RME-111

UNITED STATES ATOMIC ENERGY COMMISSION

GRAND JUNCTION OPERATIONS OFFICE

PRODUCTION EVALUATION DIVISION

URANIUM RECONNAISSANCE AND DRILLING IN THE SANOSTEE AREA SAN JUAN COUNTY, NEW MEXICO AND APACHE COUNTY, ARIZONA

By

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February, 1959
(Grand Junction, Colorado)

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URANIUM RECONNAISSANCE AND DRILLING IN THE SANOSTEE AREA

SAN JUAN COUNTY, NEW MEXICO AND APACHE COUNTY, ARIZONA

ABSTRACT

The Sanostee area of northwest New Mexico and northeast Arizona includes a portion of the Defiance monocline, on the eastern edge of the Defiance uplift. Sedimentary rocks of Triassic, Jurassic, and Cretaceous ages are exposed in the area. Uranium is found in two Jurassic formations: the Todilto limestone and the Salt Wash and Recapture members of the Morrison formation.

In the Todilto, uranium occurs chiefly on joint planes and in vugs along the flanks of small anticlinal folds. Uranium in the Salt Wash sandstone is associated with lateral and vertical changes in permeability, with mudstones and siltstones, and with carbonaceous material. In the lower Recapture, uranium is closely associated with fossil logs; in the upper Recapture it is associated with lateral and vertical changes in permeability and with mudstones and siltstones.

On the Project No. 1 drilling (Contract No. AT(05-1)-259) thirty-three core holes were drilled, for a total of 17,732 feet. Seven of these penetrated the Todilto limestone. Another seven were drilled through the Salt Wash member of the Morrison formation. The remaining 19 holes penetrated only the mineralized zone of the upper Recapture member of the Morrison formation.

On the Project No. 2 drilling (Contract No. AT(05-1)-281) forty-eight air rotary holes were drilled, for a total of 18,750 feet. All holes penetrated the upper altered zone of the Recapture.

No ore-grade deposits have been found in the Todilto. Ore-grade deposits occur in the Salt Wash and lower Recapture, but none have been found that are large enough to be mineable. Deposits in the upper Recapture average about 0.15 percent U_3O_8 and are a few thousand tons in size. The drilling disclosed three low-grade ore deposits in the upper Recapture. Assays indicate high lime and low vanadium content of the deposits.

NOTE ECONOMIC CONCL.

PART I: RECONNAISSANCE

By

J. W. Blagbrough

INTRODUCTION

Purpose and Scope

Reconnaissance work began in the Sanostee area in October, 1953, and was completed in November, 1954. The objectives of this work were to map in detail the Roy Mesa and Enos Johnson claim areas so that ore guides could be determined and the areas could be evaluated for drilling and to complete a general reconnaissance of the favorable Mesozoic sedimentary rocks in the area and evaluate them for further exploration.

Methods

Plane table maps were made of the upper Recapture unit and the Salt Wash member of the Morrison formation in the Enos Johnson claim area. Formation contacts, mineralization, sedimentary trends, lithologic variations, altered zones, and joints were mapped, as well as topography and structure. A detailed map was made of the South Peak mine. Rim stripping uncovered favorable zones in the Salt Wash and Recapture which could not have been mapped otherwise.

A detailed mapping program was conducted on the Todilto limestone exposed on Roy Mesa in an effort to determine the mineralization controls and to find commercial deposits. The map, made from aerial photographs, shows the Todilto outcrop, joints, folds, and mineralized areas, as well as topography and structure.

A geologic map with a scale of one inch to 500 feet was made from aerial photographs of the Sanostee Wash area. Sections were measured in the favorable formation to determine lithologic variations. All mineralized outcrops in the Salt Wash and Recapture were mapped. Many of the favorable areas were checked with a scintillation counter, and all anomalies found were mapped. Navajo Indians were employed to prospect some favorable areas, and all mineralized outcrops reported by them were examined by geologists. Some of the areas were stripped by bulldozer for sampling and further study.

Geography

Location and accessibility

The Sanostee area is in San Juan County, New Mexico, and Apache County, Arizona, within the Navajo Indian Reservation (fig. 1). This area of about 70 square miles is approximately 25 miles southwest of Shiprock, New Mexico. A road leading west from U. S. Highway 666 extends 10 miles to Sanostee School, thence 4 miles up Sanostee Wash, where several unimproved truck roads lead to various parts of the area. Highway 666 and the gravel road to Sanostee School are all-weather roads; dirt roads in Sanostee Wash and the truck roads are subject to washouts in the summer and are occasionally blocked by snow in winter.

The southern part of the area is drained by Sanostee Wash and the northern part by Bear Creek (fig. 2).

Topography

The altitude at the western edge of the Sanostee area is approximately 8,500 feet; at the eastern edge it is 6,500 feet. The major land forms developed in resistant formations are mesas, canyons, and benches; those developed in the more easily eroded rock units consist of gentle slopes and rounded mesas with irregular drainage patterns. The Defiance monocline trends northwest and dips northeast; canyons generally are eroded at right angles to the structure or parallel to it. A series of benches commonly occur between canyon floors and mesa tops. Owing to the ruggedness of the Sanostee Wash area, roads are few, and much of the area is accessible only on foot or horseback.

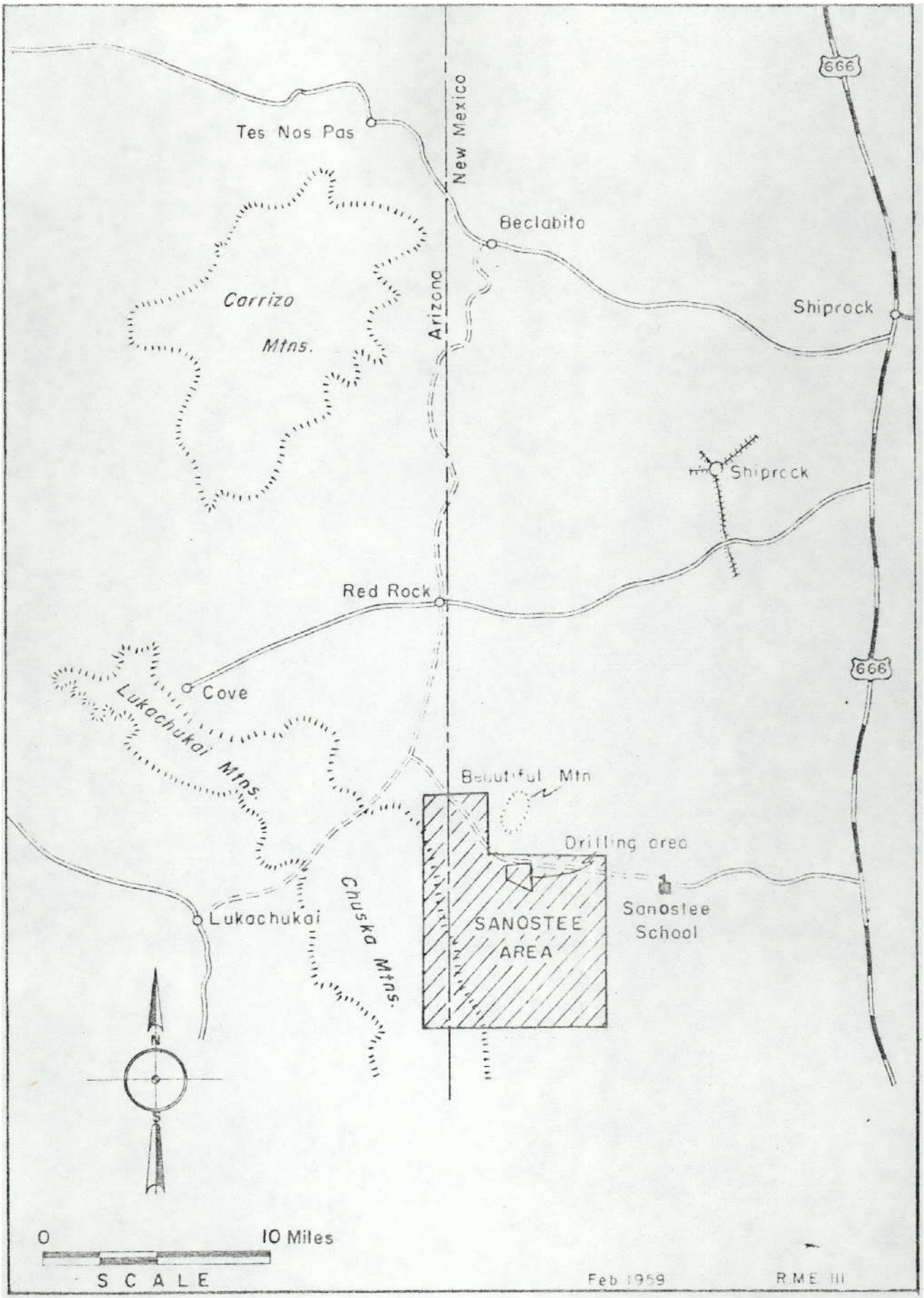

Figure 1. Location of the Sanostee drilling area
San Juan County, New Mexico, and Apache County, Arizona

Sanostee Creek, draining eastward into Chaco River, and Bear Creek, flowing north to Red Wash, are the two major drainages of the area. Sanostee Creek, Red Wash, and the Chaco River discharge into the San Juan River. Sanostee Creek is perennial except for brief periods in late summer; all other creeks are intermittent.

Climate and Vegetation

Annual rainfall on the eastern edge of the area is approximately 7.5 inches; toward the west, in the Chuska Mountains, it is about 18 inches. Most precipitation occurs during winter as snow or during July, August, and September as torrential showers. Summer temperatures frequently rise to about 95° F. Winters are cold, but sub-zero temperatures are rare. Vegetation is determined by altitude: Ponderosa pine, scrub oak, and Douglas fir grow above 7,500 feet; pinon, juniper, and various shrubs grow at lower altitudes.

Acknowledgements

Mining companies and individuals working in the area made the results of their drilling, rim stripping, and airborne surveys available to the Atomic Energy Commission. Their cooperation and assistance is greatly appreciated.

MINING AND EXPLORATION ACTIVITIES

The Sanostee area is within the Navajo Indian Reservation and is under the jurisdiction of the Bureau of Indian Affairs, U. S. Department of the Interior, Window Rock, Arizona. Leases and mining permits must be approved by the Navajo Tribal Council. All claims are held by Navajos, but most have been assigned or leased to individual and mining companies.

Exploration in the area by prospectors includes approximately 2,500 feet of rim stripping in the Recapture member of the Morrison formation on the north side of the Enos Johnson claim during the summer of 1952, about 2,500 feet of rim stripping in the Salt Wash member of the Morrison formation on the Joe Ben No. 3 claim in the summer of 1953, and approximately 3,500 feet of Recapture rim stripping on the Kee and Tohe and Castle Tsosie claims in the summer of 1954. The Bee-Shoshee Mining Company wagon-drilled closely spaced holes on the Reed Henderson, Carl Yazzie, and Kee and Tohe claims. Airborne radiometric surveys were made by three private concerns; two significant anomalies were discovered by one of them.

Three Atomic Energy Commission reconnaissance parties worked in the Sanostee area prior to this study. In June, 1951, approximately 5,000 feet of rim was stripped on the Enos Johnson claim by the Commission. A plane table map was made of part of the area, and sampling of some mineralized outcrops was done. This work is covered in a report by Droullard and Jones (1951).

In the spring of 1953, a second reconnaissance party continued this study on the basis of mining done since 1951. In the late summer of 1953 a sampling program was carried out in a bleached zone of the Recapture member

on the Enos Johnson claim to determine if this zone constituted a large low-grade ore body. The sampling showed that the zone averages less than 0.05 percent U_3O_8.

An airborne radiometric survey of the Morrison formation outcrop was started by the Atomic Energy Commission in June, 1953, but was abandoned in July owing to turbulent atmospheric conditions (Siapno, 1953). No significant anomaly was discovered.

The Sanostee area is included in a U. S. Geological Survey water supply investigation report (Harshbarger and Repenning, 1954) on the structure and stratigraphy of the Chuska Mountain area, of which the Sanostee area is a part. A Geological Survey Oil and Gas Investigations Map (Beaumont, 1954) describes the geology of Beautiful Mountain anticline and the eastern edge of the Sanostee area.

GEOLOGY

The Sanostee area lies along the Defiance monocline, a northwest-trending, northeast-dipping structure separating the Defiance uplift from the Four-Corners platform (fig. 3). The Hogback monocline, which forms the inner rim of the San Juan Basin, lies a few miles east of Sanostee School. The Defiance uplift, the Four-Corners platform, and the Hogback monocline are all structural elements of the San Juan Basin (Kelley, 1951). The Chuska Mountains, erosional remnants of sedimentary and igneous rocks, lie immediately west of the Sanostee area. Beautiful Mountain, capped by a Tertiary lava flow, is north and east of the area.

Owing to greater uplift in the western part of the area, Triassic rocks are exposed near the chuska Mountains, and progressively younger rocks crop out eastward. Tertiary Chuska sandstone rests unconformably on the Triassic Chinle formation in the extreme west edge of the area, but it lies on Cretaceous Mesaverde in the vicinity of Beautiful Mountain (figs. 2 and 6).

Stratigraphy

The Triassic system is represented in the Sanostee area by the Chinle formation and the Wingate sandstone of the Glen Canyon group. Rocks of Jurassic age are the Entrada sandstone, Todilto limestone, Summerville formation, and Bluff sandstone of the San Rafael group and the younger Morrison formation, which includes the Salt Wash, Recapture, Westwater Canyon, and Brushy Basin members. The Cretaceous rock units are the Dakota sandstone, Mancos shale, and Mesaverde group. The Mesaverde intertongues with the Mancos shale, and is represented by three units -- the Gallup sandstone, Dilco coal member of the Crevasse Canyon formation, and an unnamed sandstone unit, probably the "Stray" sandstone. The Chuska sandstone is the only sedimentary deposit of the Tertiary system. Triassic, Jurassic, and Tertiary systems are made up of fluvial, eolian, and lacustrine sediments; the Cretaceous system is a complex group of continental and marine rocks (fig. 2, 4, 5, and 6).

Uranium has been found in the Todilto limestone and in the Salt Wash and Recapture members of the Morrison formation.

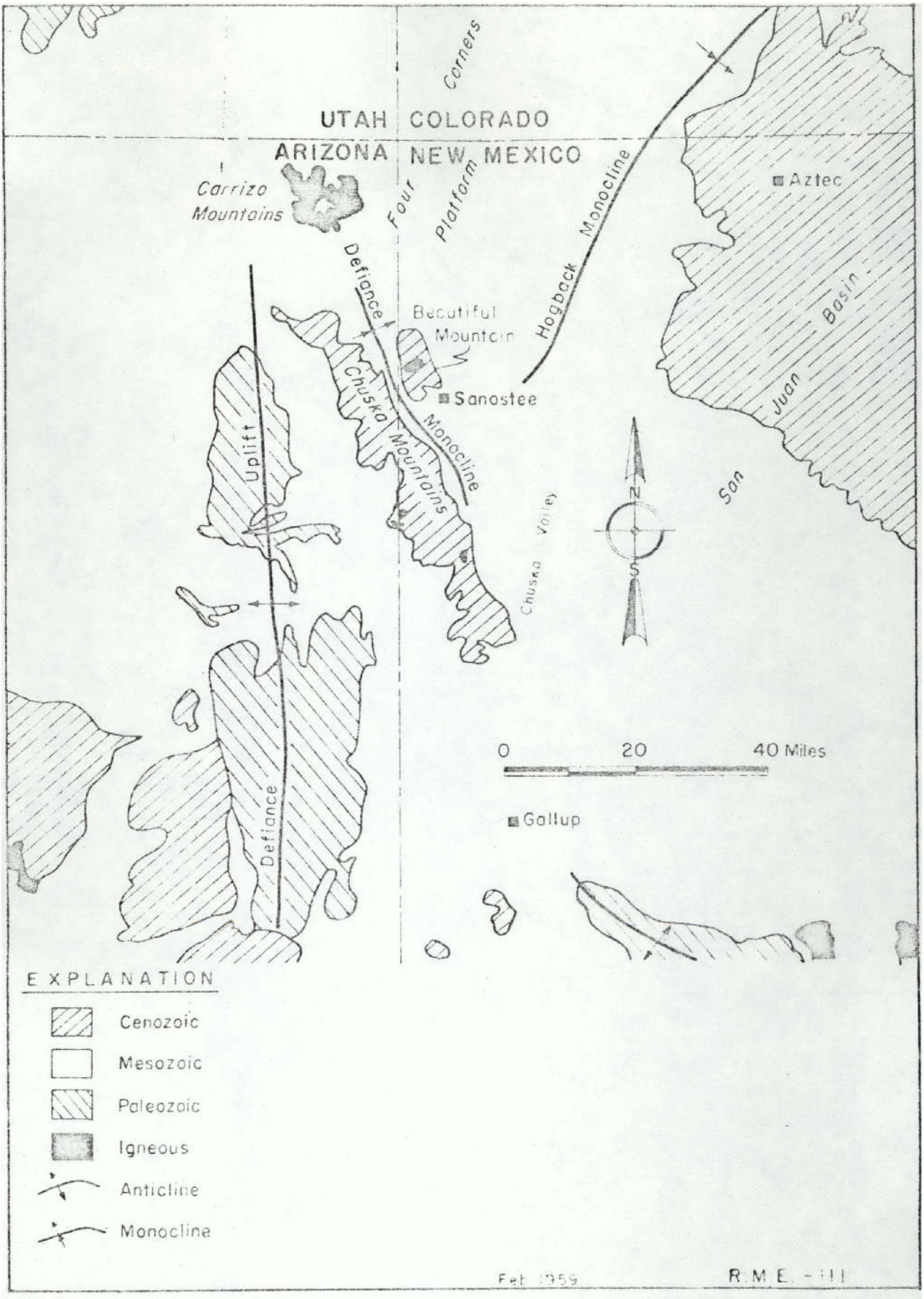

Figure 3 Regional geology of the Four Corners area

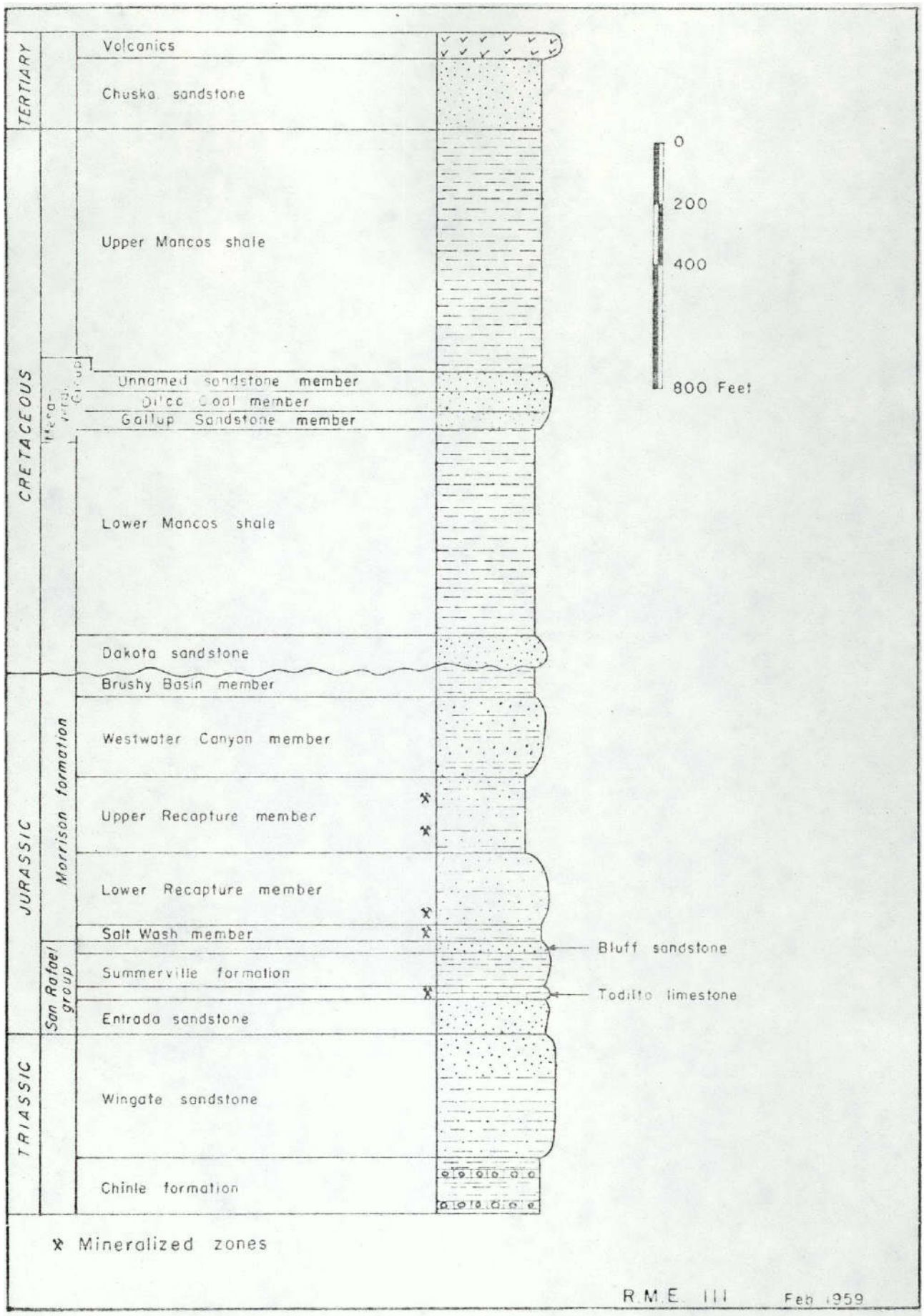

Figure 4. Columnar section of the Sanostee area, San Juan County, New Mexico

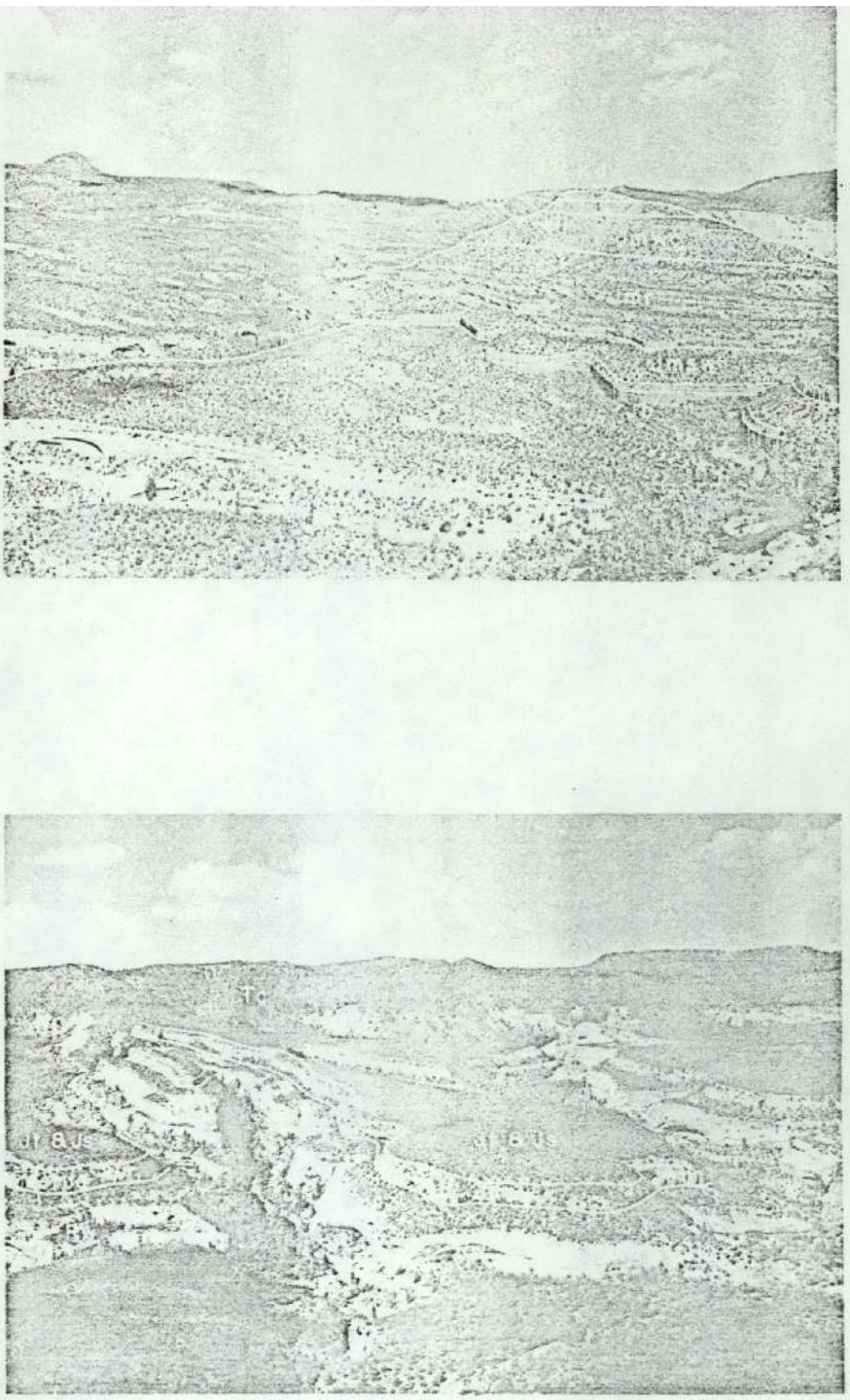

Figure 6. Triassic, Jurassic, and Cretaceous sediments exposed in the Sanostee area, San Juan County, New Mexico. For meanings of symbols see figs. 2 and 5.

Todilto Limestone, Jurassic

The Todilto is an impure dense gray very fine-grained thin-bedded limestone. The formation ranges in thickness from 6 1/2 feet in the northern part of the Sanostee area to 10 feet in the southern part. The limestone is transitional downward into the Entrada sandstone and upward into the Summerville formation. In the Sanostee area the Todilto is divided into two lithologic units. The lower unit is composed of flat-lying slabby beds of less than 1 foot in thickness; the beds of the upper unit are somewhat thicker, ranging from 1 to 2 feet. The upper unit contains countless small folds with some coarsely recrystallized calcite. Nearly all the uranium observed in the Todilto is associated with the folds. A 6-inch bed of oolitic limestone occurs at some places at the top of the Todilto, and uranium has also been observed in it.

Salt Wash Member, Morrison Formation, Jurassic

The Salt Wash has an average thickness of about 50 feet in the Sanostee Wash area and 75 feet in Bear Creek Canyon area. It decreases in thickness southward.

The Sanostee area lies on the southeast edge of the Salt Wash fan described by Craig et. al. (1955). Southward from Sanostee the Salt Wash grades into the base of the overlying Recapture and is not present south of Toadlena, about 15 miles southeast of Sanostee.

The Salt Wash, the basal member of the Morrison formation, is an alternating sequence of green and red mudstones and siltstones and light gray and red sandstones. Mudstones and siltstones make up 60 to 75 percent of the Salt Wash in the Sanostee area; commonly they grade laterally into sandstones. Sandstones are medium to very fine-grained, poorly sorted, and moderately cemented. Very fine-grained sandstones predominate. Some arenaceous beds contain carbonaceous trash and logs; all have fluvial festoon bedding and current lineation. A study of sedimentary structure indicates that the direction of paleostream flow on the Enos Johnson claim was chiefly to the southeast.

The Salt Wash commonly forms a slope between the resistant Bluff sandstone below and the Recapture member above. Contact between the Salt Wash and Recapture is generally distinct, the Recapture being the coarser-grained. In some places sandstones of the Recapture fill paleostream channels cut into the Salt Wash. One or two feet of reworked Bluff is usually found at the base of the Salt Wash.

Thickness of the Salt Wash increases from 50 feet in the vicinity of the Enos Johnson claim to 125 feet eleven miles north, near Red Rock Trading Post. The percentage of mudstone decreases from south to north. There are three facies of Salt Wash, similar to those in the Lukachukai Mountains described by Masters (1953). The flood-plain facies of mudstone and minor sandstone is exposed in the Sanostee Wash area. Thick, continuous sandstone with minor mudstone is characteristic of exposures around Red Rock. An intermediate zone of interbedded lenticular mudstone and sandstone is exposed in Bear Creek Canyon.

Recapture Member, Morrison Formation

The Recapture is approximately 475 feet thick in the Sanostee Wash area and is about 500 feet thick in Bear Creek Canyon. It is divided into an upper and a lower lithologic unit. The lower Recapture, about 275 feet thick, is exposed as a series of three predominantly red sandstone cliffs separated by benches. This unit consists of red and light-gray, coarse- to fine-grained sandstone showing festoon and planar bedding, with minor interbedded red siltstone and mudstone. Sand grains of fine grade predominate. Carbonized fossil logs occur in the lower beds. The contact between the upper and lower units of the Recapture is gradational and based largely on degree of friability.

The upper unit of the Recapture is a friable light-red to light-gray sandstone; because of weakness of the cement it usually forms a gentle rounded slope, bearing a mantle of soil, between the more resistant lower Recapture and the overlying Westwater Canyon member of the Morrison formation. The upper part of the Recapture is about 200 feet thick; it consists of coarse- to very fine-grained predominantly red with some light-gray sandstones and minor amounts of interbedded red and green mudstones. The sandstone units have festoon and planar bedding and grade laterally into mudstones and siltstones. Contact between the Recapture and Westwater Canyon is sharp, as the Westwater Canyon forms a cliff above the Recapture and is a medium- to coarse-grained yellow-brown sandstone.

In the area around the Enos Johnson claim a conspicuous zone of light-gray sandstone ranging in thickness from 50 to 150 feet occurs in the upper Recapture 10 to 40 feet below its contact with the overlying Westwater Canyon. The thickness of this zone decreases both north and south of the Enos Johnson claim, and it is not recognizable northwest of the Dennet Nezz claim or south of the Carl Yazzie claim. At both these localities light-red sandstone interfingers with light-gray sandstone. The color zones thicken and thin abruptly, ranging in thickness from 5 to 20 feet. These features appear to be epigenetic: the gray sandstone is bleached; the conspicuous zone on the Enos Johnson claim is near the center of bleaching; and the other two localities are on the boundaries of bleaching.

The larger ore deposits of the area are in this zone of light-gray sandstone.

The Sanostee area lies on the north edge of the conglomeratic facies of the Recapture fan, the source of which was south of Gallup, New Mexico (Craig et. al., 1955). Sedimentary structures in the upper part of the Recapture at Sanostee Wash indicate that the paleostreams were flowing from the southeast.

Igneous Rocks

No igneous rocks are exposed in the Sanostee area. Lava flows and volcanic necks occur in the Chuska Mountains and on Beautiful Mountain and volcanic necks in Chuska Valley (fig. 3). The composition and texture of the volcanic rocks of the Chuska Mountains and Chuska Valley have been discussed by Williams (1936).

Structure

The Sanostee area is on the northwest-trending Defiance monocline, which is the eastern edge of the Defiance uplift (fig. 3). The Defiance monocline is believed by Harshbarger and Repenning (1954) to be the steeply dipping eastern flank of an asymmetrical anticline entirely covered by Chuska sandstone except for its steep eastern side. Between the anticline and the Defiance Plateau to the west is a syncline in pre-Chuska rocks. The syncline is concealed by Chuska sandstone, and its presence is indicated only by the structural attitude of the pre-Chuska rocks on each side of the mountains. Bedding in the report area dips northeast 1 to 15 degrees. In general, the dip is steepest near the Chuska Mountains and decreases eastward, however, a local steepening of the dip occurs in the eastern part of the Sanostee Wash area where the strike of the Dakota formation, Brushy Basin, Westwater Canyon, and Recapture swings slightly eastward. Folding in the Sanostee area is considered Laramide in age, as early Tertiary rocks are undeformed.

Four miles east of the Sanostee area the axis of Beautiful Mountain anticline trends northward through Sanostee School (fig. 2). Four miles north of the school the axis swings to about N. 10° E. and continues for a distance of 5 miles. The northern half of the anticline is folded asymetrically, the eastern flank dipping from 9 to 13 degrees and the western flank dipping from 1 to 3 degrees. An asymetrical syncline trending about N. 20° W. lies west of Beautiful Mountain anticline. The west limb of this syncline is part of the Defiance monocline. The dip of beds along the western limb of the syncline increases westward from the axis to the Chuska Mountains. Six miles east of Beautiful Mountain anticline is Tocito dome, separated from Beautiful Mountain anticline by a syncline.

Two well-developed sets of joints cut the rocks of the Sanostee area. Both dip normal or nearly normal to the regional dip and in strike are generally within 30 degrees of normal to each other. One joint set is nearly parallel to the northwest trend of the Defiance uplift, the other is essentially parallel to the regional dip of formations in which they occur.

The joint pattern has had a profound effect on drainage and topography, most noticeable in the Wingate and Entrada sandstones. The canyons are oriented chiefly parallel to and normal to the trend of the Defiance uplift, in conformity with dominant strikes of the joint sets. Mesa and bench rims commonly parallel the joint sets. The relation of the joint system to the Defiance uplift indicates they were formed at the same time.

Geologic History

Outlined below are the important geologic events which have taken place in the Sanostee area since the beginning of Triassic time.

1. Deposition of fluvial, eolian, and lacustrine sediments in the Triassic and Jurassic period. Ore-bearing formations of the Sanostee area were deposited during this period of continental sedimentation.

2. Deposition of the Cretaceous Dakota sandstone, the basal deposit of the transgressing Mancos sea (Pike, 1947), followed by marine Mancos shale, the complex continental and marine Mesaverde group, and younger Cretaceous rocks.

3. Regional uplift (Laramide Revolution) and formation of folds, and joints; erosion; uranium ore deposition (?).

4. Deposition of the continental Miocene (?) Chuska sandstone on the surface of erosion.

5. Intrusion of plugs, dikes, sills and extrusion of lava flows in and on the Chuska sandstone in middle and late Pliocene.

6. Uplift of the entire Colorado Plateau; initiation of the canyon cutting cycle of late Pliocene and Pleistocene.

URANIUM DEPOSITS

Four stratigraphic units of Jurassic age contain uranium minerals in the Sanostee area: the Todilto limestone, and the Salt Wash, lower Recapture, and upper Recapture members of the Morrison formation (fig. 4).

Todilto Limestone

The uranium minerals tyuyamunite and metatyuyamunite occur sparsely in the upper 5 feet of the Todilto limestone from the Reed Henderson claim, at the south edge of the Sanostee area, to the saddle that separates Bear Creek Canyon from the north branch of the Sanostee Wash (fig. 2). No uranium is known in the Todilto limestone in its outcrops in Bear Creek Canyon.

The uranium minerals occur chiefly on joint planes and as lining of vugs in areas of recrystallized calcite, especially on the flanks of anticlinal folds. Chlorite, hematite, and manganite are commonly associated with the mineralized folds. The small anticlinal folds have a width of about 3 feet, a height of 1 or 2 feet, and a length of 10 or 15 feet. Between anticlines beds are flat rather than bowed downward. In areas of intense folding the fold axes are from 5 to 20 feet apart. The axes frequently have a common orientation in areas of intense folding, but they do not appear to parallel any of the Laramide structures. The folds are not reflected in the lower portion of Todilto nor in the Summerville formation above. The areas of most intense folding are those most highly mineralized. Coarse-textured calcite is commonly found in the folds. Since the folds are confined to the upper part of the Todilto limestone and not reflected in older Todilto or in younger rocks, they are presumed to be diagenetic, as is also the coarsely crystallized calcite associated with them.

Salt Wash Member, Morrison Formation

On the Enos Johnson claim and on the north side of Sanostee Wash as far north as the Kee and Tohe claim (fig. 5), portions of the Salt Wash contain oxidized vanadium minerals, including uranium vanadates. No uranium in Salt Wash has been reported south of the Carl Yazzie claim, nor

north of the Kee and Tohe claim, nor in Bear Creek Canyon. The minerals occur in light- to medium-gray sandstone in the upper part of the Salt Wash. The lower portion, which contains a large percentage of siltstone and mudstone, does not contain uranium.

Uranium is disseminated in sandstone as grain coatings and as cement. Three types of occurrence are known in the Salt Wash. In one, the minerals are directly above or below a mudstone, in very fine-grained light-gray sandstone. The mudstone in the vicinity of uranium is altered from normal red to green. The mineralized zone is thin and tabular and parallels the mudstone for 25 to 50 feet. It ranges in thickness from a few inches to 2 feet. At places the sandstone fills a scour in the mudstone, and uranium is concentrated in the scour.

A second type of deposit is in a light-gray very fine-grained sandstone lens rich in carbonaceous trash. The uranium occurs in carbon trash and at places forms a halo around it. The mineralized area ranges from a few inches to 2 feet in thickness and from 25 to 50 feet in diameter. Limonite is commonly associated with the carbon-trash type of deposit.

A halo of uranium around a carbonized log constitutes the third type of deposit. The logs have diameters of 1 to 2 feet and commonly are 3 or 4 feet long. Uranium fills fractures in the log and is also disseminated in the very fine-grained light-gray sandstone around it.

Recapture Member, Morrison Formation

Mineralized fossil logs occur in the lower Recapture from 30 to 70 feet above its contact with the underlying Salt Wasn. Such logs have been found on the Dennet Nezz and David Kee claims (fig. 5) on the north side of Sanostee Wash and on the White Cone claim on the west side of Bear Creek Canyon (fig. 2). The logs are partly calcified, have a diamater of 2 to 3 feet and are 5 to 15 feet long. Uranium is in fractures in the logs and is also disseminated through a few feet of the enclosing sandstone. Adjacent to the logs, fine-grained sandstone is altered from red to light-gray. Mineralized areas have diameters as much as 4 feet.

The upper Recapture contains the largest and most highly mineralized zones in the Sanostee area. Uranium occurs in the upper Recapture from the Carl Yazzie claim north to the H. B. Roy No. 1 claim in Bear Creek Canyon (fig. 2). The largest and richest deposits are in the Enos Johnson claim area. Conspicuous mineralization is confined to a zone of light-gray sandstone with a maximum thickness of 60 feet which occurs from 10 to 170 feet below the Recapture-Westwater Canyon contact. Mineralized zones range from 20 to 300 feet in length and from a few inches to 20 feet in thickness.

The chief uranium mineral is carnotite. Some schroeckingerite has been reported by Droullard and Jones (1951). Other than carnotite, no vanadium minerals have been identified, but some samples contain a higher ratio of vanadium to uranium than is present in carnotite, so that the presence of other vanadium-bearing minerals is indicated. Hematite, chlorite, and limonite are commonly associated with the higher grade deposits, and these minerals in some places mask the color of the carnotite. Chlorite is an

ingredient of siltstone in the low-grade deposits. Chlorite, hematite, limonite, and carnotite coat and cement the sand grains. In richer deposits banding of the cementing materials cuts across the bedding.

Two types of uranium occurrences are found in the upper Recapture. In the first, uranium occurs above or below a mudstone or siltstone unit, in a medium- to fine-grained light-gray sandstone. The siltstone or mudstone is commonly 2 or 3 feet thick and is altered from red to green. The mineralized zone is a few inches to 2 feet thick and ranges in grade from a trace to as much as 1 percent U_3O_8. Uranium is for the most part fairly continuous along the siltstone or mudstone unit, and some uraniferous zones can be followed for a distance of 300 feet. The richest deposits occur along mudstones which lie unconformably on sandstones; deposits along siltstones are commonly low in grade.

The second type of mineralized zone ranges in thickness from a few inches to 20 feet and has a lateral extent of as much as 300 feet. The uranium is in a medium- to fine-grained light-gray thick sandstone lens as a halo around lime concretions that range in diameter from a few inches to 6 feet. Thin, irregular stringers and pebbles of mudstone and siltstone also have halos of uranium which are as much as 3 feet thick. The mudstones are chiefly red, but siltstones are altered to green. Uranium is also found in sandstone lenses containing red mudstone galls. Where it forms a halo around and impregnates the lenses, it is commonly 1 or 2 feet thick. A thick mudstone or siltstone usually underlies the mineralized sandstones, and the lens is capped with an altered mudstone or siltstone.

Ore-Grade Deposits

The deposits in the Salt Wash are small, approximately 150 tons, and have an average grade of about 0.15 percent U_3O_8, 0.70 percent V_2O_5, and 15 percent $CaCO_3$. The deposits have a diameter of 25 to 50 feet and are oval in shape with an average thickness of $1\frac{1}{2}$ feet.

Ore-grade material from deposits in the lower Recapture has been shipped from the Joe Ben No. 1 and the Dennet Nezz claims. These deposits have a maximum diameter of 20 feet and a thickness of 1 or 2 feet and contain between 5 and 10 tons of material averaging 0.30 percent U_3O_8 and 0.30 percent V_2O_5. The lime content is high, because the uranium is closely associated with calcified logs. Logs of ore grade have been observed on the Dennet Nezz, David Kee, and White Cone claims.

Studies made of the South Peak mine on the Enos Johnson claim of mineralized outcrops indicate that the upper Recapture contains large deposits of low-grade uranium ore. The deposits are elongated, having a length between 500 and 600 feet and a width between 150 and 200 feet. Mineralization may not be continuous throughout the body. The thickness ranges from one foot to 15 feet of discontinuous mineralization. Grade of deposits ranges from 0.12 to 0.20 percent U_3O_8, 0.20 percent V_2O_5, and 5 to 10 percent $CaCO_3$. Upper Recapture ore has been shipped from the Enos Johnson, Horace Ben, and Kee and Tohe claims.

Unlike most concentrations of uranium minerals in the Morrison formation, nearly all those of the Sanostee area have a relatively low vanadium content.

In this respect they resemble the deposits of the Grants district in New Mexico. The genesis of the Grants and Sanostee deposits may therefore have been significantly different from the genesis of other Morrison deposits of the Plateau.

No ore-grade deposits have been found in the Todilto limestone in the Sanostee area. Some mineralized Todilto limestone was shipped from one claim, but the material ran less than 0.10 percent U_3O_8.

Ore Controls and Guides

All uranium deposits in the Salt Wash at Sanostee are either closely associated with carbon or are directly above or below a green mudstone. The host rock is a light- to medium-gray sandstone rather than a red sandstone. Zones of light-colored sandstone associated with green mudstones or carbon are considered favorable.

Uranium in the lower Recapture is associated with fossil logs, and the sandstone in the vicinity of these logs is altered from red to a light-gray color. The sandstone alteration associated with fossil logs is a guide to the small deposits.

The chief ore controls in the upper Recapture appear to be lateral and horizontal variations in permeability and inclusions within sandstone units of materials which may have been chemical precipitants. Ore is found directly above a siltstone or mudstone in a medium- to fine-grained sandstone or in thick medium- to fine-grained sandstone units which contain small stringers and pebbles of mudstone and siltstone, mudstone galls, and concretions of calcium carbonate. Zones showing these features are considered favorable for the occurrence of ore. Ore is also found in medium- to fine-grained sandstone lenses in channels of paleostreams. Outcrops show that these ore-bearing sandstones grade laterally into siltstone and mudstone flood-plain deposits.

Ore in the Recapture occurs in light-gray sandstones which are part of an altered zone 50 to 150 feet thick. Mudstones and siltstones that have an appreciable lateral extent and are closely associated with ore are altered from red to green.

A selenium indicator plant, Astragalus pattersoni, grows profusely in the vicinity of the ore bodies, but it is also found in areas of subore-grade uranium.

Mode of Deposition

Eardley (1951) believes that the monoclines of the Colorado Plateau were produced by faulting in the Precambrian basement. The Defiance monocline, which was formed during the Laramide orogeny, is believed to have been of this origin, and it is suggested that ore-bearing solutions gained access to favorable formations through fractures which were opened during the Laramide orogeny. Variably permeable stream sediments, such as those of the Salt Wash and Recapture, provided favorable lithologic features and favorable chemical environments for precipitation of uranium from mineralized solutions.

CONCLUSIONS AND RECOMMENDATIONS

Ore-grade uranium deposits occur in the Salt Wash and the lower and upper Recapture, and appreciable subore-grade uranium occurs in the Todilto limestone.

The deposits in the Salt Wash are small, the largest having a diameter between 25 and 50 feet and a thickness of 2 feet. The grade averages between 0.15 and 0.20 percent U_3O_8. The Salt Wash in the Sanostee area contains a percentage of mudstone too high for large ore bodies like those found in the Lukachukai Mountains a few miles to the northwest. The uranium occurs in a light-gray sandstone and is controlled by carbon and lateral and vertical changes in permeability. Uranium in the lower Recapture is found closely associated with fossil logs in a light-gray sandstone. The deposits have a length of between 10 and 20 feet and a width and thickness of 2 or 3 feet. The grade averages between 0.30 and 0.50 percent U_3O_8. Uranium deposits in the Salt Wash and lower Recapture are too small to be mineable.

Ore bodies in the upper Recapture have diameters that are measured in hundreds of feet. Thickness ranges from 1 foot of continuous mineralization to 20 feet of spotty mineralization with an average grade between 0.15 and 0.20 percent U_3O_8. The ore is in a light-gray sandstone and is controlled by small stringers and galls of mudstone, which may have acted chemically to precipitate the ore, and lateral and vertical changes in permeability. The upper Recapture ore bodies are good drilling targets because of their large size.

PART II

DRILLING

By

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R. W. Lott

INTRODUCTION

The purpose of these drilling projects was to investigate the relationship of ore to sedimentary trends, to aid in determining ore guides and controls in the upper Recapture, and to determine the value of wide-spaced drilling in the Salt Wash and Todilto limestone in the Sanostee area.

PROJECT NO. I

A total of 17,732 feet was core drilled in 33 holes in four areas in the Sanostee No. 1 project, which began July 9, 1954, and ended January 11, 1955 (fig. 7). Samples were assayed for uranium, vanadium, and calcium carbonate.

In Area 1, Holes P-1 to P-17 were drilled on approximately 400-foot centers along the longitudinal direction of the mesa. Rim studies of festoon bedding, crossbedding, and contacts between high sandstone and high mudstone zones had suggested a northwest-trending paleostream channel. The northeast pattern of drilling was established to cross the trend and determine its relationship to ore deposition. Holes P-1, P-3, P-5, and P-7, completed at the base of the Todilto limestone, were drilled for stratigraphic information, particularly on the upper Recapture bleached zone, the mineralized zones in the Salt Wash, and the Todilto limestone. The remaining holes penetrated only the upper Recapture and were "bottomed" near the upper and lower Recapture contact.

One hole, P-30, was drilled in Area 2, east of the Horace Ben mine, for stratigraphic information for correlation in the Sanostee No. 2 air rotary drilling project.

Area 3, on the north central edge of the main mesa, contains holes P-19 to P-23, inclusive, P-31, P-32, and P-33. The last three were drilled later to offset P-23, which penetrated the Todilto limestone; all other holes were drilled only through the upper Recapture.

In Area 4, on a lower Recapture bench surrounding the western flank of the mesa, holes P-24 to P-29 and P-18 penetrated only the Salt Wash. The results of the drilling are shown on figs. 7, 8, and 9 and in table 1.

No mineralogic studies have been made of uranium minerals in the Sanostee area. All uranium minerals observed were vanadates, either carnotite or tyuyamunite, however vanadium-uranium ratios suggest that other uranium

Table 2. Drill-hole data for Sanostee Project No. 2

Hole No.	Total Depth	Logging Depth	Maximum cts./Sec.	Classification
AA-1	435'	417'	1050	weak
AA-2	450'	447'	4070	ore
AA-3	475'	465'	3370	ore
AA-4	470'	455'	2750	ore
AA-5	475'	470'	4550	ore
AA-6	380'	334'	6370	ore
AA-7	400'	395'	8200	ore
AA-8	270'	260'	7780	ore
AA-9	315'	310'	1415	strong
AA-10	270'	255'	3600	ore
AA-11	210'	195'	2580	ore
AA-12	180'	174'	1500	strong
AA-13	485'	482'	1190	strong
AA-14	470'	469'	500	barren
AA-15	445'	444'	650	weak
AA-16	450'	450'	660	weak
AA-17	450'	448'	840	weak
AA-18	440'	436'	1000	weak
AA-19	400'	396'	3700	ore
AA-20	415'	412'	8175	ore
AA-21	470'	468'	5075	ore
AA-22	445'	443'	630	weak
AA-23	445'	442'	1300	strong
AA-24	450'	440'	5000	ore
AA-25	445'	442'	1500	strong
AA-26	445'	440'	2000	ore
AA-27	455'	440'	5800	ore
AA-28	290'	287'	660	weak
AA-29	380'	377'	161	barren
AA-30	215'	214'	840	weak
AA-31	195'	195'	550	barren
AA-33	210'	202'	1560	strong
AA-34	485'	479'	3000	ore
AA-35	270'	262'	3000	ore
AA-36	355'	355'	300	barren
AA-37	345'	344'	222	barren
AA-38	355'	355'	285	barren
AA-39	330'	329'	1440	strong
AA-40	329'	327'	1500	strong
AA-41	360'	355'	219	barren
AA-42	355'	355'	300	barren
AA-45	300'	296'	4000	ore
AA-47	515'	510'	2324	ore
AA-48	500'	500'	720	weak
AA-49	475'	475'	780	weak
AA-50	480'	476'	300	barren
AA-51	495'	493'	960	weak
AA-70	480'	453'	6250	ore

and vanadium minerals are present, probably as oxides. In general, chemical assays run higher than radiometric assays, particularly in the richer samples. Lime associated with the richest ore zones usually occurs as interstitial calcite. Assays indicate calcium carbonate to be in excess of 25 percent in some of the richer ore zones. Several holes encountered 5 percent V_2O_5 in the ore zone, one ore hole had no vanadium, and one had 44 percent V_2O_5, the highest vanadium concentration found.

Upper Recapture host rocks are of two slightly different types. Both are light-gray sandstone lenses in a sequence of impermeable mudstones or siltstones, and in both uranium minerals are disseminated or occur as sand-grain coatings. The predominant type is medium- to fine-grained and contains numerous red and green mudstone galls. A deposit of this type occurs at the western edge of the mesa and is the richest in the Sanostee area. The second type is a fine- to very-fine-grained, sandstone cemented with calcite and commonly associated with thin zones of dark-red to black iron stain. An altered zone surrounding the iron stain is most commonly green and has sandgrain coatings of chlorite and ferrous iron.

In Area I in the upper Recapture, uranium is in the lowermost beds in a bleached zone approximately 100 feet thick and 35 feet below the Westwater Canyon-Recapture contact. The deposits range from 1 to 10 feet in thickness and from 0.01 to 0.28 percent U_3O_8 in grade (fig. 8). The ore commonly does not have a sharp contact with the barren rock but has 1 to 5 feet of mineralized rock above and a lesser amount below. Deposits in the upper Recapture are low in grade, have a moderate lateral extent, and range from 1 to 6 feet in thickness.

In Area 3 subore-grade uranium is found in two zones (fig. 9). The upper, highly mineralized zone is 110 feet below the Westwater Canyon-Recapture contact, and the lower, weakly mineralized zone is approximately 145 feet below the contact.

Mineralized sandstones in the Salt Wash mostly fine-grained, light-greenish-gray to white, 1 to 6 feet thick, and occur between thick red mudstone units in the upper part of the member, where the lenses are thicker and more favorable than in the lower part. Green mudstones throughout the Salt Wash have anomalous radioactivity. Mineralization is very sparse and low grade in the Salt Wash; in only two holes did gamma logs justify radiometric and chemical analysis. Drill hole P-3 contained a 1-foot interval that assayed 0.03 percent U_3O_8, and hole P-27 contained four 1-foot intervals that assayed 0.01 percent radiometrically. Rim studies of the Salt Wash show that uranium minerals are disseminated in light-gray to white sandstone units from 3 to 6 feet thick and that generally the deposits are less than 200 tons in size and 0.10 to 0.20 percent U_3O_8 in grade.

No uranium deposit of commercial grade was found in the Todilto limestone as a result of drilling during the Sanostee No. 1 project. In only one hole did the gamma log justify a chemical assay; a 1-foot sample contained only 0.01 percent U_3O_8. The average thickness of the Todilto limestone is approximately 8 feet, and anomalous radioactivity is generally restricted to the top 2 feet.

PROJECT NO. 2

A total of 18,750 feet was air rotary drilled in 48 holes in three areas in the Sanostee No. 2 project between March 29 and August 11, 1955. Thirty-eight holes were in Areas 1 and 3 on the Enos Johnson claims, and 10 were in Area 2 on the Horace Ben claim (figs. 5 and 7). All holes were completed at a depth just below the upper 100 feet of altered Recapture sandstone.

Samples were of little value because of contamination by sloughing in the hole. No samples were obtained from the ore zone below the Westwater Canyon-Recapture contact because of ground water. No stratigraphic information was obtained from electric logs because it was impossible to distinguish on the logs the interlensing mudstones, siltstones, and fine-grained sandstones in the upper Recapture. Gamma logs indicate 20 holes were in ore, 8 strongly mineralized, 11 weakly mineralized, and 9 barren (figs. 7 and 10, table 2). The ore is largely low grade and occurs in small pods having a vertical range of 80 feet. All ore and mineralized holes were in the northwest trend.

CONCLUSIONS

The bleached zone of the upper Recapture is the only favorable host for uranium found in these drilling projects. Deposits in this unit are low grade, have a moderate lateral extent, and range from 1 to 6 feet in thickness. Twenty-four holes into the upper Recapture showed ore-grade uranium (0.10 percent U_3O_8 or more), and 11 were mineralized (0.05 to 0.10 percent U_3O_8). The results suggest a large, spotty, low-grade deposit, approximately 1,500 feet in length and several hundred feet in width and two smaller deposits about 200 feet in length. These deposits all contain ore-grade uranium ranging from 0.10 to 0.28 percent U_3O_8.

The drilling substantiated the validity of the ore guides and controls postulated for the upper Recapture in the reconnaissance report, but not for the lower Recapture, Salt Wash, and Todilto limestone, as no ore-grade material was found in these units. The drilling established a relationship between the northwest-trending paleostream channel in the upper Recapture and ore deposition, as all ore and mineralized holes fell within the trend.

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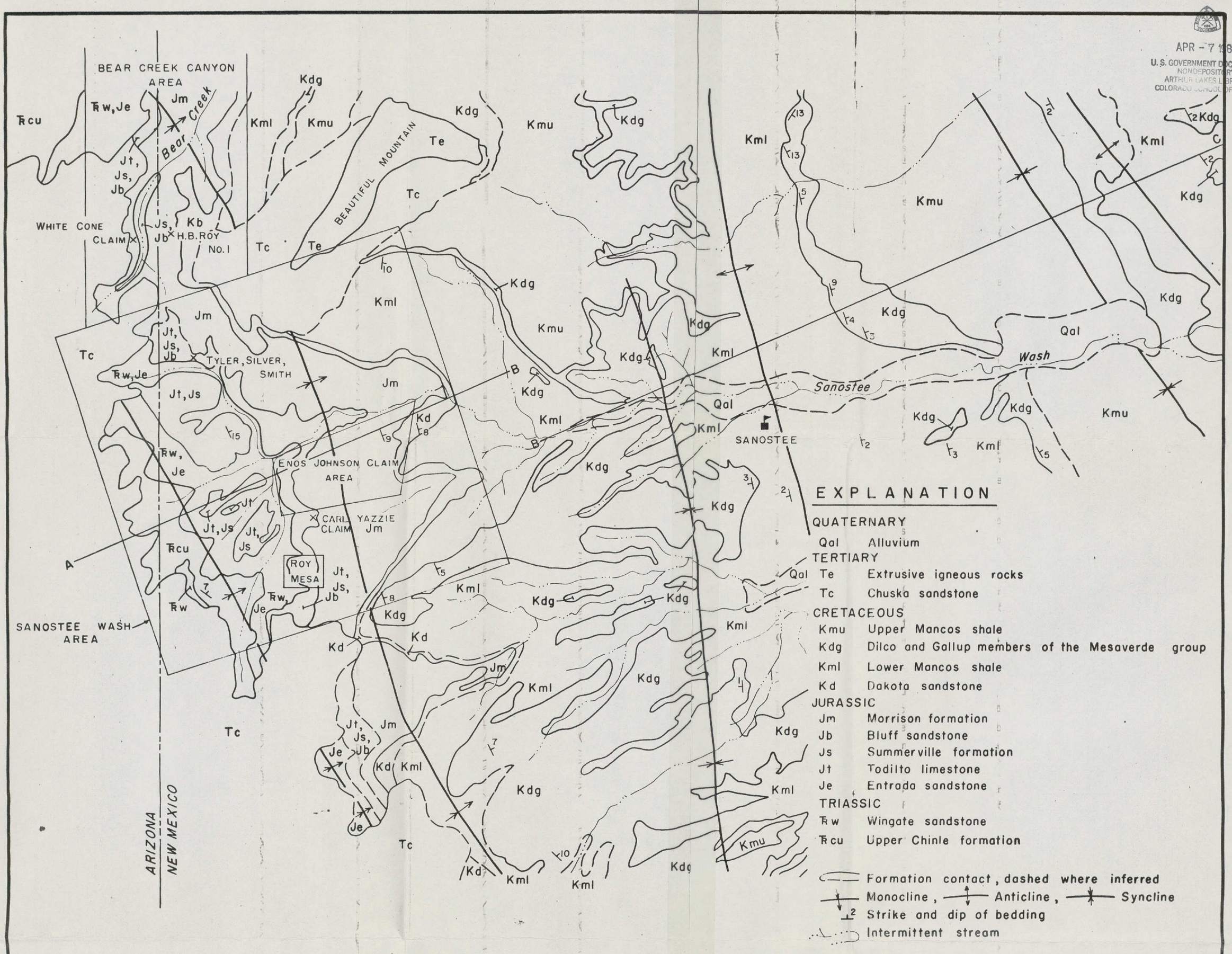
APPENDIX

Table 1. Drill-hole data for Sanostee Project No. 1

Hole No.	Depth	Upper Recapture Interval Sampled	Upper Recapture Classif.	Saltwash Interval Sampled	Saltwash Classif.	Todilto Interval Sampled	Todilto Classif.
P 1	966	313.5-314.5	ore		barren	943-944	weak
P 2	545	404 -405.2	ore				
P 3	1018	391 -395	ore	790-791	weak		barren
P 4	570	414 -415	strong				
P 5	970		barren		barren		barren
P 6	545	379 -380	weak				
P 7	1020	401 -402	strong		barren	1013-1014	weak
P 8	515	321.5-322.5	weak				
P 9	502	392 -394	weak				
P 10	475	357 -359	weak				
P 11	486		barren				
P 12	832		barren		barren		barren
P 13	433	269 -271	weak				
P 14	845		barren		barren		barren
P 15	455	311 -312	weak				
P 16	475		barren				
P 17	417	370 -374	weak				
P 18	315		barren				
P 19	505		barren				
P 20	503		barren				
P 21	506	424 -427	weak				
P 22	515	408.5-410.5	weak				
P 23	995	405 -408	ore		barren	977-978	weak
P 24	316				barren		
P 25	230				barren		
P 26	205				barren		
P 27	243			202-203	weak		
P 28	315				barren		
P 29	346				barren		
P 30	255	183 -184	weak				
P 31	474	397 -398	weak				
P 32	465	413 -414	weak				
P 33	475	399 -402	weak				



NOTE: Geology adapted from Harshbarger and Repenning, 1954

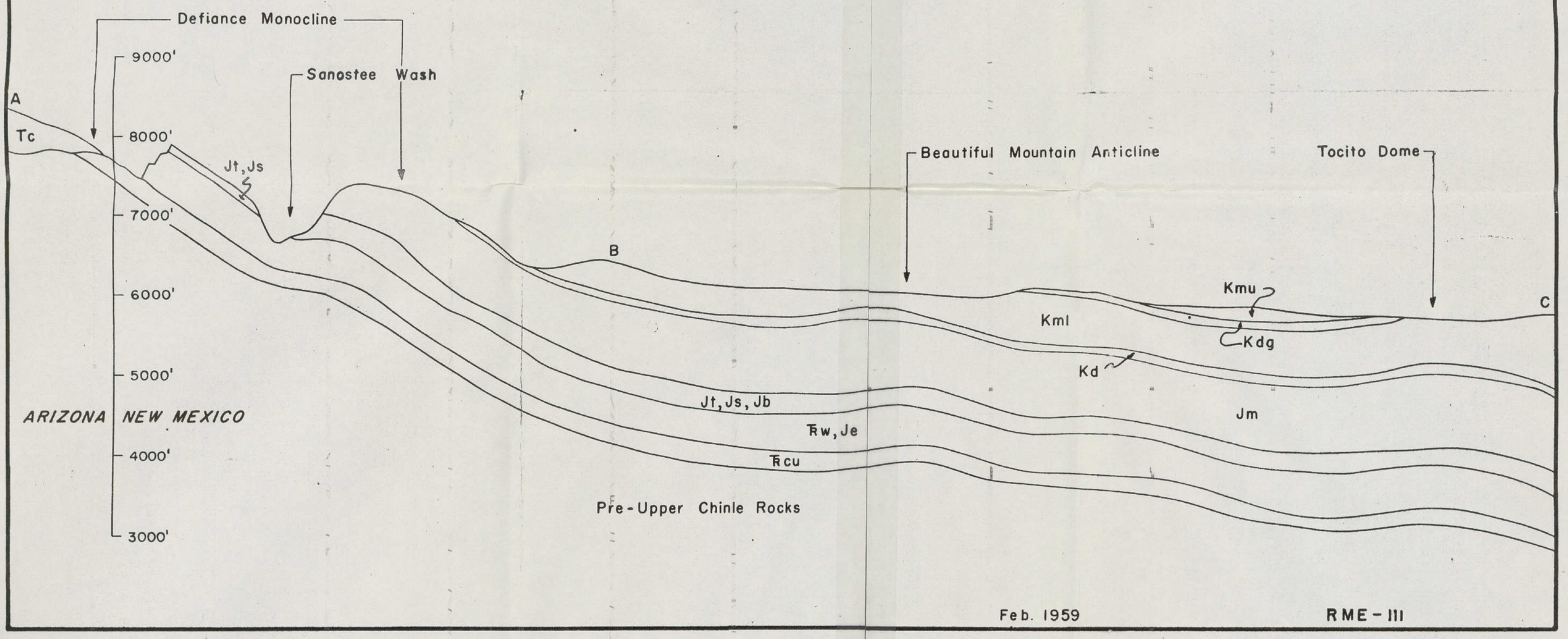


Figure 2. Geology of the Sanostee area, Arizona — New Mexico

Note: Base map compiled from uncontrolled aerial mosaic.

Geology by: J.W. Blagbrough and D.A. Thieme - 1954

0 1000 2000 3000 Feet
SCALE

Trw, Je
Jt, Js
Jt, Js, Jb
Jms
Jmr
Jmw, Jmb
Kd, Km
Kd
Kmv

Reed Henderson
H.B. Roy No. 2
Carl Yazzie
Joe Ben No. 3
South Peak Mine
Horace Ben
Enos Johnson & Enos Johnson, Jr.
Joe Ben No. 1
Joe Ben No. 2
David Kee
Kee and Tohe
Alfred Talk
Dennet Nezz No. 3
Dennet Nezz No. 2
Sanostee Wash

EXPLANATION

- Formation contact, dashed where inferred
- Exposure of mineralized zone, including ore
- Prospect
- Mine
- Unimproved road
- Strike and dip of bedding
- Intermittent stream

CRETACEOUS
- Kmv Mesaverde group
- Km Mancos shale, lower unit
- Kd Dakota sandstone

JURASSIC

Morrison Formation
- Jmb Brushy Basin member
- Jmw Westwater Canyon member
- Jmr Recapture member
- Jms Salt Wash member

San Rafael Group
- Jb Bluff sandstone
- Js Summerville formation
- Jt Todilto limestone
- Je Entrada sandstone

TRIASSIC
- Trw Wingate sandstone

Note: Mineralized folds in the Jt are not shown.

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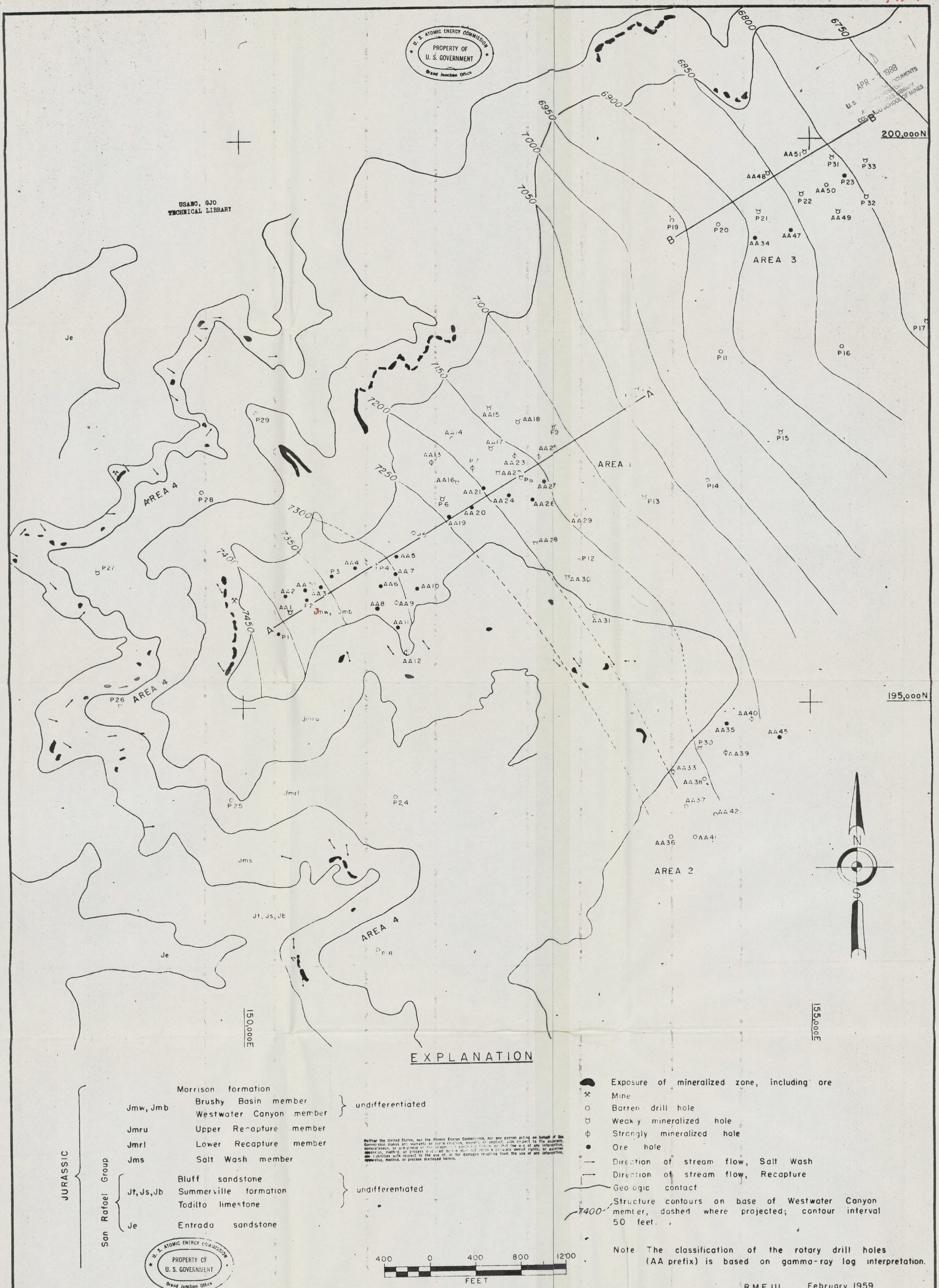
Figure 5. Geologic map showing uranium mineralization Sanostee Wash area

Fig 7



EXPLANATION

JURASSIC	San Rafael Group	Jmw, Jmb	Morrison formation: Brushy Basin member; Westwater Canyon member	undifferentiated
		Jmru	Upper Recapture member	
		Jmrl	Lower Recapture member	
		Jms	Salt Wash member	
		Jt, Js, Jb	Bluff sandstone; Summerville formation; Todilto limestone	undifferentiated
		Je	Entrada sandstone	

- Exposure of mineralized zone, including ore
- Mine
- Barren drill hole
- Weakly mineralized hole
- Strongly mineralized hole
- Ore hole
- Direction of stream flow, Salt Wash
- Direction of stream flow, Recapture
- Geologic contact
- 7400 Structure contours on base of Westwater Canyon member, dashed where projected; contour interval 50 feet.

Note The classification of the rotary drill holes (AA prefix) is based on gamma-ray log interpretation.

400 0 400 800 1200
FEET

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Figure 7. Structure and drill hole locations, Sanostee Wash area, San Juan County, New Mexico

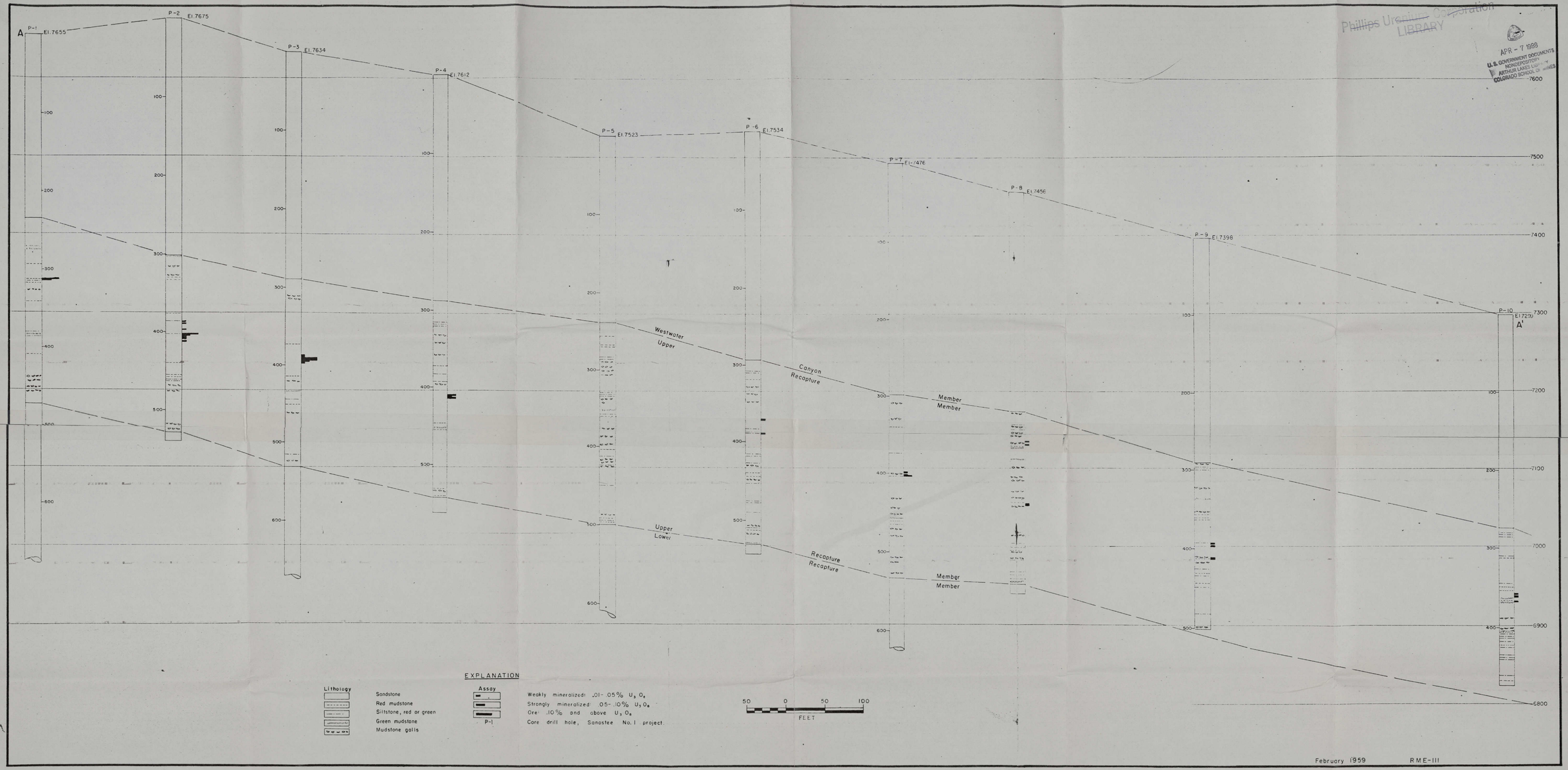

Figure 8. Cross section A–A'

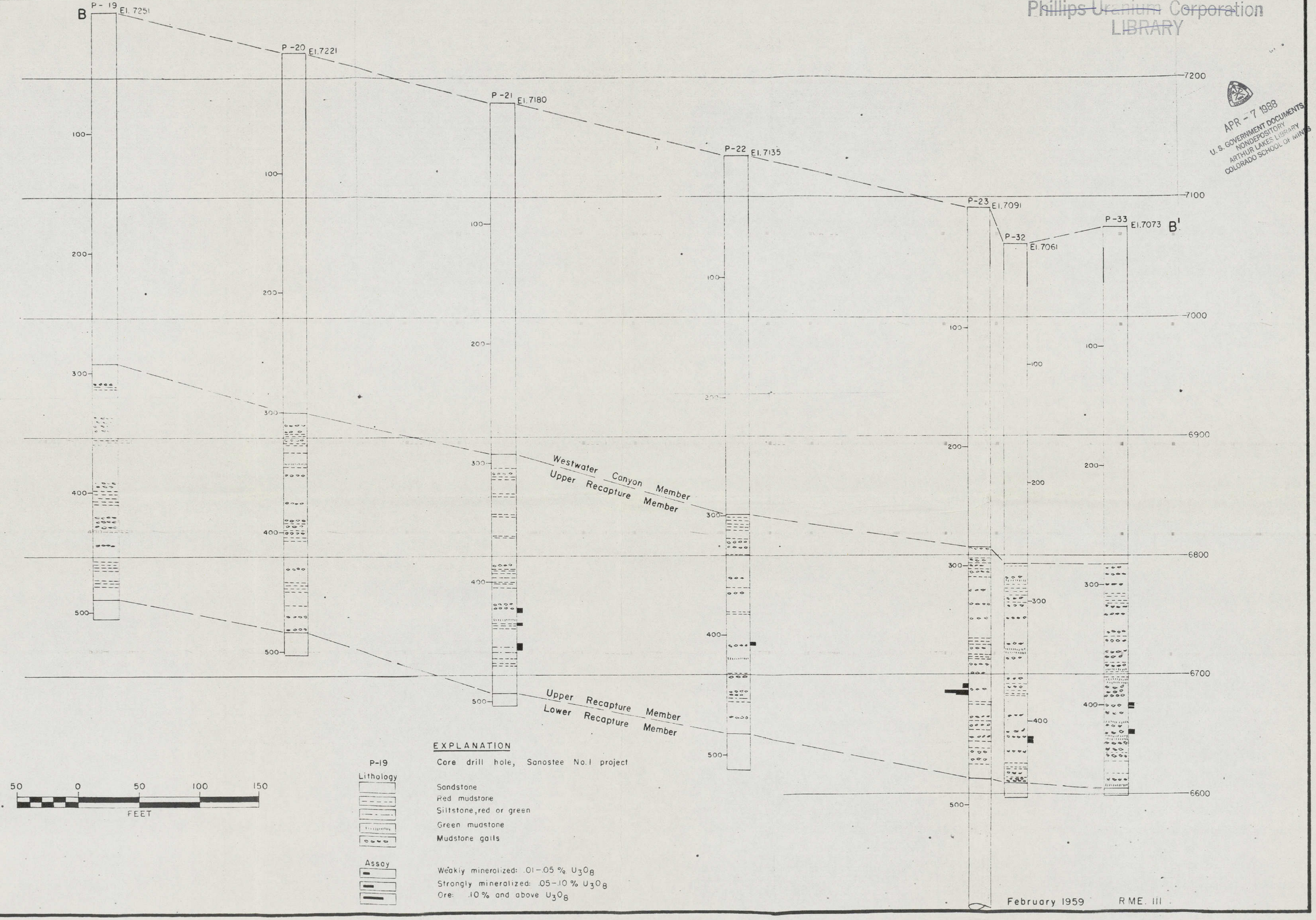

Figure 9. Cross section B–B'

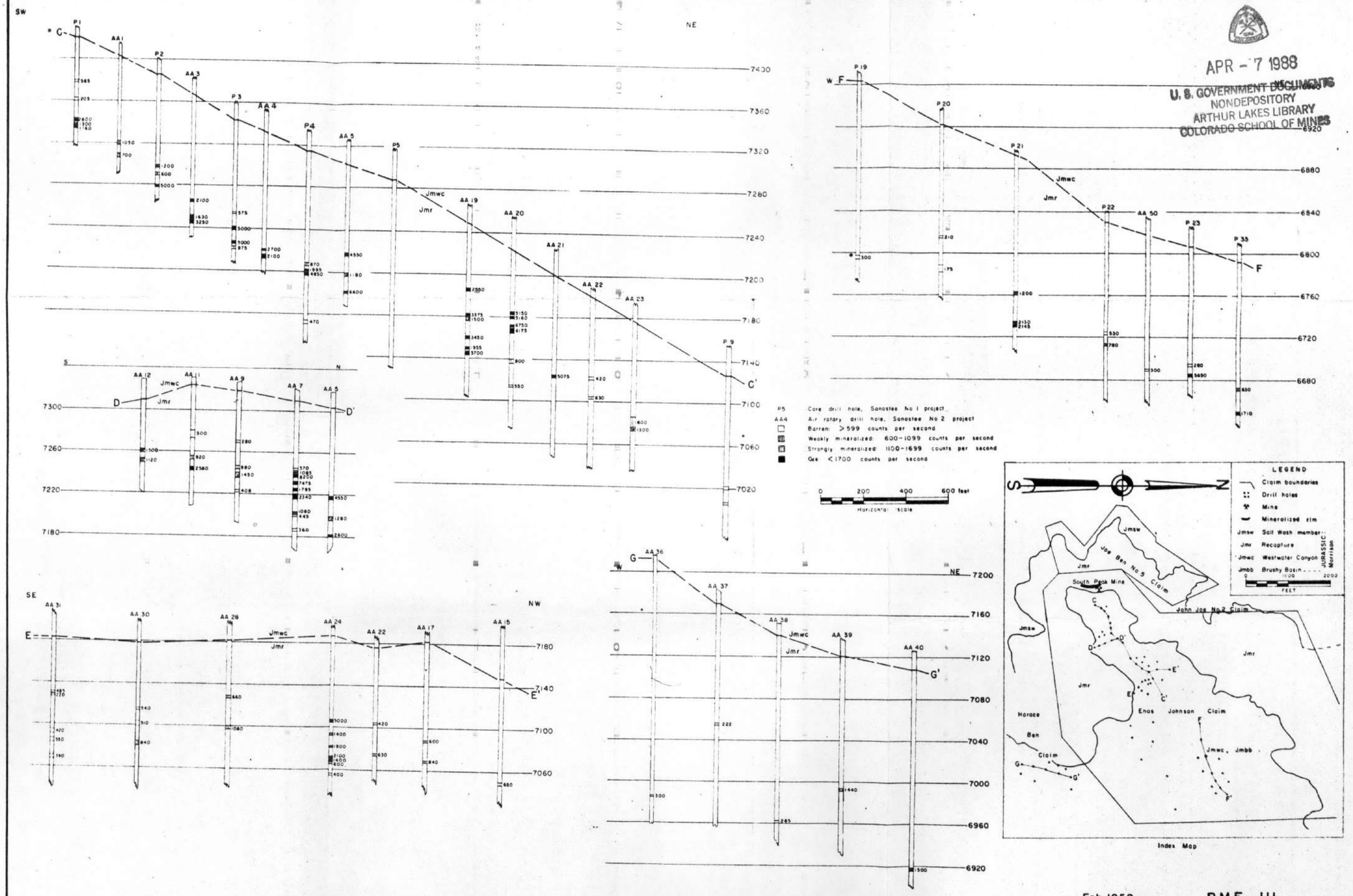

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Figure 10. Cross sections, with index map of South Peak Mine, Sanostee area, San Juan County, New Mexico.

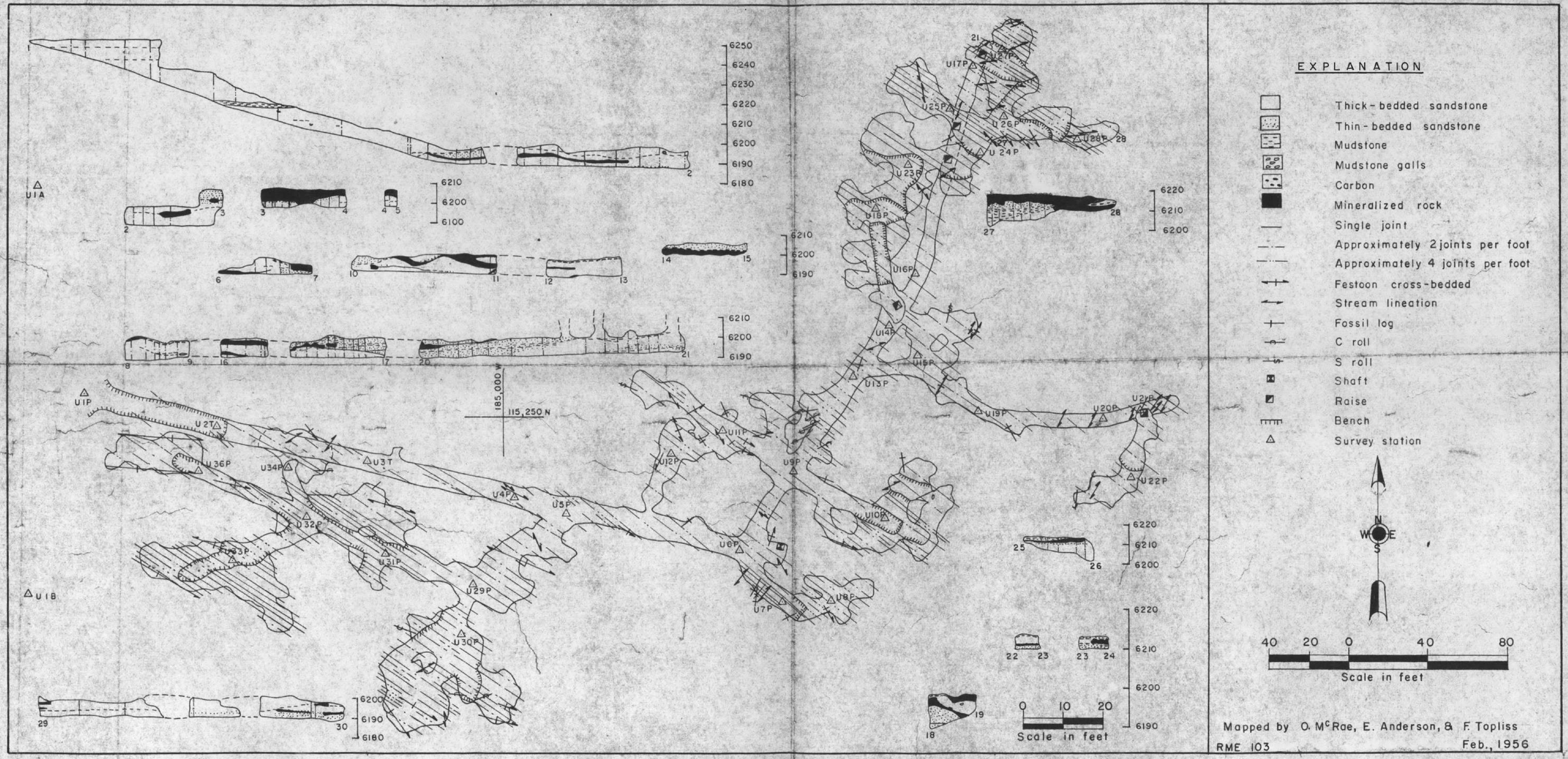

Figure 15. Geologic map and sections of the Fawn Springs No. 9 Mine, Bull Canyon, Montrose County, Colorado