.S. Geological Survey in the Deer Flat area from August 24 to December 17, 1953, and from April 3 to October 22, 1954. A total of 141 holes were drilled, with an aggregate length of 28,971 feet. Approximately 3 percent of the footage was in holes spaced about 300 feet apart, and the remainder was in holes about 50 to 200 feet apart. All holes were drilled to delimit channels and to determine the size of the uranium deposits in the channels.

Channels were delimited in the four areas containing the Hideout No. 1, W. N., Camel, and Sandy No. 3 properties (pl. 1). The geology of these areas is described in the section on mines and prospects, and geologic details and the location of the drill holes are shown in plates 3, 5, 7, and 8.

GEOGRAPHY

The Deer Flat area comprises parts of Tps. 34, 35, and 36 S., R. 17 E., and parts of Tps. 35 and 36 S., R. 18 E., Salt Lake meridian. It can be reached by way of a graded dirt road about 13 miles long that connects with old State Highway 95 on Elk Ridge, about 32 miles west of Blanding, or by one about 16 miles long that connects with the new State Highway 95 on Grand Flat, about 35 miles west of Blanding (fig. 1).

Altitudes in the area range from about 5,400 feet at the bottoms of the canyons to 8,440 feet on the tops of the mesas. The topography of the area is characterized by steep-walled canyons separated by gently sloping esplanades and steep-sided buttes, mesas, and ridges (pl. 1). Deer Flat and Piñon Point are relatively flattopped ridges that are southwesterly extensions of the Elk Ridge upland.

Piñon and juniper forests grow on much of the outcropping sandstone, and sagebrush and grass on the soil-mantled areas between bedrock exposures. Grassy flats in the middle of Deer Flat are surrounded by dense forest growth which roughly outlines the rim of the mesa. The slopes along the sides of the mesa are also covered by piñon and juniper. The vegetation is typical of the Foothills zone—defined by Pesman (1948, p. 5–6) as the altitude equivalent of the Transition zone of Merriam (1898)—in semiarid to arid climatic conditions; but some of the plants are characteristic of the lower part of the Montane zone (Canadian of Merriam), or of the upper part of the Plains zone (Upper Sonoran of Merriam). The woody plants in the area include serviceberry, mountain mahogany, scrub oak, manzanita, buckbrush, Mormon tea, snowberry, cliff rose, round leaf buffaloberry; and at higher elevations near springs and in moist areas, yellow pine, Douglas fir, quaking aspen, gooseberry, and wild rose. Common herbs growing in the area include *Senecio*, *Cryptantha*, *Phlox*, *Balsamorhiza*, *Oenothera*, *Gilia*, *Penstemon*, *Allium*, *Aster*, *Lupinus*, and *Stanleya*. Most of Deer Flat has been disked and planted in forage grasses by the U.S. Bureau of Land Management. Ricegrass and Russian-thistle grow in profusion along roads and bulldozer cuts.

The climate is semiarid to arid. The streams are intermittent, flooding after heavy summer rains, sudden thaws, and hailstorms, but flowing sedately in the springtime when the snows are slowly melting.

Springs issue from the base of the Moss Back member of the Chinle formation of Triassic age around the heads of Hideout Canyon and Deer Canyon, and also on the northwest side of Piñon Point.

GEOLOGY

The rocks exposed in the Deer Flat area are all sedimentary; the nearest igneous rocks are in the Abajo Mountains, about 20 miles to the east, and in the Henry Mountains, about 30 miles to the west. The sedimentary rocks are of Permian to Recent age. The Permian rocks all belong to the Cutler formation, which includes, in ascending order, the Cedar Mesa sandstone member and the Organ Rock tongue. They are overlain successively by the Hoskinnini member of the Moenkopi formation of Triassic(?) age, and the upper member of the Moenkopi formation of Early and Middle(?) Triassic age, and by the Chinle formation of Late Triassic age, which includes, in ascending order, (1) the Shinarump member, (2) a mudstone-sandstone unit, (3) the Moss Back member, and (4) a limy unit. The Quaternary deposits are alluvium, colluvium, sand, soil, cemented talus, and landslides (pl. 1). The Organ Rock tongue of the Cutler formation and the Hoskinnini tongue of the Moenkopi formation thin toward the north and the Shinarump member of the Chinle formation pinches out northward, whereas the upper member of the Moenkopi formation thickens to the north. No angular discordance between the formations was seen, however, and the contacts are therefore regarded as disconformable.

The tongue of red beds and the underlying light-colored sandstone member that make up the Cutler formation and the Hoskinnini member of the Moenkopi formation were deposited in continental environments, perhaps near the shore of an inland sea. The upper member of the Moenkopi formation consists of red shales and red, brown, and yellowish-brown sandstone and contains the numerous ripple marks characteristic of shallow-water deposits. The Chinle formation consists of interbedded stream-deposited sandstone, conglomerate, mudstone, and siltstone, with local beds of bentonite that probably represent stream-worked volcanic ash.

The rocks in the Deer Flat area lie on the west flank of the Elk Ridge anticline (Benson and others, 1952) a slightly elongate dome superimposed on the larger Monument upwarp. Both the anticline and the upwarp are asymmetric, with steeply dipping east limbs and gently dipping west limbs; the rocks of the Deer Flat area have extremely gentle southwestward dips, ranging from 1° to 3°. The Moenkopi and Cutler formations are cut by a few normal faults which trend northwestward and are nearly vertical. According to Baker (1933, p. 78), Hunt (1956), and Eardley (1951, p. 408), the Monument upwarp was formed during the Laramide orogeny, in Late Cretaceous or early Tertiary time.

The ore deposits in the Deer Flat area contain copper as well as uranium but are valued mainly for uranium. Most of them are in sandstone, so they have been classified as "sandstone-type" uranium deposits (Schnabel, 1955); they are in the Shinarump member of the Chinle formation where it fills channels in the top of the Moenkopi formation. In the northern two-thirds of the area, however, where the Shinarump member is absent, small copper-uranium deposits are found in other sandstones of the Chinle formation that fill shallow channels in the Moenkopi formation.

STRATIGRAPHY

CUTLER FORMATION (PERMIAN)

CEDAR MESA SANDSTONE MEMBER

Only the upper 450 to 470 feet of the Cedar Mesa sandstone member of the Cutler formation is exposed in the area. It crops out in the canyons, where cliffs of massive yellowish-orange and reddish-brown sandstone are separated by gentle slopes of reddish-brown siltstone. Reddish-brown sandstone constitutes about half of the upper 40 feet of the Cedar Mesa member, and the upper 100 feet contains lenses and concretions of gray impure limestone. These rocks are all much lighter colored than the overlying red beds of the Organ Rock tongue.

The most abundant rock in the Cedar Mesa member is a fine-grained dominantly pale yellowish-orange crossbedded sandstone, cemented by calcite, dolomite, and limonite. The grains, which are subangular to well rounded, consist mainly of quartz commonly with secondary overgrowths. The rock also contains a few grains of microcline and plagioclase and wisps of muscovite and bleached biotite. The reddish-brown siltstone between the sandstone beds is composed of silt-size quartz grains cemented by calcite, limonite, and hematite. Locally at contacts with either overlying or underlying sandstone, the siltstone is bleached to a light yellowish gray in a zone as much as 18 inches thick.

Most of the sandstone contains long sweeping cross-laminations of the type commonly formed in sand dues. The laminae dip rather consistently southeastward, suggesting deposition by winds that generally came from the northwest. The individual laminae are 1 to 6 inches thick, but they form trough and planar sets (McKee and Weir, 1953, p. 387) as much as 50 feet thick. Cross-laminations at the tops of the sets are truncated by widespread parting planes of gentler dip.

The contact between the Cedar Mesa sandstone member and the overlying Organ Rock tongue is not well exposed, but where it was observed the Cedar Mesa seems to grade upward from thick layers of crossbedded sandstone into a transitional zone composed of alternating thin layers of light-colored sandstone, reddish-brown sandstone, and reddish-brown siltstone. The proportion of siltstone gradually increases upward, and the top of the Cedar Mesa member is placed at the top of the highest light colored sandstone in the transition zone.

ORGAN ROCK TONGUE

The Organ Rock tongue of the Cutler formation forms the bases of the mesas, ridges, and buttes in the area. It consists of 120 to 282 feet of interbedded reddish-brown siltstone and fine-grained sandstone. The rocks consist mainly of well-sorted fine-grained quartz cemented by hematite, calcite, and quartz. In the upper part of the tongue, there are a few lenses of conglomerate consisting of well-rounded pebbles and cobbles of siltstone and quartzite as much as 3 inches in diameter in a siltstone matrix. The conglomerate lenses are as much as 6 feet thick, and pass either gradually or abruptly both laterally and vertically into nonconglomeratic siltstone. All the rocks have locally been bleached yellowish gray in zones as much as a foot wide along joints, faults, bedding planes, clastic dikes, and lenses of relatively permeable sandstone.

The upper part of the Organ Rock tongue is cut by clastic dikes 2 to 3 inches wide composed of medium- to coarse-grained sandstone. The sandstone in some of the dikes is rudely banded parallel to the dike walls, as if the dike had formed by forcible injection of wet sand. The material forming the dikes probably came from the sands of the overlying Hoskinnini member of the Moenkopi formation, for it is similar to the overlying sandstone, and no material similar to that in the dikes has been found below them.

Nodular-weathering massive ledge-forming siltstone forms the upper part of the Organ Rock tongue in the southern part of the area but this rock is not present in the northern part of the area. The siltstone beds may have been truncated northward, which would account for the thinning of the Organ Rock tongue from 280 feet at the south end of Deer Flat to 120 feet just north of the mapped area, or they may grade laterally into sandstone. The Organ Rock tongue is disconformably overlain by sandstone of the Hoskinnini member of the Moenkopi formation, which fills fissures and small scours in the top of the underlying unit.

MOENKOPI FORMATION (TRIASSIC)

HOSKINNINI MEMBER

The Hoskinnini member of the Moenkopi formation of Triassic(?) age (Stewart, 1959) was originally described and named by Baker and Reeside (1929, p. 1422) in the Monument Valley area, Utah. They considered it to be the top member of the Cutler formation of Permian age. Recently Stewart (1959, p. 1854) has proposed that the Hoskinnini is part of the Moenkopi formation and therefore possibly of Triassic age. In the absence of diagnostic fossils, only physical stratigraphic relations bear on the age and correlation of the unit. In the Deer Flat area the Hoskinnini has characteristics which identify it as strongly with the underlying Cutler formation as with the overlying Moenkopi formation. These same characteristics can be used equally well to identify the Hoskinnini as a formation separate from both the enclosing units. The unit is part of the Permian and Triassic red-bed sequence of the Rocky Mountain region; as such, it carries all of the uncertainties of age designation that are implicit in that sequence. That is, this red-beds sequence is generally conceded to include the time plane that separates the Permian from the Triassic, but the fossil record commonly exhibits a gap from Guadalupe or Leonard to medial Early Triassic (*Meekoceras* zone) (McKee, 1954, p. 15). As nearly as can be determined, the Hoskinnini member was deposited within this time interval. Furthermore, it is possible that the Hoskinnini was deposited at the same time that the upper part of the Kaibab was being laid down in the Grand Canyon region, and so it may actually be of Permian age as originally proposed by Baker and Reeside.

The Hoskinnini member forms cliffs on the sides of the buttes and mesas. The entire unit forms cliffs in the southern part of the area, but northward the upper part breaks down progressively to a debris-covered slope, and in the northern part of the area only the lower half of the unit forms cliffs. The thickness of the Hoskinnini diminishes from about 80 feet at the south end of Deer Flat to about 60 feet at the north edge of the map area.

The measured section on page 82 is typical for the Hoskinnini member as exposed in the north and west part of the Deer Flat area, and the measured section on page 84 is typical for the rest of the area.

The Hoskinnini member consists mainly of reddish-brown very fine grained to very coarse grained sandstone, which is distinctive because of its poor sorting. Large amber-colored quartz grains are scattered through a fine-grained matrix, and they also form discrete lenses and spindles which are commonly twisted and faulted as if they had been deformed shortly after deposition. The sandstone contains much interstitial red silt and is commonly cemented by calcite and hematite.

The rocks of the Hoskinnini member are locally bleached along joints, faults, and bedding planes, and also in masses of coarse-grained sand. Bleaching is most obvious in the upper few feet of the member in the northwestern part of the area, where the upper sands are coarser than elsewhere and are locally impregnated with a petroleum residue.

Near the middle of the Hoskinnini member a bed of highly calcareous sandstone, 2 to 8 feet thick, forms a persistent light yellowish-orange band on the cliffs throughout the area. This bed is slightly crumpled and is cut by a few normal and reverse faults that seem to have been formed while the bed was still soft. The deformation is most pronounced in the northern part of the area, where the bed is thickest.

The upper 10 feet of the Hoskinnini tongue contains some randomly oriented vertical dikes of banded sandstone which is slightly coarser than the surrounding rock. The origin of these dikes is not known. They may be injected clastic dikes—although there is no source material nearby—or they may represent spring action in the Hoskinnini before the sediments were consolidated.

The top of the Hoskinnini member is a gently undulating surface with minor scours filled by siltstone of the upper member of the Moenkopi formation and reworked sand of the Hoskinnini member, but as no angular discordance was seen between the Hoskinnini and the upper member of the Moenkopi the contact is regarded as discomformable.

UPPER MEMBER

The upper member of the Moenkopi formation, of Early and Middle(?) Triassic age, forms steep slopes, interrupted by sandstone cliffs, above the Hoskinnini member on the sides of all the mesas in the area. The thickness of the upper member ranges from a minimum of about 195 feet at the south end of Deer Flat to a maximum of about 290 feet about three-quarters of a mile northeast of the Hideout No. 1 mine (fig. 3); in most of the area, the Moenkopi is about 240 to 250 feet thick. The upper unit of the upper member is thinnest in the southern part of the area, where the total thickness of the formation is least, a fact suggesting that this upper unit may have been partly cut out by erosion before the Shinarump member of the Chinle formation was deposited, but owing to the absence of key beds this is hard to prove. Channels as much as 20 feet deep were cut into the top of the formation by streams flowing in early Chinle time.

The upper member of the Moenkopi in the Deer Flat area can be roughly divided into three units—a lower and an upper unit composed of reddish-brown shale and siltstone with a few grayish-orange and reddish-brown sandstone beds, and a middle unit composed of pale-red massive crossbedded sandstone interbedded with reddish-brown shale and siltstone.

The siltstone of the Moenkopi is generally thinly laminated, ripple marked, and very micaceous. Mudcracks and raindrop imprints indicate that it represents mud that was exposed to the air shortly after deposition. Shale pebbles as much as 2 inches in diameter, probably formed by reworking of lower beds of the Moenkopi, form intraformational conglomeratic zones at the base of some of the sandstone beds. The ripple marks are in part asymmetrical (current type) and in part symmetrical (wave type).

The sandstone is mostly reddish brown, grayish orange, or pale red, fine to medium grained, ripple marked, and thin to thick bedded. Many of the sandstone beds are cross-laminated, but some are massive. The grains are well sorted and well rounded, and consist predominantly of colorless or amber quartz cemented by calcite, hematite, and silica. About 30 to 40 feet above the base of the upper member is a layer of grayish-orange sandstone that shows faults, slump structures, overturned asymmetric folds, and flow casts. These features affect beds 6 to 18 inches thick and are commonly truncated by the next overlying bed, a feature cited by Shrock (1948) and Nevin (1949) as evidence of penecontemporaneous deformation. At some horizons within the Moenkopi formation, sandstone fills channels as much as 15 feet deep in underlying shale.

Fragments of fossil ganoid fish scales and a fragment of what may be a fish of the species *Coelacanthus* were identified by D. H. Dunkle of the U.S. National Museum. They were found in a very fine grained, thinly laminated, ripple-marked sandstone about 40 feet below the Shinarump member of the Chinle formation at the Camel area (pl. 1). In drill cores from the W. N. mine area ganoid scales were found in the upper 5 feet of the Moenkopi formation.

The sediments that constitute the upper member of the Moenkopi formation appear to have been derived from land areas to the east and southeast, and to have been deposited on a broad flood plain that sloped gently toward the Triassic sea to the west and northwest (McKee, 1954, p. 25 and 28). The thin even bedding and the oscillation ripple marks in the siltstone beds indicate deposition in quiet water. Crossbedding of the sandstone and the presence of channels filled with sandstone indicate deposition from streams flowing across the flood plain toward the sea. The alternating sequence of sandstone and siltstone in the middle unit may reflect either a shifting of the strand line or alternating changes in the type and quantity of source material. The ripple marks, mudcracks, raindrop imprints, and fossil fragments all indicate that the Moenkopi sediments were deposited in shallow water. No evidence was found in the mapped area to indicate whether or not this water was marine. However, Thomas E. Mullens (1960) reports that bedded gypsum occurs in the Moenkopi formation in the Red House Cliffs, about 20 miles to the southwest, and others have shown that the Moenkopi contains marine limestone about 70 miles to the northwest (C. B. Hunt, 1953, p. 53; and Gilluly, 1929, p. 83).

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The commonly red rocks of the Moenkopi formation have become pale grayish green or grayish yellow along some joints and faults. Similar discoloration commonly affects mudstone and siltstone in zones as much as 18 inches wide at the contacts with sandstone in the Moenkopi, at erosional contacts along the base of the Shinarump member of the Chinle formation, or, where the Shinarump member is absent, at the contacts with sandstones in the mudstone-sandstone unit of the Chinle formation.

CHINLE FORMATION (TRIASSIC)

The Chinle formation of Late Triassic age is divisible into four lithologic units in the Deer Flat area. These are from oldest to youngest: (1) the Shinarump member, comprising from 0 to about 50 feet of gray, yellowish-gray, yellowish-brown, and pinkish-gray fine-grained to very coarse grained and conglomeratic crossbedded massive sandstone, interbedded with gray, yellowish-gray, and purplish-red mudstone; (2) a mudstone-sandstone unit, comprising 120 to 160 feet of variegated mudstone, siltstone, and sandstone; (3) the Moss Back member, comprising 45 to 110 feet of yellowish-gray fine- to coarse-grained and conglomeratic sandstone, with lenses of siltstone and conglomerate; and (4) a limy unit, comprising as much as 320 feet of interbedded marlstone, bentonitic siltstone, and fine-grained sandstone, with lenses of coarse-grained and conglomeratic sandstone and many silicified logs. The siltstone and sandstone of the mudstone-sandstone unit (2) grade into the Shinarump, and in some places they intertongue with sandstone of the upper part of the Shinarump. Channels in the top of the mudstone-sandstone unit are filled with sandstone and conglomerate of the Moss Back member, which grades into the limy upper unit (4).

The Chinle formation caps all the mesas and most of the buttes in the area (pl. 1). The sandy Shinarump member of the Chinle generally forms a steep cliff above the Moenkopi formation. The mudstone-sandstone unit slopes up steeply from the top of the Shinarump member to the edge of a bench cut on sandy beds about 90 to 120 feet above the Moenkopi. This bench, which is about 100 to 300 feet wide, has a gentle slope, but steepens a little toward the base of the cliff formed by the sandstone of the Moss Back member. Most of the limy unit of the Chinle has been eroded and replaced by a mantle of soil. Where is has been partly eroded, as in the eastern part of the area, the unit forms gentle to steep slopes, largely covered with rock debris and residual soil.

The Chinle formation can be traced continuously across Elk Ridge and southward along Comb Wash to Monument Valley, and it is correlated with the type locality near Chinle, Ariz., on the basis of similar fossils, lithology, and stratigraphic position (Gregory, 1917, p. 47). The vertebrate and invertebrate fossils collected from the Chinle in northern Arizona are of Late Triassic age (Gregory, 1917, p. 46–48; Camp and others, 1947, p. 4), and plant fossils from the Chinle farther south in Arizona are also Late Triassic (Daugherty, 1941, p. 9).

Correlation of individual members of the Chinle formation recognized in the Deer Flat area with members of the Chinle in Monument Valley is uncertain. The type locality of the Shinarump member is not even in Monument Valley, but instead is near Kanab, Utah (Stewart, 1957, p. 442); it cannot be traced continuously from Deer Flat to either locality. No diagnostic fossils were found in the Shinarump member of the Deer Flat area, so it is correlated with both sections on the basis of similar lithology and stratigraphic position. The mudstone-sandstone unit is possibly equivalent to the Monitor Butte member in Monument Valley (Witkind and Thaden 1962), but the Moss Back member pinches out south of Elk Ridge and is not present in Monument Valley (Stewart, 1957, p. 453, 461)). The limy unit may correlate with the Petrified Forest member of Gregory (1950, p. 67), which has been recognized in Monument Valley by Stewart (1957, p. 457, 461).

SHINARUMP MEMBER

GENERAL CHARACTER

The Shinarump member of the Chinle formation, which contains most of the ore found in the Deer Flat area, fills channels in and blankets an erosional surface on the Moenkopi formation. The Shinarump member pinches out northward and is not present in the northern two-thirds of the area (pl. 1). Where present, it ranges in thickness from less than 1 to about 50 feet.

In this report, the Shinarump member is regarded as including only a sequence of light-colored fine- to coarse-grained and conglomeratic crossbedded sandstone interbedded with mudstone, resting directly on the Moenkopi. What Gregory (1938, p. 48) mapped as Shinarump conglomerate just east of Deer Flat on Elk Ridge is a stratigraphically higher unit that Stewart (1957, p. 461) named the Moss Back member of the Chinle formation. Sandstone of the Shinarump member commonly forms a narrow bench at the base of the slopes formed by the main body of the Chinle. The Shinarump grades into the overlying mudstone-sandstone unit of the Chinle formation. It is therefore regarded as the basal member of the Chinle formation in the Deer Flat area, and as being of Late Triassic age (Gregory, 1950, p. 66).

LITHOLOGY

Beds in the Shinarump member pinch and swell so erratically that general statements about the average thickness and lithology of this member are meaningless. A sandstone lens within it may thin from 30 feet to less than 1 foot in an outcrop length of 500 feet. Lateral and vertical changes in lithology are even more abrupt than changes in thickness, so that no section of the Shinarump member can be regarded as typical. The variable lithology of this unit is illustrated by the logs from the drill holes on Deer Flat. (See p. 87–112.)

The Shinarump member in the area commonly can be roughly divided into three units—a lower and an upper unit composed of light-colored crossbedded sandstone containing a few beds of mudstone, and a middle unit composed of gray mudstone and siltstone containing a few beds of fine-grained sandstone. In places, however, the Shinarump member is all sandstone; in other places only the middle and upper units are present.

The lower part of the lower sandstone of the Shinarump member consists of medium- to coarse-grained and conglomeratic sandstone which grades upward into fine- to medium-grained cross-laminated sandstone that contains much kaolinite and light-gray mudstone and whose bedding planes are marked by numerous seams of light-gray mudstone. The pebbles in the conglomeratic zones consist of yellowish-gray to pink quartz, gray to black quartzite, red chert, and gray mudstone. Many of these pebbles consist of siltstone from the Moenkopi, and are flattened and deformed indicating that they were soft when they were deposited. The pebbles commonly are as much as 2 inches in diameter, and some of the mudstone pebbles are as much as 4 inches across. The sandstone interfingers with gray and sandy mudstone and siltstone and grades into it both laterally and vertically (pl. 4).

The medial unit consists mostly of mudstone and siltstone, but these rocks commonly grade laterally into a conglomerate composed mainly of pebbles as much as 3 inches in diameter of siltstone from the Moenkopi formation. As the siltstone pebbles are well rounded and undeformed, they must have been well indurated before they were transported to their present position. They thus indicate that the Moenkopi formation was being eroded at the same time that the Shinarump member was being deposited. The conglomerates in this unit are especially well exposed and persistent along the outcrop of the Shinarump northeast of the Hideout No. 1 channel, which indicates that the pebbles in them probably came from a hill of Moenkopi that lay north of the pinchout of the Shinarump (pl. 1). This unit fills channels in the underlying sandstone, and locally intertongues with it (pl. 4).

The upper unit of the Shinarump member consists of very fine to very coarse grained crossbedded sandstone containing as much as 5 percent of feldspar. The quartz grains in this rock are commonly made angular by secondary crystal faces. This unit fills channels cut in rocks of both of the other units, and it interfingers with and grades laterally and vertically into the mudstone-sandstone unit of the Chinle formation.

Most of the weathered sandstone in the Shinarump member is light yellowish gray to light yellowish brown, but some of it is colored reddish brown by abundant limonite and hematite; near the pinchout of the Shinarump in Deer Canyon the sandstone is very light gray to light pinkish gray. In mine workings and drill core the sandstone is mostly light gray, but in some places where it has been partly oxidized it is light brown or reddish brown. Sandstone near ore is commonly gray or yellowish brown, but near some heavy concentrations of sulfides it is streaked with red.

In outcrops the mudstone and siltstone in the Shinarump member are mostly gray to yellowish gray, but these tints shade into dark gray a few feet underground. The siltstone in the upper part of the Shinarump is commonly gray mottled with purplish red, so that where it is not overlain by sandstone of the Shinarump it cannot be distinguished from the siltstone in the mudstone-sandstone unit of the Chinle. The red color commonly changes to gray along fractures and contacts with sandstone, and some of the gray rock is veined with secondary hematite and limonite.

Fossil plant fragments are locally abundant throughout the Shinarump member. Fern leaves and stems and fragments of trees are erratically distributed in many beds. Most of the plant material has been coalified, and some of it is almost completely replaced by pyrite and calcite. Within the ore deposits the plant fragments are largely replaced by ore and gangue minerals. Coalified plant fragments form seams and pods of low-rank coal, and in places the sandstone is impregnated with carbonaceous material. Black vitreous material also impregnates the sandstone near plant fragments, and in places the sandstone contains disseminated droplets and grains of asphaltite.

Most of the sand grains in the Shinarump member are detrital grains of quartz, but 3 to 5 percent of them are detrital feldspars (microcline and a little plagioclase). Overgrowths on the quartz grains are bounded by crystal faces that have the same optical orientation as the parent grains. Overgrowths are especially characteristic of the ore-bearing sandstones, and are abundant near most of the ore. They are also abundant, however, in barren sandstone that is relatively free from interstitial material; the open pore-space in the more permeable rocks apparently favors the growth of quartz crystals.

The cement in the sandstone consists mainly of calcite, quartz, dolomite, limonite, and clay; locally, near outcrops, it contains oxides of iron and manganese. Rock that is colored yellow and brownish red by limonite and hematite at the outcrop can be traced in mine workings into gray rock that contains finely disseminated pyrite. As relict cores of pyrite occur in limonite-hematite concretions at the outcrop, much of the limonite and hematite in the Shinarump was presumably derived from pyrite. Calcite and dolomite embay quartz grains and fill the space between grains. On freshly broken surfaces of some of the sandstone, cleavage plates of calcite as much as a 3 mm wide can be seen to enclose several grains of quartz. Thin sections of this sandstone show separate quartz grains "floating" in relatively large anhedral calcite grains, suggesting that most of the calcite replaced interstitial material, but the ragged and scalloped edges of many of the quartz grains indicate that they too were replaced by calcite. Some of the rocks contain euhedral crystals of dolomite which appear to be contemporaneous with the calcite.

The clay minerals in the Shinarump rocks include kaolinite (identified by A. D. Weeks and M. E. Thompson, written communication, 1953), alunite, and montmorillonite. Alunite layers as much as 3 inches thick extend along beds in the Shinarump member at the prospect in the SW¼NW¼ sec. 17, T. 36 S., R. 18 E., on the south side of Upper Lost Parks (pl. 1). Flakes of montmorillonite are erratically distributed in all rock types of the Shinarump member.

SEDIMENTARY STRUCTURES

Rocks of the Shinarump member show sedimentary structures that include crossbedding, even bedding, groove casts, and ripple marks. Crossbeds range in thickness from about 0.1 to 3 inches and form sets ranging from 1 to 10 feet in length which have been classified by McKee and Weir (1953, p. 385) as planar (bounded by plane surfaces) and trough sets (bounded by curved surfaces). Even beds are as much as 6 inches thick; in general, they are flat lying, but some have initial dips and others have been tilted during penecontemporaneous deformation. Groove casts are commonly found on the bottoms of sandstone beds. They consist of sandstone that fills grooves an inch or more in width that were cut by water flowing over the underlying sediment. The fillings of linear scours in the top of the Moenkopi formation are similar features. Ripple marks are poorly developed, and the few that were observed are asymmetrical (current type). The crossbeds are more prevalent than the other sedimentary structures and are, therefore, more useful in determining the direction of streamflow during deposition. Most of the crossbeds in the Shinarump in the Deer Flat area dip in a quadrant between northwest and southwest, suggesting that in general the streams that deposited the Shinarump flowed westward.

There are folds and faults in the rocks of the Shinarump member that clearly resulted from penecontemporaneous movement—movement of unconsolidated sediment in places where deposition was especially rapid or where streams cut into recently deposited sediments. Some of this early deformation probably resulted also from differential compaction of mud.

The folds are most common in mudstone and in sandstone interbedded with mudstone. These folds are generally confined to one bed or lens and are truncated by the overlying beds.

Small faults, most of them normal but a few reverse, are found throughout the Shinarump; they are most numerous within 10 to 15 feet of the base. Some of the faults displace the beds as much as a foot. None are slickensided. Where they cut muddy sandstone or interbedded sandstone and mudstone, the fault planes are coated with films of clay, and if the mudstone involved in the faulting contains mica, the clay films commonly contain small flakes of mica oriented parallel to the fault planes. Clay films are absent where the faults are wholly in clean sandstone. Where thin-bedded sandstone is faulted the beds appear to be rumpled; this is due to closely spaced tiny step faults, parallel to the larger faults nearby. The faults, like the folds, are generally confined to a single bed, and end abruptly at the top and the base of the deformed unit. According to Nevin (1949, p. 201–204), all these features indicate penecontemporaneous deformation.

CHANNELS

Most of the uranium deposits in the Deer Flat area occur in channels that were cut by streams flowing on the top of the Moenkopi formation and which were filled with sediments of the Shinarump member. The largest and richest deposits are localized in sandstone that fills shallow spoon-shaped hollows in the floors of the channels; these hollows are locally called scours. Channels and scours, and the sediments in them, were therefore studied intensively in order to develop methods of finding the channels where the deposits are concealed. The only positive criterion for recognizing a channel is depression of the channel floor below adjacent areas on the top of the Moenkopi.

During the mapping, 20 channels filled with the Shinarump member were examined in the outcrop. All but one of these trend at large angles to the line of outcrop, so that their lengths cannot be determined except by drilling. Their widths range from 50 to as much as 700 feet, and average about 330 feet. Their depths range from about 2 to 20 feet. The results of diamond drilling made it possible to follow some of the channels as much as 2,000 feet from the outcrop; some of them probably extend much farther. Two channels in the northern two-thirds of the area, where the Shinarump is absent, were found to be filled with sandstone that appears to be equivalent to sandstone that overlies the Shinarump, and are therefore included in the mudstone-sandstone unit of the Chinle formation. This sandstone contains small deposits of uranium and copper minerals.

Four channels filled with Shinarump, in which the sandstone contained uranium minerals at the outcrop, were partly explored by drilling by private companies under contract to the U.S. Geological Survey (pls. 1, 3, 5, 7, and 8). The results of the drilling are summarized, and each of these channels is described, in the section on mines and prospects. Tabulation of drill-core data (table 1), however, shows some lithologic differences between the sediments in channels and those outside of channels that might prove useful in recognizing concealed channels. As shown in table 1, the average thickness of the Shinarump member is between 6 and 10 feet greater in channels than on the banks of channels. The ranges of thicknesses in the two positions overlap each other to such an extent that thickness should be used cautiously in deciding whether or not the Shinarump is in a channel. In the Hideout No. 1 area, for example, a thickness of 35 feet or more of the Shinarump would probably represent channel deposition and a thickness of less than 21 feet would probably represent bank deposition, but a thickness between 21 and 35 feet might indicate either position. The average total thickness of mudstone is greater in Shinarump rocks that fill channels than in those on channel banks, but the wide range of mudstone thickness renders this criterion, and also the average percentage of mudstone, useless. The average thickness of mudstone in the lower 10 feet of Shinarump (the ore zone) seems to vary unsystematically from one channel to another, but it is least in the Hideout No. 1 channel, which contains the most ore. The average thickness of medium- to coarse-grained and conglomeratic sandstone in the lower 10 feet of the Shinarump is slightly less in the channels than outside the channels.

TABLE 1.—*Thicknesses of the Shinarump member of the Chinle formation in drill cores and some of its prominent lithologic features, grouped by areas and position with respect to channels, in Deer Flat area, White Canyon district, San Juan County, Utah*

Channel	Number of drill holes	Thickness (ft)		Thickness of mudstone (ft)		Percentage of mudstone		Thickness (ft) of mudstone in lower 10 ft		Thickness (ft) of medium- to coarse-grained and conglomeratic sandstone in lower 10 ft	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Hideout No. 1	45	34.7	21.3–48.9	8.2	0.3–21.7	23.7	1.3–81.8	1.7	0.0–8.6	5.7	0.0–10.0
Hideout No. 1 [1]	10	25.2	17.3–34.7	7.2	.5–23.6	28.6	2.6–86.7	1.8	.0–9.0	6.3	.0–10.0
W. N.	35	30.6	15.5–38.2	6.9	.0–15.4	22.5	.0–51.1	3.8	.0–8.6	3.1	.0–10.0
W. N. [1]	5	24.8	22.5–27.5	4.1	.5–11.3	16.5	2.1–45.2	2.4	.0–8.6	4.9	.5–10.0
Sandy No. 3	15	33.1	22.4–42.1	7.8	.0–20.0	23.6	.0–51.1	3.2	.0–10.0	5.3	.3–10.0
Sandy No. 3 [1]	7	23.2	18.9–28.5	5.4	.0–17.6	23.3	.0–93.1	2.8	.0–9.4	5.7	.0–9.4
Camel	18	20.7	7.6–41.4	5.7	.0–21.3	27.8	.0–60.0	3.2	.0–7.1	4.4	.0–9.1
Camel [1]	4	14.1	4.1–23.4	4.2	.6–4.2	29.8	8.1–47.8	3.9	.6–10.0	2.9	.0–5.8

[1] Outside the channel.

DIRECTION OF FLOW IN CHANNELS

Certain sedimentary structures in the Shinarump member, including crossbeds that dip more than 4°, groove casts, and ripple marks, afford evidence regarding the direction of flow of the streams that deposited the sediments of the member. Current directions are also indicated by the orientation of fossil logs and of small linear scours in the top of the Moenkopi formation.

In order to determine whether such features can be used to project channel trends from the outcrop, the field data were treated by a statistical method adapted from Reiche (1938). The trend of each structure observed is considered as a unit vector, and the vector sum of a number of trends gives a resultant trend. The resultant trend is the vectorial average of all sedimentary structure trends measured in a given channel fill. The consistency of the structure trends is expressed numerically as the resultant length divided by the number of measurements. If all the trends were identical, the consistency factor would be 1.0; if the trends had a random orientation, it would be zero.

At the Camel channel, the Shinarump member consists almost entirely of a single lens of sandstone about 16 feet thick. The 15 readings, taken on crossbeds, ripple marks, and linear scours cut into the top of the Moenkopi formation, gave a resultant trend of about N. 55° W. (fig. 2). Contours based on drill-core and outcrop data (fig. 20) show that the channel has the same trend. The cross-laminations dip more than 4° N.W., and the apparent regional dip in that direction is less than 2°, indicating that the streams which deposited the Shinarump in the Camel channel flowed generally northwestward.

At the W. N. mine, crossbedding is poorly developed in the lower part of the Shinarump member (channel fill), but well developed in the upper part. The 44 readings taken on the sedimentary structures gave a resultant trend of S. 61° W. (fig. 2). Measurements of 33 dip directions of crossbeds in the upper part of the Shinarump member in the W. N. channel indicate a channel trend of approximately S. 43° W. (fig. 2), and 11 observations in the lower part indicate a channel trend of S. 87° W. (fig. 2). Of the 11 measurements in the channel fill, 3 were made on cross-strata, 2 on fossil logs, 3 on linear scours, and 3 on groove casts. Contours based on drill-core and outcrop data (fig. 19) show that the channel has a general trend of about S. 80° W. Near the outcrop, where the 11 observations in the channel fill were made, the channel trends nearly west, virtually the same as the resultant trend of the sedimentary structures in the channel fill.

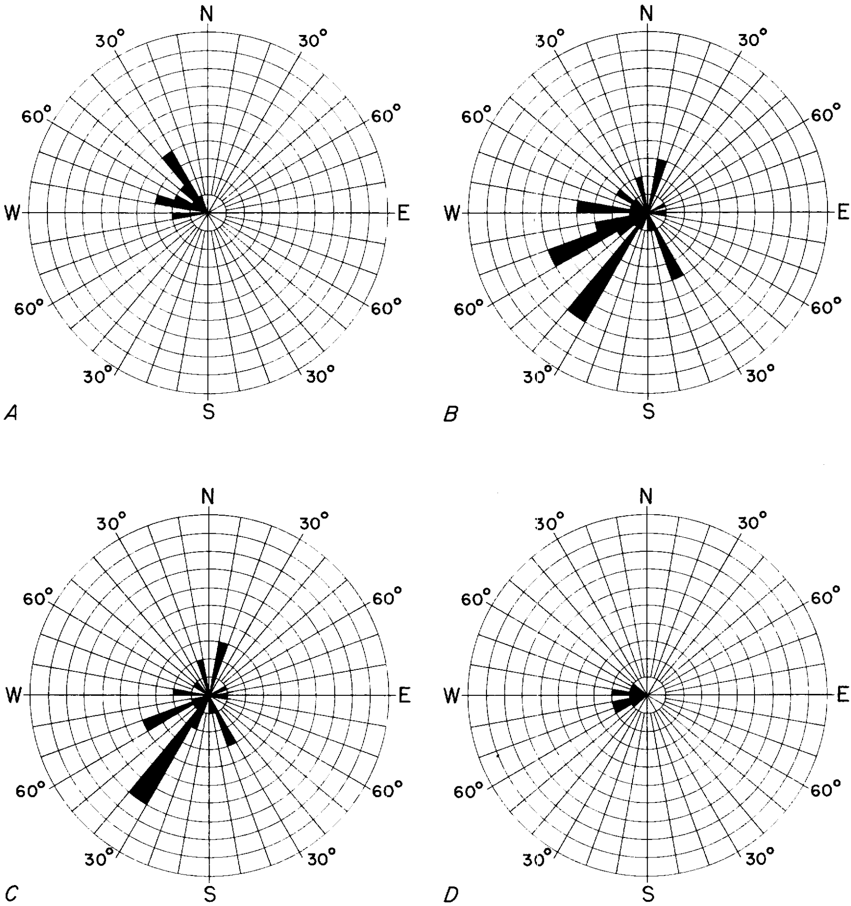

FIGURE 2.—Sedimentary structure trends in the Shinarump member of the Chinle formation at the Camel and W. N. channels. *A*, On the basis of 15 readings taken by P. C. Franks and D. A. Brew, on small linear scours, festoon crossbeds, and ripple marks, 1 division equals 1 reading. The resultant trend is N. 55° W., the consistency factor is 0.93. *B*, On the basis of 44 readings taken by P. C. Franks, 1 division equals 1 reading. The resultant trend is S. 61° W., the consistency factor is 0.49. *C*, Represents 33 of the 44 readings; 1 division equals 1 reading. The resultant trend is S. 43° W., the consistency factor is 0.39. *D*, Represents 11 of the 44 readings: 1 division equals 1 reading. The resultant trend is S. 87° W., the consistency factor is 0.93.

The crossbedding at the Hideout No. 1 channel was studied by G. A. Williams (written communication, 1953). He found that the crossbeds along 200 feet of mine workings (within 6 to 8 feet above the channel floor) gave a resultant dip direction of N. 81° W. and a consistency factor of 0.75; but the crossbeds along the outcrop (observed beyond the edge of the channel and throughout the entire thickness, 30 to 35 feet, of the Shinarump member) gave a resultant dip direction of S. 88° W. and a consistency factor of 0.74. The actual channel trend near the outcrop is about N. 70° W. as determined by mapping and diamond drilling (pl. 3, figs. 16 and 17). A linear scour and a festoon crossbed at the outcrop trend N. 65° W.

The trends of the channels seem to be indicated more closely by the sedimentary structures in the material that filled the channels than by those in material that was deposited either above the channel filling or in the interchannel areas. This is probably because the water that deposited the sediments on the floors of the channels flowed almost parallel to the walls of the channels, whereas the water that deposited the higher beds did more swinging from side to side.

MODE OF DEPOSITION

The sediments of the Shinarump member blanket an erosional surface on the top of the Moenkopi formation. McKee (1954) indicates that this erosional surface may represent only part of Middle Triassic time rather than part of Early Triassic and all of Middle Triassic times as suggested by Gregory (1913, 1938, 1950) and by Stokes (1950).

The channels in the top of the Moenkopi were certainly cut by streams. Some may have been cut long before any Shinarump sediments were deposited; others were doubtless cut during the deposition of the earliest Shinarump sediments; and some may have been cut down to bedrock through previously deposited Shinarump sediments during local floods. Leopold and Maddock (1953, p. 30–33) have shown that this has been done by some modern streams.

The large size of the pebbles in the basal Shinarump indicates that, at least during floods, the currents in the streams were strong and probably capable of scouring channels. After the larger depressions in the top of the Moenkopi were filled with sediment the streams began to meander across the alluvial valleys; the thick channel-filling mudstones and siltstones probably represent sedimentation in cutoff meanders on a broad flood plain. Local hills of Moenkopi were cut down and the material derived from them was redeposited on top of older sediments of the Shinarump, or in channels eroded into them. As depositional conditions changed, more and more silt and fine-grained sands were deposited, so that the fluviatile sandstone of the Shinarump grades into and intertongues with the variegated siltstone and sandstone of the mudstone-sandstone unit.

Local folding of beds in the Moenkopi formation before the deposition of the Shinarump member of the Chinle formation, and perhaps even during its deposition, may have helped to determine the location of channels and may also have caused thick sediments to accumulate in the synclinal areas. Comparison of contours on the top and bottom of the Moenkopi indicates that the Moenkopi thins along the anticlinal bend of the monocline northeast of the Hideout No. 1 mine (fig. 3), suggesting that the beds were folded and eroded before the Shinarump was deposited. Similar truncation of folded beds in the Moenkopi has been observed on the Colorado Plateau by Baker (1933, p. 36, 37, and 77) in the Moab district of Utah; by McKnight (1940, p. 61–62, 129) in the area between the Green and Colorado Rivers; and by Stokes and Phoenix (1948) and Cater (1954) along the flanks of the salt anticlines in western Colorado. Minor flexures, such as the one northeast of the Hideout No. 1 channel, may have altered the course of the streams that flowed across the top of the Moenkopi and caused them to turn and flow down the dip of the beds. Streams so influenced by the flexures would cut into the Moenkopi until they reached local base level; their channels would thus be cut deepest where they crossed the uplifted flexures, and would become shallower beyond them. The remnant of the Hideout No. 1 channel may illustrate this condition; the channel is deepest about 900 feet west of the synclinal bend that marks the west side of the monocline, and it becomes shallow and poorly defined in the low dips to the west. The relation of this ancient channel to the monocline is markedly similar to that of present-day stream channels to the monoclines of the Colorado Plateau; many of these channels are relatively deep where they cross monoclines, but become shallow in the flat-lying beds.

MUDSTONE-SANDSTONE UNIT

The mudstone-sandstone unit of the Chinle formation consists chiefly of mudstones and siltstones interbedded with a smaller amount of very fine- to coarse-grained and conglomeratic sandstone. Thin lenses of gray to light-tan limestone and marlstone occur locally. The rocks of this unit exhibit a wide variety of colors including light to dark gray, bluish gray, yellowish gray, blue, dusky red, pale red, pale purplish red, reddish purple, orange, yellowish brown, and light brown; red and brown hues are dominant in the lower 30 to 40 feet, and grays predominate in the remainder.

The mudstone-sandstone unit in this area can be roughly divided into three subunits—the lower one composed of reddish to gray sandy mudstone with a few beds of sandstone, the middle one composed of light-gray sandstone with a few beds of mudstone, and the upper one composed of gray sandy mudstone containing a few beds of sandstone.

The lower mudstone subunit is 30 to 40 feet thick and is distinctive because of its color, a mixture of dark purplish-red, dusky-red, bluish-gray, gray, and yellowish-gray splotches ("purple-white" zone of Finch, 1953, p. 31). Its color and lithologic features are remarkably similar to those of the Temple Mountain member of the Chinle formation of the San Rafael Swell, Utah (Robeck, 1956). The mudstone and siltstone contain fine to coarse grains of quartz and carbonaceous plant fragments that serve to distinguish it from the Moenkopi formation.

Commonly brecciated in the lower few feet, the mudstone subunit contains lenses of weakly mineralized jasper in a zone about 20 to 30 feet above its base. In the Hideout No. 1 area (pl. 1) a sandstone bed 2 to 4 feet thick about 30 feet above the Shinarump member contains lenses of jasper banded in orange, red, blue, and gray. Blocks of this resistant rock, as much as 6 inches thick and 2 to 3 feet long, litter the slopes below the sandstone outcrop. Some of the larger blocks are very calcareous within a thin rind of chalcedony. Many of the blocks are anomalously radioactive, and some are coated with malachite. In the drill core, the sandstone bed can be recognized, but none of the chalcedony, so conspicuous at the outcrop, was found. The sandstone in the core, however, is well cemented with calcite and light-gray silica, and it commonly shows a radioactivity anomaly, especially near interbeds of pyrite-rich carbonaceous mudstone. Weathering at the outcrop may have formed the chalcedony, leached out the calcite, and oxidized the pyrite to hematite and limonite.

Hematite and limonite form a large part of the cement between breccia blocks and impregnate many beds of sandy mudstone. Hematite also forms rootlike concretions that are strikingly similar to the hematitic root casts that are common in certain soils. The iron-rich zones grade downward into brecciated calcite-cemented mudstone and sandstone which may represent a zone of calcite enrichment in a fossil profile of weathering, for the fragments in the breccia are very similar to the blocky soil structures found in recent soils. It is possible that this subunit contains several fossil soils, and that it represents a long period of slow accumulation of sediments interspersed with times of nondeposition when weathering and soil formation were dominant.

The sandstone beds in the lower subunit are yellowish brown, yellowish gray, and light purplish red; they intertongue with mudstone and siltstone (pl. 3) and range in thickness from 2 to 15 feet. In the northern part of the area, where the Shinarump member is absent, sandstone in this subunit locally rests on the Moenkopi formation. At two localities (sample locs. 2, 3; fig. 15), moreover, this sandstone occupies small channels in the top of the Moenkopi and was found to contain small deposits of uranium ore (fig. 15).

The middle subunit is a light-gray to light yellowish-gray to light-red, very fine- to fine-grained, ripple-laminated, intricately cross-bedded, calcareous sandstone that forms a persistent bench covered by rock debris and landslide blocks around the mesas and buttes. Locally this sandstone becomes resistant enough to cap mesas and buttes; it caps Home Mesa and also some of the hills in the western half of the area (pl. 1). The sandstone may grade laterally within a short distance into either mudstone or conglomerate. An example of lateral gradation of sandstone to mudstone is shown in core from drill holes 35 and 36 (p. 86–90), where bed 10 of the mudstone-sandstone unit in hole 35 is correlative with beds 6 and 7 of the same unit in hole 36, only 75 feet away (pl. 3). Penecontemporaneous folding and faulting is common in this sandstone. Most of the faults have normal displacements ranging from a fraction of an inch to as much as 2 or 3 inches. In places the beds have dips as high as 90° and are truncated by overlying flat beds. These relations probably resulted from slumping of unconsolidated sand layers at places where deposition was not taking place (see beds 8 and 9, mudstone-sandstone unit, drill-core log 109, p. 108–109).

The mudstone of the upper subunit is similar to that in the lower submit except that it is gray and the sand grains in it are smaller. At the top of the upper subunit there is a discontinuous fine- to medium-grained conglomeratic calcareous sandstone that resembles some of the sandstone in the Moss Back member except that it is gray and contains much more carbonized plant material and more mudstone (pl. 5). This sandstone contains pebbles as much as 2 inches in diameter; these are mostly of red, brown, and gray chert and gray to black limestone, but some are of mudstone. Pyrite has replaced many of the plant remains and limestone pebbles.

Fossil plant fragments are common throughout the mudstone and siltstone of the mudstone-sandstone unit, and are particularly abundant in a zone from 50 to 60 feet above its base. Specimens from this zone were examined by R. W. Brown of the U.S. Geological Survey (written communication, 1954), who reports that they are all fragments of *Podozamites emmonsi* Newberry, and adds, "Except that these plants are Triassic in age, not much more can be said."

MOSS BACK MEMBER

The Moss Back member (Stewart, 1957) of the Chinle formation underlies Deer Flat and Upper Lost Parks, and caps Piñon Point and many unnamed buttes (pl. 1). The sandstone of the Moss Back member forms cliffs as much as 90 feet high around the mesa rims. The dominant rock in the Moss Back member is light yellowish-gray crossbedded ferruginous, calcareous, micaceous sandstone containing lenses of conglomerate and siltstone. The sandstone is mostly fine to medium grained, but some is coarse grained. The pebbles in the conglomerate beds are mostly of dark-gray and gray quartzite, gray and brown siltstone, gray limestone, and gray and red chert, but some are of gray quartz. All the pebbles are remarkably well rounded, and a few near the base of the member are as much as 3 inches in diameter. The siltstone in the member is commonly light yellowish gray to gray and is thin bedded. Deformation of the siltstone beds seems to be the result of Laramide folding, which produced faults and fracture cleavage in these incompetent beds.

Silicified logs are widely distributed in the Moss Back member, and calcified logs occur sporadically. Segments of logs 1 to 3 feet long and as much as 2 feet in diameter are common, and a few logs as much as 8 feet long and 3 feet in diameter have been found. Some large silicified tree trunks with root remnants flaring from one end were found lying on the top of the Moss Back, suggesting the presence of a forest there in Late Triassic time, but no stumps in place were seen. It is difficult, however, to distinguish a silicified root from a small silicified trunk, and some of the objects in the upper few feet of the Moss Back member that have been regarded as small logs may be the fossil roots of trees.

LIMY UNIT

The limy unit of the Chinle formation in the Deer Flat area is poorly exposed except in road cuts. It forms rounded hills with steep, rubble-covered slopes in the eastern part of the area. It is 400 to 500 feet thick to the west in the White Canyon area, but only the lower 320 feet of the unit is represented in the map area. The beds that are exposed in the area are varicolored in shades of red, yellow, blue, and gray. They consist of marlstone and bentonitic mudstone and siltstone interbedded with layers and lenses of fine- to coarse-grained sandstone. In some places they contain silicified logs, the largest of which are as much as 30 feet long and 6 feet in diameter.

QUATERNARY ROCKS

Quaternary deposits are present in the stream gullies, along the sides of mesas, and on the tops of the larger mesas. They include colluvium, alluvium, windblown sand, sandy silt, and landslide material, but only sandy silt and landslide material are differentiated on the map (pl. 1). Alluvium occurs along the stream courses and on the floors of the canyons, but it occurs in areas that are too small to be shown on the maps.

SANDY SILT

The sandy silt shown on the geologic map (pl. 1) consists mainly of angular rock fragments in a matrix of fine-grained, poorly bedded silt and sand. However, that on Deer Flat consists mainly of sandy silt which contains only a small amount of rock fragments. Sandy silt mantles the top of all the larger mesas, but it is so thin on all but Deer Flat that it is not shown on the maps.

The sandy silt on Deer Flat ranges in thickness from about 17 feet near the center of the mesa to a few inches near the rim. Where the silt is thin, trees grow abundantly; where it is thick, shrubs, herbs, and grasses predominate. The silt is dark brown in the upper 2 or 3 feet, but toward the base it becomes light grayish brown and calcareous. It breaks and weathers in veritcal prismatic columns that range from 1 to 3 inches in diameter. The silt is similar to loessial deposits observed by Hunt (1956, p. 38) east of the Abajo Mountains; he believes they are of pre-Wisconsin age.

LANDSLIDES

The landslide material consists largely of rock slides in which the original bedding of the rocks is greatly disturbed or even obliterated, and of what Reiche (1937, p. 538) called Toreva blocks. These are single blocks that have dropped and tipped backward toward the cliff from which they slid, without otherwise disturbing the original bedding of the rocks.

Rock slides or débris avalanches locally mantle the bedrock around the mesa flanks (pl. 1); in places the lower part of the Organ Rock tongue is almost completely covered with thin sheets of rock debris. Some of the landslide sheets lap high onto the mesa sides and form cones that extend as high as the base of the Moss Back member of the Chinle formation where it caps the large mesas. The rock fragments in these deposits range from pebble size to boulders more than 10 feet in diameter; they are enclosed in a pasty matrix of mudstone and clay of the Chinle formation, cemented and veined with calcium carbonate. The landslide material is being actively dissected and gullied during rains by rills and torrents which have transported and redeposited much of it as alluvium. These landslide deposits are similar to the larger debris avalanches along the Colorado River east of Hite, which Hunt (1956, p. 38) believes to be of Wisconsin age or older. Some of it is overlain by deposits of calcareous tufa, too small to show on the map, which confirm the belief that the landslides occurred in a period of more humid climate.

The Toreva blocks in this area are composed of rocks from the Moss Back member and the upper and middle parts of the mudstone-sandstone unit of the Chinle formation. During a time of wetter climate, water probably softened mudstone layers in the Chinle, and the more competent rocks near the edges of the mesas slid in large blocks that now form part of the debris-littered bench along the perimeter of Deer Flat (pl. 1). There are vertical joints roughly parallel to the cliffs in the area particularly where Toreva blocks are present on the benches. One of these blocks, at the Hideout No. 1 claim, was mapped and was penetrated by several drill holes (pl. 3). The landslip surface is indicated in the cross section (pl. 2). The bases of the blocks derived from the mudstone-sandstone unit are not easily recognized because they are only a few feet lower than the normal stratigraphic position of that unit. Groups of large sandstone blocks from the Moss Back member are more conspicuous and dip more steeply into the mesa (pl. 2).

The Toreva blocks probably slid during the Pleistocene, when much more water was available to lubricate the clays. They must have been in their present position when the prehistoric Indians occupied the area, because ashes of campfires and ruins of Indian cliff dwellings are found on the rubble that mantles the Toreva blocks and along the cliffs from which the blocks came. The cliffs have probably receded from the landslip plane by mass wasting, but they must have remained relatively stable during the long period of prehistoric occupation. The ancient dwelling places, abundant artifacts, and numerous fragments of black-on-gray, gray corrugated, and plain gray pottery are found near masonry structures that are composed of well-coursed and well-fitted slabs held together by mortar containing rock fragments and charcoal. According to A. P. Hunt (1953, p. 17), these objects represent cultures that probably range from early Fremont to recent Shoshonean. The Fremont Indians occupied this part of Utah from about A.D. 500 to A.D. 1300, when climatic conditions apparently became unfavorable for continued existence (Hunt, 1953).

STRUCTURE

The sedimentary rocks in the Deer Flat area dip gently southwestward and form part of the west flank of the Elk Ridge anticline, a large, slightly elongate dome superimposed on the larger elongate Monument upwarp, which extends northward about 90 miles from near Kayenta, Ariz., to an area near the junction of the Colorado and Green Rivers in southeastern Utah (fig. 1). The Elk Ridge anticline, like the Monument upwarp, is an asymmetric fold with a steeply dipping east limb and a gently dipping west limb. Superimposed on the gentle dip in the Deer Flat area are a northwestward-plunging anticlinal nose flanked on the northeast by a complementary syncline, some local monoclines, and a few small normal faults. The strata generally strike N. 12° to 45° W. and dip 1° to 3° SW., except in local monoclinal flexures, where they may dip as much as 7° SW. In the northern half of the area there are steeply dipping normal faults trending N. 10° to 70° W. The southernmost fault (pl. 1) has a stratigraphic displacement of 18 feet, with downthrow on the northeast. The other faults displace the beds from 6 to 32 feet with the greatest displacement on the northeasternmost fault. The most prominent joints throughout the area are in two sets, one of which trends N. 45° to 55° E. and dips from 65° SE. to vertical, while the other set trends N. 35° to 70° W. and dips 85° SW. to 72°NE. A less prominent joint set trends N. 10° to N. 25° W. and dips from 80° E. to vertical. Structural details in the area are delineated by the structure contours in plate 1, and figures 3 and 4.

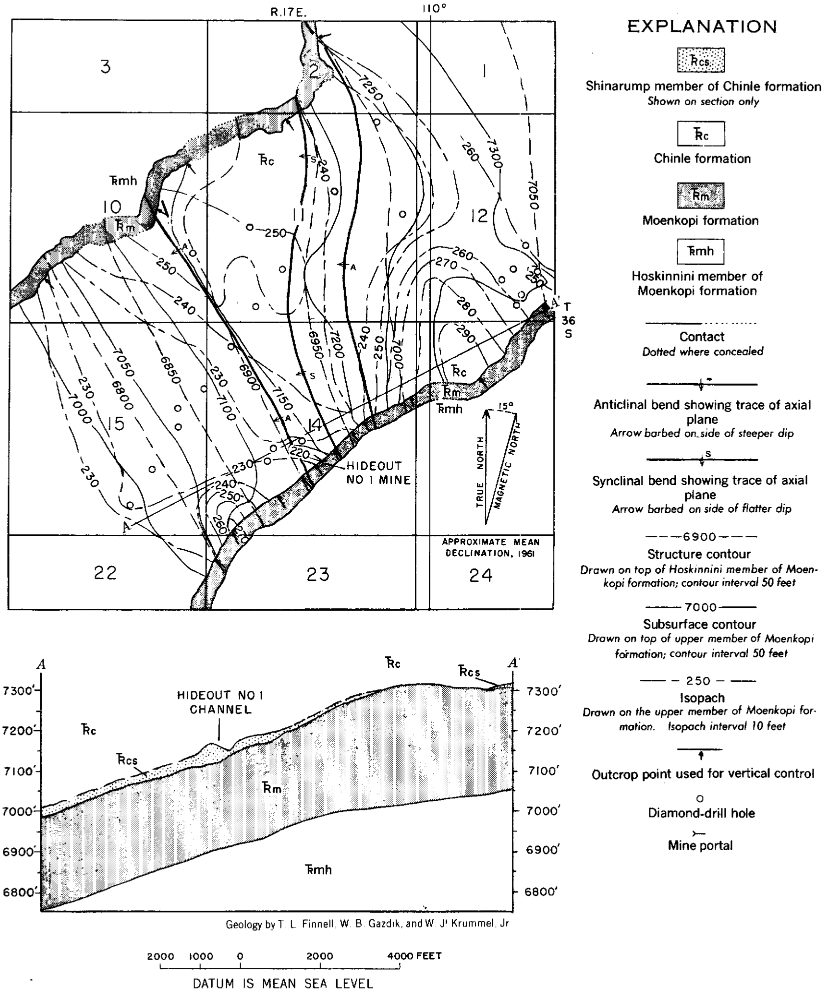

FIGURE 3.—Map of part of the Deer Flat area showing contours on top and base of the upper member of the Moenkopi formation, and subsurface cross section showing the eroded surface of the Moenkopi formation.

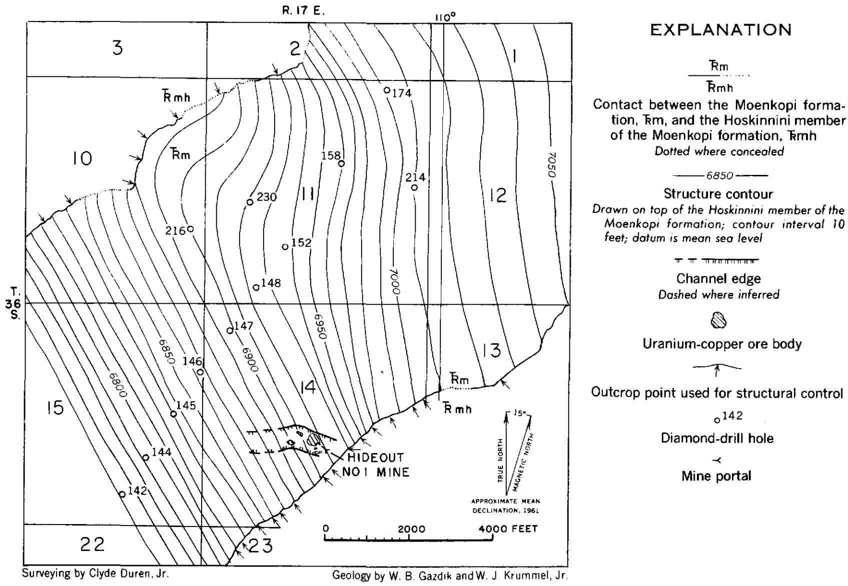

FIGURE 4.—Structure contours on the top of the Hoskinnini member of the Moenkopi formation, Deer Flat area.

Along faults and joints some beds are commonly altered from reddish brown to yellowish and grayish orange, as much as 1 foot from the fractures. Fracture surfaces may be coated with calcite, limonite, gypsum, or combinations of two or more of these. In the Shinarump member of the Chinle formation and in the upper part of the Moenkopi formation the fractures are locally filled with uranium and copper minerals.

The age of the faulting is problematical. The youngest unit cut by the faults is the upper member of the Moenkopi formation of Early and Middle(?) Triassic age. Younger formations were probably faulted, but they have since been eroded away along the fault trace.

The throw of each fault seems to diminish laterally from a point near the middle of the fault trace, and to pass into joint zones which can be traced thousands of feet beyond the places where no displacement can be seen. Although lack of sufficient exposures prevented observation of structural details associated with these faults, they are apparently similar to faults observed elsewhere in the White Canyon area. Faults 10 miles west-northwest of the Deer Flat area show less and less displacement in the higher beds until there is no visible displacement along the fracture plane. One of these faults has formed a local monocline (fig. 5), and probably it is no exception; many of

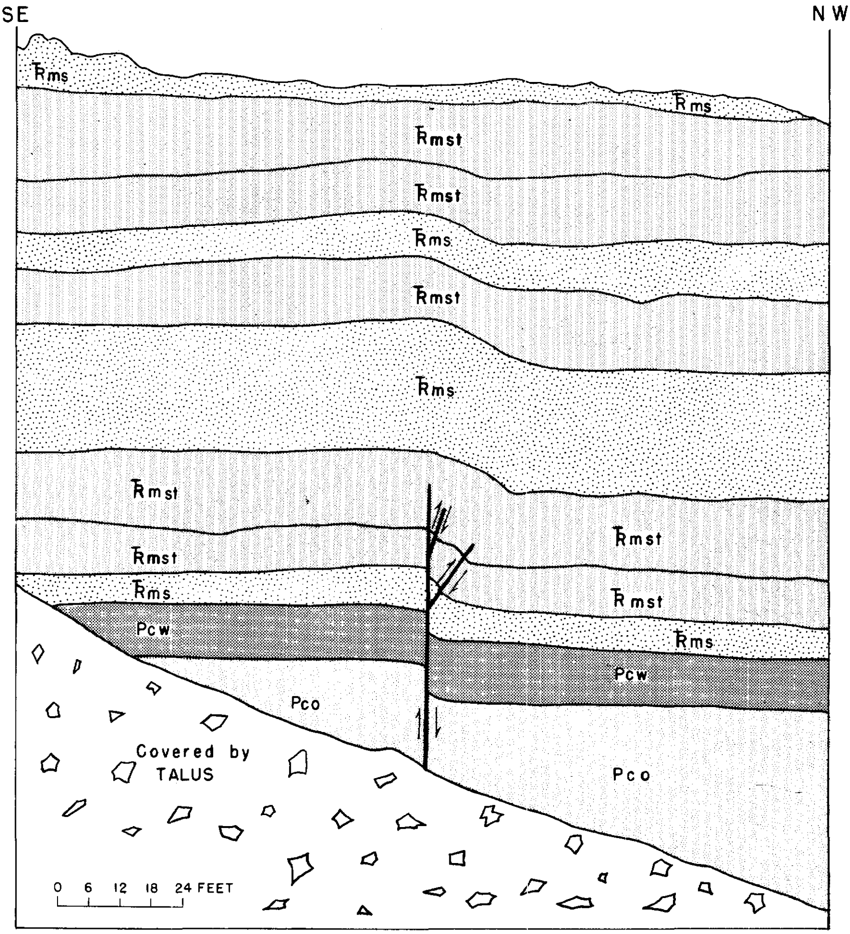

FIGURE 5.—Sketch showing small fault that passes upward into a monoclinal flexure with almost as much structural relief as the fault. Short reverse faults dip toward the upthrown block. Organ Rock tongue, Pco, and White Rim member, Pcw, of the Cutler formation; siltstone, ₮mst, and sandstone, ₮ms, of the Moenkopi formation.

the small flexures noted along the western flank of the Monument upwarp, including the monocline indicated in figure 3, may be thus related to buried faults.

According to Hunt (1956, p. 73) and Eardley (1951, p. 408), the principal deformation in the region seems to have occurred during the Laramide orogeny, in Late Cretaceous and early Tertiary time. Hunt says:

In early Paleocene time * * * folding * * * progressed eastward to the area of the Plateau. The northwestward-trending Circle Cliffs upwarp was formed, and apparently fully so, because its folded rocks are truncated by nearly horizontal

Paleocene lake beds (Flagstaff limestone). Formation of a volcanic highland, probably accompanied by upwarping, had started in the San Juan Mountains in latest Cretaceous time and continued to grow during Paleocene time. This highland shed volcanic sediments (Animas formation) on the Colorado Plateau. Pre-Wasatch deposits in the Uinta Basin indicate that mountains were forming to the east and to the west of the basin, and also at the Unita Mountains. A montainous area south of the Plateau that may be of this age is recorded by the deposits of gravel on the Mogollon Rim which were derived from pre-Cambrian rocks.

Presumably, other folds within the Plateau also began to form at this time. These include the San Rafael Swell, Uncompahgre Plateau, and the Monument, Kaibab, Defiance, and Zuni upwarps.

No evidence that dates the structure of the Monument upwarp more closely than this was found in the Deer Flat area. Some evidence is given of slight deformation in Permian and Triassic times, however, by variations in the thickness of the Cutler and Moenkopi formations. Figure 3 shows a local monocline, superimposed on the regional dip, that appears to have been truncated in Triassic times by the streams that cut the widespread erosion surface on top of the Moenkopi. It also seems probable, from northward thinning of the Organ Rock tongue of the Cutler formation and the Hoskinnini member of the Moenkopi formation and the northward pinching out of the Shinarump member of the Chinle formation, that the northern two-thirds of the area was a structural high during the deposition of the Organ Rock and Hoskinnini, and again during the deposition of the lower part of the Chinle.

MINING HISTORY AND PRODUCTION

According to Gregory (1938, p. 107), prospecting for copper ore in the White Canyon district may have begun as early as 1880. Prospectors were especially active in 1906 and 1907, when the price of copper was high, but very little copper ore was produced. At that time the copper deposits in White Canyon appeared to be the most promising, and Deer Flat seems to have been neglected until 1948, when J. Wiley Redd of Blanding, Utah, discovered ore on what he named the Hideout No. 1 claim. He later sold this claim to the Shumway brothers of Blanding, who in turn sold it to F. A. Sitton of Dove Creek, Colo. Interest in the copper deposits of the Deer Flat area was revived in 1948 by the U.S. Atomic Energy Commission's offer to buy domestic uranium ores, because some of these deposits were known to contain uranium (Gregory, 1938, p. 107; Butler and others, 1920, p. 622).

The first shipment of uranium ore from the Deer Flat area was made in 1949 by F. A. Sitton, who mined and shipped more than 100 tons of medium-grade uranium ore, containing 3.44 percent copper,[1] from the oxidized part of the Hideout No. 1 ore deposit, in the southwest scour of the Hideout No. 1 channel (pl. 2 and fig. 16). In 1951 he shipped 35 tons of submarginal ore from the Dead Buck mine (pl. 5). All mining was then suspended until August 1952, when oxidized ore was again mined from the southwest scour of the Hideout No. 1 channel (fig. 16). The ore at the outcrop contained as much as 20 percent $CaCO_3$, but as the workings were extended the $CaCO_3$ content diminished to less than 3 percent. Mining in the southwest scour continued until August 1953, when the operation was suspended because no ore was in sight and the miners wanted to wait for the results of drilling in other parts of the channel. Ore found by the drilling revived the miners' interest, and they began to drive tunnels toward it. Mining in the Hideout No. 1 channel continued intermittently through 1957.

At the Sandy No. 3 channel, Burdett and Merwin Shumway did exploratory drifting in August 1953, and they produced ore from this deposit as recently as 1956.

In the W. N. area, some low-grade submarginal uranium ore was produced from the W. N. channel before 1955, and by December 31, 1955, ore deposits found by drilling had yielded a few thousand tons of uranium ore containing about 0.4 percent copper. In addition, more than 1,000 tons of uranium ore containing less than 0.1 percent copper was mined from the south branch of the W. N. channel (pl. 5).

At the Mirador No. 1 claim on Home Mesa (pl. 1), the Knapp Exploration Co., of Cortez, Colo., produced in 1954 a few hundred tons of uranium ore containing about 0.1 percent copper. This ore was in a sandstone bed that fills a channel in the top of the Moenkopi formation; the sandstone is in the mudstone-sandstone unit of the Chinle formation.

The total production from the mines in the area to the end of December 1955 had been more than 10,000 short tons of ore, averaging more than 0.20 percent U_3O_8 and 0.74 percent copper; production continued in 1956 and 1957.

[1] Production and grade published by permission of Mr. F. A. Sitton.

ORE DEPOSITS

The ore deposits in the Deer Flat area lie roughly parallel to the bedding but cut across it in detail. The uranium minerals replace quartz, feldspar, clay, and fossil plant fragments, and also fill fractures and interstices in the sandstone adjacent to mineralized plant fragments. The deposits are mainly in the lowest 10 feet of the Shinarump member of the Chinle formation where it fills channels in the top of the Moenkopi formation, although small local concentrations of uranium and copper are found in sandstone and siltstone in the Chinle above the Shinarump member. Widespread concentrations of uranium in chalcedony lenses of the mudstone-sandstone unit of the Chinle formation are generally of low grade (table 3, field nos. H–28–52 and H–66–52). The best deposits of the latter type are in the northern part of the area (secs. 4 and 5, T. 35 N., R. 17 E.), where the chalcedony is only 8 to 15 feet above the top of the Moenkopi (table 3, field no. TLF–12–54). North of the pinchout of the Shinarump member two ore deposits occur in carbonaceous shale and sandstone that are believed to be part of the mudstone-sandstone unit of the Chinle. The sandstone fills small channels in the top of the Moenkopi.

Most of the uranium ore deposits are in sandstone, but some are concentrated in mudstone and siltstone in the lower part of the Shinarump and in the top 2 feet of the Moenkopi. Small masses of mudstone in the Hideout No. 1, Sandy No. 3, and W. N. mines are highly mineralized (pls. 4, 6, and 8), but more commonly the mudstone and siltstone in the channels are only weakly mineralized, in zones less than a foot thick.

The copper in the Deer Flat deposits is almost all closely associated with uranium. Sulfides of copper and iron are mingled with uraninite, and the copper sulfates and carbonates with limonite, the secondary uranium and uranium-copper silicates, carbonates, and phosphates. The relations between copper, uranium, and radioactivity are shown in figure 6, in which data representing 183 core samples from 39 diamond-drill holes are plotted on a logarithmic scale. This diagram shows that the copper content is commonly higher than the U_3O_8 content in samples containing more than 0.15 percent U_3O_8, but may be either greater or less in samples containing less than 0.15 percent U_3O_8. The presence of copper minerals, especially in a channel, indicates that uranium minerals may be nearby.

The ore bodies range in size from small tapering bodies as much as 2.5 feet thick, 8 to 10 feet wide, and 20 to 30 feet long, to irregular

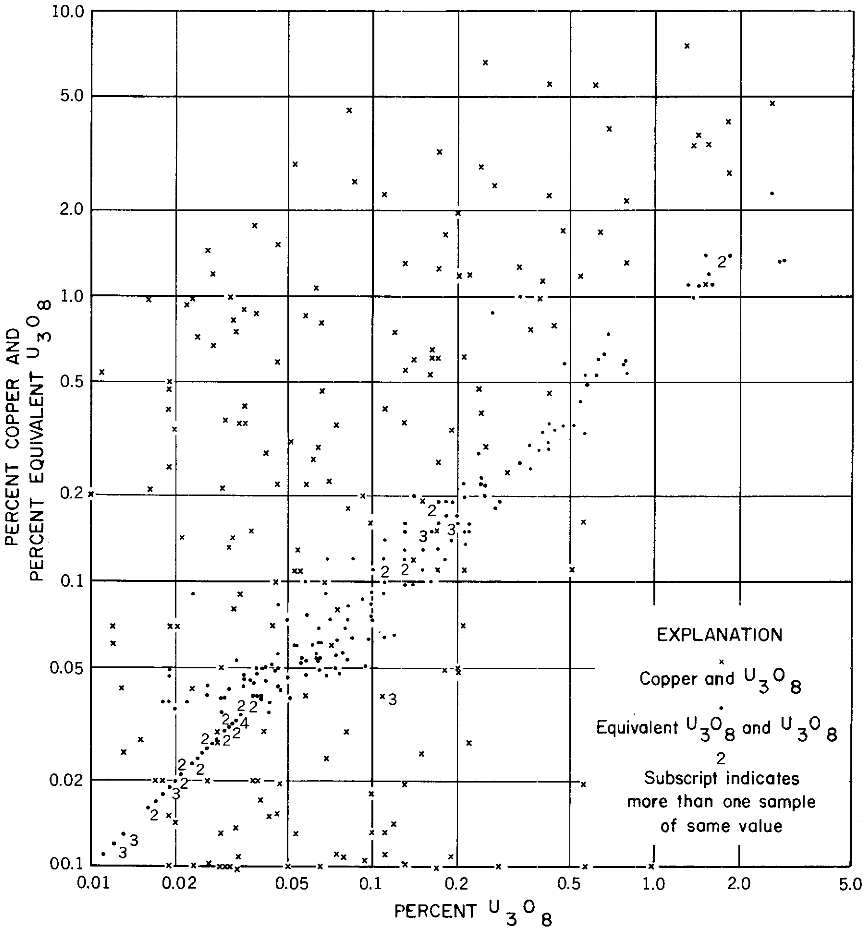

FIGURE 6.—Scatter diagram showing uranium, equivalent uranium, and copper content of 183 drill-core samples, mostly from drill holes in the Hideout No. 1 and W. N. channels, Deer Flat area.

tabular bodies as much as 14 feet thick, 150 feet wide, and 220 feet long. The ore is gray to brownish gray where unaltered, but oxidizes to yellowish brown. The distribution of minerals within the ore deposits seems to depend primarily on the original distribution of the fossil plant fragments. Where the plant fragments are large, many have been replaced to form large high-grade pods of uranium and copper minerals. Where the plant remains are tiny disseminated fragments, the ore minerals are likewise disseminated. As all stages between these extremes occur, the grade of the rock may vary erratically in a short vertical or horizontal distance. The percentage of U_3O_8 in the deposits thus ranges from less than 0.10 to more than 3.0, and averages about 0.56. The copper content varies in the same erratic fashion and ranges from less than 50 ppm to about 10 percent; it averages about 1.9 percent (fig. 6).

Coalified plant fragments are found in all the ore deposits, and the carbonaceous material in the ore commonly contains uranium. Coalified leaves and woody plant fragments are locally abundant throughout the Chinle formation, and many are partly replaced by pyrite. Plant material was readily replaced by uranium and copper minerals, which often preserve the structure of plant cells. The mineralized carbonaceous material is most commonly soft and sooty charcoallike mineral. Not all of the carbonaceous material, however, is mineralized, and its presence does not necessarily indicate that ore deposits are near by.

MINERALOGY

The principal uranium ore minerals in the deposits are uraninite and its oxidation products uranophane, bayleyite, schroeckingerite, zippeite (and related uranyl sulfates), and a little autunite. The copper sulfides in these deposits are chalcopyrite, bornite, chalcocite, and covellite, and the oxidized copper minerals are malachite, azurite, brochantite, and native copper. Secondary copper-uranium minerals, such as torbernite, occur in the oxidized zone near the outcrop. The gangue minerals are secondary quartz, calcite, dolomite, manganosiderite, gypsum, pyrite, jarosite, black manganese oxides, limonite, barite, galena, sphalerite, hematite, alunogen, boothite, and erythrite. We saw all these minerals except alunogen, boothite, and the uranium-copper minerals torbernite and metatorbernite, but those four were found at the W. N. mine by Gruner and others (1954, p. 24). The minerals preserve plant-cell structure, replace quartz and feldspar, fill fractures and interstices in sandstone, and coat joints and mine walls.

URANIUM MINERALS

The principal ore mineral, uraninite, fills fractures, impregnates sandstone, and commonly preserves plant-cell structure (Weeks, Coleman, and Thompson, 1959). A common result of plant-cell replacement is illustrated in figures 7 and 8, where the cells are filled with uraninite and the cell walls are replaced by calcite that contains disseminated sulfides. But the reverse is true in some places; uraninite may preserve the walls of cells, as in figure 9, and calcite and chalco-

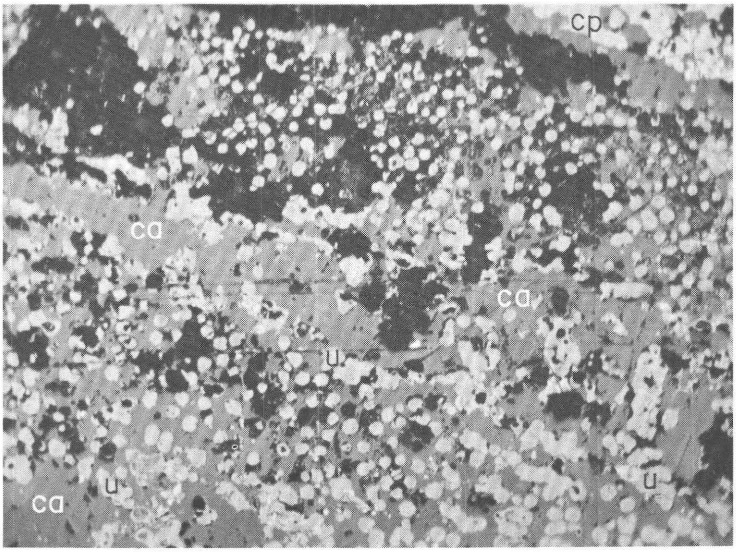

FIGURE 7.—Photomicrograph of poorly preserved plant-cell structure in uranium-copper ore. Uraninite (u) has replaced the walls of some cells, but apparently has filled many cells. Calcite (ca) fills the space around the uraninite. Chalcopyrite (cp) embays and engulfs calcite. Black and dark-gray areas are unpolished. Hideout No. 1 mine. × 146.

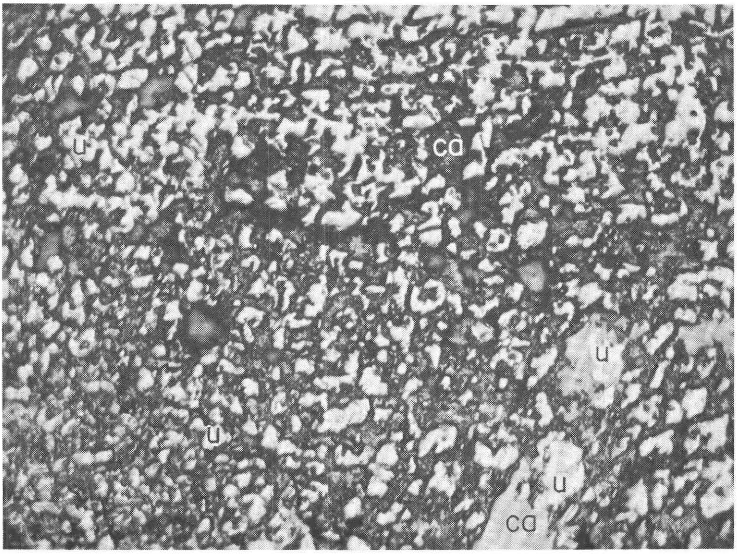

FIGURE 8.—Photomicrograph of plant-cell structure preserved in uraninite (u) and calcite (ca). Dark-gray and black areas are unpolished and probably contain some residual carbon. Hideout No. 1 mine. × 146.

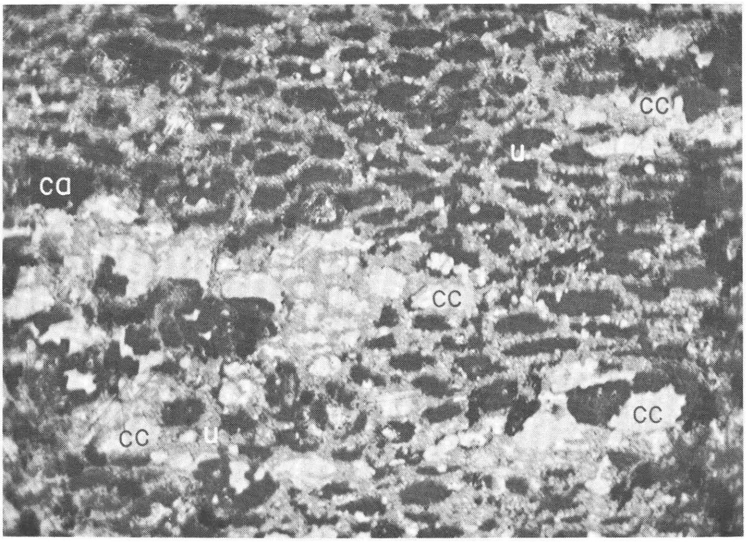

FIGURE 9.—Photomicrograph of fossil plant-cell structure preserved in chalcocite (cc), uraninite (u), and calcite (ca). Uraninite shows a strong preference for cell walls and contains round blebs of chalcocite. Chalcocite and calcite fill cells and locally cut through the cell walls. All these minerals appear to be contemporaneous. Hideout No. 1 mine. × 146.

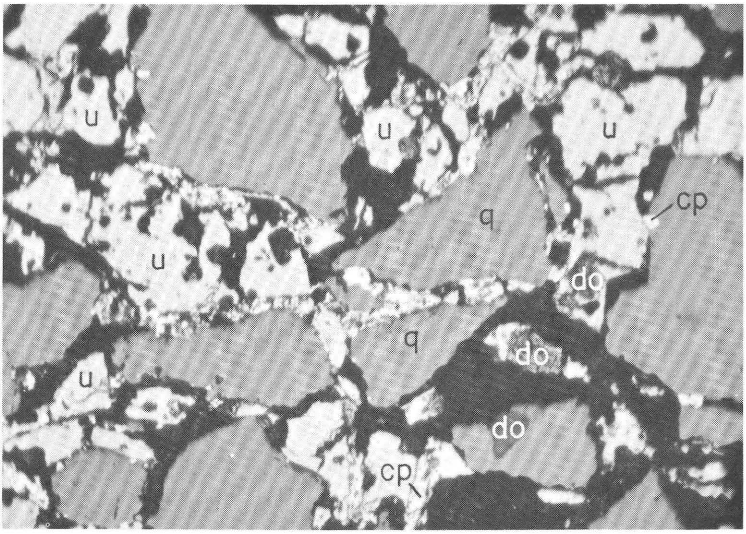

FIGURE 10.—Photomicrograph of uraninite and chalcopyrite (cp) impregnating sandstone. Uraninite (u) fills fractures in quartz grain (q) near center of field. Note fractured and partly replaced dolomite(?) crystal (do) below and to the right of the central quartz grain. The lower end of this crystal projects into a quartz grain, and the remainder is engulfed and veined by uraninite. Black and dark-gray areas are unpolished. Hideout No. 1 mine. × 146.

cite may fill the intervening spaces. Uraninite forms veinlets cutting quartz grains and selectively replaces feldspar grains along cleavage planes. Grains of uraninite as much as a millimeter in diameter may almost completely fill the spaces between quartz grains near replaced wood (fig. 10). Uraninite also coats quartz grains and locally embays them (fig. 14). Pyrite is embayed and veined by uraninite. Fractures in uraninite are filled with calcite, chalcopyrite, chalcocite, and barite, and with a soft black material that is probably sooty uraninite and organic matter.

Uranophane (identified by Alice D. Weeks and Mary E. Thompson of the U.S. Geological Survey, written communication, 1953) is disseminated in sandstone near outcrops at the Hideout No. 1 mine and also forms botryoidal crusts along fractures and bedding planes, particularly in siltstone beneath mineralized sandstone.

Bayleyite and schroeckingerite form an efflorescent coating on the mine walls and on fracture planes. The coatings form within 3 weeks after the tunnels are driven, and they are most common on walls of sandstone in which the cement contains much calcite and dolomite. These facts indicate that the uranium in these minerals was carried in solution by water percolating through the ore-bearing sandstone, but this evidence does not indicate the source of the uranium. The uranium may have come from the oxidized ore nearby, or from the relatively unoxidized ore that was found by drilling, or from uranium deposits a long distance updip, or it may never have been deposited from the original mineralizing solutions until the day the solution evaporated on the mine walls.

The sodium and magnesium analogs of zippeite (found in the W. N. mine by Alice D. Weeks and Mary E. Thompson, written communication, 1954) occur with uraninite and also in coatings on fracture surfaces and mine walls. At the prospect in NE¼SW¼ sec. 24, T. 35 S., R. 17 E., on the northwest side of Piñon Point (pl. 1), a mineral tentatively identified as autunite forms tiny fluorescent plates coating fracture surfaces in siltstone of the Moenkopi directly below a mineralized sandstone in the Chinle.

COPPER MINERALS

Chalcopyrite forms euhedral crystals in calcite, thick coatings or shells around bornite, and micrographic intergrowths with bornite and chalcocite. The chalcopyrite is generally separated from uraninite by a layer of calcite, but locally it forms embayments and irregular veinlets in uraninite (fig. 11).

Bornite fills fossil plant cells and forms large islandlike masses in calcite. Much of it forms the lagoonal part of bornite-chalcocite atoll structures. (fig. 12). Some of it has been replaced by covellite,

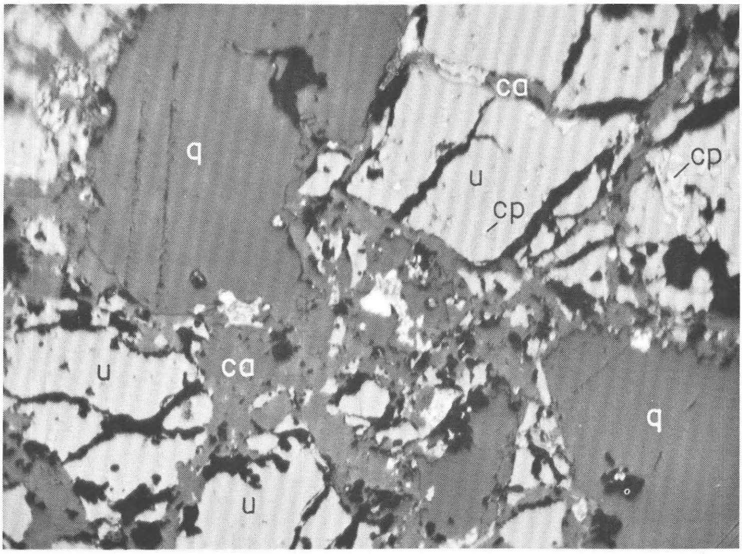

FIGURE 11.—Photomicrograph of uranium-copper ore. Large uraninite grains (u) contain tiny blebs of chalcopyrite (cp) and are cut by chalcopyrite veinlets. Quartz grains (q) embayed by calcite (ca) and by chalcopyrite and uraninite. One quartz grain (lower right) has well-developed crystal faces; one of these is partly coated with uraninite, but the others are jaggedly embayed by carbonates. Fractures in the uraninite are filled with calcite and with material that did not polish (black or dark gray). Hideout No. 1 mine. × 146.

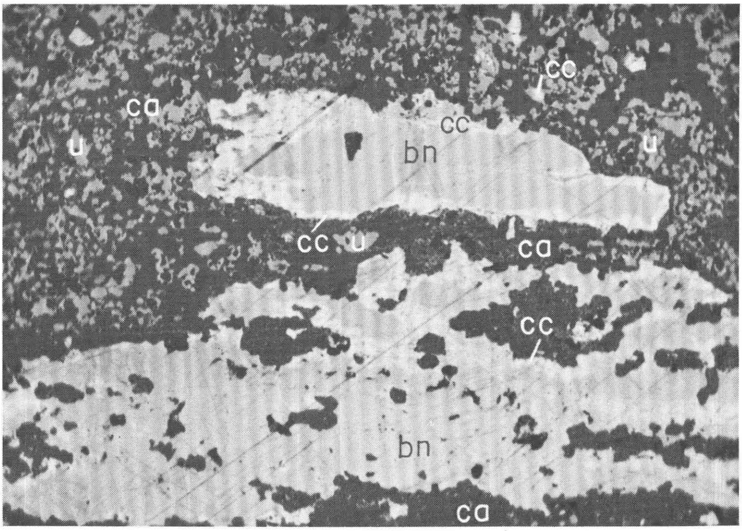

FIGURE 12.—Photomicrograph of uranium-copper ore. Bornite (bn) is surrounded by chalcocite (cc) and by calcite (ca). Uraninite (u) is disseminated in the calcite together with a little chalcocite. Black areas are unpolished. Note relict cleavage in bornite. Covellite feathers are visible at higher magnifications along such cleavage lines. Hideout No. 1 mine. × 146.

which follows cleavage directions in the bornite. A few grains of bornite are completely enclosed in a shell of chalcopyrite, and are penetrated along crystallographic planes by chalcopyrite in spindle- and lath-shaped blades (fig. 13). Bornite is always separated from uraninite by a thin shell of covellite, chalcopyrite, or calcite.

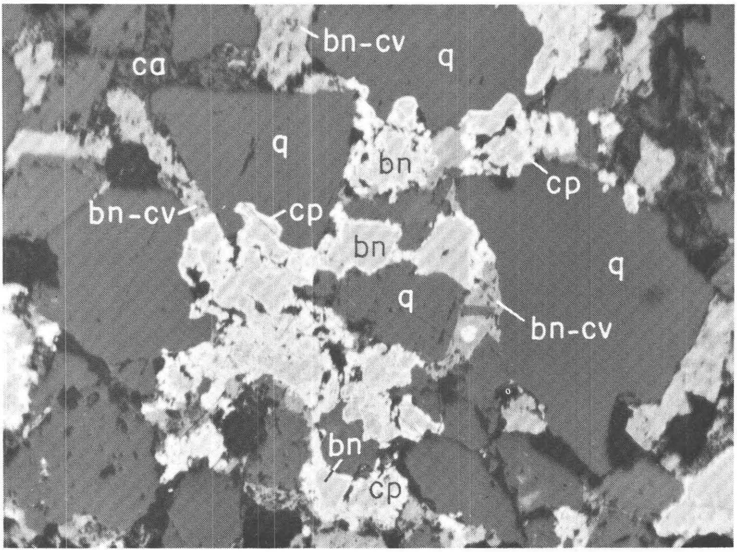

FIGURE 13.—Photomicrograph showing quartz replaced by copper minerals. Bornite (bn) is rimmed by and intergrown with chalcopyrite (cp). Bornite-covellite intergrowths (bn-cv) embay quartz (q). Calcite (ca) fills interstices in upper left corner. Hideout No. 1 mine. × 146.

Covellite forms thin, bladelike inclusions in chalcocite and bornite, cell fillings, large irregular masses in calcite, and rims between bornite and uraninite. Some covellite is partly replaced by chalcocite, and some grades into blue chalcocite, as if the chalcocite had formed at the expense of the covellite.

Chalcocite is the most abundant copper sulfide in the Hideout No. 1 mine, where it replaces carbonates and quartz and forms veinlets in fractured uraninite. Chalcocite veinlets also cut the carbonates and bornite-chalcopyrite intergrowths. Chalcocite together with other minerals occupies the cells of fossil wood (fig. 9).

The copper sulfides oxidize to aggregates of oxides, carbonates, and sulfates, including cuprite (J. W. Gruner, oral communication, 1952), malachite, azurite, brochantite (Stern and Weeks, 1952, p. 1059), and some unidentified uranium-copper carbonates and sulfates. These secondary minerals fill pore spaces and fractures and are disseminated in sandstone around the oxidizing minerals. They occur chiefly in the Shinarump member but are also found in sandstone higher in the Chinle formation.

GANGUE MINERALS

In addition to the detrital quartz, clay minerals, and feldspar that constitute the ore-bearing sandstone, the principal gangue minerals are calcite, dolomite, manganosiderite, limonite, jarosite, secondary quartz, manganese oxides, and gypsum. Minor gangue minerals include pyrite, sphalerite, galena, barite, and hematite.

Large subhedral grains of calcite cement sandstone and are among the minerals that preserve plant-cell structure. Concretionary masses of calcite-cemented sandstone are irregularly distributed through the Shinarump member of the Chinle formation, and such masses, as much as 15 feet wide, 100 feet long, and 8 feet thick, accompany the uranium ore in the southwest scour of the Hideout No. 1 mine. Some of the calcite associated with ore is earlier than the uranium minerals, but most of it cuts or engulfs uraninite (figs. 7 and 8); both early and late carbonate minerals are shown in figure 14, which also shows replace-

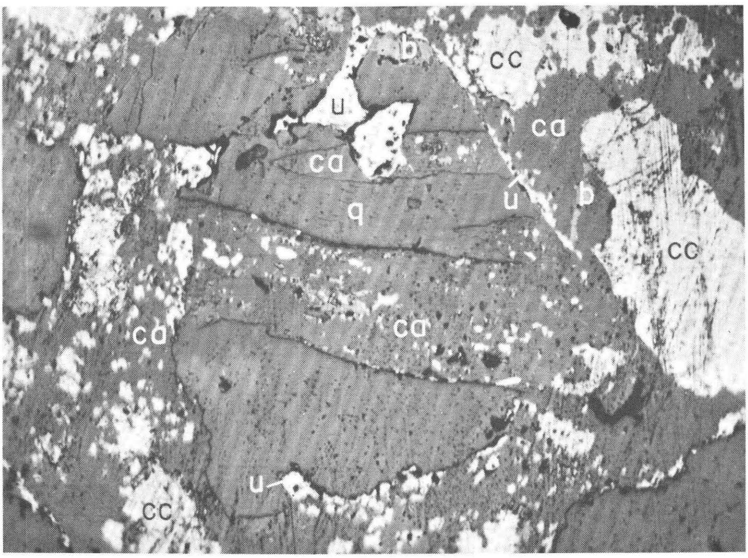

FIGURE 14.—Photomicrograph of uranium-copper ore. Note penetration of quartz (q, high relief) by calcite (ca, low relief) in the fractured central quartz grain. Uraninite (u, high relief) embays quartz and coats the upper right edge of the center grain. Chalcocite (cc, scratched grains) is disseminated in the calcite. Some large scalloped grains of chalcocite with veinlets and embayments of barite (b) are near the right edge of the field. Barite replaces the upper tip of the central quartz grain. Irregular veinlets and blebs of barite are sparsely disseminated in the calcite. Hideout No. 1 mine. × 146.

ment of quartz by calcite or dolomite and uraninite. The copper sulfides seem to be partly earlier and partly later than calcite, but they may all be of the same age (figs. 9, 13). Calcite veins filling joints are common in outcrops of the Shinarump member.

Dolomite and manganosiderite form elliptical masses as much as an inch in diameter in a matrix of uraninite and copper sulfides. Dolomite rhombs are common in calcite-cemented rock, and dolomite may have supplied the magnesium in the bayleyite crusts that form on the mine walls. Manganosiderite is found in relatively unoxidized ore containing no manganese oxide.

Dolomite was identified by W. F. Outerbridge, U.S. Geological Survey, in a sample of a carbonate mineral from the ore deposit in the Hideout No. 1 channel (serial No. 226678; field No. H–83–54, film No. 2154). According to A. J. Gude, 3d, also of the Geological Survey, the manganosiderite yields an X-ray-diffraction pattern closely resembling that of siderite (serial No. 229871, field No. TLF–17–54, charts 1414 and 1416). It gives an excellent manganese bead with borax, and its index of refraction falls between those of rhodochrosite and siderite, which are the end members of an isomorphous series that includes manganosiderite (Palache and others, 1951, p. 173).

Limonite spots as much as 1 inch in diameter are scattered through the sandstone of the Shinarump member without any apparent relation to channels or to ore deposits. Limonite also coats fractures in the strongly oxidized ore bodies, especially those in which pyrite and chalcopyrite are abundant. Limonite is the main constituent of the dark-brown desert varnish on exposed rock surfaces.

Hematite is the main coloring agent in all the red and pink rocks of the area. Local impregnations of hematite are common near oxidized pyrite and chalcopyrite, but hematite is not common in the ore deposits. Hematite coats sand grains and forms tiny veinlets in gray siltstone. The Chinle formation locally contains hematite concentrations parallel to the bedding and root-shaped concretions as much as 3 inches in diameter and 12 inches in length; both these features may represent fossil lateritic soils.

Jarosite coats fractures and bedding planes near coalified wood that contains pyrite. This association is so common as to indicate that jarosite forms instead of limonite or hematite when pyrite oxidizes in the presence of abundant coalified plant material. According to A. F. Trites, Jr. (oral communication, 1955), the formation of jarosite could have been caused by the reducing effect of the fossil plant material.

Secondary overgrowths on quartz grains are characteristic of the ore-bearing sandstone and are abundant near almost all the ore. The overgrowths are also abundant, however, in permeable sandstones that do not contain uranium deposits. Both detrital grains and overgrowths of quartz are locally embayed and cut by uraninite, calcite, and copper sulfides (figs. 10, 12, and 14).

Euhedral crystals of pyrite are sparsely disseminated throughout the ore. Some pyrite grains that must be older are completely enclosed in detrital quartz. In the Hideout No. 1 mine, mudstone directly above the ore-bearing sandstone contains fossil wood fragments that have been replaced by pyrite of two distinct kinds. One kind is very fine grained and faithfully preserves the plant-cell structure; the other, which consists of relatively large cubes and pyritohedrons, surrounds and cuts the fine-grained variety. Cubes of pyrite in ore are locally embayed and veined by uraninite. Pyrite is common throughout the Chinle formation, where it fills fractures, forms concretions, and partly replaces coalified plant fragments.

Sphalerite fills fractures and forms aggregates as much as half an inch in diameter. It is associated with copper sulfides and uraninite in carbonized wood fragments at the W. N. mine, and occurs in the same way at the Mirador No. 1 claim on Home Mesa.

Grains of galena are disseminated in high-grade ore at the Hideout No. 1 mine, and also at the W. N. mine (Theodore Botinelly, oral communication, 1955).

Black manganese oxides are disseminated in oxidized ore-bearing sandstone. They also coat fractures in sandstone and form scattered blebs as much as half an inch in diameter.

The selenite variety of gypsum fills fractures in the mudstone and sandstone of the Shinarump member wherever it crops out. Seams of gypsum are also associated with sulfide concentrations in sandstone and in partly replaced fossil wood near uranium ore. Green gypsum is associated with chalcopyrite, malachite, and azurite at a prospect in the SW¼–NW¼ sec. 17, T. 36 S., R. 18 E., on the south side of Upper Lost Parks (pl. 1); the green color is probably due to some admixed copper mineral.

Veinlets of clear tawny-yellow barite fill fractures in the ore bodies at the Hideout No. 1 mine. These veinlets cut uraninite, the sulfides, and much of the calcite and dolomite.

REPLACEMENT CHARACTERISTICS

Ore minerals have replaced many of the fossil plant fragments within the ore bodies, but they have not affected all of them; they have affected few plant fragments outside the ore bodies. The large uraninite grains that locally impregnate the sandstone (figs. 10 and 11) must have replaced some mineral—it may have been quartz, clay, feldspar, or carbonate minerals—but they have not preserved any relics or textural features of the replaced material. Small bays of uraninite and copper sulfides extend into quartz, and they penetrate the feldspars, especially plagioclase, along cleavage planes. No gradation between bays of secondary minerals and completely replaced material was seen apart from a few fingerlike projections of calcite and uraninite into quartz (fig. 14). If large grains of ore minerals have replaced fossil plant remains or asphaltic material, the only evidence of the fact is their enclosing black sooty specks that may be residual organic material.

Chalcopyrite has replaced bornite along cleavage planes (fig. 13) to yield a texture similar to that which forms when two mineral phases exsolve from solid solution (Schwartz, 1931, p. 196). The bornite grains that have this texture, however, are also surrounded by chalcopyrite, and the chalcopyrite blades have fuzzy edges and widen where they intersect one another. According to Schwartz (1942, p. 363) these facts favor a replacement origin.

PARAGENESIS

The sequence of mineralization is difficult to determine because many of the minerals have selectively replaced plant-cell structures. Where, for example, the walls of wood cells have been replaced by uraninite and the other parts filled with calcite, it is difficult to decide whether the filling or the replacement came first, or whether the two were simultaneous. Fracture fillings in plant fragments are equally difficult to interpret. Shrinkage cracks commonly develop during coalification of plant material, and these may become filled with minerals either before or after replacement of the plant material by the same or different minerals.

The general sequence of mineral deposition is believed to be as follows: The detrital grains were first cemented with calcite, dolomite, and quartz; this process was followed by the first stage of mineralization, represented by pyrite and chalcopyrite. Uraninite began to form while chalcopyrite was still being deposited. During the late stages of uranium deposition, the ore was fractured, chalcopyrite continued to be deposited, and chalcocite began to form. After uranium deposition ceased, chalcopyrite, chalcocite, bornite, and covellite were introduced, along with calcite and perhaps dolomite. Carbonate minerals continued to be formed throughout the process of mineralization, of which the final stage was the introduction of barite.

OXIDATION

In this area, uraninite oxidizes to form silicates and sulfates, together with minor quantities of carbonates and phosphates, in an oxidation zone that extends as much as 150 feet underground. According to Lindgren (1933, p. 831–834) and Bateman (1949, p. 277), the copper sulfides commonly oxidize through the series chalcopyrite, bornite, covellite, and chalcocite, and finally to a mixture of carbonates and sulfates. The sulfides in the Deer Flat area generally bear out this view, but locally part of the sequence has been reversed, apparently by addition of excessive amounts of iron, so that some chalcopyrite has formed at the expense of bornite. Chalcopyrite and bornite are replaced by limonite, which veins and encloses remnants of the sulfides. Manganese oxides apparently form through oxidation of manganiferous carbonates, and some manganese is carried by water into the surrounding sandstone, to be deposited as oxides in open spaces and along fractures. Some manganese oxide appears to have been precipitated by evaporation of solutions at the outcrop. Pyrite oxidizes to hematite, limonite, and jarosite. Hematite and limonite concretions have formed in places around pyrite and give the rock a speckled appearance. Jarosite, as noted earlier, is commonly associated with pyritiferous fossil plant fragments.

The uraninite from apparently unoxidized ore at the Hideout No. 1 mine has a dull sooty appearance which suggests that it is partly oxidized, even though obviously secondary minerals are not present. In order to determine the oxidation state of this uraninite, A. J. Gude 3d, of the U.S. Geological Survey, measured the unit cell edges in X-ray powder photographs of two samples of uraninite from the mine. The lengths of the cell edges in the samples average about 5.39 angstroms (table 2), as compared to 5.47 angstroms for uraninite

TABLE 2.—*Unit cell dimensions for two uraninite samples from the Hideout No. 1 mine, Deer Flat area, White Canyon district, San Juan County, Utah*

[Analysts, A. J. Gude 3d, and R. W. Marquiss]

Serial No.	Field No.	Film No.	Crystallographic direction	Cell dimension in angstrom units
226677	H-82b-54	2400	A	5. 386 ± 0. 002
226679	H-84a-54	2401	A	5. 394 ± 0. 005

from pegmatites. The unit cell dimensions, however, of other uraninite specimens from the Colorado Plateau average 5.40 (Rosenzweig and others, 1954, p. 355). The results of previous research indicate that uraninite with this cell dimension is highly oxidized. According to Brooker and Nuffield (1952, p. 373), unoxidized uraninite has the composition $UO_{2.0}$ but highly oxdized uraninite may reach the composition $UO_{2.75}$. The composition of the Hideout uraninite as determined from the graph in their paper is $UO_{2.6}$.

RELATIONS BETWEEN RADIOACTIVITY AND URANIUM CONTENT

The uranium content (determined chemically) of a sample may be appreciably different from the equivalent uranium content (estimated from radioactivity and symbolized as eU). The observed differences between eU and U in samples from the Deer Flat area are probably due to differential leaching or enrichment. Table 3 gives the percentages of U_3O_8 and eU_3O_8 for each sample whose location is shown in figure 15, and its position relative to the outcrop; these data indicate

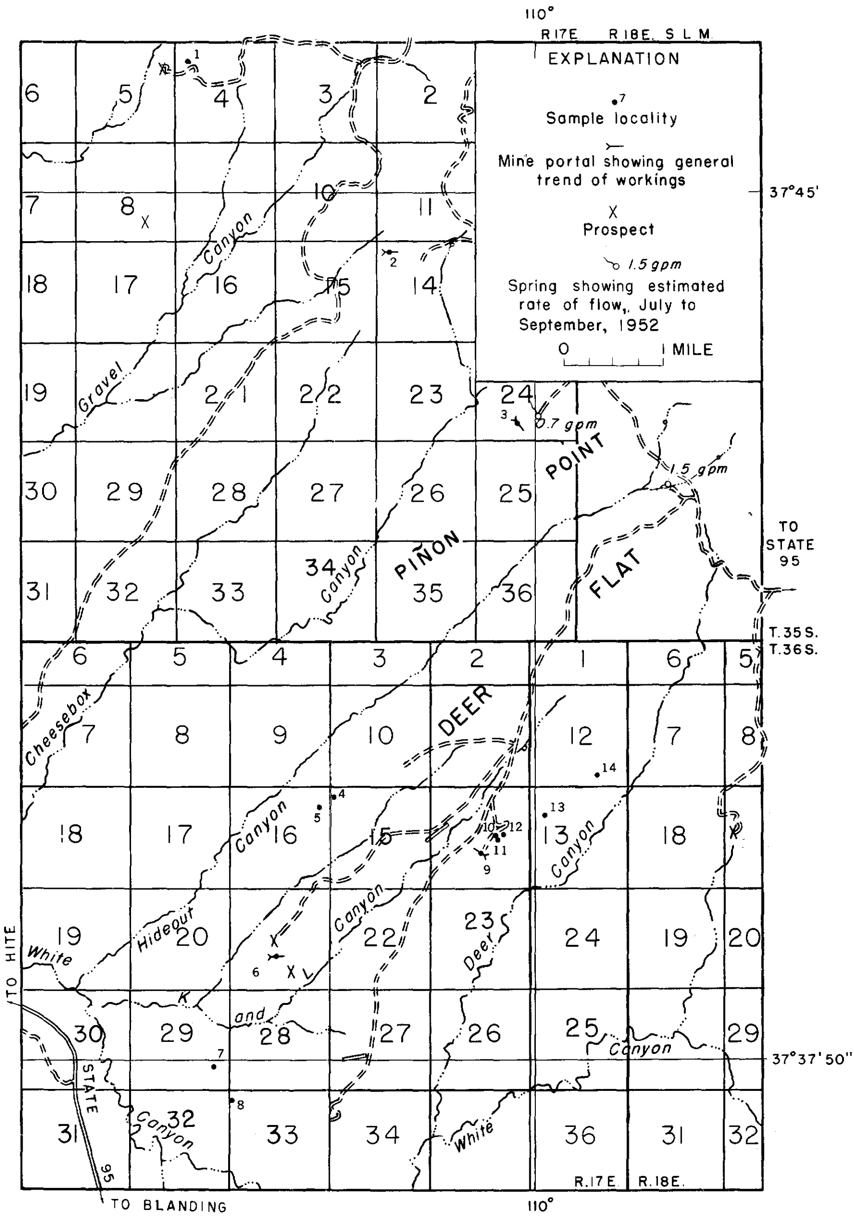

FIGURE 15.—Map showing distribution of samples listed in table 3, which notes the geologic setting of the samples.

that some samples taken a few feet underground contain about as much uranium as the radioactivity would indicate, or even more, whereas samples from oxidized outcrops commonly contain less uranium than the radioactivity would indicate.

TABLE 3.—*Radiometric and partial chemical analyses of selected samples from uranium-copper deposits in the Chinle formation, Deer Flat area, White Canyon district, San Juan County, Utah*

[Localities shown on fig. 15. Analysts: Radiometry, S. P. Furman; chemistry, C. G. Angelo, H. E. Bivens, G. W. Boyes, Jr., R. F. Dufour, W. D. Goss, H. H. Lipp, E. C. Mallory, Jr., J. P. Schuch, D. L. Skinner, James Wahlberg, and J. E. Wilson]

Laboratory serial No.	Field No.	Locality No.	Rock type	Percent							Remarks
				eU_3O_8	U_3O_8	$CaCO_3$	Cu	Fe_2O_3	MnO	P_2O_5	
D-229084	TLF-12-54	1	Chalcedony	0.084	0.063						Chinle (outcrop).
229085	13-54	2	Carbonaceous shale	1.6	2.50						Chinle (25 ft underground).
229086	14-54	2	Carbonaceous sandstone	1.3	1.35						Do.
228118	8-54	3	do	4.9	2.52	0.3	9.36	6.56	<0.001	0.04	Chinle (outcrop).
228119	9-54	3	do	5.9	1.28	<.1	3.26	10.32	<.001	.02	Do.
228120	10-54	3	do	1.5	.27	.1	.94	10.77	.005	.04	Do.
228121	11-54	3	do	1.1	.38	<.1	3.60	11.51	.030	.11	Do.
203907	1-53	4	Sandstone	.034	.038		7.88				Chinle(?) (float).
203908	2-53	4	Chalcocite replacement of wood.	.93	.28		38.21				Do.
203909	4-53	5	Carbonaceous siltstone	.18	.016		.23				Shinarump member(?) (outcrop).
203747	WN-3-53	6	Carbonaceous sandstone	6.8	6.71	.70	3.22				Shinarump member (20 ft underground).
203911	TLF-8-53	7	Carbonaceous fragments in sandstone.	.44	.31		.08				Shinarump member (outcrop).
203910	5-53	8	Carbonaceous siltstone	.02	.009		.02				Shinarump member(?) (outcrop).
80534	H-28-52	9	Chalcedony	.006	.007	21.8		1.93	.355	<.1	Chinle (outcrop 20 ft above Shinarump member).
80535	66-52	10	do	.013	.008	6.0		2.85	.039	<.1	Chinle (float 10 ft above Shinarump member).
80116	TLF-30-52	11	Conglomerate	.022	.015	.1	.68				Shinarump member (outcrop).
80117	31-52	12	do	.049	.014	1.5	.67				Do.
80118	33-52	12	Siltstone	.008	.004	.3	.01				Do.
80119	35-52	12	Conglomerate	2.0	.33	.2	2.19				Do.
80120	36-52	12	Sandstone	1.9	.13	.2	.94				Do.
80121	40-52	13	Carbonaceous sandstone	.16	.035	2.6	1.76				Do.
80122	41-52	13	do	2.0	.44	2.7	3.04				Do.
80123	44-42	14	do	.064	.042	.5	7.76				Do.

Figure 6, which gives data for core samples that probably are not appreciably oxidized, shows that many core samples containing less than 0.20 percent U_3O_8 have excessive radioactivity, whereas the reverse is generally true of samples containing more than 0.20 percent U_3O_8.

The reason for the excessive radioactivity of many weathered samples is that the weathered uranium-bearing rocks have been differentially leached, with the result that part of the uranium has been removed, while radioactive daughter products, such as ionium (Th^{230}) and radium (Ra^{226}), have been left behind (Rosholt, 1954). Similar relations have been observed by other workers, not only on the Colorado Plateau but in the Colorado Front Range. Phair and Levine (1953, p. 358–369) have shown that in dump material at Central City, sulfuric acid formed by oxidation of pyrite and chalcopyrite has selectively leached most of the uranium from pitchblende, leaving "hot spots" whose high radioactivity is almost entirely due to radium sulfate, a substance much less soluble than uranium sulfate.

The deficient radioactivity of some comparatively unoxidized samples from mine workings, and of the richer samples from drill cores, may be due to partial loss of daughter products, loss of radon, or enrichment in uranium. The excessive radioactivity of the leaner samples from drill cores may be due to removal of uranium by reactions that did not have such conspicuous effects as weathering.

If the material at the outcrop is virtually unweathered, its radioactivity can give an approximate measure of its uranium content. The uranium content may even increase underground, though it is unsafe to assume that it will. An instrument for detecting radiation, such as a Geiger counter or a scintillation counter, can be useful in appraising unweathered rock, but may give highly misleading results if used on deeply weathered rock.

HEAVY METALS

According to Huff (1955, p. 251), lead, zinc, and copper in greater quantity than is usual in sediments are found at the Oyler mine in the Capitol Reef area, Wayne County, Utah, in bleached siltstone in the Chinle formation above the Shinarump member. To determine whether that is the case in the Deer Flat area, 28 drill-core samples of siltstone and mudstone from the mudstone-sandstone unit of the Chinle formation were analyzed for heavy metals by chemists of the U.S. Geological Survey (table 4). The results indicate that the dis-

TABLE 4.—*Heavy-metal content of 28 samples from drill cores in the Chinle and Moenkopi formations, Deer Flat area, White Canyon district, San Juan County, Utah*

[Analyst, G. C. Campbell]

Drill hole and collar altitude (ft)	Uranium mineralization [1] (distance in feet above Moenkopi)	Field No.	Distance above formation or member (ft)		Laboratory serial No.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Description of sample
			Above Moenkopi	Above Shinarump					
DF-39 (7368.9)	Ore from −0.3 to 4.9; and from 40.1 to 41.0.	GP-1	141.6	101.2	54-5367	30	70	130	Gray mudstone of the Chinle, 10 percent fine to medium sand, a little mica.
		-2	126.6	86.2	5368	30	50	70	Gray mudstone of the Chinle.
		-3	81.1	40.7	5369	10	50	20	Do.
		-4	42.6	2.2	5370	70	20	20	Gray to olive-brown mudstone of the Chinle.
DF-40 (7393.4)	Weakly mineralized from 0.3 to 1.1.	-5	151.6	119.1	5371	10	20	20	Gray mudstone and siltstone of the Chinle.
		-6	108.6	76.1	5372	20	20	50	Gray mudstone of the Chinle, plastic.
		-7	80.6	48.1	5373	50	50	20	Gray mudstone of the Chinle.
DF-43 (7393.4)	Barren	-8	154.0	135.9	5374	20	20	20	Gray siltstone of the Chinle, much muscovite.
		-9	119.0	99.9	5375	20	20	20	Gray mudstone of the Chinle, variable amounts of carbon, a little mica.
		-10	73.7	54.6	5376	10	20	20	Purplish-red and gray mudstone of the Chinle, abundant medium sand.
		-11	64.4	45.3	5377	<10	20	20	Gray, red, and brown mottled mudstone, breccia.
DF-45 (7390.1)	Mineralized from −0.6 to 0.0; and 41.4 to 41.7.	-12	152.4	109.1	5378	20	50	130	Gray mudstone of the Chinle, plastic.
		-13	106.6	63.3	5379	20	20	20	Gray mudstone of the Chinle, breccia.
		-14	85.6	42.3	5380	40	20	20	Gray mudstone of the Chinle, much mica, numerous fractures.
		-15	74.6	31.3	5381	<10	20	20	Purplish-red mudstone of the Chinle.
DF-88 (6997.4)	Ore grade from 2.1 to 2.9	-16	114.4	79.9	5382	10	20	20	Gray very fine grained silty sandstone of the Chinle, some carbon.
		-17	74.9	40.4	5383	30	20	20	Gray mudstone of the Chinle.
		-18	17.9	−16.6	5384	30	70	70	Dark-gray mudstone of the Shinarump member, much medium sand, carbon seams.
DF-98 (7539.5)	Mineralized from 9.3 to 11.7	-19	108.0	86.7	5385	10	20	20	Gray siltstone of the Chinle, variable amounts of muscovite.
		-20	49.6	28.3	5386	200	20	20	Do.
		-21	4.0	−17.3	5387	30	20	20	Reddish-brown and gray mottled mudstone of the Shinarump member, 40 percent sand.
		-22	−0.8	−22.1	5388	40	20	50	Dusky-red mudstone of the Moenkopi, thin laminated, much muscovite.
DF-109 (7548.7)	Mineralized from 0.2 to 0.8	-23	125.6	84.2	5389	10	20	20	Gray muddy sandstone of the Chinle, abundant flakes of carbon.
		-24	51.7	10.3	5390	30	20	50	Gray mudstone of the Chinle, breccia, 20 percent medium sandstone.
DF-134 (7782.0)	Weakly mineralized from 8.6 to 9.6.	-25	130.2	96.2	5391	<10	20	20	Gray siltstone of the Chinle, much muscovite, sparse carbon.
		-26	78.1	44.1	5392	<10	20	50	Gray siltstone of the Chinle, much muscovite, variable amounts of carbon.
		-27	27.9	−6.1	5393	<10	20	20	Purplish-red siltstone of the Shinarump member, much muscovite.
		-28	2.5	−31.5	5394	<10	20	20	Dark-gray mudstone of the Shinarump member, much carbon, 15 percent sand.

[1] Core is classified as follows: Ore, contains 0.10 percent or more U_3O_8; mineralized, contains from 0.05 to 0.09 percent U_3O_8; weakly mineralized, contains from 0.02 to 0.049 percent U_3O_8; barren, contains less than 0.02 percent U_3O_8.

tribution of these metals does not vary much either vertically or horizontally, and that it bears no apparent relation to the ore deposits. For these reasons, geochemical prospecting for uranium through determination of the heavy-metal content of the rocks does not appear to be feasible in this area. A slightly abnormal amount of copper would no doubt be found in the Shinarump member; but, as shown in figure 6, most of the copper in that member is accompanied by radioactive elements, so that determination of copper would only give results that could be obtained more easily with such instruments as the scintillation counter.

LOCALIZATION AND ORIGIN

All the ore deposits in the Deer Flat area were localized in permeable sandstone, chiefly of the Shinarump member, that fills channels cut in relatively impermeable shale, and that was also overlain by relatively impermeable rock. The relation of the ore to permeable and impermeable rocks is well shown in the isometric fence diagram of the Hideout No. 1 ore deposit (pl. 4) and also in cross sections of the W.N. and Sandy No. 3 channels (pls. 5 and 8).

The occurrence of smaller quantities of uranium and copper minerals outside the channels indicates that the ore solutions moved through permeable rocks that do not fill channels, but that the channels supplied the necessary physical setting for concentration of large quantities of ore. One obvious effect of the thicker sandstone in channels would be to allow the solutions to spread out and reduce their velocity.

The three channels that contain significant ore deposits are in rocks of especially low dip (see pl. 1). One of these channels, the Hideout No. 1, was mapped in enough detail to delineate the structure beneath it; the ore-bearing part of the channel is clearly in beds that dip less steeply than those in the monocline to the east (fig. 4). Furthermore, part of the channel is on a structural terrace (fig. 3).

The ore minerals in the Deer Flat deposits are concentrated in and near fossil plant material, and they have partly replaced both it and the nearby detritus and cement of the host rock. They also fill microscopic fractures in quartz grains.

The replacement features of the ore minerals indicate that the ore deposits were epigenetic in origin; that is, the ore minerals were introduced into previously deposited sediments. The time at which the ore was deposited can be inferred from the age of the uraninite, which is included in the sequence of ore deposition. The age of the uraninite from Deer Flat has not been determined, but the age of the uraninite from the Happy Jack mine about 14 miles northwest, which is also in the Shinarump member (Trites and Chew, 1954), has been estimated by Stieff and others (1953, p. 17) through measurement of the Pb^{206}/U ratio as 65 million years. The Deer Flat uranium deposits are presumably about the same age. This age is much less than the accepted age of the Chinle formation, which is about 160 million years (Marble, 1950, p. 18). The estimated age is closer to that of the Laramide orogeny, which is Late Cretaceous or early Eocene.

The source of the ore metals that form the Deer Flat deposits is not known, nor is the manner of their introduction into the sediments. We are convinced that the movements of the mineralizing solutions through the rocks of the Chinle formation were partly controlled by structure. For example, a structural terrace would tend to guide laterally migrating solutions into a channel that crosses the terrace. The occurrence of the deposits in rocks of unusually low dip and the coincidence of the Hideout No. 1 deposit with a structural terrace indicate a less direct structural control. Many structural geologists have proposed that tension joints in folded beds commonly radiate outward from the convex side of the folds (Balk, 1937, p. 98 and 102; and Turner, 1948, p. 182–183). This suggests that tension in folded beds may increase upward in anticlines and downward in synclines. If the same inference can be drawn about anticlinal bends and synclinal bends, then it is possible that sets of longitudinal joints in the rocks of synclinal bends are tension joints related to the folds, and that they may extend to great depth. If the monoclines in the Deer Flat area are the surface expression of buried faults that were channelways for ore solutions rising from a deep source during the Laramide orogeny, these solutions, after rising above the faults, must have traveled along joints for a thousand feet or more, and they may be the solutions that caused the discoloration of the rocks adjacent to the joints.

The presence of uranium and copper minerals in beds of permeable sandstone above the Shinarump member indicates that the uranium-bearing solutions moved almost vertically through the rocks and spread laterally in the sandstone. Apparently the ore solutions deposited uranium and copper minerals wherever they reached rocks that were amenable to replacement.

STATISTICAL INTERPRETATION OF ASSAY DATA

Samples of rock from Deer Flat, including mill pulps and selected specimens of ore, were analyzed by a rapid semiquantitative spectrographic method in the Denver spectrographic laboratory of the U.S.

Geological Survey. The analytical method is described by A. T. Myers as follows (written communication, 1957):

In this procedure a weighed amount of the powdered sample is burned in a controlled d.c. arc and the spectrum recorded on a photographic plate. Selected lines on the resulting plate are visually compared with those of standard spectra prepared in a manner similar to that for the unknowns. The standard spectra were prepared from mixtures of materials containing 68 elements in the following concentrations—10 percent, 4.6, 2.2, 1.0, 0.46, etc. These values were chosen so that the concentrations of the elements decrease from 10 percent to about 0.0001 percent by a factor of the reciprocal of the cube root of 10. This factor provides a geometric concentration series having three members for each order of magnitude and which is consistent with the relation between the blackness of the spectral line and the amount of an element present. By means of a comparator showing enlarged adjacent images of the sample spectra and the standard spectra, visual estimates are made of concentrations of the elements in the sample which are then reported as being between two standards in the following manner: x indicating the middle portion (5–2) of an order of magnitude; $x+$ the higher portion (10–5); and $x-$ the lower (2–1).

The above method of reporting is used because the inherent limitations of this particular method of spectrographic analysis make the precision of the determinations less than the precision attained in preparing the standards. Major sources of error are (1) chemical and physical differences between the samples and the standards, (2) the omission of complete quantitative procedures for sample preparation, and plate calibration, and (3) lack of duplicate determinations. Experimental work has shown that approximately 60 percent of the reported results fall within the proper portion of an order of magnitude.

In addition to the spectrographic analyses, samples of 0.30 percent eU_3O_8 or less were analyzed fluorimetrically for U_3O_8 content, and all other samples were analyzed volumetrically for U_3O_8 content. Samples containing 0.1 percent copper or more were analyzed electrolytically, and all others were analyzed colorimetrically. All calcium that dissolved from a sample in a glacial acetic acid leach process is reported as $CaCO_3$.

The analyses show (table 5) that 22 elements are present in more than 65 percent of the samples in quantities above the limits of sensitivity (table 6), and that 8 elments are present in less than 65 percent of the samples in quantities above the limits of sensitivity. The limits of sensitivity for the 30 elements in table 5 are shown in table 6 along with the limits of sensitivity for 30 additional elements that were looked for but not detected in the spectrographic analyses.

The mathematical treatment to determine the geometric means and geometric deviations of the data is the same as that used by Miesch (1955), and by Shoemaker and others (1959, p. 28), so that direct comparison of the results can be made.

TABLE 6.—*Standard sensitivities for the elements for the analyses listed in table 5, determined in the U.S. Geological Survey laboratory by the semiquantitative method described by Myers and Barnett (1953)*

	Percent		Percent		Percent
Ag	0. 00005	Hf	0. 05	Rh	0. 005
Al	. 001	Hg	1. 0–0. 1	Ru	. 005
As	. 05	In	0. 001	Sb	. 01
Au	. 003	Ir	. 005	Sc	. 001
B	. 005	K	. 5, [1] (0. 001)	Si	. 001
Ba	. 0001	La	. 005	Sm	. 01
Be	. 0001	Li	.01, [1] (0. 0001)	Sn	. 001
Bi	. 001	Mg	. 001	Sr	. 0001
Ca	. 001	Mo	. 001	Ta	. 05
Cd	. 005	Mn	. 0005	Te	. 08
Ce	. 05	Na	.05, [1] (0. 0005)	Th	. 05
Co	. 0005	Nb	. 001	Ti	. 0005
Cr	. 0001	Nd	. 01	Tl	. 01
Cu	. 00005	Ni	. 0005	U	. 05
Dy	. 05	Os	. 005	V	. 001
Er	. 005	P	. 1	W	. 01
Fe	. 001	Pb	. 001	Y	. 001
Ga	. 001	Pd	. 0005	Yb	. 0001
Gd	. 005	Pt	. 003	Zn	. 02
Ge	. 0005	Re	. 005	Zr	. 001

[1] A second exposure is requir ed for the higher sensitivity listed, using a 20-mgm sample charge.

Analyses of five samples of mill pulp from ore mined between drill holes DF–14 and DF–27 (fig. 16), 40 to 90 feet east of drill hole DF–26, show some statistical differences in chemical composition from drill-core samples (table 7). The geometric means of aluminum, titanium, zirconium, beryllium, and boron are consistently higher in drill core than they are in mill pulp indicating that the material shipped to the mill contained less mudstone and other fine-grained rock than the material from drill core. No doubt this is the result of the miners' practice of increasing the grade of the ore by discarding the generally low grade mudstone. The higher content of cobalt and molybdenum in the mill pulps may be partly due to contamination from the steel grinding plates at the mill. This contamination may have been even greater than the 0.0003 percent cobalt and 0.002 percent molybdenum reported by Myers and Barnett (1953) as the average for the Denver laboratory of the U.S. Geological Survey. The consistently lower geometric deviations (antilog of the log standard deviations) for the mill-pulp samples as compared with the drill-core samples may be partly due to lumping the variations, both lateral and vertical, in the chemical composition of ore-bearing sandstone into a few large samples of mill pulps.

TABLE 7.—*Summary and comparison of the geometric mean and geometric deviation of partial chemical analyses and semiquantitative spectrographic analyses of drill-core and mill-pulp samples from the Shinarump member of the Chinle formation at the Hideout No. 1 ore deposit, Deer Flat area, White Canyon district, San Juan County, Utah, and of average chemical compositions of samples of mill pulp from deposits in Upper Triassic rocks of the Colorado Plateau* (*Miesch, 1955*)

		Number of samples	U_3O_8 (percent)	Cu (percent)	Al	Fe	Ti	Mn	Ca	Mg	Na	K	Ag	B	Ba	Be
	ORE															
	(U_3O_8>0.02 percent)															
	Geometric mean:															
1	Hideout No. 1 mine	39	0.12	0.44	5.43	3.10	0.14	0.021	0.46	0.49	0.15	0.77	0.00013	0.0028	0.039	0.00014
2	Hideout No. 1 mill pulps	5	.39	.96	1.47	1.47	.068	.015	.32	.32	.068	.27	-----	-----	.032	-----
3	Other deposits	38	-----	.03	2.2	1.5	.13	.024	.7	.17	.08	~.48	<.0001	.0014	.07	.00007
	Geometric deviation:															
4	Hideout No. 1 mine	39	4.08	6.89	2.74	1.96	1.86	2.15	3.04	2.19	4.20	3.32	2.67	1.83	1.74	2.19
5	Hideout No. 1 mill pulps	5	1.52	1.52	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.41	-----	-----	1.0	-----
6	Other deposits	38	-----	10.10	2.21	1.90	2.26	2.85	4.14	2.99	3.04	-----	-----	-----	3.22	-----
	Correlation coefficient with uranium:															
7	Hideout No. 1 mine	43	-----	.700	−.356	.345	−.254	.064	−.026	.104	−.350	−.294	.221	−.174	.014	.024
8	Median (percent) Hideout No. 1 mine	39	.069	.55	x+	x	.x−	.0x−	.x	.x+	.x−	.x	.0000x+	.00x	.0x	.000x−
	BARREN															
	(U_3O_8<0.02 percent)															
	Geometric mean:															
9	Hideout No. 1 mine	4	.014	.018	10.0	1.78	.32	.010	.26	.15	.12	.80	.00022	.0033	.021	.00010
10	Other areas	32	-----	.010	3.3	1.2	.18	.012	.25	.13	~.1	<.15	<.0001	~.0016	.05	<.0001
	Geometric deviation:															
11	Hideout No. 1 mine	4	-----	3.71	1.47	2.08	1.56	2.69	4.28	1.0	1.47	2.08	3.78	1.0	3.16	2.15
12	Other areas	32	-----	3.33	2.85	3.40	2.50	10.00	7.19	4.72	-----	-----	-----	-----	4.06	-----

TABLE 7.—*Summary and comparison of the geometric mean and geometric devation of partial chemical analyses and semiquantitative spectrographic analyses of drill-core and mill-pulp samples from the Shinarump member of the Chinle formation at the Hideout No. 1 ore deposit, Deer Flat area, White Canyon district, San Juan County, Utah, and of average chemical compositions of samples of mill pulp from deposits in Upper Triassic rocks of the Colorado Plateau (Miesch, 1955)*—Continued

		Number of samples	Co	Cr	Ga	La	Mo	Ni	Pb	Sc	Sr	V	Y	Yb	Zn	Zr
	ORE															
	(U_3O_8>0.02 percent)															
	Geometric mean:															
1	Hideout No. 1 mine	39	0.0023	0.0063	0.00083	--------	0.0029	0.0034	0.0050	0.00023	0.014	0.0086	0.0011	0.00020	0.016	0.012
2	Hideout No. 1 mill pulps	5	.0032	.0015	--------	--------	.0068	.0032	.0037	--------	.0079	.005	.0015	.00017	.0046	.0068
3	Other deposits	38	.0025	.0030	<.0005	<.002	~.0017	.0025	.0064	<.001	.014	.063	.0017	--------	.031	.018
	Geometric deviation:															
4	Hideout No. 1 mine	39	2.99	1.69	3.59	--------	4.28	2.0	3.08	3.63	4.08	1.85	3.64	2.06	2.11	1.56
5	Hideout No. 1 mill pulps	5	1.0	1.0	--------	--------	1.0	1.0	1.41	--------	1.41	1.52	1.72	1.41	1.52	1.0
6	Other deposits	38	4.16	2.74	--------	--------	--------	3.22	3.16	--------	2.59	4.40	3.61	--------	4.16	2.03
	Correlation coefficient with uranium:															
7	Hideout No. 1 mine	43	.119	−.238	−.323	--------	−.056	−.110	.467	.122	−.169	−.107	.393	.110	.369	.096
8	Median (percent) Hideout No 1 mine	39	.00x	.00x+	.000x+	--------	.00x	.00x	.00x	.000x−	.00x+	.0x−	.00x−	.000x−	.0x−	.0x−
	BARREN															
	(U_3O_8<0.02 percent)															
	Geometric mean:															
9	Hideout No. 1 mine	4	.0046	.0082	.00021	--------	.0068	.0068	.0046	.00015	.0068	.012	.00082	.00032	.018	.018
10	Other areas	32	~.0005	.0014	<.0005	<.002	~.0005	>.0009	.001	<.001	.006	.0030	.0016	.00024	--------	.025
	Geometric deviation:															
11	Hideout No. 1 mine	4	3.78	1.47	1.56	--------	2.43	1.87	2.69	1.87	1.0	1.47	2.08	1.0	2.08	1.47
12	Other areas	32	--------	2.44	--------	--------	--------	--------	--------	--------	5.13	4.52	2.31	2.42	--------	3.39

On comparing the geometric means of the elements in samples from Deer Flat with those from other Triassic rocks of the Colorado Plateau as reported by Miesch (1955, p. 129), we find them to be approximately equal for some elements and higher or lower for others. The relatively high aluminum content of barren Shinarump from Deer Flat (table 7) indicates that the host rock there contains more mudstone than elsewhere. The ore contains more copper at Deer Flat than elsewhere on the plateau. There are differences also, in the amounts of boron and chromium—elements commonly contained in detrital minerals—which may indicate that the Shinarump sediments in the Deer Flat area had a different source than the Chinle sediments in other districts.

The geometric deviations of aluminum, sodium, and strontium are higher than is reported by Miesch (1955, p. 129); perhaps there is more variation of these three elements within the Hideout No. 1 deposit than there usually is between separate ore deposits. Barium, vanadium, and zinc appear to be much less variable; their geometric deviations are only about half as large as those found by Miesch (1955, p. 129) in "ore" samples, which may indicate important variations in the concentration and distribution of these elements. In the "barren" samples from this deposit, the geometric deviation of copper is approximately the same that Miesch reports for copper in barren sandstones of Late Triassic age.

The geometric means of barium, yttrium, and zirconium in the Hideout No. 1 cores are markedly lower than for the other Triassic ores. The differences in values for yttrium and zirconium here and elsewhere may be due to a difference in the sources of the Chinle sediments, since these elements commonly occur in certain detrital minerals that are irregularly distributed.

Studies of individual deposits in other districts, as opposed to averages for groups including many deposits, may reveal similar statistical differences between samples of different deposits. The significance of the differences summarized in table 7 cannot be judged from our present limited knowledge. Some of the differences are probably due to variations in the methods of sampling. The "ore" samples used by Miesch (1955) were all obtained from mill pulps, and all represent material from widely scattered localities that was mined and shipped as ore. A few were from shipments that contained less than 0.10 percent U_3O_8, either with or without sufficient vanadium content to qualify as ore. The "barren" samples, selected on the basis of low radioactivity, were collected at relatively great distances from mineralized ground. The Hideout No. 1 samples, on the other hand, are mainly from diamond-drill holes that penetrated a single ore body. Thirty-nine of the samples from drill cores contained 0.02 percent or more of U_3O_8, and therefore were classed as "ore" in the statistical analysis. The four "barren" samples from drill core contained less than 0.02 percent U_3O_8, and were from rock that was either immediately adjacent to ore layers or between them.

Correlation coefficients of uranium with each of the elements reported in the spectrographic analyses (table 5) were calculated for the 43 samples from drill cores. Some of the correlation coefficients among various selected elements, particularly the metallic ones, were also calculated and are presented in table 8. This table shows three

TABLE 8.—*Some correlation coefficients among 16 selected elements reported in spectrographic analyses of 43 samples from drill core, Hideout No. 1 deposit, Deer Flat area, White Canyon district, San Juan County, Utah*

Values of correlation coefficient for 3 levels of confidence and 42 degrees of freedom calculated by linear interpolation from a table by Davies (1949, p. 276)

Confidence level (percent)	*Significant value of correlation coefficient (independent of algebraic sign)*
10	0.252
5	.297
1	.385

	U	Cu	Pb	Zn	Fe	Co	Mg	Zr	Mn	Ba	Ca	Mo	Ni	Sr	Cr	Al
U	U															
Cu	+.70	Cu														
Pb	+.47	+.32	Pb													
Zn	+.37	-	+.45	Zn												
Fe	+.34	-	-	-	Fe											
Co	+.12	−.17	-	-	+.00+	Co										
Mg	+.10	-	-	-	-	-	Mg									
Zr	+.10	-	-	-	-	-	-	Zr								
Mn	+.06	-	-	-	+.37	-	-	-	Mn							
Ba	−.01	-	-	-	-	-	-	-	-	Ba						
Ca	−.03	+.18	−.51	−.30	-	-	+.55	-	+.29	+.20	Ca					
Mo	−.06	−.16	-	-	−.42	-	-	-	−.01	−.44	-	Mo				
Ni	−.06	−.32	-	-	-	+.69	-	-	-	-	-	+.31	Ni			
Sr	−.17	-	-	-	-	-	-	-	-	+.38	+.20	-	-	Sr		
Cr	−.24	-	-	-	-	−.22	-	+.21	-	-	-	-	-	-	Cr	
Al	−.36	−.45	-	-	−.03	+.03	+.04	+.16	-	-	-	-	-	-	+.39	Al

levels of significance for different values of correlation coefficients. The coefficients of correlation in tables 7 and 8 were obtained by using an adaptation of the product-moment method, in which the data are assigned to class intervals and then manipulated in a correlation table constructed by Blair (1944, p. 280).

According to Snedecor (1946, p. 166), rank correlations between groups of independently variable data containing more than eight samples may be tested for significance in the same table that is used for testing product-moment correlations. For some of the elements, however, the analyses show a narrow spread of values; if one of a pair of elements has a spread of fewer than five classes, the product-moment method can give a spurious correlation. Because of this possibility, all the pairs in which the values for one of the elements has a spread of less than five classes were tested for correlation by using a modified form of Kendall's rank-correlation method, according to a method described by Stuart (1953, p. 105–110). The results of these tests are compared with the product-moment coefficients for such pairs in table 9. They are all lower than those obtained by the product-moment method, but only the rank-correlation coefficient for the calcium-zinc pair is below the 10 percent significance level.

TABLE 9.—*Comparison of rank-correlation coefficients with product-moment correlation coefficients. Values of the correlation coefficients for different levels of significance are the same as those in table 8*

Groups of elements tested for correlation	Number of class intervals	r_c [1]	r [2]	Difference
Al–U	6–9	−0. 29	−0. 36	0. 07
B–U	3–9	−. 15	−. 17	. 02
Be–U	4–9	+. 03	+. 02	. 01
Cr–Al	4–6	+. 31	+. 39	. 08
Cr–Co	4–6	−. 12	−. 22	. 10
Cr–U	4–9	−. 18	−. 24	. 06
Fe–Al	4–6	−. 07	−. 03	. 04
Fe–Co	4–6	−. 02	+. 004	. 016
Fe–Mn	4–5	+. 30	+. 37	. 07
Fe–Mo	4–7	−. 33	−. 42	. 09
Fe–U	4–9	+. 26	+. 34	. 08
Mg–Ca	5–6	+. 45	+. 55	. 10
Ni–Co	4–6	+. 61	+. 69	. 08
Ni–Cu	4–11	−. 27	−. 32	. 05
Ni–Mo	4–7	+. 28	+. 31	. 03
Ni–U	4–9	−. 12	−. 11	. 01
Ti–U	4–9	−. 24	−. 25	. 01
V–U	3–9	−. 10	−. 11	. 01
Zn–Ca	4–6	−. 22	−. 30	. 08
Zn–Pb	4–7	+. 36	+. 45	. 09
Zn–U	4–9	+. 29	+. 37	. 08
Zr–Al	3–6	+. 12	+. 16	. 04
Zr–Cr	3–4	+. 14	+. 21	. 07
Zr–U	3–9	+. 08	+. 10	. 02

[1] Correlation coefficients calculated by Stuart's (1953) modification of Kendall's rank-correlation method.
[2] Correlation coefficients calculated by Blair's (1944) product-moment method.

A significant coefficient of correlation between two elements does not prove that the elements correlate with each other, but the higher the correlation is, the more unlikely it is that the correlation is due to pure chance. For example, at a significance level of 1 percent a coefficient of correlation equal to or greater than 0.385 means that out of 100 sets of 43 samples each, 1 set might, by pure chance, have a correlation coefficient equal to or greater than 0.385.

The positive correlation coefficients of both copper and iron with uranium supports the evidence obtained from the fieldwork and study of polished sections that uranium minerals are intimately associated with copper sulfides and copper-iron sulfides. Lead and zinc also show significant correlations with uranium. Radiogenic lead would be expected to correlate with uranium, since it is a product of radioactive decay. The amount, however, of radiogenic lead resulting from radioactive decay of uranium in samples from the Colorado Plateau should equal only about 1 percent of the uranium present (T. W. Stern, oral communication, 1955), but in the Hideout No. 1 samples the amount is much greater than 1 percent. This fact indicates that lead was introduced during processes of uranium mineralization. The Hideout No. 1 deposit contains a little galena, and both galena and sphalerite were found in other deposits in the Deer Flat area. Zinc has a lower coefficient of correlation with uranium than lead, perhaps because no zinc is generated by radioactive decay, or perhaps because zinc is more mobile than lead in an oxidizing sulfate environment and may therefore have been partly removed by oxidizing solutions.

The positive correlation of yttrium with uranium (table 7) may indicate some introduction of yttrium by the ore solutions, but it may only mean that the mineralized sandstone was originally richer in yttrium-bearing detrital minerals than the barren sandstone and the mudstone. Another possibility is that yttrium is concentrated in the fossil plant fragments.

The negative correlation of aluminum with uranium and copper is consistent with the field observation that uranium and copper minerals are more abundant in relatively clean sandstone than in muddy sandstone or in mudstone. Much of the aluminum probably occurs in kaolinite, which according to Schultz (1955, p. 124–125) is the most abundant clay mineral in the lower part of the Chinle formation in this region.

Sodium and potassium also correlate negatively with uranium, perhaps because they occur chiefly in clay minerals. Gallium also correlates negatively with uranium, probably because it occurs in clay or in fine-grained detrital minerals contained in the mudstone.

Barium, calcium, and magnesium have a weak correlation with uranium. The strong correlation of magnesium with calcium, together with its apparent lack of correlation with aluminum, probably means that most of the magnesium is in carbonate. Calcite and dolomite are present in ore specimens, and polished sections give evidence that they were introduced both earlier and later than uraninite and may represent separate phases of mineralization. Barite is apparently later than uraninite. It is surprising that barium does not have a strong negative correlation with uranium, for barite is presumably deposited from sulfate solutions, which might dissolve uraninite if their pH were low. Polished sections show little if any replacement of uraninite by barite (fig. 14). Under laboratory conditions, however, barium sulfate may precipitate from solution through a wide range of pH (Leonard B. Riley, oral communication, 1956), and it therefore seems likely that the solutions from which the barite was precipitated were not acidic enough to dissolve appreciable amounts of uraninite.

The weak correlation of aluminum with magnesium indicates that chlorite is not a major constituent of the clay. The strong correlation of chromium with aluminum suggests either that the clay minerals contain chromium oxide substituted for aluminum oxide within the clay structure, or that the chromium occurs in the mudstones as a constituent of detrital minerals other than chlorite.

The strong correlation of manganese and iron, together with the weaker correlation of manganese and calcium, indicates that most of the manganese occurs in the carbonate, manganosiderite, which may be one of the early carbonates.

Cobalt correlates strongly with nickel, and nickel correlates moderately well with molybdenum. All three are noncorrelative with uranium and copper, and cobalt and molybdenum are noncorrelative with iron. This suggests that cobalt, molybdenum, and nickel are not wholly contaminants, though they are distributed independently of copper and uranium.

Strontium is noncorrelative with uranium and calcium, but has positive correlation with barium. This suggests that strontium may occur in a sulfate associated with the barite, but strontium is too scarce to form identifiable strontium minerals.

The correlation coefficients indicate that the associations among the elements in the ore deposit are similar to those that can be inferred from the field and laboratory observations of the mineralogy of the deposit. The statistical analysis of chemical and spectrographic data thus confirms and supports these observations.

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DESCRIPTIONS OF SELECTED MINES AND PROSPECTS

HIDEOUT NO. 1 AREA

The Hideout No. 1 claim is in sec. 14, T. 36 S., R. 17 E. (pl. 1). This and the contiguous claims are owned by the White Canyon Mining Co. of Cortez, Colo. The area mapped includes part of the Hideout No. 1 channel, which was first drilled by a private company under contract to the U.S. Geological Survey. This area was geologically mapped on a scale of 1 inch to 200 feet (pl. 3), and the part of the claim in the vicinity of the mine workings was also mapped on a scale of 1 inch to 20 feet (pl. 2). The underground workings of the Hideout No. 1 mine were mapped by compass and tape measurements on a scale of 1 inch to 20 feet (fig. 16).

The uranium-copper deposits at the Hideout No. 1 mine are mostly in sandstone in the lower 10 feet of the Shinarump member of the Chinle formation, at places where it fills scours in the Moenkopi formation and is overlain by mudstone or siltstone (pl. 4 and fig. 17). Coalified wood fragments, in sandy siltstone or mudstone as well as in sandstone, commonly contain uranium in the Hideout No. 1 mine, and the uranium in mudstone seems to be concentrated in fossil plant material.

Small concentrations of uranium and copper minerals are found in the sandstone and mudstone in the Chinle above the Shinarump member, but none of them are of ore grade. Copper and uranium minerals also occur sparsely in rocks that do not seem to be in any channel.

The uranium minerals in the mine are uraninite, bayleyite, schroeckingerite, and uranophane; the copper minerals are chalcopyrite, bornite, chalcocite, covellite, malachite, and azurite. Other minerals associated with the deposits are calcite, manganosiderite, dolomite, jarosite, gypsum, limonite, montmorillonite, pyrite, manganese oxides, and barite.

The Shinarump member of the Chinle formation in the Hideout No. 1 mine area ranges from 17 to 49 feet in thickness. It intertongues with and grades laterally as well as upward into the variegated siltstone and fine-grained sandstone of the mudstone-sandstone unit.

Two very prominent sets of joints cut the rocks in the vicinity of the Hideout No. 1 claim. The most prominent set strikes N. 45° to 70° E. and dips from 65° SE. to vertical; the other strikes N. 35° to 45°W. and dips 85° SW. to 72° NE. (pl. 2). A less prominent set of joints trends N. 10° E. to N. 25° W., and dips from 80° E. to vertical. The joints are more conspicuous in the Shinarump member and the underlying Moenkopi formation than they are in the beds above the Shinarump. Penecontemporaneous normal faults with displacements as

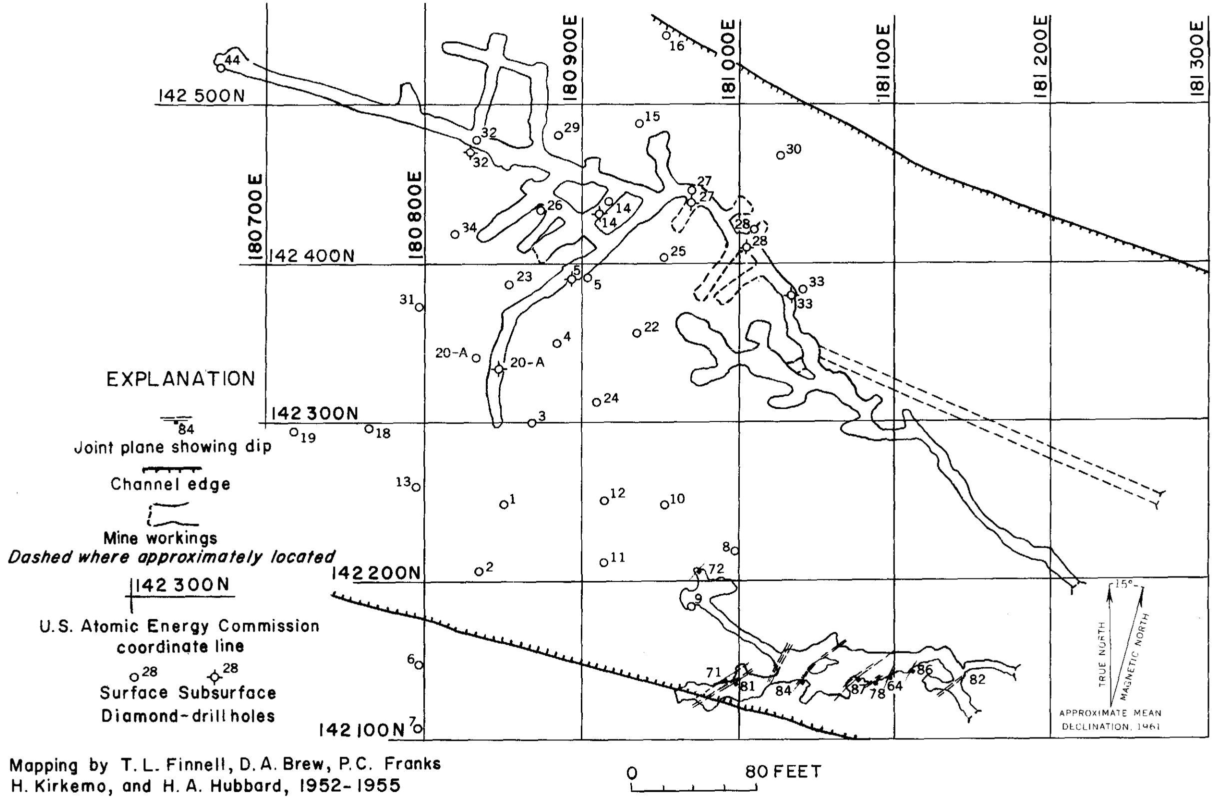

Figure 16.—Map of Hideout No. 1 mine workings, April 1955.

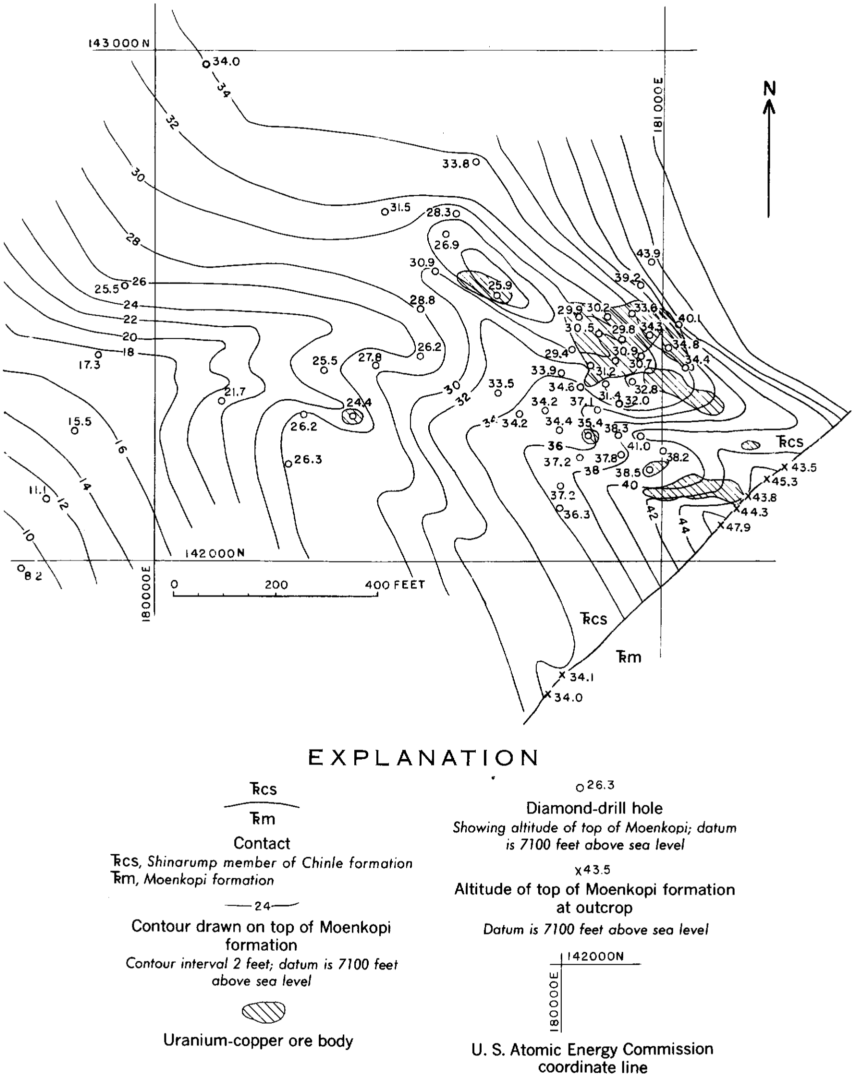

FIGURE 17.—Map showing contours on top of the Moenkopi formation in and near the Hideout No. 1 channel and location of ore bodies in the channel.

much as 6 inches cut the upper 14 feet of the Shinarump. The faults of largest throw strike north and dip 52° to 65° W., and those of smaller throw strike about N. 47° W. and dip 70° to 75° NE. (pl. 2). The ore-bearing parts of the Shinarump commonly contain shattered quartz pebbles and appear to be slightly brecciated, but no faults were seen that cut ore. The possible control of this channel by pre-Shinarump structure has been discussed in the section on channels.

Diamond drilling for the U.S. Geological Survey was started on the Hideout No. 1 claim August 24, 1953, and continued until June 10, 1954, except for the winter. The distribution of the 55 holes drilled in and near this claim and the relation between the holes and the channel are shown on plate 3. Holes DF–1 to DF–7 were placed on 50-foot centers along a line that is normal to the inferred trend of the small scour in the Hideout channel, and lies 150 feet N. 70° W. of what was in August 1953 the deepest part of the Hideout No. 1 mine workings. These holes show that the small scour near the southwest bank of the Hideout channel is separated from the main channel by a low ridge, only 1 to 2 feet high, on the channel floor (pl. 4 and fig. 17). Diamond-drill holes DF–14 to DF–17 extend the line of holes to the northeast and define the northeast side of the Hideout channel.

Ore was cut by holes DF–4, DF–5, and DF–14, indicating a large ore body in the main channel. Therefore, offsets were drilled on 50-foot centers at the corners of equilateral triangles to delimit the ore body and determine its relation to the channel. Structure contours on the top of the Moenkopi formation indicate that the ore body is updip from a scour in the bottom of the channel.

Holes DF–35 to DF–40, and hole DF–42 are on a second line, about 400 feet N. 70° W. of the first line. DF–39 penetrated ore in a small tributary channel, and an additional hole, DF–51, was therefore drilled to define the southwest bank of the channel (pl. 3 and fig. 17).

Holes DF–48, 49, 50, 52, and 55, drilled on 150-foot centers along a line normal to the inferred trend of the channel and about 1,200 feet from the channel outcrop, showed that the course of the channel swings from N. 70° W. to S. 70° W. within a distance of 600 feet (pl. 3 and fig. 17). In these holes the Shinarump member is thin and the channel is shallow and indistinct.

All the other holes except DF–43 and DF–54 were drilled either as offsets of ore holes or to explore the channel between the lines of holes. DF–43 was drilled to investigate an area of low resistivity outlined by geophysical methods; the hole penetrated 19 feet of medium- to coarse-grained and conglomeratic sandstone that contains very little mudstone or clay and is only moderately well cemented (core log, p. 93–95). This sandstone, though in the Shinarump member, does not seem to fill a channel. DF–54 showed that DF–50 was on the channel bank rather than on a hump in the channel floor.

The Hideout channel is 300 to 500 feet wide, and its deepest part is cut about 15 feet into the Moenkopi formation (pl. 3). The channel becomes shallow and poorly defined about 1,200 feet west of the place where it is exposed (fig. 17).

W. N. AREA

The W. N. area is on the southwest side of Deer Flat, in sec. 21, T. 36 S., R. 17 E. (pl. 1). The W. N. mine is owned by the White Canyon Mining Co., which has operated it intermittently since 1953. The area near the mine was mapped on a scale of 1 inch to 200 feet (pl. 5), and the outcrops near the mine and the mine workings were mapped by compass and tape measurements on a scale of 1 inch to 20 feet (pl. 6).

The uranium-copper deposits at the W. N. mine are mainly in sandstone in the lower 10 feet of the Shinarump member at places where it fills scours in the Moenkopi formation (figs. 18 and 19). Coalified plant fragments and "asphaltite" contain most of the uranium in the deposits, but some ore minerals are disseminated in sandstone both within the deposits and in sandstone that is not in recognized channels. The uranium minerals in the mine are uraninite, zippeite, and an unidentified secondary uranium sulfate (Weeks, written communication, 1955); the copper minerals are chalcopyrite, bornite, chalcocite, covellite, and malachite. Other minerals associated with the deposits are galena, sphalerite, pyrite, calcite, jarosite, limonite, gypsum, manganese oxides, boothite, and alunogen. We found pink cobalt bloom near sulfide concentrations, and Gruner and others (1954, p. 24) report an unidentified pink cobalt mineral. Grains of black, vitreous asphaltite are disseminated in sandstone in the lower part of the Shinarump member. A brown viscous liquid—an unidentified petroleum substance—seeps from a sandstone lens in the roof of the south adit of the W. N. mine, opposite subsurface station 3 (pl. 6).

The Shinarump member at the W. N. mine can be subdivided into two parts which may be equivalent to the middle and upper units at the Hideout No. 1 mine. The lower part, which ranges in thickness from less than 1 to 13 feet, rests with marked disconformity on the Moenkopi formation. It fills the W. N. channel and locally extends beyond its banks (pl. 6). It is composed of lenticular and interbedded sandstone, mudstone, and conglomerate, which may grade into one another over short horizontal distances (pl. 6, cross sections). The rocks are for the most part unstratified, or at best poorly stratified, but locally they show crossbeds and flat beds. The sandstone contains as much as 20 or 30 percent mudstone and clay, and coalified wood and asphaltite are found in almost every exposure. It shows many contemporaneous faults and folds.

The upper part of the Shinarump member rests disconformably on an erosional surface on the lower part, and in some places it fills channels that have been cut all the way through the lower part. The upper part ranges in thickness from 10 to 35 feet, and in places it extends beyond the banks of the W. N. channel to rest with marked disconformity on the Moenkopi formation. The rocks of the upper part are massive crossbedded friable sandstone and conglomeratic sandstone, containing a few mudstone layers as much as a foot thick. The cross-stratification is on a moderate scale, partly planar and partly of the trough type. The sandstone contains as much as 10 percent interstitial clay and the quartz grains commonly have secondary crystal overgrowths. This part contains coalified wood (both fragments and logs), asphaltite, and interbedded mudstone, but all these are much less abundant than in the lower part.

The top of the Moenkopi formation at the W. N. mine strikes N. 30° W., and dips about 2° SW. Joints that cut the rocks at the mine are all nearly vertical and are in two prominent sets. One set trends N. 20° E. to N. 50° E., nearly parallel to the rim of Deer Flat; the other set trends N. 45° W. to N. 68° W.

The rocks of the Shinarump member in the W. N. channel are cut by irregularly oriented fractures, most of them less than 2 inches long but some of them several feet long. These fractures cut pebbles and quartz grains, which shows that they were formed after the sediments were consolidated. Some of the fractures contain ore minerals, but most of them, especially those with slickensided surfaces, are filled with gypsum and jarosite.

At one point on the channel outcrop (pl. 6, between stations FR–8 and FR–9) a sandstone lens about 50 feet long, overlain and underlain by mudstone, is cut by two groups of normal faults that dip toward the middle of the lens. The middle part of the lens is about 5 feet below its edges. The faults at the north end of the lens strike N. 65° W. and dip 60° to 70° SW.; those at the south end strike about

N. 80° W. and dip 20° to 40° NE. The eastward convergence of the faults indicates that the sandstone lens was displaced not only downward but westward. Cross sections across the W. N. channel (pls. 5 and 6) here and farther east show that the top of the Shinarump member above the channel is depressed. This feature is attributed to compaction of the channel sediments.

Diamond drilling for the U.S. Geological Survey to investigate the W. N. channel was started in June 1954 and completed in August 1954. Holes were drilled on 150-foot centers along 3 lines, approximately normal to the inferred trend of the channel (pl. 5). The first line was 250 to 350 feet east of the channel outcrop; the second, 800 to 1,200 feet east; and the third, 1,400 to 1,800 feet east. Additional holes were drilled on 300-foot centers to investigate the ground between the lines of holes, and the limits of ore bodies were determined with holes drilled on 100-foot centers from the holes that penetrated ore. Two additional holes were drilled on 50-foot centers in the adjacent Dead Buck channel (fig. 18), and 2 more on 300-foot centers east of the last line of holes.

The configuration of the eroded surface at the top of the Moenkopi indicates that the W. N. channel trends approximately S. 80° W. and is about 700 to 1,000 feet wide (figs. 18, 19). The channel has an irregular floor and is about 10 to 15 feet deep. Its banks are not everywhere well defined, and it seems to be joined by tributary channels. Three lows, two of which merge near the outcrop, extend roughly parallel to the W. N. channel (figs. 18, 19); on either side of that channel there are two terraces, possibly cut by tributaries on the top of the Moenkopi formation.

Figure 19 is a contour map of the W. N. channel as it would appear if the top of the Moenkopi, now dipping about 2° S. 60° W., were made horizontal. In figure 19 three of the lows in figure 18 appear as closed depressions, and the terraces of figure 18 appear as tributary channels. As the removal of the regional dip would also remove the initial topographic gradient on top of the Moenkopi formation, the closure of the depressions is probably exaggerated.

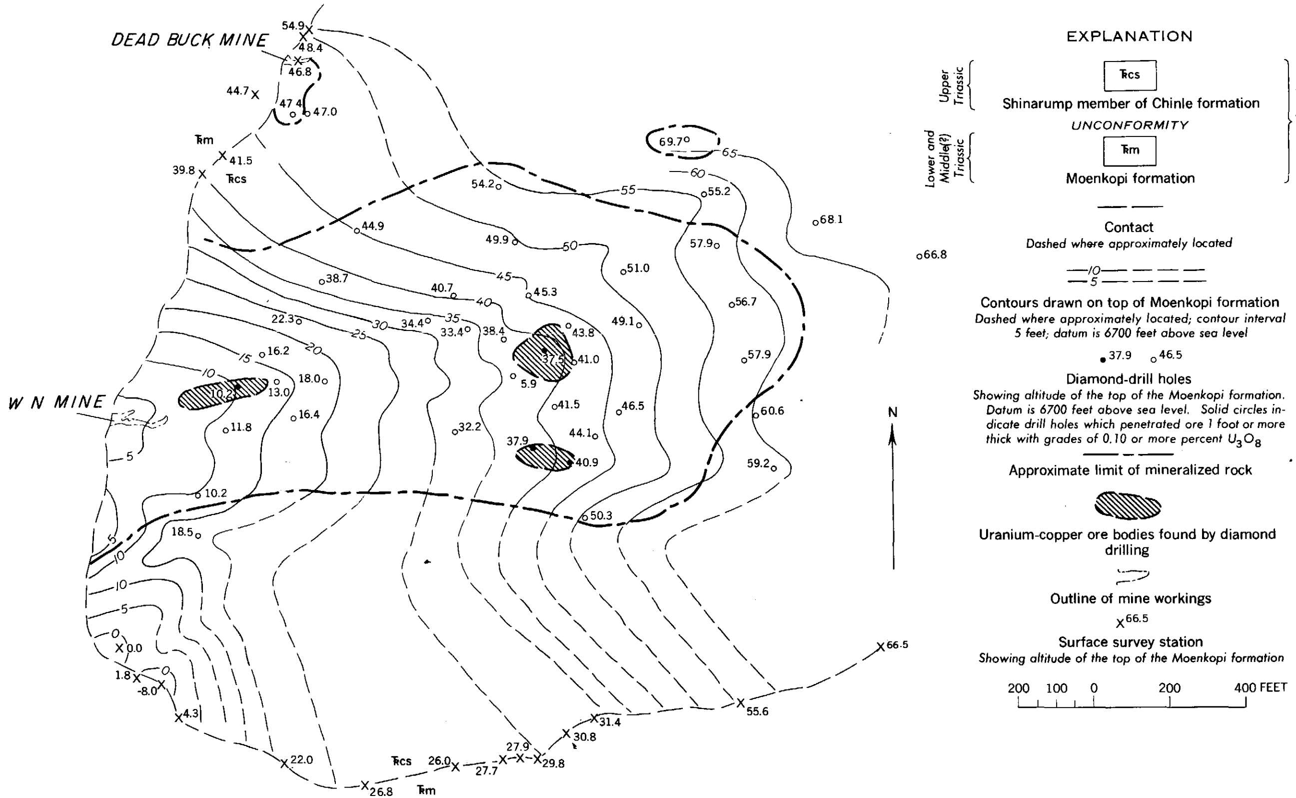

Figure 18.—Map showing contours on top of the Moenkopi formation, and location of ore bodies at the W. N. channel.

COMPARISON OF W. N. AND HIDEOUT NO. 1 CHANNELS

The W. N. channel and the Hideout No. 1 channel were compared (table 10) in the hope that differences in lithology of the host rock and configuration of the channels might indicate factors that are important for the localization of uranium-copper ores. It was also hoped that the comparison might explain why there is less ore at the W. N. mine than at the Hideout No. 1, even though the W. N. channel is the larger of the two. Most of the data used in the comparison were obtained from the U.S. Geological Survey's logs of core drilled in the channels. Since the ore at both mines is generally restricted to the lower 10 feet of the Shinarump member of the Chinle formation, most of the comparisons apply to material within that interval.

TABLE 10.—*Comparison of the W. N. and Hideout No. 1 channels, Deer Flat area, White Canyon district, San Juan County, Utah*

	Hideout No. 1 channel	*W. N. channel*
Average thickness of Shinarump member of Chinle formation (all thickness in feet)	35	30
Average sandstone-mudstone ratio	3.1:1	3.6:1
Average sandstone-mudstone ratio in ore zone	4.8:1	1.7;1
Percent medium- to coarse-grained and conglomeratic sandstone	32	37
Percent medium- to coarse-grained and conglomeratic sandstone in ore zone	40	20
Average thickness of medium- to coarse-grained and conglomeratic sandstone penetrated by drill holes in ore zone	2.1	2.5
Range of thickness of individual beds of medium- to coarse-grained and conglomeratic sandstone penetrated by drill holes in ore zone	0–10	0–9
Average number of medium- to coarse-grained and conglomeratic sandstone beds penetrated by drill holes in ore zone	1.8	0.8
Range of number of medium- to coarse-grained and conglomeratic sandstone beds penetrated in individual drill holes in ore zone	0–9	0–3

It was found that the mineralogy, coalified wood content, size and grade of ore bodies, and position of ore bodies relative to scours in the channel floors are similar in the two channels. It was also found that the average thickness of the Shinarump member is about 35 feet at the Hideout mine and 30 feet at the W. N. mine—a difference that seems too small to affect the localization of ore.

Sandstone constitutes about 80 percent of the lower 10 feet of the Shinarump member in the Hideout No. 1 channel, but only 60 percent in the W. N. channel.

Most of the ore found in the Hideout No. 1 mine is in medium- to coarse-grained and conglomeratic sandstone, whereas some of the ore in the W. N. mine extends into fine- to medium-grained sandstone.

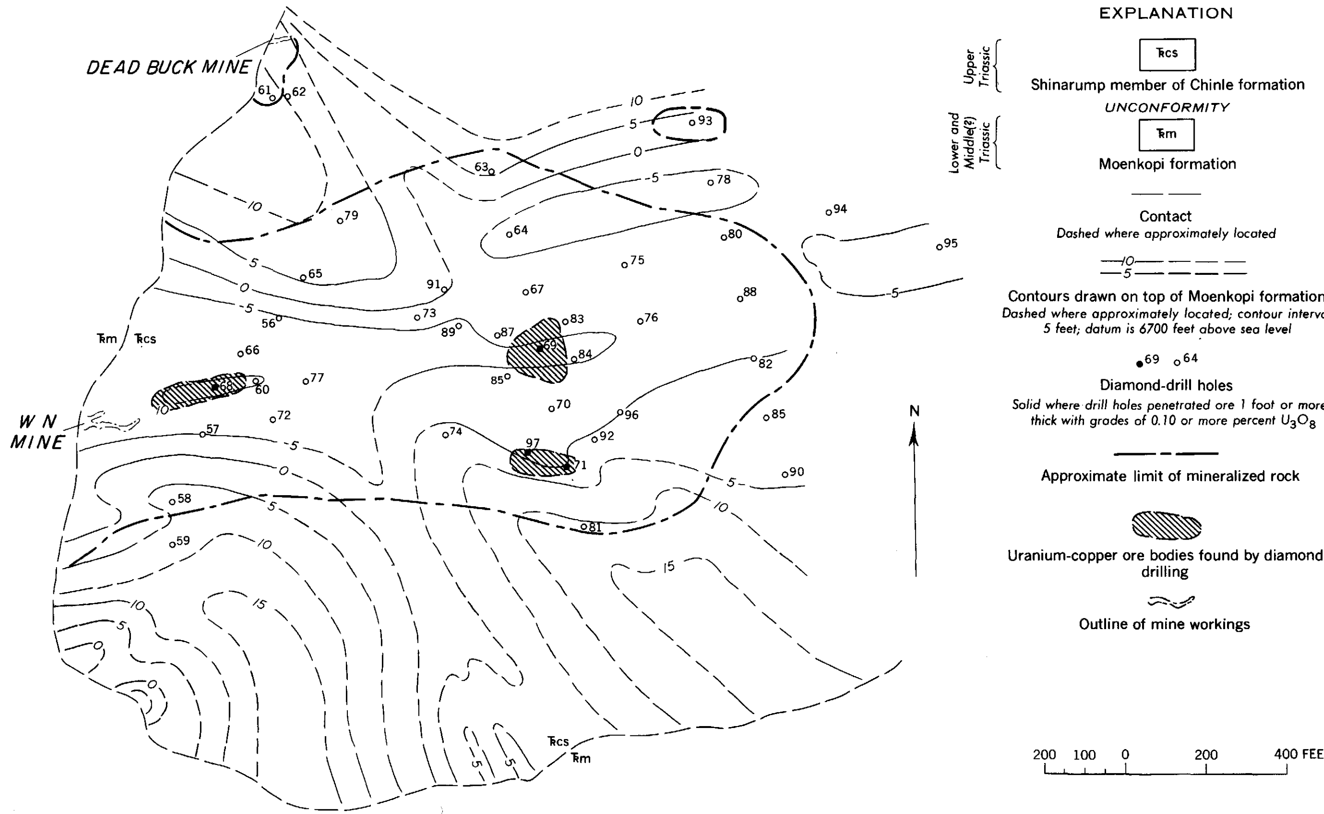

Figure 19.—Map showing contours on the restored top of the Moenkopi formation and location of ore bodies at the W. N. channel.

Medium-grained to conglomeratic sandstone constitutes about 20 percent of the lower 6 feet of the Shinarump member at the W. N. mine, and about 40 percent of the lower 6 to 8 feet of that member at the Hideout mine. At both mines, these rocks occur in lenses, but the lenses seem to be larger, more continuous, and more interconnected in the Hideout channel than in the W. N. channel. At the W. N. mine the sandstone lenses in the ore zone are commonly surrounded by mudstone, but at the Hideout mine very few of them are. At the Hideout mine, moreover, the channel fill is separated from the upper part of the Shinarump member by a relatively continuous mudstone layer, which may have helped confine the ore-bearing fluids to the channel. No such continuous mudstone layer separates the lower and upper units of the Shinarump member at the W. N. mine.

The depth of the channels at the two mines is about the same, ranging from 12 to 15 feet. The width of the channels, however, is considerably different: the W. N. channel is about 700 to 1,000 feet wide, and the Hideout channel only about 300 to 500 feet wide. The smaller width of the Hideout channel as compared with the W. N. channel probably accounts indirectly for the greater tonnage of ore at the Hideout mine. The stream in the narrower channel presumably had the swifter current and deposited more of the coarse-grained material in which ore was most readily deposited. The greater continuity of the beds in the Hideout No. 1 channel, moreover, would help to give them greater effective permeability.

CAMEL AREA

The Camel channel is in the S½ sec. 12, T. 36 S., R. 17 E., on the southeast side of Deer Flat (pl. 1). This prospect is owned by the White Canyon Mining Co. During September 1954, private companies under contract to the U.S. Geological Survey drilled 22 holes (98–119) on 150-foot centers in the Camel channel area (pl. 7). When the northeasternmost of 6 holes, drilled on a line normal to the inferred trend of the channel (N. 55° W.), reached the base of the Shinarump at a level 10 feet lower than the projected position of the channel bank, more holes were drilled, extending the line 300 feet farther to the northeast. In the cross section along this line (pl. 7) the Shinarump is shown as filling two adjacent channels. Contours based on drill holes (fig. 20) indicate that the larger and deeper chan-

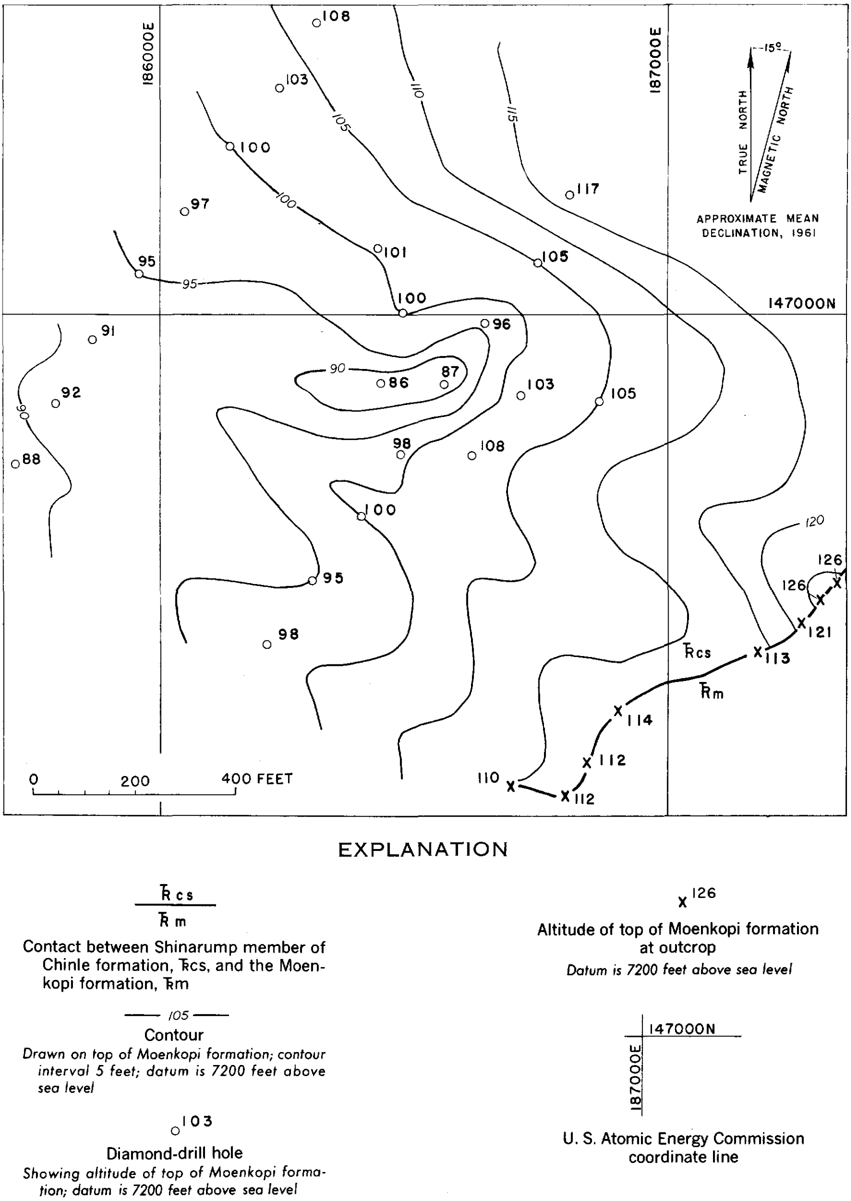

FIGURE 20.—Map showing contours on top of the Moenkopi formation in the Camel channel area.

nel trends westward, and that the smaller and shallower channel is tributary to it.

The Shinarump member is about 10 to 30 feet thick at the outcrop in this area, and in the Camel channel it consists mainly of fine- to medium- and coarse-grained locally conglomeratic sandstone interbedded with a large proportion of mudstone and containing much interstitial kaolinite. It contains pebbles of quartz and siltstone, and also pebbles and cobbles of clay, as much as 4 inches in diameter, in which there are small concentrations of uranium and copper minerals. Coalified wood fragments as much as an inch in diameter are locally abundant but are generally rare. The Shinarump member is thin at the south end of the outcrop (pl. 7), and it pinches out about 1,500 feet southwest of the channel edge (pl. 1). Along the northeast edge of the channel, near the end of the bulldozer cut shown in plate 7, the sandstone in the Shinarump member grades laterally into an alternating sequence of sandstone and siltstone.

In the Camel channel the Shinarump member is only weakly mineralized near mudstone beds and is virtually barren where it contains no mudstone beds. The lack of uranium deposits here is probably due to the fact that the Shinarump is generally thin and contains very few mudstone beds where it is thickest (pl. 7); it also contains little fossil plant material.

SANDY NO. 3 AREA

The Sandy No. 3 channel is in the N½ sec. 17, T. 36 S., R. 18 E., and crops out on the southeast side of Upper Lost Parks (pl. 1). The Sandy No. 3 mine is owned by Burdett and Merwin Shumway of Blanding, Utah. The area around the mine was mapped on a scale of 1 inch to 200 feet (pl. 8).

The uranium deposits in the Sandy No. 3 channel are localized near the base of sandstone of the Shinarump member, which fills the channel. Most of the ore that has been mined (pl. 8) was in small bodies 6 to 8 feet wide, 10 to 20 feet long, and as much as 2 feet thick. The ore averaged less than 0.20 percent U_3O_8, but its grade was somewhat improved by patches of sooty uraninite. Coalified plant fragments contain much of the uranium, but some uranium minerals are finely disseminated in sandstone, and coat joint surfaces and bedding planes. The uranium minerals in the mine are uraninite, uranophane, and an unidentified green uranium-copper mineral; the copper minerals are chalcopyrite, malachite, and native copper. Other minerals associated with the deposits are pyrite, gypsum, calcite, limonite, and jarosite.

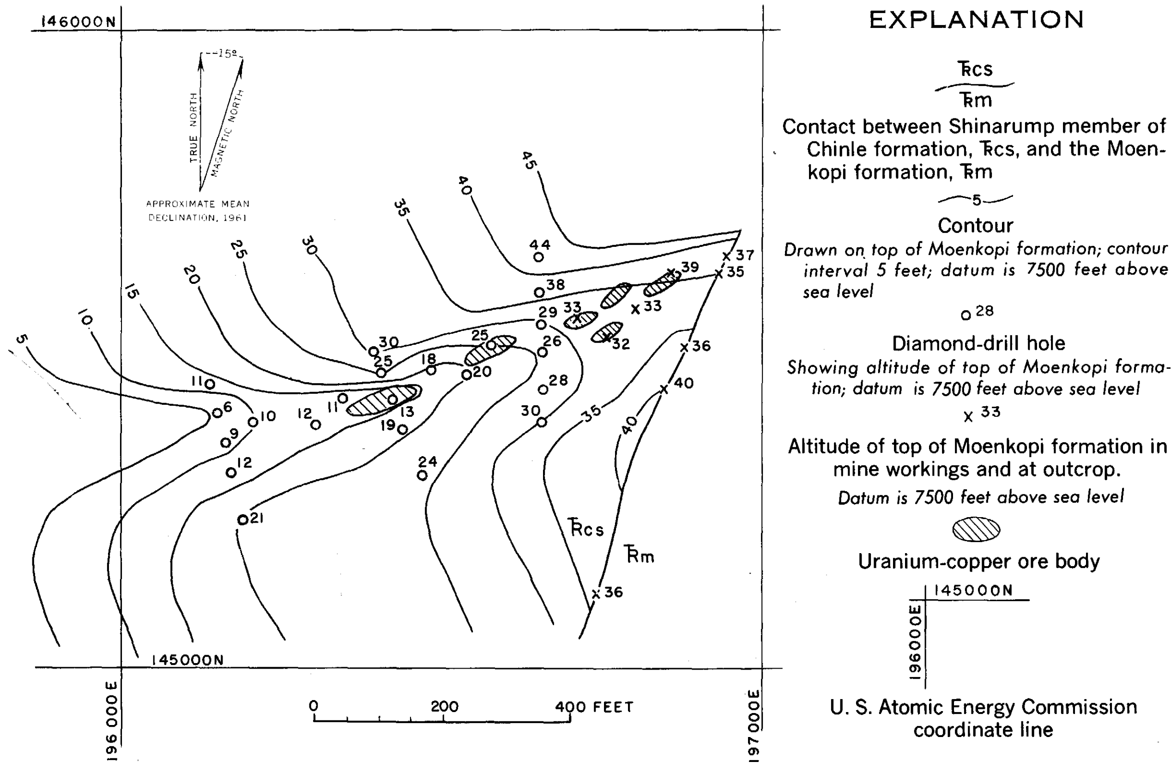

FIGURE 21.—Map showing contours on the top of the Moenkopi formation in the Sandy No. 3 channel area.

The Shinarump member in the Sandy No. 3 area is as much as 42 feet thick (table 1), and consists of fine- to coarse-grained and conglomeratic sandstone containing lenses of mudstone and siltstone.

The top of the Moenkopi formation at the Sandy No. 3 channel strikes about N. 46° W. and dips about 1° SW. The beds of the Shinarump member and the Moenkopi formation are cut by two sets of vertical joints that strike about N. 70° W. and N. 30° E. Some of the joints in the Shinarump member are filled with thick (half an inch) veinlets of limonite. Where one of these veinlets extends into the Moenkopi, its walls have been partly altered to what seems to be alunite in a zone as much as an inch wide, extending as much as a foot below the base of the Shinarump member. The alteration is probably due to sulfuric acid derived from the oxidation of pyrite to limonite along the joints.

During September and October 1954, 22 holes on 50-foot centers were drilled on the Sandy No. 2 and Sandy No. 3 claims by private companies under contract to the U.S. Geological Survey. These holes are in 3 lines about at right angles to the channel trend; the distances of these lines from the channel outcrop are respectively 300 feet S. 87° W., 550 feet S. 70° W., and 810 feet S. 70° W. The results of the drilling indicate that the channel trends S. 70° W. (fig. 21), and 4 holes drilled by the claim owners indicate that the channel extends beneath Upper Lost Parks for at least 1,400 feet (pl. 8). A single line of holes drilled by the claim owners along the road about half a mile west of the Sandy No. 3 portal cut a mineralized channel no more than 230 feet wide and 8 to 10 feet deep. If this is the Sandy No. 3 channel, its trend must swing from about S. 70° W. to about N. 80° W. in a distance of 1,700 feet. This is possible, but the Hideout and W. N. channels turn from north of west to south of west, as if turning away from the pinchout of the Shinarump member. If the channels are not the same, the one that is not the Sandy No. 3 could be traced by drilling to determine how much mineralized ground it contains.

GUIDES FOR EXPLORATION

The Deer Flat area has been so intensively prospected that most of its outcropping uranium deposits have probably been found, but a group of geologic criteria for recognizing ground favorable for ore, and hence for finding concealed deposits, has emerged from drilling tests.

The geologic guides that appear to be most useful in outlining favorable ground, in their general order of importance, are as follows:

1. All known ore deposits in the area occur in channels cut in the top of the Moenkopi formation and filled with sandstone of the Chinle formation, commonly belonging to the Shinarump member, and especially in scours, or partly closed depressions in the bottoms of channels. (See p. 51.) Channels and scours can be recognized only by establishing accurate elevations on the top of the Moenkopi formation. The sandstone that fills the channels may be thicker, thinner, or the same thickness as that on the channel banks; thickness of the host rock alone is not a reliable criterion for recognizing either channels or scours. Although the reason for the relation of uranium ore to scours is not clear, it may be a combination of favorable lithology with undulations of the channel floor that would influence the movement of uranium-bearing solutions.

2. Ore-bearing sandstone is gray, yellowish gray, or yellowish brown. Some barren sandstone beds are of these colors, but they are more commonly light gray, light yellowish gray, or pinkish. The only other distinctive feature of ore-bearing sandstone is that it invariably contains coalified plant fragments.

3. Coalified plant fragments localize uranium minerals within the ore-bearing sandstone. Carbonaceous material is widespread throughout the Chinle formation, and every significant ore deposit contains some. All the carbonaceous material, however, does not contain uranium, nor do all the uranium minerals replace it.

4. The ore bodies are overlain and underlain by lenses of mudstone or muddy sandstone. Sandstone that contains few or no mudstone or clay lenses is unfavorable for ore. On the other hand sandstone in which the interstices are mostly filled with mudstone and clay is also unfavorable. Mudstone associated with uranium ore is commonly gray and yellow, but it may also be mottled with red.

5. Anomalous radioactivity indicates the presence of uranium daughter products and should be investigated. Anomalies at the outcrop may help delimit an otherwise obscure mineralized channel, and anomalies in drill holes within channels indicate areas where additional holes should be drilled close together.

6. Uranium ore is consistently associated with covellite, bornite, chalcocite, chalcopyrite, malachite, azurite, brochantite, cuprite, pyrite, jarosite, limonite, gypsum, calcite, montmorillonite, kaolinite, manganese oxides, and quartz overgrowths on detrital grains. The copper minerals are generally associated with radioactive minerals, but the other minerals mentioned are widely distributed so that their significance when they are found in drill cores is hard to judge.

7. Local structures may have controlled ore deposition. The principal uranium deposits in the Deer Flat area are in channels where

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dips are lower than they are in nearby areas (pl. 1). Detailed study at the Hideout No. 1 channel (fig. 3) shows a channel on a local terrace that is downdip from a monoclinal steepening in the regional dip (fig. 4). This monoclinal flexure may have increased the gradient of the streams and thus caused the channel to be deepened, and it may also reflect a fault at depth that tapped a deep source of uranium.

CONCLUSIONS

Uranium in the Deer Flat area is mainly localized in channel fiills. Ore bodies found by diamond drilling are in sandstone that fills scours in channels cut into the top of the Moenkopi formation. Ore-grade material is found in all lithologic types, but the better ore is mostly in the coarser sandstone. Coalified wood evidently has an important effect on the localization of ore, perhaps it provides a reducing environment for ore deposition. From comparative studies of sandstone-mudstone ratios and grain size, and of lenticularity and continuity in favorable beds at the W. N. and Hideout mines, it appears that ore-grade material is localized in medium- to coarse-grained or conglomeratic sandstone interbedded with a relatively small amount of mudstone, resting on channel floors. The essential condition seems to be the presence of favorable host rock in a channel, overlain by a relatively continuous layer of mudstone that will confine the ore-bearing solutions.

The approximate course of a channel can often be found by averaging the dip directions of cross-strata and trends of ripple marks in the sediments at the bottoms of the channel and by plotting the trends of linear scours in the top of the Moenkopi.

In view of the above-noted coincidence of an ore-bearing channel with a small structural terrace at the Hideout No. 1 mine, it seems likely that accurate structure contouring can help in finding local structures that favor ore deposition.

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REPRESENTATIVE STRATIGRAPHIC SECTIONS

Section of the Hoskinnini member of the Moenkopi formation at the south end of an elongate ridge in the S1/2 sec. 36 (unsurveyed), T. 35 S., R. 16 E. Measured by H. A. Hubbard

	Thickness (ft)
Covered. No Hoskinnini float found above this point:	
4. Similar to unit 2 except that it weathers slightly grayish	8.3
3. Sandstone, dark reddish-brown (10*R*3/4),[1] weathering same color, very fine grained matrix, well cemented with calcite, enclosing many large rounded to subangular quartz grains, most of which are concentrated in light-colored pods. Underlies a smooth concave slope. Grades into those above and below	3.2
2. Sandstone, medium dark-gray (*N* 4), weathering grayish-orange (10*YR* 7/4), fine- to medium-grained, fairly well sorted; few large subrounded quartz grains, some of which have secondary crystal faces; well-cemented, calcareous. A black petroleum-like substance partly fills interstices and colors the rock. Bedding cannot be seen except at the bottom, where one irregularly folded bed ½ to ¾ inch thick can be seen. Forms bench with an irregular upper surface. Basal contact wavy	3.8
1. Sandstone, reddish-brown (10*R* 4/4), weathering same color, very fine to fine-grained with some grains as much as 2 mm in diameter, well-sorted; frosted quartz grains; firmly cemented, calcareous; forms cliff. Lower 2 to 3 ft irregularly mottled or altered to grayish-pink (5*R* 8/2). Many thin layers in which coarser grains are grouped to form bent lenses	28.4
Contact with Organ Rock tongue of the Cutler formation a sharply defined gently undulating surface.	
Total Hoskinnini member	43.7

Section of Shinarump member of the Chinle formation, Moenkopi formation, Hoskinnini member of the Moenkopi formation, and Organ Rock tongue of the Cutler formation at the south end of Deer Flat, in the E1/2 sec. 33, T. 36 S., R. 17 E. Measured by H. A. Hubbard.

Shinarump member of the Chinle formation:	
Covered.	
17. Sandstone, pale yellowish-gray, composed of moderately to well sorted subrounded quartz grains; weakly cemented, calcareous; parallel bedding; forms bench and low overhanging cliff	3.2
16. Sandstone, similar to unit 14 except that it contains no carbonaceous material; includes thin bed of quartzite pebbles (largest 1 in. in diam.) 5 in. above its base. Fills small channel in unit below	2.3

[1] Color symbol in parentheses is taken from Goddard, E. N., and others, 1948, Rock-color chart: Washington, National Research Council.

	Thickness (ft)
Shinarump member—Continued	
15. Sandstone, brownish-gray, fine- to medium-grained, moderately well sorted; composed of rounded to subangular quartz grains with a few opaque minerals, much white interstitial clay; fairly well cemented, calcareous; thinly bedded. Beds are slightly contorted and fill channels in underlying beds. Contains carbonaceous material along some bedding planes. Contains abundant patchy limonite stains; upper and lower margins of limonite patches commonly coincide with bedding planes	3.2
14. Sandstone, grayish-red purple (5*RP* 4/2), medium- to coarse-grained, well-sorted; composed of subangular to subrounded quartz grains, some with secondary overgrowths; some white interstitial clay; rock friable; no calcite cement; forms vertical cliff. Has abundant limonite stains; some carbonaceous material in matrix. Two-inch layer of green mudstone 2 ft above base. Base of Shinarump member. Contact between Moenkopi formation and Shinarump member is an undulating surface; Shinarump fills channels in the top of the Moenkopi	5.1
Total Shinarump member of the Chinle formation	13.8
Unconformity.	
Moenkopi formation:	
13. Mudstone, yellowish-gray (5*Y* 8/1); thin-bedded, parallel bedding planes half an inch and less apart; spangled with mica flakes; limonite stains along bedding planes, particularly at the top of the unit; forms rubble-covered slope	2.5
12. Covered	32.5
11. Siltstone, grayish-orange pink (10*R* 7.5/3) weathering pale reddish-brown; composed mostly of silt-sized, subrounded quartz grains with a few opaque grains; firmly cemented, calcareous; thin irregular bedding; forms sloping bench. A layer 1.2 to 6.2 ft from the base of mudstone and siltstone like those of the unit below	21.2
10. Alternating sequence of mudstone and siltstone, mostly siltstone; top layer of siltstone over 20 feet thick. Siltstone is pale grayish-red (5*R* 5/2) to grayish-pink (5*R* 8/2), weathering pale-brown (5*YR* 5/2). Some contains a few very small colorless to amber quartz grains; well-cemented, calcareous; forms rounded ledges. The mudstone is similar to the mudstone in unit 8 and is deformed penecontemporaneously	53.1
9. Covered	35.5
8. Sequence of three sandstone beds alternating with siltstone and mudstone beds. Sandstone grayish-orange (10*YR* 7/4), weathering same color, fine- to medium-grained, fairly well sorted; grains mostly of quartz, subrounded to subangular (angularity due to secondary overgrowths), a few opaque grains; firmly cemented with calcite; cross-laminated, with individual sets of cross-laminations 6 to 18 in. thick; forms cliffs 3 to 8 ft high. Siltstone, pale reddish-brown (10*R* 5.5/3), weathering same color, contains very small quartz grains; firmly cemented, calcareous, forms debris-covered slope. Mudstone layer 6 to 8 in. thick under each sandstone, moderate reddish-	

Moenkopi formation—Continued	*Thickness (ft)*
brown (10*R* 4/6), weathering same color; paperthin bedding, interbedded with siltstone. A little gypsum in stringers and at upper contact with sandstone	27.5
7. Covered	22.4
6. Sandstone, pale grayish-orange, weathering medium-brown; composed mainly of small rounded quartz grains, with a few black opaque grains; well-cemented, calcareous; parallel bedding planes ⅛ to ¼ in. apart; forms ledge	.5
Upper part of Moenkopi formation	195.2
Hoskinnini member of Moenkopi formation: Contact covered.	
5. Sandstone, moderate reddish-brown (10*R* 5/6), weathering dark reddish-brown, fine- to medium-grained, poorly sorted; composed mainly of subrounded to rounded colorless to amber quartz grains; firmly cemented, calcareous; thin to thick horizontal beds; forms "ledgy" cliff or a series of benches. Many horizontal holes formed by weathering along bedding planes. Colored light green along some bedding planes by minor alteration	24.2
4. Sandstone, yellowish-gray (5*Y* 8/1) to moderate reddish-brown (10*R* 4/6), weathering to pale-red, medium-grained, well-sorted; composed of subrounded quartz grains, well cemented with calcite; horizontal beds 2 to 4 ft thick that contain irregularly folded and faulted laminae; forms ledge. Local color variations along outcrop	1.3
3. Sandy siltstone, pale reddish-brown (10*R* 5/4), sand grains are in irregular lenses and zones parallel to bedding and range from fine to coarse (mostly medium); composed of subrounded to subangular amber quartz grains with a few black opaque grains; matrix minerals are too small to be identified. Firmly cemented, calcareous; bedding planes obscure; weathers to rough spheroids. The bottom 6 to 8 in. is light greenish gray (5G*Y* 8/1), fine-grained to coarse-grained, poorly sorted; composed of subrounded to rounded quartz grains, a few claystone pellets and lenses	47.2
Contact between Organ Rock tongue and Hoskinnini member is a gently undulating surface with 6 in. maximum relief.	
Total Hoskinnini member of Moenkopi formation	72.7
Organ Rock tongue of the Cutler formation:	
2. Siltstone, dark reddish-brown (10*R* 3/4), becoming progressively lighter downward; contains visible small grains of colorless to amber quartz; firmly cemented, calcareous; weathers locally into spheroids. The lower part of the unit is altered to light greenish gray parallel to the bedding and in irregular blebs. The alteration in the upper part of the unit is more continuous and follows joints as well as bedding planes. Most of the unit forms a steep concave slope covered with rock fragments along most of its outcrop, but the upper 60 ft forms a concave smooth cliff where it is protected by the Hoskinnini member	139.7

Organ Rock tongue—Continued	*Thickness (ft)*
1. Siltstone, grayish-red to dark reddish-brown; sparse calcite forms irregular masses as much as eight times the size of other mineral grains; sparse grains of colorless to amber quartz; firmly cemented, calcareous. Poorly cemented rock, in which there is much calcite on joints and on the weathered surface, forms slopes below ledges of coarser grained, better cemented rock; most of unit forms steep slope covered with partly disintegrated rock. Lower contact covered. Base of Organ Rock tongue put at top of highest exposure of underlying yellowish-gray sandstone	143.2
Total Organ Rock tongue	282.9

Section of Organ Rock tongue of Cutler formation at north end of butte in sec. 27, T. 35 S., R. 17 E. Measured by H. A. Hubbard

	Thickness (ft)
Hoskinnini member of Moenkopi formation: Poorly sorted red standstone.	
Organ Rock tongue of Cutler formation:	
8. Sandstone, dark reddish-brown (10*R*3/4) altered to pale green along a few bedding planes, composed mainly or subrounded grains of fine amber quartz, a few of which have secondary overgrowths; well-cemented, calcareous; contains a few secondary calcite crystals; thin parallel bedding locally cut by narrow channels 1.5 to 8 in. deep; unit is massive; forms knobby cliff	13.2
7. Sandstone, reddish-brown (10*R* 4.8/4.2), weathering moderate reddish-brown (10*R* 4/6). composed of very fine to silt-sized well-sorted quartz grains, many of the larger ones with secondary overgrowths; firmly cemented, calcareous; closely spaced bedding planes faintly visible in places; forms smooth cliff	3.6
6. Siltstone, moderate reddish-brown (10*R* 4/4), weathering same color, composed of fine well-sorted quartz grains, a few of which have secondary overgrowths; well-cemented, calcareous; bedding planes obscure, closely spaced where visible; forms cliff	15.0
5. Siltstone, similar to that above, and grading into it but without visible quartz grains. Contains interfingering layers of siltstone pebbles similar to unit 2	.9
4. Conglomerate siltstone, pale yellowish-orange (10*YR* 8/4), weathering grayish-green. Well-cemented, calcareous; forms massive ledge. Matrix of siltstone encloses pebbles as much as 3 in. in diameter, but mostly ⅜ to ½ in. in diameter, most of the pebbles are red siltstone but a few are of quartzite; poorly sorted at base, but sorting improves upward; grain size diminishes upward	3.8
3. Siltstone, similar to unit 1, but with no ledges. A zone ½ to 3 in. thick at the top is altered to greenish gray	15.4

Organ Rock tongue—Continued	*Thickness (ft)*
2. Conglomeratic siltstone; matrix reddish-brown except for lower 0.3 to 0.5 ft, which is light yellowish brown; composed of very fine to fine well-sorted and well-rounded quartz grains, firmly cemented; calcareous. Conglomerate forms two layers, one, 4 in. thick, at the base and the other, a little more than 1 in. thick, about 8 in. above the base. It consists of quartzite pebbles 1/16 to 1¼ in. in diameter, which are poorly sorted but well rounded. Unit forms narrow bench; rock surface underlying the unit is irregularly channeled	0.9
1. Unit forms concave slope, covered except for ledges that crop out in the lower 40 ft. The cover, which is only a few inches thick, is composed of disintegrated bedrock fragments as much as 6 in. in diameter. Bedrock as seen from poor exposures in two gullies is chiefly dark reddish-brown (10*R* 3/4) siltstone mixed with a little fine-grained well-sorted sand composed of quartz grains and sparse irregularly oriented mica flakes; firmly cemented, calcareous; thin almost shaly horizontal bedding with no cross-laminae; weathers readily. Siltstone alternates with ledges, 6 in. to 1 ft thick, of massive dark reddish-brown fine-grained well-sorted sandstone, consisting of well-rounded quartz grains firmly cemented with carbonate. Contact with the Cedar Mesa sandstone member is arbitrarily placed at the top of a bed of light-colored sandstone	132.5
Total Organ Rock tongue	185.3

SELECTED CORE LOGS FROM DEER FLAT AND UPPER LOST PARKS

Core log 35 of Chinle formation at the Hideout No. 1 claim, sec. 14, T. 36 S., R. 17 E.

Total depth. 252.5 ft	Map coordinates. 142,497 N; 180,518 E. (pl. 3)
Collar altitude. 7,380.0 ft	Date logged. Dec. 12, 1953
Geologic setting. In a channel	Logged by. R. L. McDonald

Chinle formation:

Moss Back member:	*Thickness (ft)*
1. Sandstone, grayish-orange, medium-grained; calcareous; much hematite and mica	36.8
2. Mudstone, light greenish-gray; much mica, a little limonite	.2
3. Sandstone, grayish-orange, medium-grained, calcareous; contains much mica and limonite, and a few pebbles of gray-green mudstone; limonite forms diffusion banding in places	30.7
4. Mudstone, dusky yellowish-gray; a little mica	.6
5. Sandstone, grayish-orange, medium- to coarse-grained; contains much limonite, a little mica, and numerous pebbles of gray-green mudstone; calcareous	22.5
6. Conglomerate, yellowish-brown; contains a little hematite and mica. Many pebbles of yellowish-brown mudstone. Coalified plant fragments, and pebbles of carbonaceous rock as much as 18 mm in diameter	.5
Total Moss Back member	91.3

Unconformity.

Mudstone-sandstone unit:	*Thickness (ft)*
1. Limestone, light-gray; contains a little muscovite and pyrite, many pebbles of gray-green mudstone, a few carbonaceous flakes	0.7
2. Sandstone, light-gray, medium- to fine-grained; much biotite and muscovite, sparse to abundant pyrite, much carbonaceous in material in flakes, films, and seams, some grains of amber quartz and pink chert. Many pebbles of gray mudstone. Numerous fractures	5.9
3. Mudstone, dark gray-green; sandy; a little muscovite	.9
4. Limestone, light-gray, sandy; containing a few pebbles of gray mudstone and some carbon flakes	.3
5. Mudstone, greenish-gray; a little muscovite	5.8
6. Limestone, light-gray, sandy; contains a little mica and gray mudstone	.9
7. Mudstone, dark greenish-gray; contains a little pyrite, much mica, and moderately abundant coalified plant fragments	23.8
8. Siltstone, medium-gray, calcareous; much mica and gray mudstone	4.8
9. Mudstone, greenish-gray, grayish-brown, and dark-gray; abundant mica. Upper part slightly calcareous	11.0
10. Sandstone, light-gray, very fine grained; much mica, many fragments of gray mudstone, becoming more numerous toward base; bedding dips 9°–10°, few normal faults	24.7
11. Mudstone, dark-gray; a little mica	1.3
12. Mudstone, dark-gray mottled with dusky brown; limestone pebbles	3.0
13. Mudstone, medium-gray mottled with red, calcareous, sandy; many fractures filled with calcite	5.3
14. Sandstone, light-gray mottled with red, medium- to coarse-grained; many grains of amber quartz; contains a little hematite, much gray mudstone; numerous fractures filled with calcite	5.0
15. Limestone, light-gray mottled with red, sandy; moderately abundant hematite; a little gray mudstone	3.1
16. Sandstone, light-gray mottled with red, medium- to fine-grained; a little gray mudstone cement	3.0
17. Mudstone, light-gray mottled with red; much hematite; lower part highly fractured	13.5
18. Mudstone, dark-gray; moderately abundant pyrite	6.8
Total mudstone-sandstone unit	119.8
Shinarump member:	
1. Sandstone, medium-gray, coarse-grained; abundant chalcopyrite, a little mica; much gray mudstone cement	0.3
2. Sandstone, brownish-gray, very fine grained; a little pyrite; much gray mudstone cement	7.9
3. Sandstone, light-olive-brown to light-gray, very fine grained; a little pyrite and mica; much gray mudstone cement; fault 0.7 ft from top	2.6
4. Sandstone, light olive-brown, very fine grained; a little mica; much brown mudstone cement	1.9
5. Sandstone, light-gray, medium- to coarse-grained; a little pyrite and mica; much gray mudstone cement; many carbonaceous flakes	1.1

Shinarump member—Continued	Thickness (ft)
6. Sandstone, light olive-gray, coarse-grained to conglomeratic; contains a little pyrite; many gray mudstone pebbles. Seam of friable mudstone 0.3 ft thick at 8.1 ft from top	10.0
7. Sandstone, medium-gray mottled with brown, very fine grained; a little mica; much gray mudstone cement	3.4
8. Mudstone, dark-gray; scattered grains of pyrite and chalcopyrite; moderately abundant carbonaceous flakes, and plant fragments	5.4
9. Sandstone, light-gray, medium-grained; much pyrite and a little chalcopyrite; much gray mudstone cement; abundant coalified plant fragments	1.9
10. Sandstone, light-gray, coarse-grained to conglomeratic; much pyrite and a little chalcopyrite; many carbonaceous flakes, fragments, and seams	5.6
Total Shinarump member	40.1
Total Chinle formation	251.2

Unconformity.

Moenkopi formation:

Mudstone, dark greenish-gray, micaceous.

Mudstone, grayish-brown mottled with greenish-gray.

Core log 36 of Chinle formation at the Hideout No. 1 claim, sec. 14, T. 36 S., R. 17 E.

Total depth. 254.4 ft	Map coordinates. 142,569 N.; 180,548 E. (pl. 3)
Collar altitude. 7,380.3 ft	Date logged. Dec. 13, 1953
Geologic setting. In a channel	Logged by. H. A. Hubbard

Grayish-brown soil with rock fragments. 1 ft thick.

Chinle formation:

Moss Back member:	Thickness (ft)
1. Sandstone, light-brown, fine- to medium-grained; much mica, limonite, and many flakes of carbon; well cemented by silica, a little white clay cement	25.2
2. Sandstone, yellowish-brown, very fine grained to fine-grained; much mica and limonite; a little white clay cement; limonite diffusion banding	9.3
3. Sandstone, light-brown, fine- to medium-grained; much mica, limonite, and many carbon flakes; a little white clay cement	4.3
4. Sandstone, yellowish-brown, very fine grained to fine-grained; much mica and limonite, a little white clay cement and a few opaque minerals; one set of limonite diffusion bands	15.6
5. Sandstone, yellowish-brown, very fine grained to medium-grained; containing about 20 percent medium quartz grains, much mica and limonite; many pebbles of green mudstone	2.9
6. Sandstone, light-brown, fine- to medium-grained; much mica and limonite; a little feldspar; a few pebbles of green mudstone	1.3
7. Conglomeratic sandstone, yellowish-brown, very fine grained to fine-grained; much mica and limonite; 40 percent green mudstone pebbles	8.3

	Thickness (ft)
Moss Back member—Continued	
8. Sandstone, dark yellowish-orange, very fine grained to medium-grained; a little mica and feldspar, and a little white clay cement, much limonite, and a few mudstone pebbles at 8.0 to 8.4 ft from top	18.9
9. Sandstone, dark yellowish-orange, very fine grained to medium-grained. A little mica and a few pebbles of green mudstone. Calcareous; very hard	1.6
10. Sandstone, light-gray, very fine grained to medium-grained; well-cemented by white and green mudstone; a few flakes of coal and mica	6.2
Total Moss Back member	93.6
Unconformity.	
Mudstone-sandstone unit:	
1. Limestone, light-gray; a few very fine to fine quartz grains	0.6
2. Mudstone, medium-gray; a little mica, carbon 30.0 to 31.1 ft from top, a few very fine quartz grains	45.3
3. Limestone, light-gray; much gray mudstone, numerous very fine quartz grains	.5
4. Mudstone, greenish-gray and reddish-brown in alternating thin beds; much mica and many silt to fine quartz grains; many thin channeling laminae	4.7
5. Mudstone, medium red-brown; a little mica; fractures filled with gypsum	3.8
6. Mudstone, greenish-gray, a little mica, much silt	18.7
7. Mudstone, medium dark-gray; a few opaque minerals; 10 percent medium quartz grains	5.3
8. Mudstone, dark-gray mottled with reddish-brown, brecciated	10.0
9. Sandstone, silty, light-gray, silt to medium-grained; a little hematite and many fine quartz grains; much gray mudstone cement	4.1
10. Sandstone, very light gray, fine- to coarse-grained; much gray mudstone cement. Mudstone pebbles make up 10 percent of volume	.5
11. Mudstone, medium-gray; much hematite, a few fine quartz grains; brecciated	8.8
12. Mudstone, medium-gray mottled with dusky red	5.6
13. Sandstone, light-gray, fine- to medium-grained; a few opaque minerals, calcareous cement; very hard, much gray mudstone cement	.3
14. Mudstone, medium-gray; much hematite and very fine grained to fine-grained quartz; brecciated	4.2
15. Mudstone, light-gray mottled with reddish purple; 5 percent fine to medium quartz grains, much hematite	5.1
Total mudstone-sandstone unit	117.5

Shinarump member:	Thickness (ft)
1. Sandstone, light-gray, fine- to coarse-grained; much hematite and gray mudstone cement	7.1
2. Sandstone, very light gray, fine- to medium-grained; a few opaque minerals and a little limonite; much white clay cement, many films of gray mudstone	4.5
3. Sandstone, dark-yellow, fine- to coarse-grained; a little limonite and white clay cement	3.7
4. Sandstone, olive-brown, fine- to coarse-grained; 40 percent gray and olive-brown mudstone cement	1.3
5. Mudstone, olive-brown, a few opaque minerals	.9
6. Siltstone, light-gray, a little pyrite	8.9
7. Sandstone, light-gray, fine- to coarse-grained; a little feldspar and white clay cement; a little carbonaceous material 2.8 to 3.5 ft from top, a few large grains of chalcopyrite	5.3
8. Sandstone, light-gray, fine- to medium-grained; a little feldspar, much white clay cement and less than 1 percent of chalcopyrite	4.7
9. Sandstone, light-gray, fine- to medium-grained; a little feldspar, much white clay cement and about 4 percent chalcopyrite	.9
Total Shinarump member	37.3
Total Chinle formation	248.4

Unconformity.

Moenkopi formation:

Mudstone, gray and red in alternating thin beds, much mica.

Core log 40 of Chinle formation at the Hideout No. 1, claim, sec. 14, T. 36 S., R. 17 E.

Total depth. 265.2 ft
Collar altitude. 7,393.4 ft
Geologic setting: On channel bank

Map coordinates. 142,783 N.; 180,626 E. (pl. 3)
Date logged. Apr. 28, 1954
Logged by. D. A. Brew

Brownish-gray soil and rock fragments.

Chinle formation:

Moss Back member:	Thickness (ft)
1. Sandstone, light-brown, very fine grained to fine-grained; some limonite and mica, seams and flakes of bluish-green mudstone, and a few carbonaceous flakes	13.8
2. Sandstone, brown, medium-grained, friable; limonite, a few opaque minerals and flakes of blue-green mudstone	1.6
3. Sandstone, light-brown to brown, fine- to medium-grained; much limonite, very few opaque minerals and flakes of blue-green mudstone. Fracture coated with limonite 4.6 to 5.4 ft from top	43.1
4. Sandstone, light grayish-brown, coarse- to very coarse-grained; a little manganese oxide and very few opaque minerals; pebbles, flakes, and blebs of bluish-green mudstone. Thin seam of mudstone at base	.6
5. Sandstone, brown, fine-grained; some limonite, pebbles and flakes of bluish-green mudstone. Fracture with a little gypsum 0.4 to 1.3 ft from top	2.0
6. Sandstone, brown, medium- to coarse-grained; pebbles and flakes of blue-green mudstone, limonite in pods as much as 4 mm long	6.0

Moss Back member—Continued	*Thickness (ft)*
7. Sandstone, brown to light-brown, fine- to medium-grained; moderately abundant limonite and gypsum, pebbles and flakes of blue-green mudstone, very few opaque minerals, limonite in pods as much as 3 mm in diameter	12.9
8. Mudstone, bluish-gray, apparently a large mudstone pebble	.1
9. Sandstone, light-brown to brown, upper part medium grained to very coarse grained grading down to medium- to fine-grained in the lower part; very few opaque minerals and little limonite. Many flakes and pebbles of bluish-green mudstone. Fracture with limonite and gypsum, 10.6 to 14.1 ft from top	14.1
Total Moss Back member	94.2
Unconformity.	
Mudstone-sandstone unit:	
1. Conglomerate, bluish-gray, coarse-grained to conglomeratic matrix; a few red chert pebbles, many pebbles of bluish-green mudstone and much mudstone cement	4.9
2. Silicified wood, brown to black, abundant pyrite, cellular structure	.5
3. Sandstone, grayish-green, fine- to medium-grained; very little mica and opaque minerals, much green and bluish-gray mudstone cement, a little red chert	1.5
4. Mudstone and siltstone, green-gray; a little carbonate, moderately abundant carbonaceous flakes and seams	21.6
5. Sandstone, grayish-green, fine-grained; a few opaque minerals and a little mica, many films and seams of blue-green mudstone, a few flakes of carbonaceous material	2.2
6. Mudstone, bluish-gray, sandy; a little calcite and mica, and very few flakes of carbonaceous material	52.0
7. Mudstone, bluish-gray mottled with purple; a little hematite and a few veinlets of calcite	3.2
8. Siltstone, gray mottled with purple, interbedded with fine-grained to very coarse grained sandstone; very few opaque minerals, moderately abundant hematite, and a little calcite	4.7
9. Sandstone, gray, coarse granules of quartz at base grading upward to fine-grained quartz; a little hematite, many pebbles of bluish-green mudstone, much calcite, many blue mudstone pebbles at base, numerous hematite veinlets throughout	3.5
10. Mudstone, blue-green gray mottled with purple; very little calcite and hematite, many grains of colorless quartz	7.7
11. Sandstone, light-gray, fine- to medium-grained; a little hematite and carbonate, much blue-green mudstone cement	1.5
12. Mudstone, mottled red, purple and gray; a few calcite veinlets	14.2
13. Sandstone, gray, very fine grained to fine-grained; calcite, secondary quartz, and much blue-green mudstone cement	2.7
14. Mudstone, mottled purple and gray; very little carbonate and hematite, brecciated	11.7
Total mudstone-sandstone unit	131.9

Shinarump member:	Thickness (ft)
1. Sandstone, brown, medium-grained; fairly well cemented; a little pyrite and calcite, very few carbon flakes, a little bluish-gray mudstone cement and a few seams of mudstone	0.5
2. Mudstone, gray; some quartz and very little pyrite(?)	.3
3. Sandstone, light-gray, medium-grained; very few opaque minerals and very little calcite, moderately abundant seams of blue-green mudstone, much white clay cement	1.8
4. Sandstone, light-gray, coarse-grained to granules; friable, a little limonite and pyrite(?), very few flakes of blue mudstone; pyrite(?) at base; much white clay cement	4.3
5. Siltstone, gray mottled with purple. Hematite, quartz. A little pyrite at the top, much blue and gray mudstone cement	5.1
6. Sandstone, light gray, fine- to medium-grained; very few opaque minerals, very little pyrite, many flakes of blue mudstone. Disseminated pyrite, much white clay cement	2.3
7. Siltstone, gray mottled with purple, many quartz grains, very little limonite. Carbonaceous material more concentrated at base, disseminated pyrite(?), minute fractures. Gray at 1.1 ft from top. Very little pyrite at the top	4.6
8. Sandstone, light-gray, medium-grained; very few opaque minerals, much pyrite. Many seams and flakes of carbonaceous material, moderately abundant flakes of brown mudstone, much pyrite 3.8 to 4.0 ft from top	4.2
9. Sandstone, light-gray, medium- to very coarse-grained and granules; little or no carbonate; a few seams and flakes of carbonaceous material, much brown mudstone cement, much white clay cement, a few pebbles of quartz, quartzite, and rose quartz, disseminated pyrite, a few opaque minerals. Pebbles of brown mudstone as much as 1 cm in diameter	6.6
10. Sandstone, light-gray, fine- to medium-grained; a little pyrite, no calcite, many seams and flakes of carbonaceous material, many flakes of blue mudstone, disseminated pyrite, much white clay cement	2.8
Total Shinarump member	32.5
Total Chinle formation	258.6

Unconformity.

Moenkopi formation:

Mudstone, blue-green; very fine quartz grains; biotite, very few flakes of carbonaceous material. Very little pyrite, about half a foot thick. Mudstone, red, slightly mottled with gray; very fine quartz grains, no calcite, little muscovite.

Core log 43 of Chinle formation at the Iris Pants claim, sec. 15, T. 36 S., R. 17 E.

Total depth. 253.7 ft
Collar altitude. 7,316.6 ft
Geologic setting. Not in a channel

Map coordinates. 143,469 N.; 177,634 E. (pl. 3.)
Date logged. May 18, 1954
Logged by. T. L. Finnell

Sand, rock debris, and brownish-gray soil.
Chinle formation:
Moss Back member:

	Thickness (ft)
1. Sandstone, light yellowish-brown, fine- to medium-grained, massive, well-cemented by silica; contains a few flakes of mica and much limonite cement, vertical fracture is coated with limonite. Sparsely disseminated white clay	4.7
2. Sandstone and mudstone in alternating thin beds, light yellowish-brown, fine grained to very coarse grained and conglomeratic; much limonite and grayish-yellow mudstone cement, many seams of mudstone, a little muscovite and much calcareous cement	2.0
3. Sandstone, light yellowish-gray, fine- to coarse-grained; much limonite, moderately abundant pebbles of gray mudstone, much mudstone cement. Limonite on vertical fracture. Conglomeratic at base	15.2
4. Mudstone and sandstone, light yellowish-gray, in alternating thin beds; mudstone is thinly laminated; sandstone is fine to medium grained; moderately abundant limonite, gray mudstone cement in sandstone	1.8
5. Sandstone, light yellowish-brown, fine- to coarse-grained; much limonite, moderately abundant pebbles of gray mudstone. Limonite diffusion bands	5.7
6. Siltstone, gray, grading upward into mudstone; a little muscovite; 15 percent fine-grained sandstone layers at base, much gray mudstone cement in sandstone layers	2.6
7. Conglomerate grading up into sandstone, light yellowish-brown, medium- to coarse-grained and conglomeratic; much limonite and a few seams of gray mudstone, much calcite cement in conglomerate, silica overgrowths on 40 percent of sand grains	7.3
8. Mudstone and sandstone in alternating thin beds, light-gray, sandstone is very fine to medium grained; many pebbles of gray mudstone and much mudstone cement in sandstone	1.7
9. Sandstone, light yellowish-brown, fine grained to very coarse grained and conglomeratic; moderately abundant pebbles of gray mudstone and mudstone cement, calcareous cement, pebbles of chert, quartzite, and siltstone	8.1
10. Mudstone, gray, 20 percent fine-grained sandstone	2.7
11. Sandstone, light yellowish-gray, fine-grained; calcareous cement, vertical fracture coated with limonite	.8
12. Conglomerate, light-gray, fine- to medium-grained matrix; many pebbles of gray mudstone and red chert	.6
Total Moss Back member	53.2

Unconformity.

Mudstone-sandstone unit:	*Thickness (ft)*
1. Mudstone and sandstone in alternating thin beds, gray. Sandstone is very fine tô fine-grained; many pebbles of gray mudstone, few pebbles of chert	3.5
2. Sandstone, gray, very fine grained to conglomeratic; many pebbles of gray mudstone, a few of red chert and one of green chert. Much calcite cement	.9
3. Sandstone, gray, fine- to medium-grained; moderately abundant muscovite. Many pebbles of gray mudstone and much mudstone cement; thinly laminated to massive	13.5
4. Mudstone, gray; many pebbles of mudstone and a few of quartzite. Calcareous cement	3.6
5. Sandstone and mudstone in alternating thin layers, light-gray; sandstone is very fine grained to fine grained; much muscovite, with many seams of gray mudstone, much mudstone cement; ripple-laminated, cut by many small normal faults	21.6
6. Mudstone and siltstone in alternating layers, gray; massive; slickensided fractures dip 40°–60°; much muscovite	35.9
7. Sandstone and mudstone in alternating thin layers, light-gray; sandstone is very fine to fine grained; much muscovite, with many seams of gray mudstone and much mudstone cement; ripple-laminated, cut by many small normal faults	5.5
8. Mudstone, gray mottled with purplish-red; more moderately abundant muscovite; thinly laminated	16.9
9. Sandstone, light-gray, medium-grained; 45 percent gray mudstone cement and pebbles	1.5
10. Mudstone, gray mottled with purplish-red; 30 percent fine- to medium-grained sandstone	4.9
11. Sandstone, gray mottled with purplish-red, fine- to medium-grained; 30 to 50 percent gray and red mudstone cement	3.4
12. Mudstone, gray mottled with purplish-red, 5 percent very fine to medium-grained sandstone; moderately abundant hematite; brecciated	8.8
13. Sandstone and mudstone in alternating beds, gray mottled with purplish-red, sandstone is medium grained to very coarse grained; much hematite, with much gray and red-mudstone cement	10.0
14. Mudstone, gray; 5 percent fine- to medium-grained sandstone	8.7
15. Mudstone, purplish-red alternating with dark-red; much hematite; fractures dip 45°	5.0
16. Mudstone, gray mottled with purplish-red; 10 to 30 percent fine- to medium-grained sandstone; much hematite; fractures dip 40°–60°	9.3
17. Sandstone, gray mottled with purplish-red, fine- to medium-grained; much hematite and gray and red mudstone cement; mottled with many seams of limonite. A few flakes of carbonaceous material; fractures dip 45°	5.4
Total mudstone-sandstone unit	158.4

	Thickness (ft)
Shinarump member:	
1. Sandstone, light yellowish-gray, medium grained to very coarse grained, grading upward to medium grained to coarse-grained; much feldspar, moderately abundant white clay cement, silica overgrowth on 80 percent of quartz grains, a few pebbles of gray mudstone	8.3
2. Sandstone, purplish-red, fine- to medium-grained; much purplish-red mudstone cement and many pebbles of mudstone. Silica cement	1.1
3. Sandstone, light purplish-red, fine- to medium-grained; cross-bedded; much red mudstone cement; silica overgrowths on 20 percent of quartz grains	5.4
4. Sandstone, light yellowish-gray, medium- to coarse-grained; many opaque minerals, much white clay cement; silica overgrowths on 90 percent of quartz grains	1.4
5. Sandstone, light-gray, medium grained to very coarse grained and conglomeratic; many opaque minerals and pebbles and seams of gray and white mudstone or clay; silica overgrowths on 75 percent of quartz grains. Calcite and clay cement	2.9
Total Shinarump member	19.1
Total Chinle formation	230.7

Unconformity.
Moenkopi formation:

Mudstone, dusky-red mottled with gray-green in alternating beds; much muscovite and a little biotite; thinly laminated.

Core log 55 of Chinle formation at the Yoke No. 1 claim, sec. 14, T. 36 S., R. 17 E.

Total depth. 263.3 ft	Map coordinates. 141,925 N.; 179,735 E. (pl. 3)
Collar altitude. 7,362.3 ft	Date logged. June 16, 1954
Geologic setting. On a channel bank	Logged by. D. A. Brew

	Thickness (ft)
Chinle formation:	
Moss Back Member:	
1. Sandstone, brown to light-brown, fine- to medium-grained; a few limonite spots, opaque minerals, and pebbles, seams, and flakes of bluish-green mudstone; a little jarosite(?), no calcite	66.7
2. Mudstone, bluish-green, sandy; no carbonate, a few flakes of carbonaceous material, very little pyrite	1.6
3. Sandstone, brown, medium-grained, well sorted; a few opaque minerals, limonite spots, many pebbles and flakes of bluish-green mudstone, a little calcite, white clay cement, and mica	15.9
Total Moss Back member	84.2

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Unconformity.

Mudstone-sandstone unit:

	Thickness (ft)
1. Mudstone, blue-gray, sandy in part; moderately abundant mica, a few flakes of carbonaceous material, very little carbonate	5.2
2. Sandstone, light-gray, medium- to fine-grained, tightly cemented with white clay; much mica, few opaque minerals, and a little bluish-green mudstone cement	20.5
3. Mudstone, bluish-gray; much mica, a few flakes of carbonaceous material, a few sandy zones and calcareous zones, and a few slickensides	36.1
4. Sandstone, bluish-gray, very fine grained; much mica, a few opaque minerals and flakes of carbonaceous material, 40 to 50 percent bluish-gray mudstone cement, little calcite	20.5
5. Mudstone, bluish-gray; 40 percent very fine quartz grains, no calcite, much mica and a few flakes of carbonaceous material	5.5
6. Sandstone, gray, fine-grained; much mica and very few opaque minerals and flakes of carbonaceous material, much bluish-gray mudstone cement, no calcite; contorted bedding at top, crossbedded	1.6
7. Mudstone, bluish-gray, sandy; much mica, a few flakes of carbonaceous material, very little calcite	6.8
8. Sandstone, light-gray, fine-grained; moderately abundant mica, a few opaque minerals, no calcite	1.2
9. Mudstone, greenish-gray, sandy; many flakes of mica and carbonaceous material, no calcite	2.0
10. Mudstone, green mottled with a little purple; very sandy; a little mica and hematite, no calcite	3.2
11. Sandstone, gray, coarse-grained, grading downward to medium-grained; very little mica, a few opaque minerals, flakes of blue-gray mudstone, carbonaceous in lower part, much white clay cement. Pyrite or marcasite fills fracture at 3.2 to 4.3 ft. from top	11.2
12. Mudstone, grayish-blue; a little pyrite and mica, no calcite, a few slickensides	.9
13. Mudstone, gray mottled with purple; moderately abundant hematite, becomes sandy towards base	20.6
14. Mudstone, bluish-gray; a little mica, moderately abundant flakes of carbonaceous material, no calcite; very sandy toward base; many slickensides	7.4
Total mudstone-sandstone unit	142.7

Shinarump member:

1. Sandstone, light-gray, coarse-grained; very few opaque minerals, much carbon, moderately abundant blue-gray mudstone cement, increasing towards base, white clay cement	2.6
2. Mudstone, gray mottled with purple; very much hematite, very sandy in part, a few sandy layers cemented with white clay, no calcite	18.6
3. Mudstone, greenish-blue, sandy; very little mica and pyrite, very few opaque minerals, carbonaceous material with pyrite; no calcite	5.0

	Thickness (ft)
Shinarump member—Continued	
4. Sandstone, gray, fine-grained; a little mica, hematite, and limonite; a few opaque minerals and seams of blue-gray mudstone, mudstone cement	1.0
Total Shinarump member	27.2
Total Chinle formation	254.1

Unconformity.

Moenkopi formation:

Mudstone, red mottled with a little bluish-green; much mica, very few sand grains; thinly laminated.

Core log 69 of Chinle formation at the W. N. claim, sec. 21, T. 36 S., R. 17 E.

Total depth. 261.0 ft
Collar altitude. 6,993.3 ft
Geologic setting. In a channel

Map coordinates. 132,011 N., 170,822 E. (pl. 5)
Date logged. July 21, 1954
Logged by. T. L. Finnell

	Thickness (ft)
Chinle formation:	
Moss Back member:	
1. Sandstone, light yellowish-gray, medium- to coarse-grained; a little limonite, few opaque minerals, many pebbles and seams of gray mudstone, much mudstone and carbonate cement	13.2
2. Sandstone, light yellowish-gray, fine- to coarse-grained, a few opaque minerals, a little limonite and gray mudstone cement and much carbonate cement	20.0
3. Sandstone, yellowish-gray, medium- to very coarse-grained; a little limonite, moderately abundant pebbles of quartz, and pebbles and seams of gray mudstone, much carbonate cement	5.6
4. Sandstone and conglomerate in alternating thin beds, yellowish-gray, medium-grained to very coarse-grained; moderately abundant limonite, many pebbles of grayish-green mudstone, much carbonate cement	3.3
5. Sandstone and conglomerate in alternating thin beds; yellowish-brown, medium-grained to very coarse-grained and conglomeratic; much limonite, moderately abundant pebbles of brown mudstone and quartzite and a few of red chert, much mudstone cement, a little muscovite	15.2
Total Moss Back member	57.3
Unconformity.	
Mudstone-sandstone unit:	
1. Sandstone, light-gray, medium-grained to very coarse grained and conglomeratic; moderately abundant pyrite and carbonaceous material, much muscovite and biotite. Many pebbles of gray mudstone, and much mudstone and carbonate cement	11.8
2. Sandstone, light-gray, medium- to coarse-grained; much pyrite, and mudstone cement, many pebbles of gray mudstone, much carbonate cement and some calcite in the small amount of carbonaceous material	3.1
3. Mudstone, gray, 10 percent fine-grained sandstone; fractures dip 50° to 60°	7.2

	Thickness (ft)
Mudstone-sandstone unit—Continued	
4. Mudstone and sandstone in alternating thin layers, dark-gray and light-gray; much muscovite, many pebbles and seams of gray mudstone in the 20 percent of fine- to medium-grained sandstone. Ripple-laminated; numerous steep normal faults	24.6
5. Sandstone and mudstone in alternating thin layers, light-gray and gray; sandstone is very fine to fine-grained; much muscovite and biotite, moderately abundant carbonaceous material, and many seams and pebbles of gray mudstone; ripple-laminated; steep normal faults	52.5
6. Mudstone, gray, very fine to fine-grained; much muscovite and carbonaceous material, massive	4.5
7. Sandstone, light-gray, very fine to fine-grained; much muscovite, many seams of gray mudstone and much mudstone cement; ripple-laminae dip as much as 75°; numerous steep normal faults	15.9
8. Mudstone, gray; much muscovite, 10 percent very fine to fine-grained sandstone	2.9
9. Mudstone, gray; a little muscovite, 10 percent fine- to medium-grained sandstone	7.9
10. Sandstone, light yellowish-gray, medium- to coarse-grained; much pyrite, especially in carbonaceous material; many pebbles of gray mudstone and much mudstone cement; slump structures	5.8
11. Sandstone and mudstone in alternating thin layers, light-gray and dark-gray, medium- to coarse-grained; much pyrite, especially in carbonaceous material, many pebbles and seams of gray mudstone, 30 percent mudstone cement	10.0
12. Mudstone and sandstone in alternating thin layers, light-gray mottled with purplish-red, moderately abundant limonite and muscovite, many pebbles and seams of gray mudstone, 20 percent fine-grained to very coarse-grained sandstone cemented with mudstone, a little carbonaceous material	16.7
13. Mudstone and siltstone in alternating thin layers, light-gray; much muscovite and carbonaceous material, two to three calcite seams	1.9
14. Sandstone and mudstone in alternating thin layers, light yellowish-gray and gray; fine- to medium-grained sandstone; much muscovite and a few seams of gray mudstone, a little pyrite in moderately abundant carbonaceous material	.8
Total mudstone-sandstone unit	165.6

	Thickness (ft)
Shinarump member:	
1. Sandstone, light yellowish-brown, medium- to coarse-grained; few opaque minerals and seams of gray mudstone, some mudstone, and carbonate cement. Quartz overgrowths on 10 percent of sand grains	4.3
2. Sandstone, light yellowish-brown, medium-grained to very coarse grained, conglomeratic at base; few opaque minerals, a little feldspar, much yellow-gray mudstone and carbonate cement	7.9
3. Mudstone, gray; much pyrite in abundant carbonaceous material, 2 percent very fine to fine-grained sandstone, much muscovite	1.0
4. Mudstone, dark-red mottled with gray, much carbonaceous material in gray; 25 percent very fine to fine-grained sandstone; slickensided fractures dip 60°	7.0
5. Mudstone, gray to dark-gray; much muscovite, a little biotite; 25 percent very fine grained to medium-grained sandstone	2.4
6. Sandstone, light-gray, very fine grained to medium-grained; much light-gray mudstone and hard, silica cement; moderately abundant carbonaceous material	.5
7. Mudstone, gray, 20 percent very fine grained to fine-grained sandstone	1.0
8. Sandstone and mudstone in alternating thin layers, light-gray, fine- to medium-grained sandstone cemented with mudstone; many pyrite crystals and seams of gray mudstone	2.2
9. Sandstone and mudstone in alternating thin layers, light-gray and dark-red, fine- to medium-grained sandstone; moderately abundant bornite and covellite, many seams of gray and red mudstone, much mudstone cement, hematite with disseminated pyrite, much carbonaceous material, moderately abundant carbonate cement	1.3
10. Sandstone, light-gray, fine- to medium-grained; moderately abundant gray mudstone cement	2.2
11. Siltstone and mudstone, light-green and gray, 5 percent very fine to fine-grained sandstone	1.2
12. Siltstone and sandstone in alternating thin layers, light gray above dark red, very fine grained to medium-grained sandstone; sparse to abundant bornite, chalcocite, uraninite(?), abundant gray and red mudstone cement, a little carbonaceous material	.8
13. Mudstone pebble conglomerate, purplish-red to dark-red; much hematite, 30 percent very fine grained to fine-grained sandstone in matrix, a little carbonaceous material	1.1
Total Shinarump member	32.9
Total Chinle formation	255.8

Unconformity.

Moenkopi formation:

Mudstone, red above gray-green; much muscovite, 0.1 ft is red at top.

Sandstone, gray and green, very fine grained; much gray-green mudstone cement; faint ripple laminae.

Mudstone, gray-green, much muscovite.

Core log 88 of Chinle formation at the W. N. No. 1 claim, sec. 21, T. 36 S., R. 17 E.

Total depth. 246.2 ft
Collar altitude. 6,997.4 ft
Geologic setting. In a channel

Map coordinates. 137,139 N.; 171,385 E. (pl. 5)
Date logged. Aug. 20, 1954
Logged by. P. C. Franks

Grayish-brown soil and rock fragments. 10 ft thick.
Chinle formation:
Moss Back member:

	Thickness (ft)
1. Sandstone, light brownish-gray, medium-grained; moderately abundant limonite specks, very little gray-green mudstone, many quartz overgrowths, a little white clay cement	5.7
2. Sandstone, light brownish-gray, medium- to coarse-grained and conglomeratic; many limonite specks, much white clay, and gray-green mudstone cement, and many pebbles of mudstone, many quartz overgrowths, and little calcite	7.6
3. Sandstone, light brownish-gray, fine- to medium-grained; moderately abundant limonite, white clay cement, a few opaque minerals, very little mica. Gray-green mudstone cement, many quartz overgrowths	3.1
4. Sandstone, light brownish-gray, medium- to coarse-grained and conglomeratic; much limonite and white clay cement, few opaque minerals, very little mica, gray-green pebbles and granules of mudstone, many quartz overgrowths, thin mudstone-pebble conglomerate in places	8.4
5. Conglomerate, yellowish-brown, matrix of medium- to coarse-grained and conglomeratic sandstone, much limonite and white clay cement. Pebbles and granules of gray-green mudstone. Moderately abundant quartz overgrowths, much carbonate and mudstone cement	.7
6. Conglomerate, light-gray, matrix of medium- to coarse-grained and conglomeratic sandstone; a little limonite and white clay cement; very little mica; pebbles and granules of grayish-green to gray mudstone and red chert; mudstone cement; few quartz overgrowths; much carbonate cement; very few flakes of carbonaceous material	1.1
7. Sandstone and conglomerate, yellowish-brown, matrix of medium- to coarse-grained and conglomeratic sandstone; a little limonite and white clay cement. Pebbles and granules of gray-green mudstone cement; abundant quartz overgrowths; much carbonate cement	2.7
Total Moss Back member	29.3

	Thickness (ft)
Unconformity.	
Mudstone-sandstone unit:	
1. Conglomerate, light-gray to gray, matrix of medium- to coarse-grained and conglomeratic sandstone; much calcite; pebbles and granules of gray-green to gray mudstone and red chert; few opaque minerals; very little mica; few quartz overgrowths; few flakes of carbonaceous material; much carbonate	9.8
2. Sandstone grading downward to conglomerate; light-gray, medium- to coarse-grained to conglomeratic sandstone; moderately abundant calcite; pebbles and granules of gray-green mudstone. many quartz overgrowths in compact medium-grained sandstone; a little chalcopyrite; few carbonaceous flakes	.8
3. Sandstone, light-gray, fine- to medium-grained; a little pyrite, mica, and limonite; few opaque minerals; much white clay cement; gray-green to gray mudstone cement and seams. Moderately abundant quartz overgrowths; little carbonate; moderately abundant flakes of carbonaceous material; ripple-laminated	15.7
4. Sandstone and conglomerate, light-gray; fine- to coarse-grained to conglomeratic; sandstone, moderately abundant pyrite, few opaque minerals, little mica, many pebbles, granules and twigs of carbonaceous material; conglomerate pebbles of gray-green to gray mudstone and red chert. Much carbonate cement, few quartz overgrowths	3.4
5. Sandstone, light-gray, fine- to medium-grained; a little pyrite, mica, and limonite; few opaque minerals; moderately abundant white clay cement. Gray-green to gray mudstone cement and seams; moderately abundant quartz overgrowths; little calcite. Moderately abundant flakes and seams of carbonaceous material, ripple-laminated	8.9
6. Sandy limestone, light-gray, with sandstone and mudstone pebbles; very little pyrite; much clay	.2
7. Mudstone, gray; much mica, interbedded with a few layers of siltstone and fine-grained sandstone; a little carbonate; many slickensided fractures	34.9
8. Sandstone and mudstone in alternating thin layers, light-gray and gray, very fine to medium-grained sandstone; much mica, very little pyrite, few opaque minerals; interbedded gray mudstone and mudstone cement; many quartz overgrowths in medium-grained sandstone; a little carbonate; very few flakes and pebbles of carbonaceous material; ripple-laminated	24.3
9. Mudstone, gray; very fine to fine sand grains; abundant mica; a few flakes of carbonaceous material; slickensided fractures	29.9
10. Sandstone, light-gray, fine- to medium-grained; few opaque minerals; gray mudstone cement; very calcareous; very few seams of carbonaceous material	.4
11. Mudstone, gray; very fine to medium sand grains; moderately abundant mica; a few flakes of carbonaceous material; slickensided fractures	2.2

	Thickness (ft)
Mudstone-sandstone unit—Continued	
12. Sandstone, light-gray, fine- to medium-grained; a few opaque minerals and flakes of carbonaceous material; very little pyrite; gray mudstone cement; many quartz overgrowths; calcareous	9.3
13. Mudstone, grayish-green to reddish-brown; a few very fine to fine sand grains; little hematite and mica; slickensided fractures	3.5
14. Sandstone, light-gray, fine- to medium-grained; a few opaque minerals and films of grayish-green mudstone; little pyrite; carbonate cement; locally conglomeratic with peebles and granules of mudstone; many quartz overgrowths; very few flakes of carbonaceous material	3.2
15. Mudstone, grayish-green mottled with reddish-brown; some very fine to coarse sand grains; a little hematite; moderately abundant mica; slickensided fractures	7.9
16. Sandstone, siltstone, and mudstone in alternating thin layers, light-gray mottled with purplish-gray, medium-grained to silty; moderately abundant hematite and limonite; very little mica, and a little gray to purplish-gray mudstone cement in sandstone; very little carbonaceous material; few laminations	12.5
Total mudstone-sandstone unit	166.9
Shinarump member:	
1. Sandstone, light-gray, medium- to coarse-grained and conglomeratic; much white clay and gray mudstone cement; few opaque minerals; a little limonite and interbedded mudstone; many quartz overgrowths	18.1
2. Sandstone and mudstone in alternating thin beds, light-gray mottled with reddish-brown; very fine grained to medium-grained sandstone; moderately abundant hematite; a little limonite and white clay cement; very little mica and pyrite. Gray to red-brown interbedded mudstone and mudstone cement; quartz overgrowths; ripple-laminated	11.1
3. Sandstone, light-gray, medium-grained; much pyrite and white clay; a little limonite, hematite, and gray mudstone cement; many quartz overgrowths; few carbonaceous flakes; friable	.9
4. Sandstone and mudstone in alternating thin layers, light-gray and gray; fine- to medium-grained sandstone; much pyrite and white clay; moderately abundant mica; a little gray mudstone cement; a little limonite, hematite, and chalcocite. Moderately abundant carbonaceous material. Medium-grained sandstone has numerous quartz overgrowths, is friable, ripple-laminated	2.6
5. Sandstone and conglomerate, light-gray; sandstone, medium- to coarse-grained to conglomeratic; white clay; a little pyrite, limonite, and hematite; a few opaque minerals; pebbles and granules of grayish-green to gray mudstone; many quartz overgrowths; friable	1.8
Total Shinarump member	34.5
Total Chinle formation	230.7

Unconformity.

Moenkopi formation:

Mudstone and siltstone in alternationg thin layers, grayish-green and reddish-brown; few tiny pyrite cubes at top; slightly laminated.

Core log 98 of Chinle formation at the Camel claim, sec. 12, T. 36 S., R. 17 E.

Total depth. 245.5 ft
Collar altitude. 7,539.5 ft
Geologic setting. In a channel

Map coordinates. 146,605 N.; 186,393 E. (pl. 7)
Date logged. Sept. 7, 1954
Logged by. P. C. Franks

	Thickness (ft)
Chinle formation:	
Moss Back member:	
1. Sandstone, light yellowish-gray to light-gray, fine- to coarse-grained and conglomeratic; 8 percent limonite specks, 2 percent hematite, trace of opaque minerals and mica. Light yellowish-green to yellow mudstone cement, and pebbles and granules of mudstone; quartz overgrowths on 90 percent of sand grains; locally calcareous; laminated	2.6
2. Sandstone, light yellowish-gray to light yellowish-brown, medium-grained; 13 percent limonite, 2 percent opaque minerals, trace of mica; a few pebbles and granules of light yellowish-green to yellow mudstone, very little mudstone cement; compact, well-sorted, laminated; quartz overgrowths on 90 percent of sand grains	2.6
3. Sandstone grading downward to conglomerate, light yellowish-brown to light-gray, fine- to coarse-grained to conglomeratic; 13 percent limonite, 2 percent opaque minerals, trace of mica, pebbles and granules of yellowish-green to yellow mudstone; quartz overgrowths on 80 percent of quartz grains; 1 percent red chert pebbles; 17 percent mudstone cement in sandstone; fine- to medium-grained sandstone is laminated, local carbonate cement, generally porous, limonite in specks	5.7
4. Mudstone, light-brown and a little light grayish-green in alternating thin layers; 3 to 5 percent mica; laminated	2.4
5. Sandstone grading downward to conglomerate, light yellowish-gray to yellowish-brown, fine-grained to conglomeratic; 3 percent limonite, 2 percent opaque minerals, trace of mica, pebbles and granules of light yellowish-gray to light grayish-green mudstone. Mudstone interbedded with fine-grained sandstone. Fine-grained sandstone is laminated, limonite in specks, quartz overgrowths on 10 percent of quartz grains, much carbonate cement, compact, 1 percent red chert pebbles	1.9
6. Mudstone, light reddish-brown to yellowish-brown; 5 percent mica; 10 percent very fine grained to fine-grained sand	4.8
7. Sandstone and conglomerate, light yellowish-gray, fine- to coarse-grained to conglomeratic; 10 percent limonite, 2 percent opaque minerals, trace of mica, 2 percent hematite. Pebbles and granules of yellowish-gray to light grayish-green mudstone; 15 percent mudstone in sandstone; quartz overgrowths on 80 percent of sand grains, limonite in specks, moderately abundant carbonate cement	7.1
8. Mudstone, light reddish-brown to yellowish-brown mottled with grayish-green; 3 percent mica, 1 percent hematite; 10 percent very fine to medium-grained sand	7.6

Moss Back member—Continued	*Thickness (ft)*
9. Sandstone, light yellowish-brown to light yellowish-gray, medium-grained; 5 percent limonite, trace of mica and opaque minerals; 7 percent yellowish-gray interstitial mudstone; limonite in specks, quartz overgrowths on 60 percent of sand grains; laminated	3.9
10. Sandstone grading downward to conglomerate, light yellowish-brown, fine- to coarse-grained to conglomeratic; 5 to 15 percent limonite, trace of opaque minerals, hematite, and mica; pebbles and granules of light grayish-green to yellowish-brown mudstone; 15 percent mudstone cement. Becomes mudstone-pebble conglomerate at base; laminated; quartz overgrowths on 80 percent of sand grains; locally calcareous	4.3
11. Mudstone, gray; 5 percent fine- to medium-grained sand	.5
12. Sandstone, light yellowish-gray to light yellowish-brown, very fine grained to fine-grained; 10 percent limonite, 2 percent opaque minerals, 1 percent mica; yellowish-brown to grayish-green mudstone cement; thinly laminated; quartz overgrowths on 80 percent of sand grains	11.6
13. Mudstones, grayish-green above and reddish-brown below, 5 to 15 percent very fine grained to fine-grained sandstone, 2 percent limonite seams; 10 percent mica, trace of hematite	2.7
14. Sandstone, light yellowish-gray to light yellowish-brown, fine- to medium-grained; 5 to 10 percent limonite, as much as 3 percent mica and opaque minerals; yellowish-brown to grayish-green and gray mudstone cement, 5 percent laminated mudstone; locally calcareous; quartz overgrowths on 80 percent of sand grains; 1 percent white clay	18.6
15. Conglomeratic sandstone grading downward to conglomerate, light yellowish-gray to light yellowish-brown, medium- to coarse-grained and conglomeratic; 5 to 10 percent limonite, trace of opaque minerals and mica; pebbles and granules of grayish-green to yellowish-brown mudstone; 15 percent mudstone, trace of red chert and pyrite; very calcareous; 60 percent quartz overgrowths	5.4
16. Sandstone, light yellowish-gray to light yellowish-brown, fine- to medium-grained; 5 to 10 percent limonite, as much as 2 percent opaque minerals and mica; yellowish-brown to grayish-green mudstone cement; 4 percent laminated mudstone; 1 percent white clay; calcareous; 80 percent quartz overgrowths	4.7
Total Moss Back member	86.4

Unconformity.

Mudstone-sandstone unit:

	Thickness (ft)
1. Mudstone grading downward to mudstone pebble conglomerate, grayish-green to yellowish-green and reddish-brown; much hematite and limonite in mudstone pebble conglomerate with a matrix of 10 to 20 percent medium- to coarse-grained to conglomeratic sandstone	1.5
2. Sandstone grading downward to conglomerate, light-gray, fine-grained to conglomeratic; as much as 5 percent pyrite, 1 to 3 percent mica, 1 percent opaque minerals; as much as 20 percent carbonaceous fragments, 5 to 15 percent gray mudstone cement and a few granules of mudstone; faintly laminated; quartz overgrowths on 40 percent of sand grains; very calcareous (40 percent locally); pyrite in carbonaceous material	32.8
3. Mudstone, grayish-green; 5 percent mica, trace of pyrite; 5 percent silt; calcareous; ripple-laminated	2.2
4. Mudstone and siltstone, reddish-brown; 5 percent mica; 30 percent siltstone; calcareous; ripple-laminated	14.7
5. Mudstone, siltstone, and sandstone in alternating thin layers; light-gray to light grayish-green mudstone and siltstone; 2 to 5 percent mica, trace of pyrite, trace of carbonaceous flakes; 30 to 40 percent very fine grained to fine-grained sandstone; very calcareous; ripple-laminated	18.0
6. Mudstone, gray above gray mottled with purplish-gray, silt-size to medium-grained; 6 percent hematite, 1 percent mica, trace gypsum; 8 percent sandstone; locally calcareous; slickensided fractures	28.4
7. Sandstone and mudstone in alternating thin layers, gray mottled with purplish-gray, very fine grained to medium-grained; 6 percent hematite, 1 percent limonite, trace of mica; gray mottled with purplish gray mudstone cement; 40 percent mudstone; few ripple-laminae	5.8
8. Mudstone, gray mottled with purplish-gray; 12 percent hematite, 2 to 3 percent limonite; 5 to 8 percent fine- to medium-grained sand; slickensided fractures	12.0
9. Mudstone and sandstone in alternating thin layers, yellowish-gray mottled with purplish-gray; 8 percent hematite, 5 percent limonite; purplish-gray mottled with yellowish-gray mudstone cement; 40 percent fine- to medium-grained sandstone, faintly laminated, quartz overgrowths on 15 percent of sand grains	6.6
Total mudstone-sandstone unit	122.0

Shinarump member:	*Thickness (ft)*
1. Mudstone and siltstone, gray; trace of pyrite, 20 percent sand with 10 percent fine- to medium-grained interbedded sandstone	4.6
2. Sandstone, light-gray, fine- to coarse-grained to conglomeratic; traces of pyrite, hematite and opaque minerals; trace of carbonaceous flakes, 30 percent light-gray to gray mudstone cement; quartz overgrowths on 60 percent of sand grains; ripple-laminated	2.5
3. Mudstone, gray, fine- to medium-grained; trace of limonite; trace of malachite(?); 5 percent sand	.7
4. Sandstone, light yellowish-gray to light-gray, medium- to coarse-grained to conglomeratic; 6 percent white clay, 15 percent mudstone; pebbles and granules of gray mudstone; quartz overgrowths on 90 percent of sand grains; friable	1.8
5. Sandstone, light yellowish-gray to yellowish-brown, medium- to coarse-grained to conglomeratic; 3 percent limonite and hematite, traces of pyrite, chalcopyrite, and opaque minerals; trace of carbonaceous material; pebbles and granules of gray mudstone; 10 percent mudstone, 4 percent white clay; 90 percent quartz overgrowths; some fractures	.6
6. Sandstone, siltstone, and mudstone, mottled purplish gray to gray; fine- to medium-grained sandstone; 4 percent hematite and limonite, trace of mica; purplish-gray to gray mudstone cement; 20 percent mudstone, 15 percent siltstone; quartz overgrowths on 15 percent of sand grains; faintly laminated	7.5
7. Sandstone grading downward to conglomerate, light-gray, fine-grained to conglomeratic; as much as 1 percent mica, traces of pyrite and opaque minerals; gray mudstone cement; grayish-green interbedded mudstone; faintly laminated; 20 percent mudstone; quartz overgrowths on 60 percent of sand grains	2.9
8. Mudstone, grayish-green; 5 percent mica; 5 percent fine- to coarse-grained sand	.7
Total Shinarump member	21.3
Total Chinle formation	229.7

Unconformity.

Moenkopi formation:

Mudstone, reddish-brown; 6 percent mica; 10 percent very fine grained interbedded sandstone.

Core log 109 of the Chinle formation at the Camel No. 12 claim, sec. 12, T. 36 S., R. 17 E.

Total depth. 255.3 ft
Collar altitude. 7,548.7 ft
Geologic setting. In a channel

Map coordinates. 147.325 N. 186.135 E. (pl. 7)
Date logged. Sept. 27, 1954
Logged by. T. L. Finnell

Brownish-gray soil and rock debris.

Chinle formation:
Moss Back member:

	Thickness (ft)
1. Sandstone, light-brown and reddish-brown in alternating thin layers, fine- to medium-grained; abundant feldspar, little muscovite or pyrite; few seams and pebbles of yellow mudstone. Much limonite cement; cross-laminated	3.8
2. Sandstone, light yellowish-gray, fine-grained; much muscovite, little carbon; many pebbles of gray mudstone and mudstone cement; horizontal bedding	6.3
3. Mudstone, yellowish-gray; much limonite and muscovite, little hematite	.7
4. Sandstone, light yellowish-gray, fine- to medium-grained; 10 to 15 percent limonite, 1 to 2 percent muscovite; many opaque minerals; little feldspar; few pebbles of yellowish-gray mudstone and mudstone cement; little calcite	6.0
5. Sandstone, light yellowish-gray, very fine grained to medium-grained; much muscovite, moderately abundant limonite, little carbon, 1 to 2 percent opaque minerals; many granules of yellowish-gray mudstone, silica overgrowths on 20 percent of quartz grains	10.4
6. Conglomerate, yellowish-brown, matrix of fine-grained to very coarse grained to conglomeratic sandstone; moderately abundant limonite; many pebbles of yellowish-gray mudstone; mudstone cement; much carbonate; one vertical fracture with limonite	1.1
7. Mudstone, yellowish-brown; moderately abundant limonite; thinly laminated	.2
8. Sandstone, light yellowish-brown, very fine grained to medium-grained; much carbonate; many pebbles of yellowish-gray mudstone, and mudstone cement	3.4
9. Sandstone, light yellowish-gray, fine- to medium-grained; much limonite and muscovite, few opaque minerals; silica overgrowths on 40 percent of quartz grains	2.9
10. Sandstone, light grayish-yellow, fine- to medium-grained; much limonite, muscovite, and yellowish-gray mudstone cement	1.6
11. Sandstone, light grayish-yellow, fine- to medium-grained; few opaque minerals; much yellowish-gray mudstone cement; limonite on fractures that dip 30°–60°	3.0
12. Sandstone, light yellowish-brown, fine- to coarse-grained at top grading down to coarse-grained; many opaque minerals, much limonite and feldspar, little carbonaceous material; a few pebbles of gray-green mudstone; silica overgrowths on 80 percent of quartz grains	9.1
13. Mudstone, grayish-green; much limonite and muscovite	.3
14. Sandstone, light grayish-yellow, fine- to medium-grained; little muscovite, much limonite; moderately abundant seams of yellow-gray mudstone; silica overgrowths on 10 percent of quartz grains; fractures coated with limonite dip 30°	2.9

Moss Back member—Continued	Thickness (ft)
15. Mudstone and sandstone in alternating thin layers, light yellowish-gray and grayish-red, fine- to medium-grained sandstone; much muscovite, little carbonaceous material; much yellow-gray and red mudstone cement; thinly laminated	5.6
16. Sandstone, light-gray and light yellowish-gray in alternating layers, very fine grained to medium-grained; much muscovite and biotite, trace of carbinaceous material; much gray mudstone cement; silica overgrowths on 10 percent of quartz grains; thinly laminated in part	12.5
17. Mudstone, light yellowish-gray; much muscovite, abundant carbonaceous material; thinly laminated	1.4
18. Sandstone and mudstone in alternating thin layers, light yellowish-gray, very fine grained sandstone; much muscovite and chlorite(?)	2.1
19. Sandstone, light yellowish-gray, very fine grained to medium-grained grading downward to fine- to medium-grained; much muscovite and yellowish-brown mudstone cement; many opaque minerals, mudstone seams, and limonite diffusion bands	37.7
Total Moss Back member	111.0
Unconformity(?).	
Mudstone-sandstone unit:	
1. Sandstone, light-gray, fine- to coarse-grained; much pyrite, red chert, carbonaceous material, gray and black mudstone pebbles and mudstone cement; thinly laminated	3.0
2. Sandstone and conglomerate in alternating thin layers, gray, fine- to coarse-grained to conglomeratic; much pyrite, carbonaceous material, and gray mudstone cement; pebbles of quartzite, red chert, quartz, mudstone, and limestone	6.9
3. Mudstone and sandstone in alternating thin layers, light-gray, very fine to fine-grained sandstone; much pyrite, muscovite, and carbonaceous material; many gray mudstone seams in sandstone; ripple-laminated; many normal faults	8.5
4. Sandstone, light-gray, very fine-grained to medium-grained; massive; a little rose quartz; much carbonaceous material; much gray mudstone cement	.8
5. Mudstone, gray; a little muscovite and carbonaceous material; thinly laminated	3.0
6. Sandstone, gray, fine- to medium-grained; much carbonaceous material; many pebbles and seams of gray mudstone; abundant pyrite in both mudstone and carbonaceous material	6.6
7. Conglomerate, gray, fine-grained to conglomeratic matrix; much pyrite and calcite; more or less abundant carbonaceous material and gray mudstone cement; many pebbles of limestone, quartzite, and mudstone	2.5
8. Mudstone, light-gray; much muscovite, carbonaceous material, and calcite; laminae dip 60° and are cut by flat-lying normal faults	4.2

	Thickness (ft)
Mudstone-sandstone unit—Continued	
9. Mudstone and sandstone in alternating thin layers, light grayish-red, very fine grained; much muscovite and red mudstone cement; laminae vertical near base changing to horizontal at top; many faults	24. 7
10. Mudstone, gray; moderately abundant muscovite; thinly laminated	3. 1
11. Mudstone, grayish-yellow, mottled with red; 30 percent fine- to medium-grained sandstone at base	2. 9
12. Sandstone, light-gray, fine- to coarse-grained; much calcite, and light-gray mudstone cement; massive	. 6
13. Mudstone, dark-red and light-gray in alternating thin layers; much hematite, little gypsum; 10 percent fine- to medium-grained sandstone; slickensided fractures coated with gypsum.	21. 3
Total mudstone-sandstone unit	88. 1
Shinarump member:	
1. Sandstone, light-gray and grayish-red in alternating thin layers, fine- to coarse-grained; much calcite and gray and white mudstone cement, silica overgrowths on 10 percent of quartz grains, hematite causes red color	4. 7
2. Mudstone and sandstone in alternating thin layers, purplish-red; 25 to 30 percent fine- to medium-grained sandstone, a little carbonaceous material	1. 4
3. Sandstone, light yellowish-gray, medium- to coarse-grained; a few opaque minerals, little feldspar, moderately abundant grayish-yellow mudstone cement, silica overgrowths on 50 percent of quartz grains	3. 7
4. Mudstone, gray; a little marcasite(?), 25 to 30 percent fine- to medium-grained sandstone, much white feldspar	. 9
5. Sandstone, light-gray, medium-grained to very coarse grained; much pyrite in abundant carbonaceous material, much gray mudstone cement, 2 to 5 percent white feldspar	1. 8
6. Mudstone, gray; 10 percent fine- to medium-grained sandstone; four slickensided fractures	. 8
7. Mudstone, gray mottled with dark-red; 10 to 15 percent fine- to medium-grained sandstone, moderately abundant carbonaceous material; many fractures that dip 20°–60°	10. 6
8. Mudstone, gray mottled with olive-brown; 10 to 15 percent fine- to medium-grained sandstone, moderately abundant carbonaceous material; many fractures that dip 30°–60°	5. 2
9. Sandstone and mudstone in alternating thin layers, fine- to coarse-grained sandstone; much kaolinite and gray and reddish-brown mudstone cement; little carbonaceous material. Thin laminae dip 10°–20°	5. 7
10. Sandstone, light-gray, fine- to coarse-grained grading down to very coarse grained; a few sulfides, little carbonaceous material, much gray-white clay cement, silica overgrowths on 30 to 50 percent of quartz grains	4. 4

	Thickness (ft)
Shinarump member—Continued	
11. Conglomerate, gray, medium- to very coarse grained matrix; much carbonaceous material and gray mudstone cement, many gray pebbles of mudstone, a little pyrite	2.2
Total Shinarump member	41.4
Total Chinle formation	240.5

Unconformity.

Moenkopi formation:

Mudstone and siltstone in alternating thin layers, gray-green above dark-red; much muscovite, little pyrite; thinly laminated.

Core log 134 of Chinle formation at the Sandy claim, sec. 17, T. 36 S., R. 18 E.

Total depth. 283.2 ft
Collar altitude. 7,782.0 ft
Geologic setting. In channel

Map coordinates. 145,351 N.; 196,152 E. (pl. 8)
Date logged. Oct. 20, 1954
Logged by. O. T. Marsh

	Thickness (ft)
Chinle formation:	
Moss Back member:	
1. Sandstone, light-brown, very fine grained; much muscovite and biotite, a little limonite and rose quartz; many fractures and cavities coated with calcite	11.5
2. Mudstone, light-gray; a little muscovite and biotite	.4
3. Sandstone, light-gray to light-brown, very fine grained to coarse-grained; much muscovite, a little biotite, limonite, carbonaceous material, and light-gray mudstone cement, well-cemented with quartz and calcite	13.1
4. Mudstone conglomerate, light-gray; black chert pebbles, little muscovite, 50 percent chips of light-gray mudstone, 50 percent light-brown medium-grained sandstone	1.0
5. Sandstone, light-brown, fine-grained; more or less abundant muscovite, biotite, and limonite, a little carbonaceous material, and white clay cement	2.3
6. Sandstone, light-brown, very fine grained; moderately abundant muscovite, biotite and limonite, a little carbonaceous material, and white clay cement	2.0
7. Sandstone, light-brown, medium-grained; much muscovite and limonite, moderately abundant biotite, a few chips of light-gray mudstone and a little mudstone cement	4.0
8. Sandstone and mudstone in alternating thin layers, brown and light-gray, medium- to coarse-grained and pebbly sandstone; a little limonite, muscovite, and black chert, 50 percent light-gray mudstone	.6
9. Sandstone, light-gray to brown, very fine grained; much muscovite and biotite, moderately abundant limonite, little carbonaceous material	2.5
10. Sandstone, light-gray to brown, medium-grained; much muscovite, rose quartz, and limonite, little carbonaceous material	9.0
11. Sandstone, light-brown, medium- to coarse-grained, much muscocovite, little limonite, biotite, carbonaceous material and white clay cement	2.5
12. Sandstone, light-brown, fine-grained; moderately abundant muscovite and biotite, much limonite, quartz cement	6.7

	Thickness (ft)
Moss Back member—Continued	
13. Sandstone, light-brown, medium- to coarse-grained; much limonite, moderately abundant muscovite, light gray chips of mudstone, little carbonaceous material, quartz cement	1.1
14. Sandstone, light-brown to light yellowish-brown, fine- to medium-grained; much limonite, moderately abundant muscovite, little carbonaceous material and gray to white clay cement, quartz cement	34.3
15. Sandstone, light-brown, coarse-grained to pebbly; little limonite and muscovite, few pebbles of black chert, moderately abundant light-brown mudstone and calcite cement	2.0
16. Conglomerate, yellowish-brown above light bluish-gray; a little pyrite, a few pebbles of red and black chert, calcareous cement	10.8
Total Moss Back member	103.8
Unconformity.	
Mudstone-sandstone unit:	
1. Mudstone, grayish-green; little muscovite and carbonaceous material	16.1
2. Sandstone, greenish-gray, coarse-grained; little carbonaceous material, much bluish-gray mudstone cement	2.6
3. Mudstone, greenish-gray; a little pyrite, muscovite, and gypsum, calcite cement	11.5
4. Sandstone, greenish-gray, very fine grained; much muscovite and bluish-gray mudstone cement, little gypsum and carbonaceous material; ripple-laminated	10.1
5. Mudstone, greenish-gray; little muscovite and calcite, 10 percent medium- to coarse-grained sandstone	14.1
6. Sandstone and conglomerate, greenish-gray, very coarse grained to coarse-grained; a little pyrite, muscovite, rose quartz, and carbonaceous material, many pebbles of greenish-gray mudstone, calcite cement	6.2
7. Sandstone, greenish-gray, very fine grained; a little gypsum, much muscovite, carbonaceous material and greenish-gray mudstone cement, calcareous cement; laminated in places	9.7
8. Sandstone, yellowish-brown, medium- to coarse-grained; much limonite, a few chips of brown mudstone and a little mudstone cement, calcareous cement	10.8
9. Sandstone, light greenish-gray, very fine grained; much muscovite, limonite, and biotite, moderately abundant carbonaceous material	2.7
10. Sandstone, yellowish-brown, medium- to coarse-grained; much limonite, a little pyrite; white clay cement	3.7
11. Mudstone, gray; moderately abundant hematite veinlets	.7
12. Sandstone, yellowish-brown, medium-grained; much limonite, a little carbonaceous material and white clay, calcareous cement	2.0
13. Sandstone, white, medium- to coarse-grained; a little rose quartz, carbonaceous material, and white clay, not calcareous	1.4
14. Mudstone, gray; much hematite, a little carbonaceous material, 10 percent medium- to coarse-grained sandstone; ripple laminated	2.7
15. Sandstone, light-gray, medium- to coarse-grained; moderately abundant light-gray mudstone cement, calcareous cement	2.5

Mudstone-sandstone unit—Continued	*Thickness (ft)*
16. Mudstone, black mottled with purple and dark-gray; much hematite, a little limonite and gypsum, 7 percent medium- to coarse-grained sandstone; slickensided fractures	6.4
17. Sandstone purple mottled with light-gray, very fine grained to coarse grained; much hematite, a little limonite and calcite	5.5
18. Mudstone, dark-gray mottled with dark reddish-brown and black; a little limonite; slickensided fractures, ripple-laminated	7.4
19. Mudstone, dark-gray; moderately abundant carbonaceous material, a little limonite on slickensided fractures	6.0
20. Sandstone, dark-gray, very fine to fine-grained; moderately abundant pyrite, a little hematite and gypsum, much carbonaceous material, fractures are filled with gypsum	4.9
21. Sandstone, very light gray, very fine grained; moderately abundant limonite, much light-gray mudstone cement, not calcareous	1.5
22. Siltstone, gray mottled with dark reddish-brown; much hematite and light-gray mudstone cement, a little limonite and carbonaceous material, not calcareous	6.9
Total mudstone-sandstone unit	135.4
Shinarump member:	
1. Sandstone, light-brown, medium- to coarse-grained; a little light-brown mudstone and quartz cement	2.7
2. Sandstone and mudstone in alternating thin layers, mottled black, white, and dark-purple, fine- to coarse-grained; much limonite and mudstone cement, not calcareous; laminated, slightly cross-bedded	5.9
3. Sandstone, light-gray, very fine grained to fine grained; a little carbonaceous material, much light-gray mudstone cement	.5
4. Sandstone, light-gray, medium- to coarse-grained; a little jarosite, rose quartz, and carbonaceous material; much gray to white mudstone cement, silica overgrowths on 10 percent of quartz grains, not calcareous, quartz cement	13.1
5. Sandstone, yellowish-brown, medium grained to very coarse grained; much limonite and light-gray mudstone cement, quartz cement	1.6
6. Sandstone and mudstone in alternating thin layers, dark-gray, very fine grained to coarse-grained sandstone; a little pyrite and gypsum, much dark-gray mudstone cement in sandstone	7.9
7. Sandstone and siltstone, light-brown, very fine grained to fine-grained sandstone; a little muscovite and limonite, much light-brown mudstone cement. Native copper on bedding planes at base	2.3
Total Shinarump member	34.0
Total Chinle member	273.2

Unconformity.

Moenkopi formation:

Mudstone, dark-brown mottled with greenish-gray; much muscovite, little limonite; penecontemporaneous slumps, ripple-laminated, few fractures; 2 percent very fine grained sandstone. Native copper on bedding planes in upper 0.1 ft.

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(Continued on next card)

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