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ABSTRACT

Eliminate

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A Major Uranium Discovery in a Frontier Area - The Anderson Mine, Yavapai County, Arizona.

Uranium mineralization occurs near the northern margin of the present Date Creek Basin in a gently-dipping sequence of Miocene lacustrine volcaniclastic sediments. The uranium is associated with lignites, carbonaceous and silicified tuffaceous mudstones, calcareous mudstones, and impure limestones and marlstones. The mineralized units are interbedded with green tuffaceous mudstones, light-colored calcareous, fossiliferous and tuffaceous, mudstones and tuffs, and a few thin sandstone and sandy siltstone beds.

The uranium deposit has a tabular blanket-type configuration with minimum dimensions of approximately 1,000 by 1,500 m. The mineralization may extend an appreciable distance down-dip. The mineralized zone is comprised of several mineralized beds which are generally from 1 to 3 m thick but occasionally ranges up to 11 m. The mineralization is stacked in most areas and aggregate thickness in excesses of 15 m are not uncommon. Most of the mineralization has grades ranging from 0.03 to 0.10% U_3O_8 with an average grade of approximately 0.06%. Elements which appear to be concentrated with the uranium mineralization include arsenic, molybdenum, organic carbon, total sulfur, and vanadium. Other elements which are anomalous in the Anderson Mine sediments include manganese, lithium, and fluorine. In portions of the ore body, there are considerable variations in the disequilibrium factor; however, the overall factor is close to one.

An early diagenetic origin for the mineralization is suggested. During compaction and dewatering of uranium-rich volcanic lake sediments the derived fluids probably came into contact with a strongly reducing paludal environment causing precipitation and fixation of the uranium. Some remobilization into fractures has occurred in more recent geologic time.

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INTRODUCTION

The Anderson Mine area is located in the Basin and Range physiographic province approximately 72 kilometers northwest of Wickenburg, Arizona (Fig. 1). The uranium deposit occurs in Tertiary rocks in the northern portion of an area designated by Otton (1977b) as the Date Creek Basin. This basin, which encompasses an area in excess of 900 Km^2, has recently gained national interest as the result of considerable land acquisition and exploration drilling by a number of companies during the past several years. The main stimulus to this exploration activity was the discovery that uranium mineralization at the old Anderson Mine was considerably more extensive than had previously been thought. This is illustrated in a recent publication by the United States Energy Research and Development Administration (1976) which states that the $30 per pound uranium reserves for the entire Basin and Range Province is 2,800,000 pounds U_3O_8 (Table 1). Exploration drilling at the Anderson Mine indicates that the reserves in this area alone are considerably in excess of this figure. This is significant in that it lends credence to the high uranium resource estimates for this province made by U.S.E.R.D.A. in the same publication.

The Anderson Mine area is located in sections 2 and 9 through 16, T. 11 N., R. 10 W. in southwest Yavapai County on the south side of the Santa Maria River. This area is situated at the northern edge of a broad plateau that has been incised by intermittent streams which drain into the Santa Maria River. Approximately 210 m of relief is present in the general mine area with elevations ranging from approximately 450 m along the river drainage to 660 m on the plateau.

The climate in this area is characterized by hot, dry summers and by short, mild winters. Annual rainfall is about 20 cm, much of it falling as thunderstorms in July and August.

The most conspicuous vegetation are saguaro and cholla cacti, paloverde and Joshua trees, and mesquite, ocotillo, and creosote bushes. Many species of smaller cacti are also present.

Previous geologic work in the area includes studies by Lasky and Weber (1944, 1949) who described the Tertiary rocks of the Artillery Mountains manganese district 25 Km west of the Anderson Mine. The Anderson Mine geology and uranium deposits were first described by Reyner et al. (1956). More recently, Otton (1977a, b) and Peirce (1977) have offered brief reports on the geology and uranium deposits of the area. Otton is in the process of making a detailed study of the Tertiary stratigraphy of the Date Creek Basin.

Anomalous radioactivity was first discovered in the Anderson Mine area by T. R. Anderson of Sacramento, California while conducting an airborne scintillometer survey in early 1955. Several hundred claims were located after a ground check of the anomaly revealed surface uranium mineralization. A limited drilling program indicated sufficient mineralization to justify a small mining operation. This mining resulted in the production of 33,230 pounds of U_3O_8 between 1955 and 1959 from ore that averaged 0.15% U_3O_8 (W. L. Chenoweth, personal communication, 1977). The production figures are summarized in Table 2. After this period, however, the property remained essentially idle until 1967 when the claims were optioned to a major oil company. This option was terminated in 1968 even though exploration drilling outlined several areas of uranium mineralization. This decision was probably influenced by the low price of uranium at that time and the remote location of the deposit. Prompted by the increasing price of uranium in 1974, Minerals Exploration Company, a wholly-owned subsidiary of Union Oil Company of California, obtained an option on the Anderson Mine property. The claims were purchased in 1975 following a drilling program on a 244 m (800 foot) grid which showed the uranium mineralization to be considerably more widespread than had previously been suspected. Subsequent drilling on a 122 m (400 foot) grid has indicated that the uranium mineralization is laterally continuous. The data generated from this program has served as the basis for this study. More recent drilling on a 61 m (200 foot) grid has further substantiated the lateral continuity of the uranium mineralization. At present, the company is completing the first phase of development drilling and is undertaking mine and mill design and feasibility studies. In addition, the company has retained consultants who are conducting extensive studies of the potential physical impacts the project will have on native wildlife, plantlife, water quality and availability, air quality, and socioeconomic impacts on neighboring communities.

If all the studies now underway indicate the project is feasible, mine preparation and mill construction could begin in 1979 and continue for approximately 18 months. Mining would begin concurrently, with mill startup to follow late in 1980. The mill would operate continuously over an expected minimum life of 15 years at a designed throughput rate of between 2,000 and 2,500 tons of ore per day. The ore would be mined initially by open-pit methods with an underground mining operation to follow.

GENERAL GEOLOGY

The stratified rocks in the northeastern Date Creek Basin have an aggregate thickness in excess of 1100 m. Intricate lithologic variations and structural relationships record a complex history of sedimentation, repeated episodes of volcanism, and nearly continuous tectonism. Even though complex, the Tertiary section is divisable into two similar stratigraphic sequences. Each sequence is characterized by a complex assemblege of arkosic sediments overlain by silicic volcaniclastics. Interstratified with and overlying these sediments are flows of silicic to basic volcanic rocks. The tectonic instability of the region is reflected by folding, recurrent block faulting, and numerous unconformities in the stratigraphic section. Particular emphasis in this study has been placed on the lake sediments at Anderson Mine since they are the principal uranium-bearing host in the northeastern Date Creek Basin.

STRATIGRAPHY

Five informal stratigraphic units are recognized in the Poachie Range and the northeastern Date Creek Basin (Figure 3). The lower, or pre-Anderson Mine succession, includes the basal Tertiary rocks and the Upper Paleogene "Arrastra" volcanics. The upper, or Anderson Mine succession includes the Lower Miocene Anderson Mine sediments, the "Flat Top" clastics, and Upper Miocene basalt and agglomerate. Both successions are unconformably overlain by Plio-Pleistocene "older" alluvium.

Basal Tertiary Rocks (Ta)

The basal Tertiary rocks consist of up to 110 m of reddish, poorly-sorted arkosic sandstone and conglomerate overlain by a rhyolitic ignimbrite and varicolored air-laid and water-reworked tuffs. These rocks are preserved in a series of tilted and down-dropped fault blocks in the Poachie Range (Figure 4). The contact between the red beds and the volcanics is generally disconformable. In places, the ignimbrite rests on an older crystalline complex, but elsewhere it rests on red beds or tuffaceous sediments.

The basal Tertiary rocks are correlated with the lower portion of the Artillery Formation of Lasky and Webber (1949). This correlation is based on the relative stratigraphic position of the unit and the correlation of the rhyolite ignimbrite. An Eocene (?) age has been assigned to this unit by Otton (1977a,b).

"Arrastra" volcanics (Tv)

Northeast of the Anderson Mine the "Arrastra" volcanics rest directly on Precambrian (?) crystalline rocks whereas to the northwest they rest with up to 35^{o} of angular discordance on the basal Tertiary rocks (Figure 3). The section as described by Reyner et al. (1956) consists of a minimum of 457 m of thick vitropheric biotite andesite, thin tuffs, and a basal basalt. Also included in the section are a series of conglomerates interstratified with basalt, biotite andesite, and augite andesite flows. Two dacitic domes located between the Anderson Mine and the Santa Maria River contributed large quantities of tuff and agglomerate to the "Arrastra" section. West of Anderson Mine, the section contains more water-reworked volcaniclastics and fewer flows. The local abundance of flows and the thickening of the "Arrastra" section in the vicinity of Anderson Mine is suggestive of a proximal source for most of the volcanics. An Upper Paleogene age is suggested for the "Arrastra" section based on its relative stratigraphic position and apparent correlation with the upper part of the Artillery Formation of Lasky and Webber (1949).

Prior to the deposition of the Lower Miocene rocks, over 120 m of relief developed on the "Arrastra" volcanics in the Anderson Mine area (Figure 5). In places, thick paleosols and colluvial deposits developed on this post "Arrastra" surface. These deposits are characterized by a lack of sorting and an abundance of andesitic rock fragments suspended in a brick-red clay matrix. As much as 20 m of colluvium filled depressions on the volcanics in the southern and eastern parts of the mine area.

Anderson Mine Sediments (Tma)

The Anderson Mine sediments range from 80 to 150 m thick and include a lower arkosic member and an upper uranium-bearing tuffaceous lutite member. The upper member is divisable into the upper and lower Carbonaceous Units, an intermediate Clastic Unit, and an upper tuff and limestone unit. In the vicinity of the Anderson Mine, the sediments thicken gradually to the south and west and thin to the north and east where they onlap the "Arrastra" paleohigh (Figure 6). The section at Anderson Mine has been tentatively correlated with fanglomerates of the Chapin Wash Formation by Reyner et al. (1956), Peirce (1977), and Otton (1977b). The Chapin Wash Formation, which may grade into and intertongue with the Anderson Mine sediments, is formed of arkosic sandstones and conglomerates interbedded with silicic and basic volcanic rocks in the western Date Creek Basin (Laskey and Webber, 1949; Shackelford, 1976; Gassaway, 1977).

You are already in the vicinity unless you are going to extend the Anderson Mine sediments to another area.

Lower Member (Tmal) L on 1

The lower arkosic member consists of up to 120 m of coarse, poorly-sorted reddish-(to yellowish-gray arkosic sediments) and locally developed (volcanic sandstones and conglomerates.) This succession represents the distal portion of a subaerial fan complex that coarsens and thickens to

Maybe upper part of Arrastra

the west and south of the Anderson Mine. Due to the paleotopography developed on the Arrastra volcanics, the lower member thins rapidly and pinches out in the northern portion of the Anderson Mine area. In the southern portion of this area the lower member consists predominantly of volcanic and arkosic sandstones and conglomerates which grade vertically into the finer-grained sediments of the upper member. Elsewhere, the lower member is formed principally of conglomerates and sandstones derived from a Precambrian (?) crystalline terrain.

Upper Member (Tmau)

The upper or tuffaceous lutite member is the principal uranium-bearing host rock in the northeastern Date Creek Basin. This member represents a paludal lacustrine succession consisting of tuffaceous mudstones and siltstones interbedded with vitric tuffs, micritic limestones, marlstones, carbonaceous lutites, and a smaller proportion of tuffaceous and arkosic sandstones. In the southern portion of the Anderson Mine area the upper member is 140 m thick and thins to 80 m where the member onlaps the volcanics to the north (Figure 6). Four general stratigraphic units are recognized in this member: A lower carbonaceous unit, an intermediate clastic unit, an upper carbonaceous unit, and an upper tuff and limestone unit.

Do you want to say "Swampy Lake" or "Swamp and Lake" deposits. If the last meaning is desired you need a hiphon or an "and" between the two words

Sub member would be a better term for these 4 "units" as the are "units" of a member of a unit. Defined on Page 6

Lower Carbonaceous Unit (Tmau1) - The lower unit infills local depressions and valleys and averages 25 m thick. Massive green-gray micaceous tuffaceous lutite beds averaging 1 m thick constitute a major portion of the unit. The remainder consists of approximately equal proportions of micritic limestone, marlstone, carbonaceous lutite, and arkosic sandstones. The lithofacies map (Figure 7) shows the distribution of these paludal-

Implies to me Large feature. Do you mean channels?

I see you want the meaning swamp and lake

This is very unclear! Do you mean in the upper Member or the upper part of the Lower Carb Submember

lacustrine sediments in the upper portion of the unit. The limestones and marlstones, which are found mainly in the western and southeastern parts of the area, are massive, light greenish-gray to off-white, and occur mainly in the upper 15 m of the unit. The thickest and most abundant limestones are found in the southeastern portion of the Anderson Mine area where they have an aggregate thickness of up to 8 m. These limestones commonly contain comminuted carbonaceous material and grade laterally into carbonaceous lutites to the west.

The lutites, which are composed of massive, gray to black interbedded carbonaceous mudstones and thin-bedded carbonaceous siltstones and lignites are the major uranium host rock in the lower unit. Interbedded with the carbonaceous lutites are light greenish-gray to reddish-gray arkosic sandstones. These clastics are fine- to medium-grained in the northern portion and fine- to coarse-grained in the southern portion of the area. Silicification and other alteration products are common throughout the finer-grained sediments in this unit.

Are these clastics Tongues of the Lower Member? I don't know either

Intermediate Clastic Unit ($Tmau_2$) - The intermediate clastic unit is about 12 m thick and consists predominately of tuffaceous sandstones and siltstones. The greenish-gray to tan sandstones are fine- to very-coarse grained and consist primarily of water-reworked tuffs and volcanics. These tuffaceous sandstones are interbedded with minor subarkosic sandstones in the southern portion of the mine area. The tuffaceous siltstones are micaceous, light greenish-gray, and massive. The remainder of the intermediate clastic unit consists of mudstones, micritic limestones, and local carbonaceous lutites. The mudstones are tuffaceous, massive, and generally greenish-gray in color. The micritic limestones are thin-bedded, and off-white in color. A lithofacies map of the upper part of this unit shows finer-grained sandstones to the northeast, and the confinement of limestones and marlstones to the western and southeastern parts of the mine area (Figure 8). The carbonaceous lutites grade into the overlying unit and are confined mainly to the upper portion of this unit (Figure 6). In this unit only minor silicification has been recognized in association with the limestones, marlstones, and finer-grained clastics.

Upper Carbonaceous Unit ($Tmau_3$) - The upper carbonaceous unit is the most laterally continuous unit in the middle member with individual beds extending for over 500 m. This unit is approximately 20 m thick and consists mainly of tuffaceous mudstones interbedded with subordinate amounts of carbonaceous lutites, tuffaceous siltstones, and micritic limestones. The remainder of this unit is formed of tuffaceous siltstones, marlstones, vitric tuffs, and a minor fraction of sandstones. The lithofacies map (Figure 9) of the middle portion of the unit shows the wide distribution of carbonaceous lutites and limestones and the abundance of tuffaceous clastic sediments in the northern part of the area.

The tuffaceous mudstone beds are massive, light greenish-gray in color, and contain carbonaceous rootlets and remnant pumice fragments. These beds which average less than 1 m thick form up to one-third of the unit in the southwestern part of the area. The abundance of organic structures, poor-sorting, and massive character of the mudstones is indicative of the gradual influx of air-falls tuffs washed in from surrounding uplands.

Carbonaceous and lignitic lutites form about one-third of the carbonaceous interval in the central mine area. Proximate analyses of these lutites indicate the impure quality of much of the carbonaceous and lignitic material (Table 3). The carbonaceous interval, though rarely exposed at the surface, crops out immediately above the "Arrastra" volcanics in the north-central part of the mine area (Figure 9). This section includes the lower carbonaceous bed described by Reyner et al. (1956), and also the most significant uranium mineralization in the Anderson Mine area.

area or stratigraphic unit or stratigraphic section?

Does this mean in the Carb bed or this submember or this area of the mine?

Commonly interstratified with carbonaceous beds are tan, gastropod-rich, tuffaceous marlstones that locally form up to one-third of the carbonaceous interval. The tan marlstones in both the upper and lower carbonaceous units are characterized by a strong petroliferous odor when broken. Analyses of the gas derived from these marlstones show an abundance of hydrogen sulfide and carbon dioxide. To the east these marlstones and carbonaceous beds grade and intertongue into micritic limestones (Figure 6). The limestone beds are up to 1.5 m thick and are very light greenish-gray to off-white in color. Varying amount of tuffaceous and pumiceous material are interspersed in these limestones. Fossils commonly found in these beds include fresh-water pelecypods, gastropods, small fish, and rush-like plant material. Locally, these massive limestones are difficult to distinguish from massive calcareous vitric tuffs.

Should have been Mentioned in Lower Description

The vitric tuffs are typically water-laid, and are most abundant in the northwestern and northern parts of the mine area (Figure 9). These silicic tuffs are medium- to fine-grained, and occur primarily in the upper part of the unit. Most tuffs grade laterally into tuffaceous lutites and are bioturbated and water-reworked. A pseudo-eutaxitic texture is characteristic of a few tuffs replaced by silica and clay minerals, but is atypical of the calcified tuffs.

Is silicification and Silica confined to the Tuffs in this submember. It is noted on page 10 that the fine grained sediments of the Lower member are silicified and on page 11 that only minor silicification has been noted in the Intermediate Clastic Sub Member.

that any barricading effect of paleo-highs, since buried, was nil. Yet Tmam4 contains no coarse clastic material that might be expected in basin margin deposition relatively close to highland source areas. What would be an explanation for this?

Upper Tuff and Carbonate Unit (Tmam4) - Up to 80 m of the upper unit is preserved in the Anderson Mine area. This unit is formed largely of tuffaceous lutites, reworked vitric tuffs, marlstones, and micritic limestones (Figure 10). The tuffaceous lutites are greenish-gray and massive, comprising the largest part of this unit. The tuffs are similar to those in the underlying carbonaceous unit, except that some are yellowish- to pinkish-gray in color. A few thin lapilli bearing pumice tuffs are recognized in the northeastern mine area. The marlstones and limestones are massive and off-white in color, and occur mainly in the eastern and southern mine area (Figure 10). Reyner et al. (1956) recognized a relatively persistent, thin-bedded marlstone that occurs near the top of the section. In much of the subsurface this marlstone is not preserved. A few thin carbonaceous beds which are rare and laterally discontinuous (Figure 6) occur in this unit. The remainder of the unit consists of minor poorly-sorted tuffaceous sandstones.

Replacing limestones and lutites in this unit are beds of chalcedony up to 1 m thick. These beds and the associated carnotite fracture-fillings are prevalent features in the old pits exposed at Anderson Mine (Figure 11). The carnotite, though the most conspicuous type of a surface mineralization, forms only a small proportion of the total uranium mineralization at Anderson Mine.

Maybe uraninite

A Lower to Middle Miocene age is suggested for the Anderson Mine sediments by the presence of Hemingfordian aged (17-21 m.y.) vertebrates (Lindsay and Tessman, 1974) and the relative stratigraphic position of the unit. The tentative correlation of these sediments to the Chapin Wash Formation and to Miocene (17.9± 0.5 m.y.) silicic volcanics described in Shackelford (1976) and Gassaway (1977) also lends credence to this age.

WHAT ABOUT the TWO OTHER STRATIGRAPHIC UNITS of Page 6 ¶2?? FLAT TOP + Upper Mio Basalt and agglom and the Plio-Pleis older Alluvium? I found them. See note at TOP of Next Page

Sedimentary Patterns and Paleoenvironments

The general configuration of the Lower Miocene Date Creek Basin closely resembled the limits of the present basin in the vicinity of Anderson Mine. The paleohighs southwest and west of the Anderson Mine area partially isolated this area from the main part of the Lower Miocene Basin (Figure 5). These highs largely confined the deposition of fanglomerates of the lower member to areas southwest and west of the Anderson Mine area. As the Lower Miocene basin filled, the lacustrine environment of the Upper Anderson Mine member expanded until it extended beyond the present-day limits of the Date Creek Basin. Subsequent erosion of these Lower to Middle Miocene lacustrine sediments has greatly diminished their present distribution.

During this Early to Middle Miocene time silicic volcanism from local and distant volcanic centers contributed large quantities of air-fall debris to the Anderson Mine environment. Silicic flows and ignimbrites which erupted from local centers in the region appear to have been confined to relatively small areas marginal to the more extensive fan and lacustrine environments. Rhyolitic rocks of this proximal volcanic facies which occur 40 to 50 Km west of Anderson Mine have been described by Lasky and Webber (1949), Shackelford (1976), and Gassaway (1977).

The lateral development of the paludal facies in the Lower and Middle Miocene lake sediments near paleohighs in the Anderson Mine area was influenced largely by flucuating lake levels, eposodic volcanism, and changing rates of coarse clastic sedimentation. During periods of restricted clastic deposition, lowering lake levels, and quiescent volcanism the paludal facies expanded as characterized by the accumulations of the lower and upper carbonaceous units (Figures 7, 9). During periods of more rapid sedimentation,

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The deposition of only limestones, marlstones, and other lacustrine sediments in the eastern and western parts of the Anderson Mine area is related to the development of paleolows by the apparent down-dropping of local grabens and the erosion of valleys in these areas prior to Anderson Mine sedimentation (Figure 5). The greatest development of limestones and marlstones occurred during periods of restricted clastic sedimentation, abundant invertebrate faunas, and rising lake levels, as characterized by the deposition of much of the upper tuff and limestone unit (Figure 10). Only mildly alkaline conditions are suggested for the lacustrine sediments by the fossil assemblege, the lack of primary saline minerals, and possibly by the authigenic mineral suite at Anderson Mine. The presence of clinoptilolite, hectorite, and illite may be indicative of a somewhat alkaline environment or may result from the diagenetic alteration of these sediments (Hay, 1966). An abundance of palm remains is indicative of tropical or subtropical conditions during Anderson Mine sediment deposition.

A model of the Anderson Mine-type of depositional environment is depicted in Figure 12. This model, though generally analogous to the regional setting in the Date Creek area, is not exclusive to west-central Arizona. Similar settings occur elsewhere in the Basin and Range province and in other silicic volcanic regions in the western United States. The most significant aspect of this depositional model from the standpoint of possible uranium accumulation is the development of paludal sediments. The formation and preservation of the carbonaceous strata resulted from the accumulation of abundant plant material as the lacustrine environment gradually onlapped and covered the paludal environment in restricted areas along the margin of the basin. The occurrence of uraniferous-bearing volcaniclastic lake sediments interbedded with these paludal sediments appears to be the most important geologic condition for the formation of a major uranium accumulation of the Anderson Mine-type.

<u>"Flat Top" Clastics (Tfc)</u>

Unconformably overlying the Anderson Mine sediments is a thick upward coarsening succession of arkosic sediments up to 170 m thick in the Anderson Mine area (Figure 6). This unit is composed largely of grayish-orange to yellowish-brown arkosic siltstones, sandstones, and conglomerates, interbedded with minor reworked greenish-gray siltstones that are well exposed near Flat Top (Figures 1, 13). The finer-grained clastics fill an east-west trending channel that was scoured as much as 100 m into the Anderson Mine section (Figure 13). Elsewhere in the region, this phase of sub "Flat Top" erosion appears to have eliminated much of the Lower Miocene section.

The "Flat Top" sections includes brown to buff siltstones interbedded locally with fine- to coarse-grained arkosic sandstones that grade upward into pebble sandstones and conglomerates. Most coarser clastics that fill local channels in the section were derived from the Precambrian (?) crystalline complex. A minor amount of material was also derived from the older volcanic highlands as recognized by Reyner et al. (1956).

The "Flat Top" clastic may be correlative to part of the Chapin Wash Formation of Lasky and Webber (1949). Based on the relative stratigraphic position, and associated structural events, the age of the "Flat Top" section is likely Middle (?) to Late Miocene.

Basalt and Agglomerate (Tmb)

Unconformably overlying the "Flat Top" clastics is a succession of agglomerate, conglomerate, and basalt. The basalt and mud-flow agglomerate rest in local channels eroded into the "Flat Top" sediments. Local water-reworking of the agglomerate produced poorly-sorted sandstones and conglomerates. The vesicular flows of basalt are up to 30 m thick but pinch out locally. An average age of 12.5 m.y. has been determined by Otton (1977b) for these flows. The succession is assigned an Upper Miocene age and is tentatively correlated with the "Late Tertiary basalt" described by Shackelford (1976) in the Rawhide Mountains, and likely with the Cobbwebb basalt or the basalt of the Sandtrap Wash Formation of Lasky and Webber (1949) in the Artillery Mountains (Figure 1).

Older Alluvium (Qts.)

The older alluvium rests unconformably on the above units (Figure 6) and is composed primarily of Precambrian (?) crystalline derived material intermixed with minor amounts of volcanic fragments (Figure 6). These moderately well-indurated fanglomerates consist mainly of poorly-sorted, Angular to well-rounded, pebble to cobble-sized clasts. The basalt clasts in this unit are very Angular suggesting that the other clasts are reworked.

A Plio-Pleistocene age is assigned to this unit based on its degree of induration, structural tilting, and apparent lack of offset by block faulting. This alluvium is tentatively correlated with the older alluvium of Shackelford (1976) in the Rawhide Mountains, and with a portion of the Sandtrap Wash Formation defined by Lasky and Webber (1949) in the Artillery Mountains.

Younger Alluvium (Qal.)

The younger alluvium in the mine area (Figure 13) includes unconsolidated valley-fill and scree that occurs in and near tributaries of the Santa Maria River. Most of the alluvium consists of unconsolidated, locally eroded volcanics and reworked conglomerates.

STRUCTURE AND DEFORMATIONAL HISTORY

Three periods of Tertiary deformation are recognized in the region. The first evidence of strong differential uplift is the sub-"Arrastra" unconformity that preceded the eruption of the "Arrastra" volcanics. The greatest differential uplift and folding occurred along a west-northwest trend that nearly parallels the present Poachie Range. During this time the basal Tertiary arkoses were tilted up to 35° to the south along this ancestral trend.

The second period of uplift and deformation followed the eruption of the "Arrastra" volcanics in late Oligocene or early Miocene times. Subsequent Miocene Anderson Mine depositional patterns and the post "Arrastra" paleogeography (Figure 5) suggest that a northwest-trending normal fault system which coincides with more recent Basin and Range faulting was active during this period.

A third period of deformation began following the infilling of the Lower Miocene basin, and occurred prior to and after the eruption of the Miocene basalt. The apparent reversal of local paleo-drainage patterns, the development of over 80 m of local relief following Anderson Mine deposition and the rejuvenation of fan complexes during "Flat Top" sedimentation is likely related to the inception of faulting (Figures 6, 11). Most younger fault trends coincide with the older post "Arrastra" structures, even though a number of older apparent "Arrastra" offsets appear to have been reversed. The trend of most normal faults is N. 45°W. Scissor-type displacement is common along these zones with reversals occurring along an axis that closely parallels the Santa Maria River. North of the river, relative displacement is down to the northeast, and south of the river displacement is down to the southwest between Anderson Mine and Palmerita Ranch. Most blocks in this area are tilted down to the southwest. The fault zones are complex, with a number of second order faults splaying off from the general N.45°W. trend (Figure 3). Secondary features such as horsts and grabens are common along these trends.

→ why Secondary How about "Resultant"

In the immediate Anderson Mine area the section has been rotated down to the south along the southern extension of three scissors faults (Figure 3). The southern regional dip of the Anderson Mine section averages approximately 8° and ranges from 0° to 14°. Locally, however, some beds have been rotated up to 45° along fault zones and on slump blocks. Displacement along a fault in the east central part of the mine area decreases from 70 m in the southern part of the property to no displacement near the Santa Maria River (Figure 12). Most displacement on this fault occurred prior to the eruption of the Miocene basalt. Considerably more offset has occurred along scissors faults west of Anderson Mine prior to and following the eruption of the Miocene basalt. Numerous small scale, northwest-trending faults with less than 5 m of displacement have sheared and fractured much of the sedimentary section across the mine area. Other shearing and folding is associated with the recent slumping of strata in the mine area. One relatively large open synclinal fold is present in the western part of the study area (Figure 13). Following the above period of basin and range faulting only minor uplift and southward tilting of the Plio-Pleistocene fanglomerates ("older" alluvium) has occurred.

Drag Folds?

Is this synclinal fold the result of your third Deformation?

How do you tilt just this one unit.

URANIUM MINERALIZATION

The uranium deposit at the Anderson Mine is a stratiform, blanket-type deposit occurring within and in proximity to carbonaceous lacustrine sediments. The deposit has minimum dimensions of approximately 1,000 by 1,500 m and may extend an appreciable distance down-dip into the subsurface to the south. Most of the mineralization occurs in 1 to 3 m thick zones which, in highly mineralized areas, have composite thicknesses in excess of 15 m. The average grade and thickness of the uranium resources at the Anderson Mine are summarized in Table 4. It should be emphasized that these figures do not constitute average ore grades and thicknesses for the deposit since detailed mining feasibility studies have not yet been completed.

The majority of the uranium mineralization is associated with carbonaceous lutite beds in the two carbonaceous units of the Upper Anderson Mine member. It also occurs in the marlstones, limestones, and tuffaceous lutite beds interbedded with or laterally adjacent to the carbonaceous lutites. Many of these interstratified beds contain finely comminuted carbonaceous plant material and abundant silicified rush-like plant remains and gastropods.

The areal distribution of the mineralization is illustrated in Figure 15 which is a grade-thickness product contour map. The tabular configuration of the deposit is evident. Two simplified cross-sections (Figures 16, 17) show the lateral continuity of the uranium mineralization. It was not possible to show details of the lithology on these sections, but the mineralization is continuous across facies boundaries and locally cross-cuts the bedding. A comparison of the grade-thickness map (Figure 15) and an isopach map of the carbonaceous sediments (Figure 18) suggests a close spatial relationship between the carbonaceous sediments and the uranium mineralization. In addition, the most significant areas of uranium mineralization appear to coincide with the greatest thicknesses of carbonaceous material. These features indicate the importance of the paludal environment in the localization of the uranium mineralization at Anderson Mine. The extension of mineralization beyond the apparent boundaries of the carbonaceous sediments is significant and may suggest the fixation of uranium by the lateral migration of hydrogen sulfide gas generated from the carbonaceous sediments.

Both oxidized and unoxidized uranium mineralization is recognized at Anderson Mine. The unoxidized mineralization chiefly occurs in the upper and lower carbonaceous units and is rarely exposed in the study area. It ranges in grade from 0.03% to 0.10% U_3O_8 and probably averages .06% U_3O_8. The oxidized uranium mineralization, which is the mineralization previously identified by Reyner et al. (1958), Otton (1977a), and Peirce, (1977), is found mainly in the northern part of the mine area. It occurs principally in silicified limestones, marlstones, and tuffaceous lutites overlying and laterally adjacent to the unoxidized mineralization. The oxidized uranium, which usually occurs in small irregular masses or as minor late-stage fracture fillings, probably has an average grade of greater than 0.10% U_3O_8 Select samples of this carnotite mineralization have assayed greater than 30% U_3O_8.

May be Tyuyamunite

Previous production from the Anderson Mine for the years 1959 through 1959 totalled 33,320 pounds of U_3O_8 from ore that averaged 0.15% U_3O_8. In addition, 10,055 pounds of vanadium were recovered from the ore (W. L. Chenoweth, personal communication, 1977).

Should this be here or in the Intro. Vanadium Reference might go to Geochem section,

MINERALOGY

Several analytical methods were used to identify the unoxidized and oxidized uranium minerals at the Anderson Mine. Initially, the distribution of the radioactive minerals in all the unoxidized samples was determined by autoradiography. The autoradiographs showed finely disseminated radioactive mineralization (Figure 19) which was judged to be too fine-grained to obtain suitable samples for x-ray diffraction analysis, therefore electron microprobe analyses and microscopic studies were initiated. These studies indicated that the unoxidized uranium mineralization consists of uranium silicate with a highly variable uranium to silicon ratio occurring in intimate association with carbonaceous material. The uranium content of this uranium silicate mineral was found to range from 4% to 20%. The chemical composition of this material suggests the mineral coffinite and an attempt was made to reconfirm this by x-ray analysis. One sample of black, sooty material with a high uranium content (determined from electron microprobe analyses) was isolated from a carbonaceous tuffaceous mudstone unit. The x-ray analysis of this uraniferous material showed no evidence for any uranium mineral. This indicates that the uranium minerals are very poorly crystallized to amorphous or too finely dispersed for conventional x-ray techniques (Breger, 1974). No autoradiographs were made for the oxidized uranium minerals as it was easily recognized in surface samples. X-ray analysis of this uraniferous material gave a perfect pattern for carnotite.

The uranium silicate mineralization, which has only been identified in the subsurface, is generally associated with carbonaceous material. Photomicrographs and microprobe scans (Figures 20, 21) reveal uranium silicate and carbonaceous material occurring either as finely disseminated in the matrix or as discontinuous and sometimes contorted veinlets and patches. It is interesting to note that very little uranium mineralization is associated with carbonaceous material which still retains cell structure (Figure 20). This may indicate mobilization of the potentially mineralized humic acid fraction of the carbonaceous material, as implied by Szalay (1964), possibly during diagenesis. The resulting ore textures are similar to those described by Granger et al. (1961) for the Ambrosia Lake deposits, where the uranium is confined to a vitrain-like material which locally surrounds cellular carbonaceous material.

The carnotite mineralization occurs as fine coatings and coarse fibrous fillings along fractures and bedding planes in surface exposures and in shallow core holes (Figure 13). This mineralization is confined to fractured and silicified light colored lutites, tuffs, limestones, and marlstones in the oxidation zone. Carnotite has previously been recognized in the Anderson Mine area by Reyner et al. (1956), Otton (1977a), and Peirce (1977).

ALTERATION

Anderson Mine member sediments have undergone extensive diagenetic silicification, calcification, zeolitization, and clay-formation. The alteration, which has affected the entire lacustrine unit, varies in both intensity and type across the study area.

Silicification is the most common form of alteration and is found in all units except the lower Anderson Mine member. It appears to have begun early and continued throughout the diagenetic history of the sediments.

The initial stage of silicification resulted in the dissemination of fine-grained multi-colored chalcedony in the sediments, the replacement and preservation of delicate fossil forms (chiefly gastropods and ostracods), and the association of silicia with disseminated uranium in carbonaceous plant material. Most of the carbonaceous beds have been partially to completely silicified. In general, the strong silicification has penetrated a few tens of centimeters into the carbonaceous beds at the upper and lower contacts of these beds with the enclosing sediments. Occasionally, entire beds of carbonaceous mudstone and siltstone have been completely silicified, but there seems to be no direct correlation between degree of silicification and intensity of uranium mineralization.

A later phase of silicification occurred subsequent to episodes of Miocene faulting and may have continued into recent times. This more recent silicification is characterized by local void and fracture filling by chalcedony resembling jasper, cristobalite (?), and opal. Much of the carnotite mineralization found in voids and fractures appears to have been contemporaneous with this later stage of silica formation.

The most extensive silicification is found predominately in the tuffs and carbonates of the upper unit of the Anderson Mine member. These beds have been exposed by erosion along the northern edge of the basin. Irregular and locally discordant masses of varicolored chalcedony have replaced limestones, marlstones and tuffaceous beds in the upper unit and occasionally some of the beds in the upper carbonaceous unit. The intensity of this silicification may have resulted from the evaporation of silica-rich fluids which could have migrated to the edge of the basin during compaction and dewatering of the lake sediments to the south. Devitrification of volacnic glass in the tuffaceous sediments during diagenesis (Murata, 1940) is the most likely source of the abundant silica in the area. Extensive alteration of glass shards within the Anderson Mine sediments supports this hypothesis. It seems likely that uranium mobilization accompanied the movement of silica during the diagenetic alteration of the tuffaceous sediments. This possibility has been suggested by Weeks et al. (1958) as the mechanism for uranium migration in some Texas coastal plain uranium deposits and by Lindsey (1975) as a possible mechanism for the movement of uraniferous fluids in the water-lain tuffs in the Thomas Range, Utah.

Diagenetic calcification has affected both members of the Anderson Mine sediments and has resulted in both the cementation and replacement of the sediments by calcite. Specifically, calcite replaces feldspars and cements the arkosic sandstones in the southern portion of the area and replaces and indurates tuffaceous and carbonaceous lutites and reworked tuffs. In addition, sparry calcite has replaced micrite in some of the marlstones and limestones of the upper Anderson Mine member. In thin-section studies, both calcite and silica can be found in cross-cutting relationships in veinlets indicating that the later stages of both may have occurred concurrently. However, in outcrop studies on the upper unit of the Anderson Mine member, calcification generally appears to be slightly younger than the silicification, particularly in the filling of voids and fractures. Leaching, dissolution, and alteraiton of the volcanic tuffs and carbonate-rich sediments probably provided the source of the calcite found in the Anderson Mine sediments.

Diagenetic alteration of the volcanic sediments has also resulted in the formation of light greenish-gray bentonitic clays. Specifically, smectite, illite, and other mixed-layer clays have been identified by x-ray techniques. These occur throughout the Upper Anderson Mine member and occasionally in the "Flat Top" clastics chiefly as indistinct whitish to greenish films and blebs within the altered sediments. In addition, Otton (personal communication, 1977) has described hectorite, a lithium-bearing magnesium bentonitic clay, in portions of the tuffaceous Anderson Mine sediments.

The alteration of the tuffaceous-rich sediments has also resulted in the formation of the zeolite clinoptilolite. Although other zeolites have not yet been identified at the Anderson Mine, Sheppard and Gude (1972) have reported analcime and erionite in similar tuffaceous sediments approximately 60 km to the northwest near Wickieup, Arizona. Work done by Coombs (1959), Hay (1963), and Lindsey (1975) on sediments similar to those at the Anderson Mine suggest that formation of clays and zeolites occurs quite early in the diagenetic process but likely postdates the initial stages of silicification and calcification.

The formation of clays and zeolites early in the diagenesis of the sediments may have been of some importance during the initial phase of uranium mineralization. Clinoptilolite-heulendite group zeolites, and to a lesser extent, montomorillonite-group clays can act as effective adsorbents of uranium from solution (Katayama, et al., 1974). Although this type of mineralization has not yet been recognized at Anderson Mine, it is possible that uranium could have been adsorbed in the early stages of mineralization and subsequently remobilized and reduced in proximity to the carbonaceous sediments. Katayama et al. (1974) reports that uranium preferentially forms coffinite (or uranium silicates) when excess silica and strongly reducing conditions prevail as was likely the case in the paludal portion of the lake sediments at Anderson Mine.

why? Most of the Carb was present when the clys were or even before.

Pyrite occurs in the carbonaceous sediments as finely-disseminated crystals and more commonly as fracture fillings. The disseminated pyrite is likely of syngenetic origin while the mineralization in veinlets was possibly formed during the diagenesis of the sediments. Pyrite is also found in portions of the arkosic sandstones in the southern part of the study area. Much of this pyrite occurs as a cementing agent around sand grains and resembles the "matrix" pyrite commonly found in unaltered sandstones in many Wyoming uranium districts. Interestingly, portions of these sandstones are limonite-stained and the pyrite, where present, is highly pitted and tarnished. It is conceivable that these limonite-stained sandstones are "altered" which suggests the possibility of "roll-front" type mineralization in these units. Minor quantities of medium-grade uranium mineralization have been found in these sands in general proximity to "altered-unaltered" contacts, but this mineralization has not been evaluated in any detail.

GEOCHEMISTRY

Quantitative analyses for U_3O_8, V_2O_5, CO_2, and total S were performed on samples representing 0.3 m (1 ft.) intervals throughout the mineralized sections of 14 widely-spaced core holes. In addition, the entire cored interval from two holes were analyzed for U_3O_8, V_2O_5, As, Mo, Li, Mn, F, organic C, and total S. This latter study was primarily concerned with the geochemistry of the unoxidized mineralization and the respective underlying and overlying unmineralized sediments. Two commercial analytical laboratories were employed to cross-check analyses.

Disequilibrium studies were undertaken to ascertain the relationship between chemical and radiometric uranium. Chemical and radiometric values from all of the core holes were plotted as in Figure 22, and disequilibrium values were calculated. These values ranged from 0.48 to 1.18, with a weighted average disequilibrium factor approaching 1.00 for the deposit. Values ranging from 0.90 to 1.10 were obtained for mineralized intervals from the unoxidized zone suggesting only minor uranium migration in these portions of the deposit. In contrast, the oxidized uranium mineralization shows erratic disequilibrium factors, generally less than 0.90 or greater than 1.10. These erratic values indicate probably remobilization of uranium in the oxidized sediments, at least until fairly recent times.

Uranium mineralization appears to be closely related to the organic carbon content of the Anderson Mine sediments (Figures 23a, 24a, 25a). The linear correlation coefficient between uranium and organic carbon of 0.55 (Table 5) further suggests an excellent positive geochemical coherence between these elements (Rankama and Sahana, 1950). In fact, a close inspection of the rock unit descriptions within the mineralized zones (Figures 23a, 24a, 25a) indicates a strong affinity to the carbonaceous rock units by uranium.

It is also apparent from Figures 23a, 24a, and 25a that arsenic, molybdenum, and total sulfur are significantly enriched within the uraniferous intervals. Ranges of values for these elements within the mineralized zones are 1 ppm to 315 ppm arsenic, 1 ppm to 915 ppm molybdenum and 100 to 24200 ppm total sulfur. Ranges of values in the unmineralized zones are 1 ppm to 80 ppm arsenic, 1 ppm to 7 ppm molybdenum and 100 to 7100 ppm total sulfur. The linear correlation coefficients for arsenic, molybdenum, and total sulfur with respect to uranium indicate only low to moderate correlation (Table 5). However, Table 5 indicates significantly higher correlation coefficients are obtained when arsenic, molybdenum, and total sulfur are compared to organic carbon. Additional correlation coefficients of 0.73, 0.52, and 0.47 were obtained by correlating arsenic and sulfur, molybdenum and sulfur, and arsenic and molybdenum respectively (Table 5). The actual significance of the intimate relationships between uranium, organic carbon, arsenic, molybdenum, and total sulfur is unclear. Further interpretation is deferred until specific minerals or complexes containing these elements can be identified.

The entire lacustrine section at the Anderson Mine appears to be enriched in vanadium with the higher values locally associated with the zones of uranium mineralization. Vanadium values range from 100 ppm to 9060 ppm in the mineralized zone and 200 to 6400 in the unmineralized zone. Over 70% of the assays from both zones exhibit vanadium values greater than 400 ppm (Figures 23b, 24b, 25b). In contrast, preliminary geochemical studies of vanadium from nonuraniferous lacustrine sediments, possibly correlative with the Anderson Mine lacustrine sediments, range from 20 ppm to 420 ppm with only 2% of the assays exhibiting values greater than 400 ppm. The available data is insufficient for determination of background and threshold values for vanadium in the Anderson Mine and surrounding areas. Nevertheless, the data indicates that the Anderson Mine sediments have been enriched in vanadium. In addition, the vanadium values obtained from the cores generally show a positive correlation with zones of uranium mineralization. The correlation between uranium and vanadium is best in the upper portion of the uranium mineralized zones or the upper zone if two mineralized zones are present (Figures 23b, 24b, 25b). The anomalous vanadium zones, typically begin several meters above the uranium zone (Figure 23b). Due to this apparent vertical zonation and the poor correlation between these two elements in the lower mineralized zones, the correlation coefficient for uranium to vanadium is low (Table 5).

Other trace elements of lesser significance which display a direct or indirect relationship with respect to the unoxidized uraniferous zones are manganese, lithium, and possibly fluorine. Manganese displays a low correlation with organic carbon and uranium (Table 5). Nevertheless, manganese concentrations up to 2300 ppm have been observed locally associated with the higher grade uranium mineralization (0.20% cU_3O_8). Manganese values outside of the mineralized zone generally range from 100 ppm to 200 ppm. Lithium generally has lower values within the mineralized zone (9-340 ppm) than in the adjacent unmineralized zones (25-560 ppm) (Figures 23b, 24b, 25b). A similar relationship for lithium elsewhere in the Anderson Mine area was previously reported by Otton (1977). Lithium also displays no correlation with any of the elements which are associated with the zones of uranium mineralization (Table 5). However, lithium does display a good correlation with respect to fluorine, as indicated by the 0.54 correlation coefficient in Table 5. Fluorine, like lithium, has lower values within the mineralized zone (140-1320 ppm) than in the unmineralized zones (425-1510 ppm). The higher values of fluorine and lithium typically occur together in the unmineralized altered tuffaceous lutites.

Even though the uranium host rocks at the Anderson Mine are fine-grained volcaniclastic sediments, definite chemical correlations with the more conventional sandstone-type uranium deposits are strikingly apparent. Anomalous values of arsenic, molybdenum, vanadium, organic carbon, and total sulfur, which have been observed at the Anderson Mine, have previously been reported in sandstone-type deposits on the Colorado Plateau (Shoemaker et al., 1959), southeast Texas (Weeks et al., 1963), Black Hills (Gott et al., 1974), and for U. S. sandstone deposits in general (Harshman, 1976). The trace element distribution implies that similar geochemical processes may have been involved in the formation of both types of uranium deposits.

ORIGIN

It seems likely that most of the uranium in the deposit at the Anderson Mine was an original constituent of the host tuffaceous lacustrine rocks. Glassy material and other minerals in the tuffaceous sediments reacted chemically with the lake water causing extensive diagenetic alteration and the development of alkaline carbonate pore water. These carbonate-bearing waters are known to be an excellent medium for the transportation of uranium and other metals in solution (Garrels et al., 1957; Garrels, 1960). It is probable that uranium and silica were released from the volcanic material during the diagenetic process as shown by the common devitrification of glassy material in the sediments, and widespread silicification and zeolitization. This process would be similar to that proposed for many of the uranium deposits in the Texas coastal plain (Weeks and Eargle, 1963; Bunker and Mackallor, 1973).

The possibility that tuffaceous rocks are the source of uranium in many ore deposits has been considered for some time by Waters and Granger (1953) in the Colorado Plateau, Denson and Gill (1956) in the northern Great Plains, and Weeks and Eargle (1963) in the Texas coastal plain. It is a good possibility that the tuffaceous sediments in the Anderson Mine sequence were the source of much of the uranium in the deposit. Geochemical sampling of these sediments away from the known mineralization indicates background uranium values ranging from 10 to 50 ppm with an average concentration of perhaps 25 ppm. It may be somewhat presumptuous to conclude that the lake sediments had an original uranium content of 25 ppm since all of these sediments have been altered to at least some degree. However, it seems reasonable to conclude that an adequate quantity of uranium was present in the sediments to account for the known uranium mineralization.

It is postulated that uranium was leached during compaction and dewatering of the tuffaceous lake sediments, transported in the groundwater as a uranyl carbonate complex and subsequently precipitated in and adjacent to carbonaceous beds. The reducing agent causing precipition was likely hydrogen sulfide gas which occurs in considerable quantities in tuffaceous marlstones interbedded with the carbonaceous units. It is possible that the mineralization process could have been aided by a change to a more arid climate. This may have caused lacustrine sedimentation to cease and high evaporation rates to begin. Rapid evaporation could have facilitated dewatering of the lake sediments and subsequent mineralization. A process similar to this has been proposed by Weeks and Eargle (1963) to account for uranium mineralization of the southeast Texas coastal plain.

Reyner et al. (1956) have suggested a hypogene origin for the uranium mineralization at Anderson Mine. This conclusion was based on field observations which showed that: 1) uranium ore has not been observed beyond the "boundary" faults; 2) intense silicification has altered mudstone and limestone; 3) limonite and hematite staining occurs on bedding and fracture planes; and 4) calcite, chalcedony, sepiolite, and manganese are found associated with the west-bounding fault. The authors feel that these observations can be explained without invoking a hypogene process. The subsurface information generated by drilling and coring indicates that the carbonaceous sediments are not present beyond the "boundary" faults. It is possible that the faulting may have controlled the location of the paludal sediments to some extent, but if the faults had acted as conduits for mineralizing solutions then one might expect mineralization to be concentrated along the faults. We have found no such association, and, in fact, the faulting offsets the mineralization. The intense silicification

to a Great extent

This is the strongest evidence for a syngentic or at least a very early diagenetic origin for the mineralization noted in the sediments is likely related to the diagenetic alteration of the tuffaceous material present in the section. The presence of hematite and limonite staining on bedding and fracture planes probably results from the oxidation of disseminated pyrite in the section. The occurrence of calcite, sepiolite, chalcedony, and manganese in the western fault zone may indicate some movement of fluids in this area; but without associated uranium, such occurrences can not be cited as significant evidence that these zones were major channelways of uraniferous solutions.

Some remobilization of the original coffinite (?) mineralization has occurred in the near-surface environment at Anderson Mine in more recent geologic time. The behavior of uranium minerals during oxidation in near-surface environments has been investigated by Garrels and Christ (1959). They conclude that uranium is oxidized to U^{+4} which is readily soluble in carbonate groundwaters except in the presence of vanadium, arsenic and phosphorus. Since vanadium and some arsenic are present in the mineralized section of Anderson Mine, carnotite and/or tyuyamunite are formed. Carnotite is nearly insoluble in an oxidizing environment; however, the significant disequilibrium in the carnotite mineralization at Anderson Mine indicates some unusual conditions. These conditions have been explained by Garrels and Christ (1959). In areas where there is active entrance of water into and evaporation from carnotite ores, movement of uranium can occur especially where carbonates are present. Carbonates are rather common in the mineralized section at Anderson Mine and would seem to facilitate the upward remobilization of carnotite by capillary action into shrinkage cracks and fractures in the near-surface environment. It is postulated that this process is responsible for the superficial resemblance of the near-surface mineralization at Anderson Mine to that of the Yeelerrie deposit of western Australia as described by Langford (1974). Also this oxidized Mineralzation is usually (almost Always) Above the Carb Facies.

Yes the carnotite is probably tyuyamunite

CONCLUSIONS

The uranium deposit at the Anderson Mine is believed to have formed during the diagenetic evolution of the Date Creek Basin. Compaction and dewatering of uraniferous volcanic-rich lake sediments led to the migration of uranium-carbonate--silica-rich formational waters upward or outward from the basin. This concept is not new as Noble (1963) has suggested that the ore fluids for the Colorado Plateau-type uranium-vanadium deposits and the Mississippi Valley-type lead-zinc deposits may be simply the connate waters which were expelled during compaction of the sediments. Jackson and Beales (1967) have taken this hypothesis one step further when they concluded that these ore fluids are the result of the normal evolution of a sedimentary basin. Where these fluids have encountered local reducing environments, which in the Anderson Mine area are characterized by hydrogen sulfide generating paludal sediments, uranium and/or selected base metal precipitation occurs.

Good

It is vital that regional guides to uranium deposits be developed for exploration in the Basin and Range. The Anderson Mine deposit may provide a valuable model for future Basin and Range uranium exploration. Important aspects of this model, which maybe useful to the exploration geologist, have been summarized below:

1. The development and preservation of reductants in or near terrains which contain potentially leachable uranium must be considered. The reducant at the Anderson Mine was hydrogen sulfide gas which was generated from the decay of paludal sediments. The preservation of these sediments was the result of gradual depositional onlap. The acid volcanics, which comprise a major fraction of the Anderson Mine sediments, were probably the source of the uranium.

2. Close attention should also be paid to the alteration products of the lake sediments which indicate that fluids capable of leaching and transporting uranium were present during diagenesis. In the Anderson Mine favorable diagenetic alteration has been implied from the pervasive silicification, calcification, zeolitization and argillization of the fine-grained Anderson Mine sediments.

3. Marked increase in values for Li, V_2O_5, U_3O_8, and possibly F in the sediments may provide an excellent regional guide to areas of potential Anderson Mine-type mineralization. Anomalous concentrations of Mo and As may not be useful regional guides as they are exclusively associated with the zones of uranium mineralization.

It is conceivable that the diagenesis of tuffaceous rich lake sediments in the Basin and Range may have resulted in the formation of large areas of low grade uranium mineralization (30-100 ppm). The Anderson Mine model may further aid exploration geologists in differentiating between these areas of noneconomic low grade uranium mineralization and areas of potential economic significance.

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Table 1. Summary by region of uranium production, reserves, and potential*

Region	Tons U_3O_8 Production to 1/1/76	Tons U_3O_8 ($30/lb.) 1/1/76 Reserves	1/1/76 Potential Resources Probable	Possible	Speculativ
(A) Colorado Plateau	197,800	326,000	433,000	632,000	103,000
(B) Wyoming Basins	59,200	233,100	313,000	84,000	31,000
(C) Coastal Plain	8,300	43,900	100,000	128,000	31,000
(D) Northern Rockies	4,800	20,100	27,000	62,000	49,000
(E) Colorado and Southern Rockies	6,400	9,000	44,000	30,000	12,000
(F) Great Plains	3,500	6,300	26,000	57,000	37,000
(G) Basin & Range	1,400	1,400	106,000	235,000	105,000
(H) Pacific Coast and Sierra Nevada	<1,000	200	10,000	42,000	56,000
(I) Central Lowlands	<1,000	0	**	**	71,000
(J) Appalachian Highlands	<1,000	0	**	**	77,000
(K) Columbia Plateaus	<1,000	0	**	**	18,000
(L) Southern Canadian Sheild	0	0	**	**	**
(M) Alaska	<1,000	0	1,000	**	**
TOTALS	282,400	640,000	1,060,000	1,270,000	590,000

*From U.S.E.R.D.A. GJO-111 (76), (1976, Table 2).
**Resources not estimated because of inadequate knowledge.

Table 2. Production figures from Anderson Mine

Year		Tons of ore	Grade (%) U_3O_8	Lbs. of ore
1955		9	0.56	101
1956		31	0.21	130
1957		3,614	0.19	14,043
1958		725	0.27	3,928
1959		6,379	0.12	15,028
	TOTAL	10,758	Ave. 0.15% U_3O_8	33,230

	% Ash	% Volatile Material	% Fixed Carbon	% Moisture	% Sulfur	B.T.U.'s/lb.
A	68.29	15.72	11.52	4.47	2.25	2943
B	73.46	20.32	2.97	3.25	1.92	1962
C	88.71	5.97	2.24	3.08	0.60	0

Table 3. Proximate analyses of carbonaceous litites from the upper carbonaceous unit of the Anderson Mine section. Samples A through C were randomly selected and analyzed "as received".

Table 4. Uranium resources from Anderson Mine.

(% U_3O_8) Cutoff	(% U_3O_8) Average Grade	(m) Average Thickness	(%) Uranium Mineralization
.02	.05	6.3	100%
.03	.06	4.2	83.1%
.05	.09	2.6	60.6%
.07	.12	2.0	47.9%

Table 5. Correlation coeffients for selected elements from two core holes taken from the Anderson Mine.

	U_3O_8	$C_{organic}$	S_{total}	As	Mo	V_2O_5	Li	Mn	F
U_3O_8	1.00	0.55	0.27	0.31	0.27	0.17	0.06	0.10	-0.11
$C_{organic}$	0.55	1.00	0.64	0.68	0.44	0.14	0.05	0.03	-0.12
S-total	0.27	0.64	1.00	0.73	0.52	-0.12	0.16	0.05	0.17
As	0.31	0.68	0.73	1.00	0.47	-0.02	0.00	0.11	0.03
Mo	0.27	0.44	0.52	0.47	1.00	-0.05	-0.05	0.00	-0.02
V_2O_5	0.17	0.14	-0.12	-0.02	-0.05	1.00	0.00	-0.33	-0.18
Li	0.06	0.05	0.16	-0.00	-0.05	0.00	1.00	-0.16	0.54
Mn	0.10	0.03	0.05	0.11	0.00	-0.33	-0.16	1.00	0.18
F	-0.11	-0.12	0.17	0.03	-0.02	-0.18	0.54	0.18	1.00

Figure 1. Location map of the Anderson Mine - Artillery Peak area in west-central Arizona.

Figure 2. View of the lacustrine section at Anderson Mine with underlying "Arrastra" volcanics and overlying "Flat Top" clastics and basalt. The sharp irregular contact between the Anderson Mine sediments and the "Arrastra" volcanics is the onlapping depositional contact between the two units. The mountains in the distance are upfaulted "Arrastra" volcanics.

Figure 3. Geologic column and idealized sections extending southwest from Anderson Mine, in the northeastern Date Creek Basin. The sections show the major facies changes and unconformities in the Tertiary sequence.

Figure 4. Generalized geologic map of the northeastern Date Creek Basin.

Figure 5. Lower Miocene post-"Arrastra" paleotopographic map of the Anderson Mine area.

Figure 6. Generalized cross-section of a portion of the Anderson Mine area. T_1 through T_4 refer to the approximate stratigraphic position of the lithofacies maps.

Figure 7. Lithofacies and paleotopographic map of the lower carbonaceous unit ($Tmau_1$) of the upper Anderson Mine member. The map is drawn near the middle of the unit as indicated by T_1 in Figure 6. A ten meter contour interval is used to show local paleotopographic relief.

Figure 8. Lithofacies and paleotopographic map of the intermediate clastic unit of the upper Anderson Mine member. The map is drawn near the top of the unit as indicated by T_2 in Figure 6. A ten meter contour interval is used to show local paleotopographic relief.

Figure 9. Lithofacies and paleotopographic map of the upper carbonaceous unit of the upper Anderson Mine member. The map is drawn near the middle of the unit as indicated by T_3 in Figure 6. A ten meter contour interval is used to show local paleotopographic relief.

Figure 10. Lithofacies and paleotopographic map of the upper tuff and carbonate unit of the upper Anderson Mine member. The map is drawn near the base of the unit as indicated by T_4 in Figure 6.

Figure 23a. Lithologic description and distribution of U_3O_8, C(organic), A_s, and Mo in a portion of the upper carbonaceous unit ($Tmau_3$), core hole #1. The core-hole location is given in Figure 15.

Figure 23b. Lithologic description and distribution of U_3O_8, V_2O_5, S, and Li in the same interval given in Figure 23a.

Figure 24a. Lithologic description and distribution of U_3O_8, C(organic, A_s, and Mo in the upper portion of the upper carbonaceous unit ($Tmau_3$), core hole #2. The core-hole location is given in Figure 15.

Figure 24b. Lithologic description and distribution of U_3O_8, V_2O_5, S, and Li in the same interval given in Figure 24a.

Figure 25a. Lithologic description and distribution of U_3O_8 C(organic), A_s, and Mo in the lower portion of the upper carbonaceous unit ($Tmau_3$), core hole #2. The core hole location is given in Figure 15.

Figure 25b. Lithologic description and distribution of U_3O_8, V_2O_5, S, and Li in the same interval given in Figure 25a.

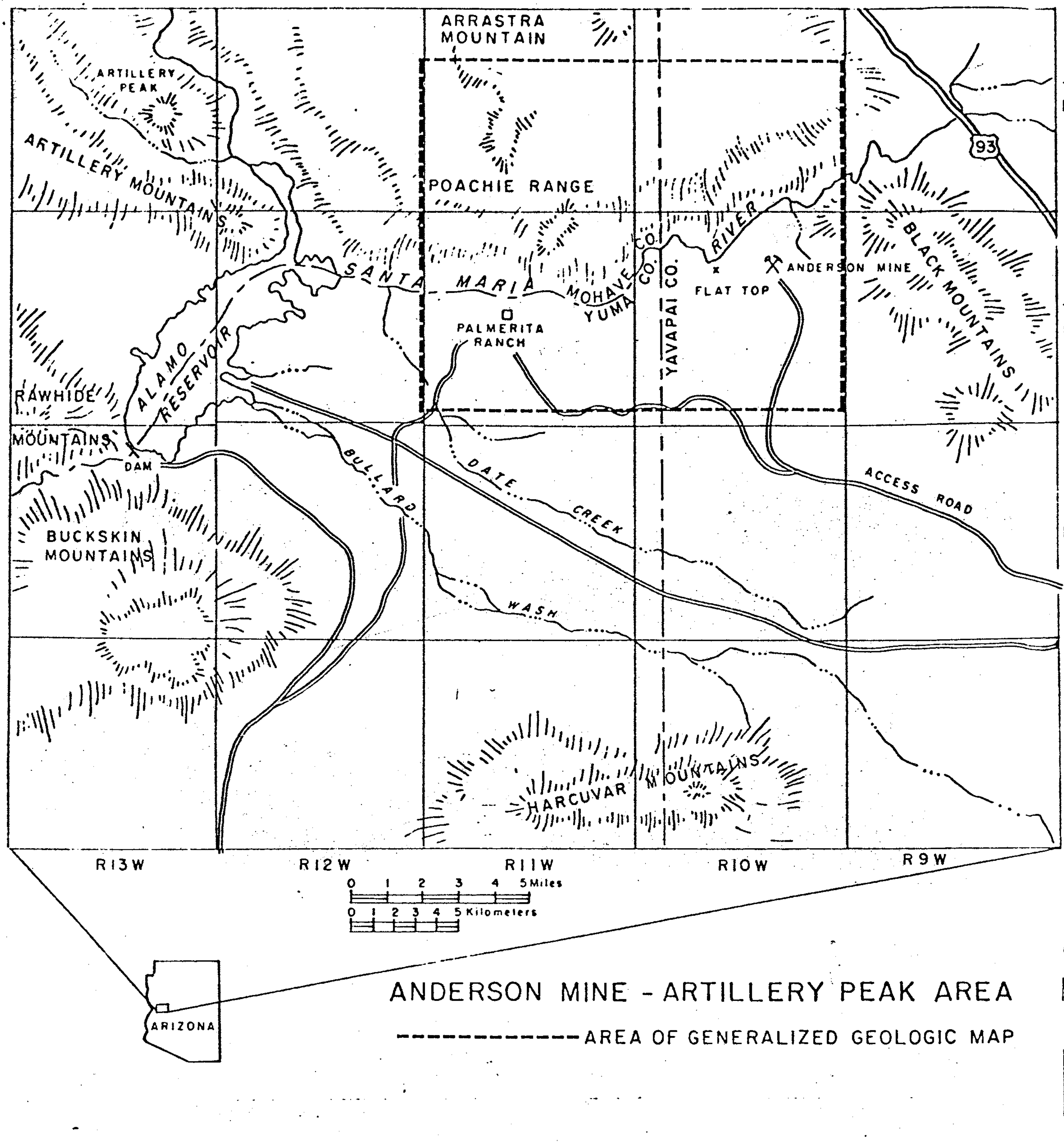


Figure 1. Location map of the Anderson Mine - Artillery Peak area in west-central Arizona.

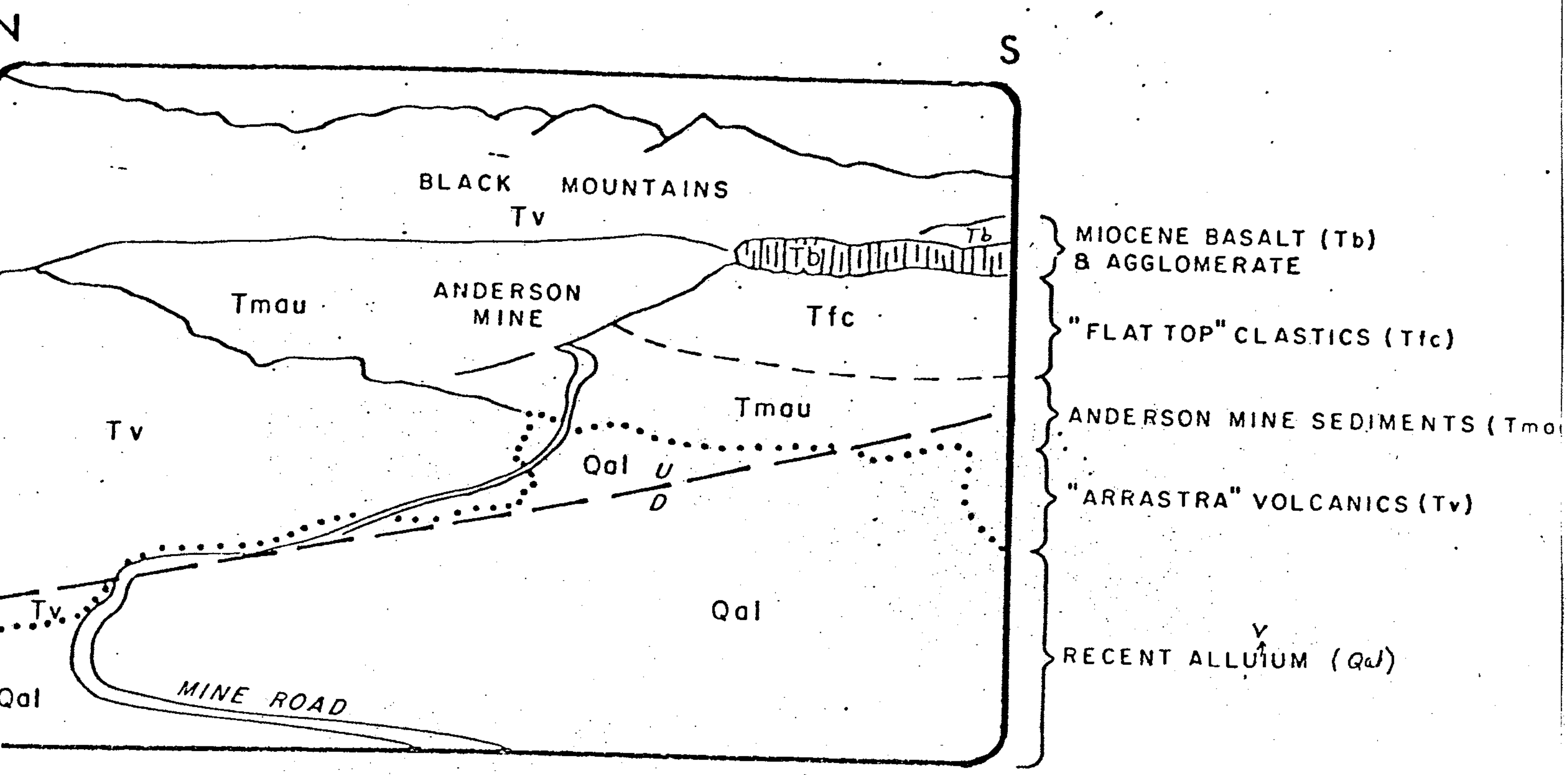


Figure 2: View of the lacustrine section at Anderson Mine with underlying "Arrastra" volcanics and overlying "Flat Top" clastics and basalt. The sharp irregular contact between the Anderson Mine sediments and the "Arrastra" volcanics is the onlapping depositional contact between the two units. The mountains in the distance are upfaulted "Arrastra" volcanics.

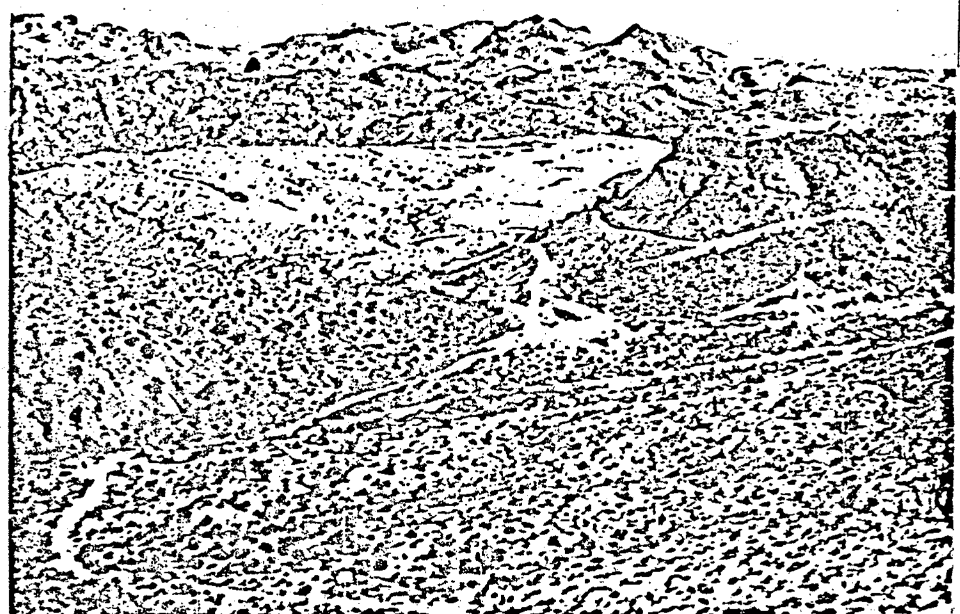


Fig. 2

IDEALIZED GEOLOGIC SECTIONS OF THE NORTHEASTERN DATE CREEK BASIN, WEST-CENTRAL ARIZONA

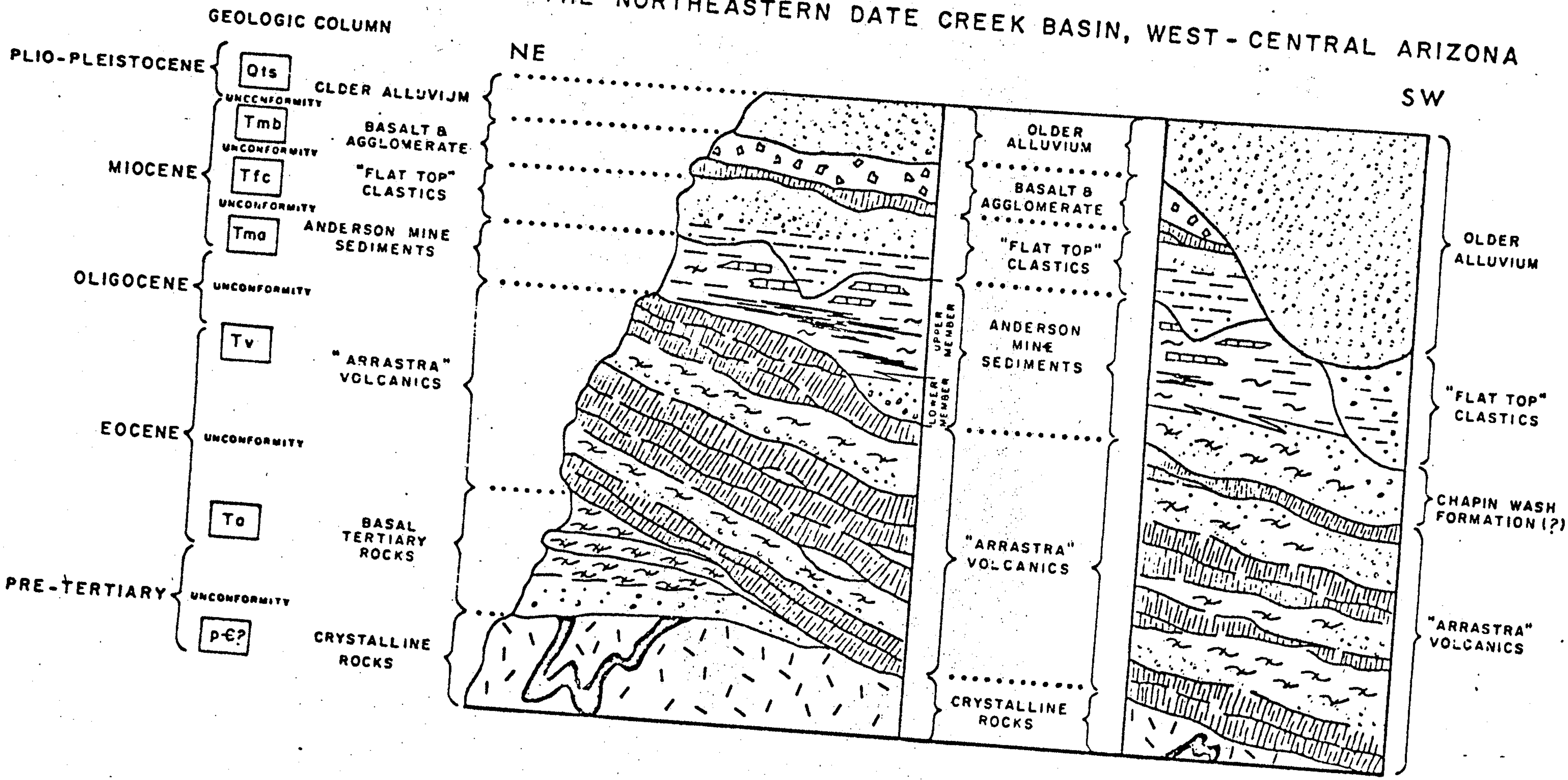
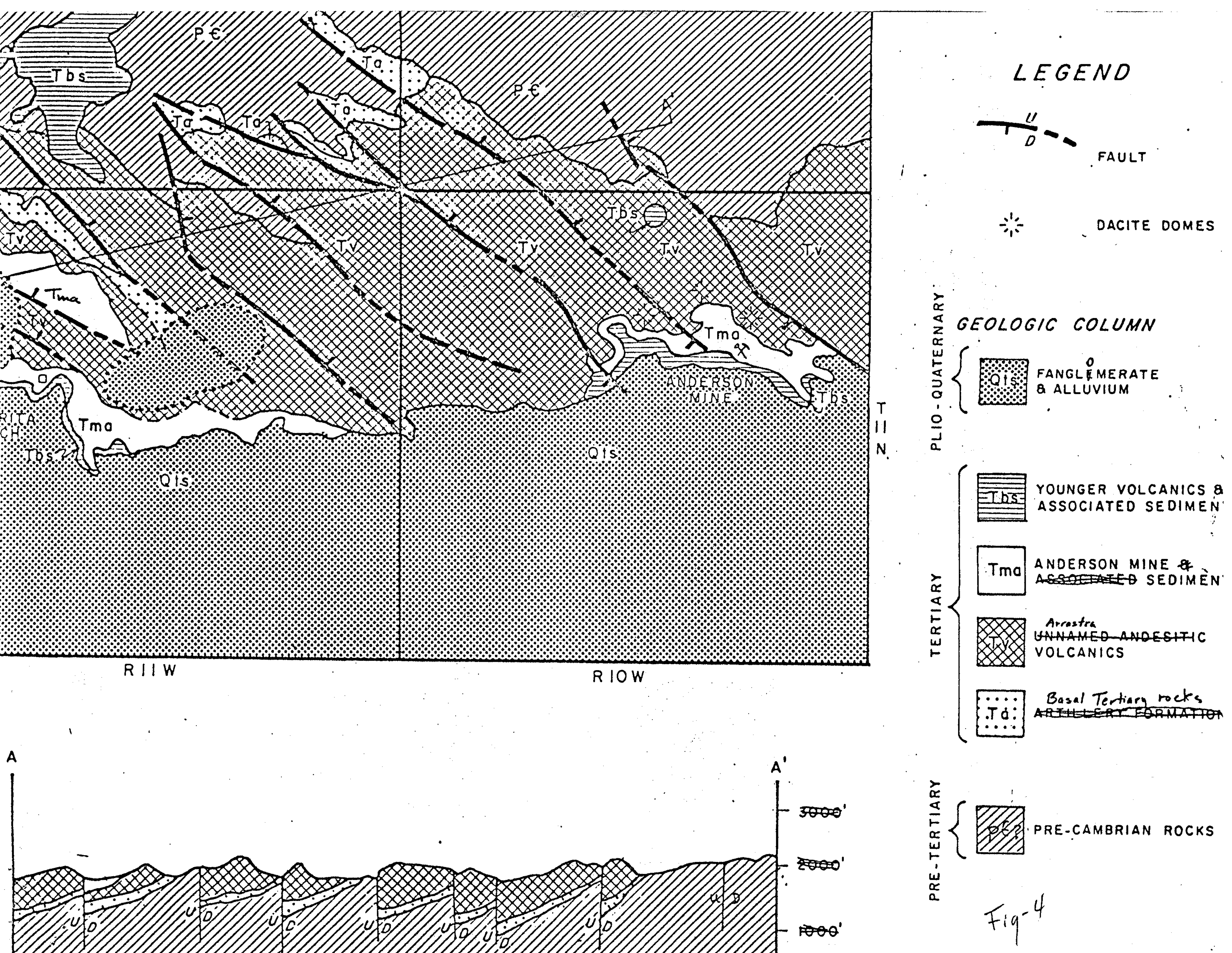


Fig. 3



LEGEND
U
D
FAULT
DACITE DOMES
GEOLOGIC COLUMN
PLIO-QUATERNARY
Qls
FANGLOMERATE & ALLUVIUM
TERTIARY
Tbs
YOUNGER VOLCANICS & ASSOCIATED SEDIMEN
Tma
ANDERSON MINE & ~~ASSOCIATED~~ SEDIMEN
Tv
Arrastra
~~UNNAMED ANDESITIC~~
VOLCANICS
Td
Basal Tertiary rocks
~~ARTILLERY FORMATION~~
PRE-TERTIARY
P€?
PRE-CAMBRIAN ROCKS
P€
Tbs
Ta
Tv
Tma
Qls
ANDERSON MINE
T 11 N
R11W
R10W
A
A'
3000'
2000'
1000'

Fig-4

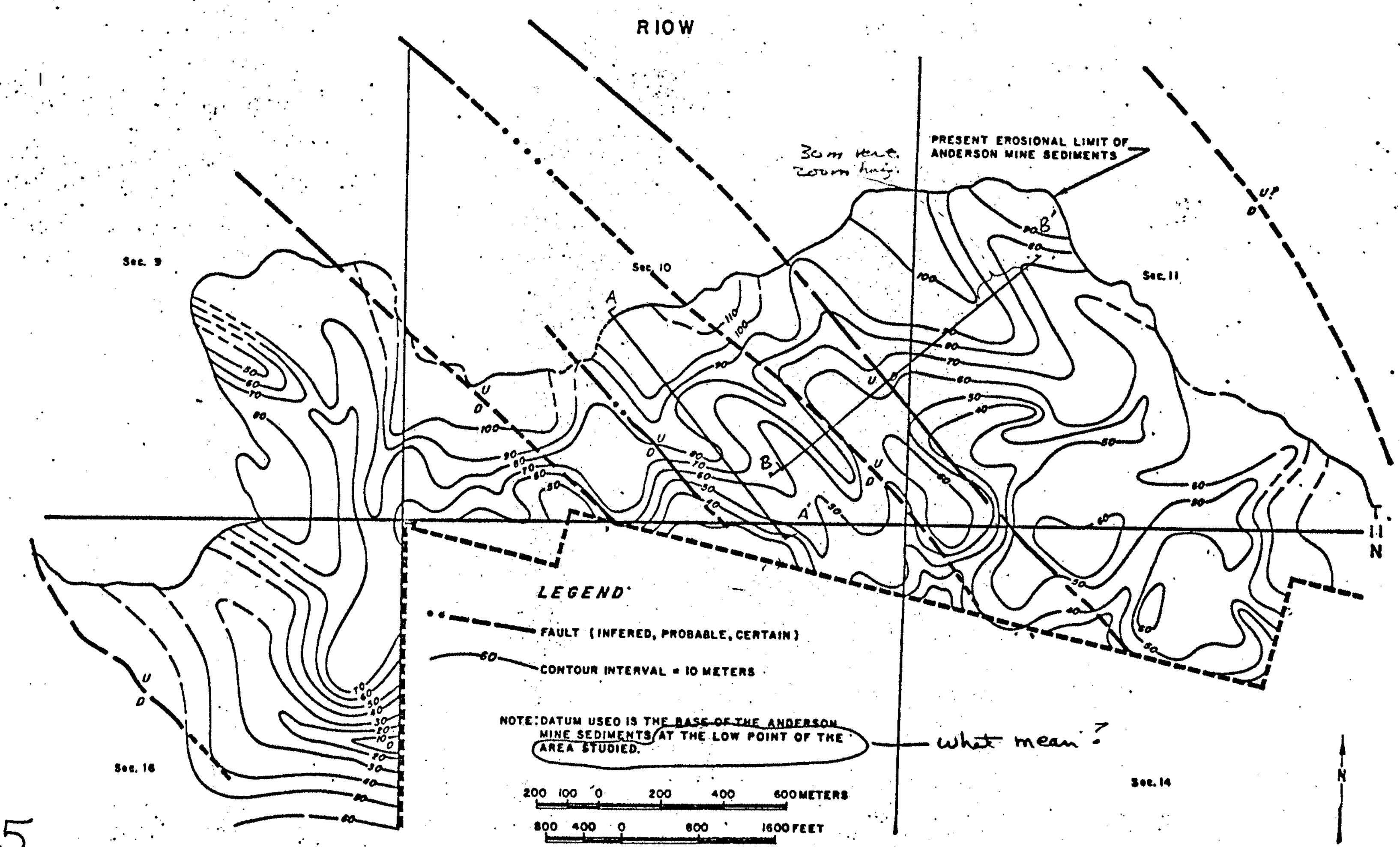

R10W
PRESENT EROSIONAL LIMIT OF ANDERSON MINE SEDIMENTS
30m vert. zoom hair
Sec. 9
Sec. 10
Sec. 11
Sec. 16
Sec. 14
T. 11 N
A
A'
B
B'
U
D
LEGEND
FAULT (INFERED, PROBABLE, CERTAIN)
CONTOUR INTERVAL = 10 METERS
NOTE: DATUM USED IS THE BASE OF THE ANDERSON MINE SEDIMENTS AT THE LOW POINT OF THE AREA STUDIED.
what mean?
200 100 0 200 400 600 METERS
800 400 0 800 1600 FEET
N

Fig. 5

IDEALIZED CROSS SECTION OF THE ANDERSON MINE AREA

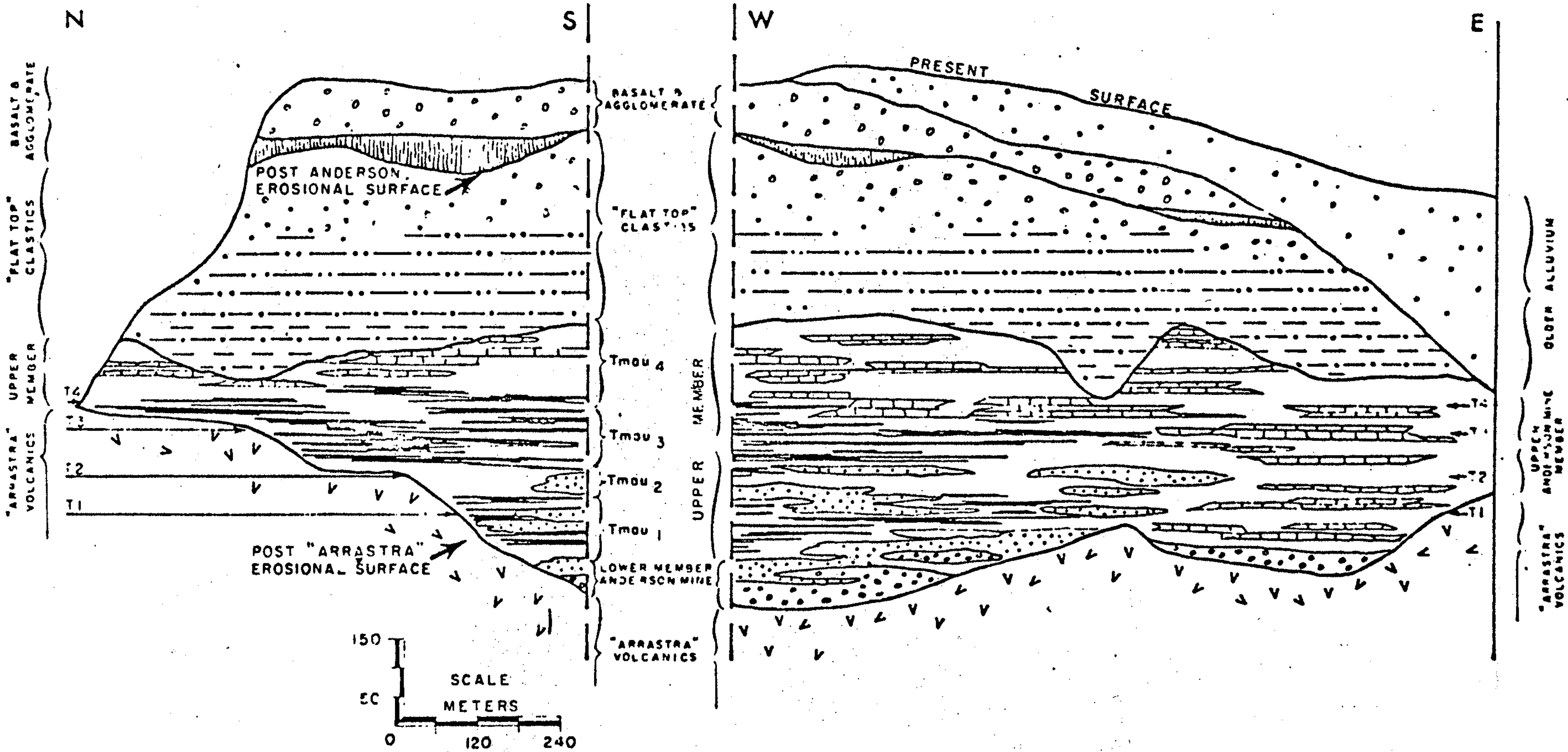


Fig. 6

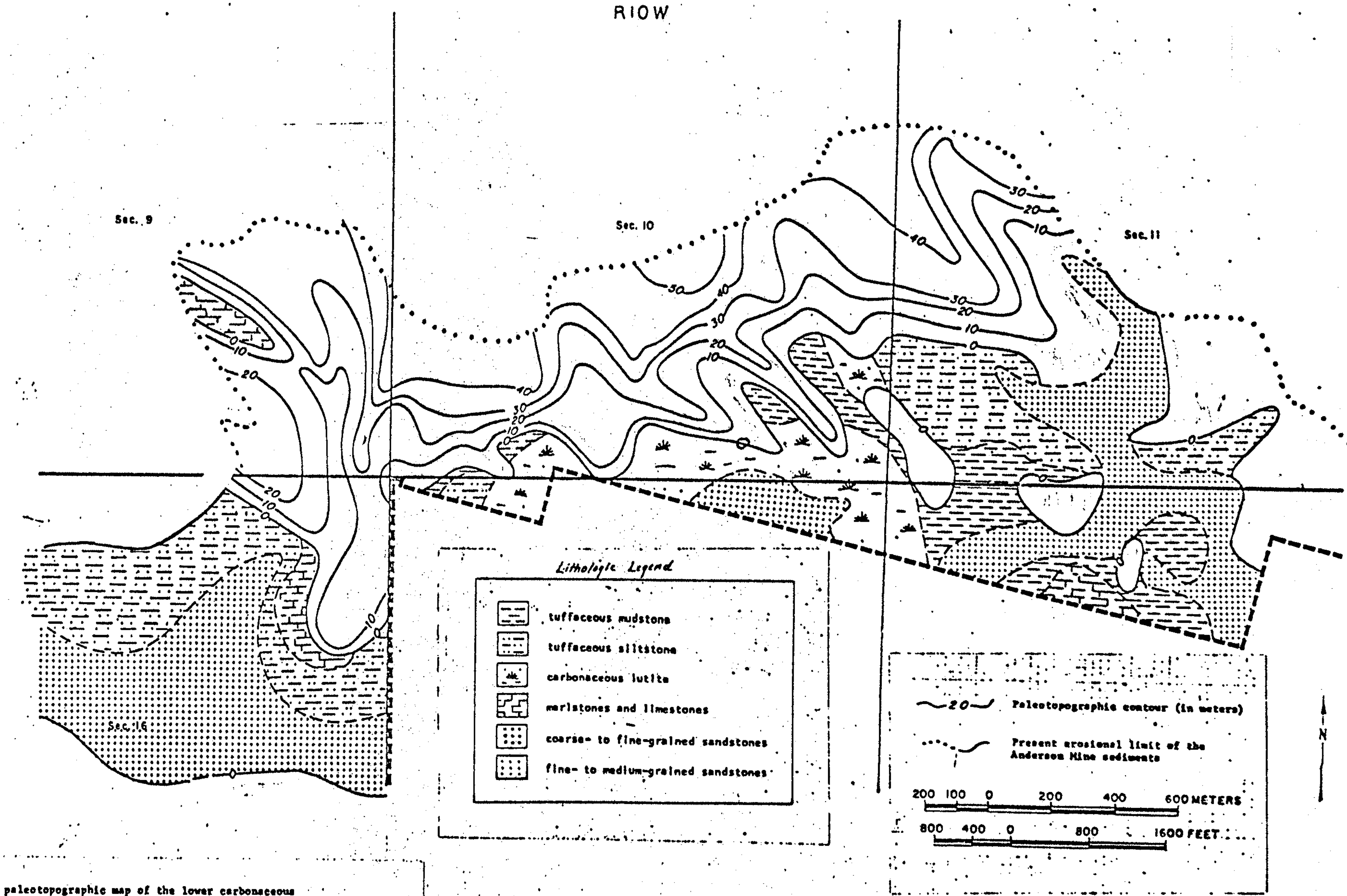


FIG. 7- Lithofacies and paleotopographic map of the lower carbonaceous unit (Tmau$_1$) of the upper Anderson Mine member. The map is drawn near the middle of the unit as indicated by T$_1$ in figure 6. A ten meter contour interval is used to show local paleotopographic relief.

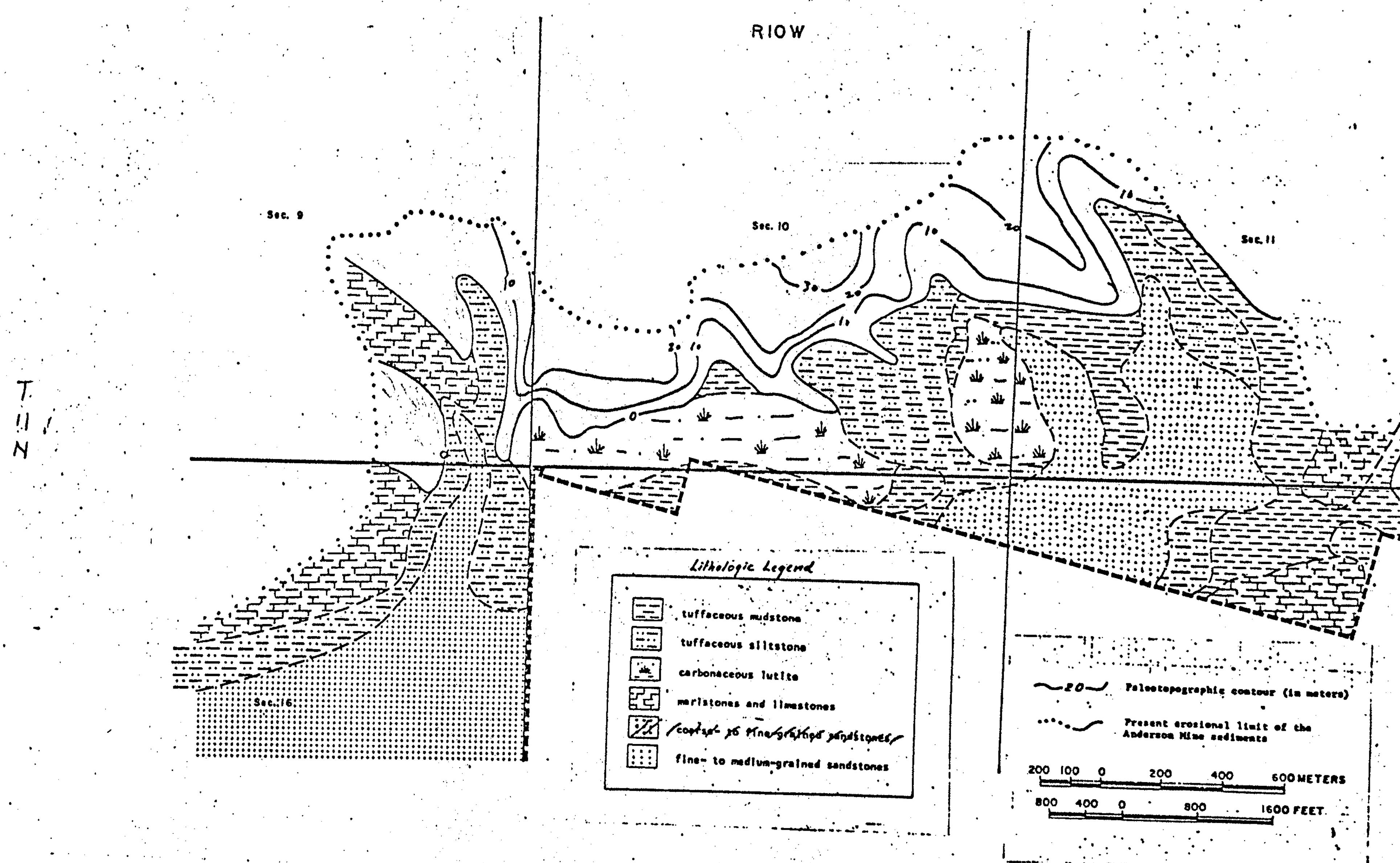


FIG. 8- Lithofacies and paleotopographic map of the intermediate clastic unit ($Tmau_2$) of the upper Anderson Mine member. The map is drawn near the top of the unit as indicated by T_2 in figure 6. A ten meter contour interval is used to show local paleotopographic relief.

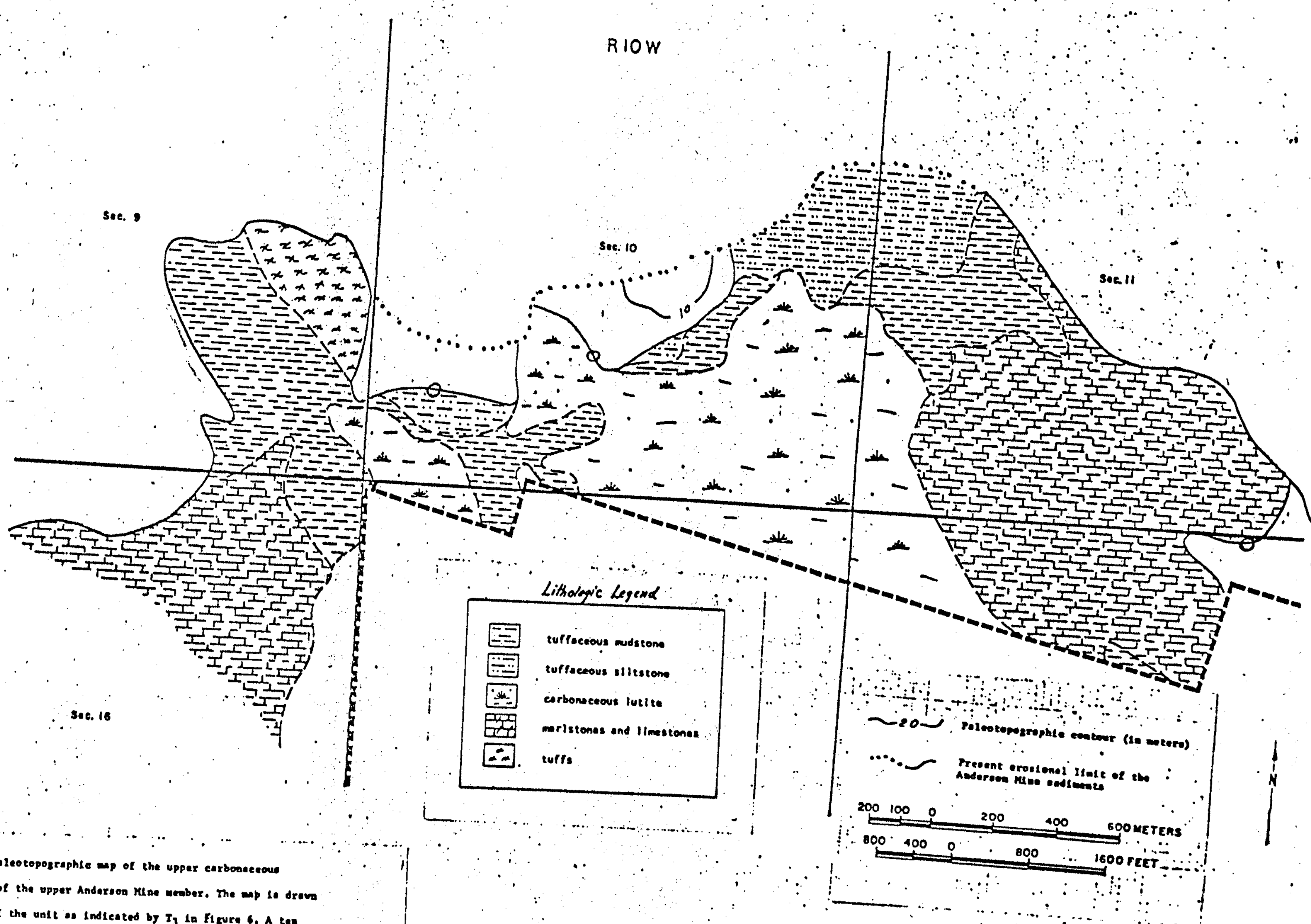


FIG. 9- Lithofacies and paleotopographic map of the upper carbonaceous interval (Tmau3) of the upper Anderson Mine member. The map is drawn near the middle of the unit as indicated by T_3 in Figure 6. A ten meter contour interval is used to show local paleotopographic relief.

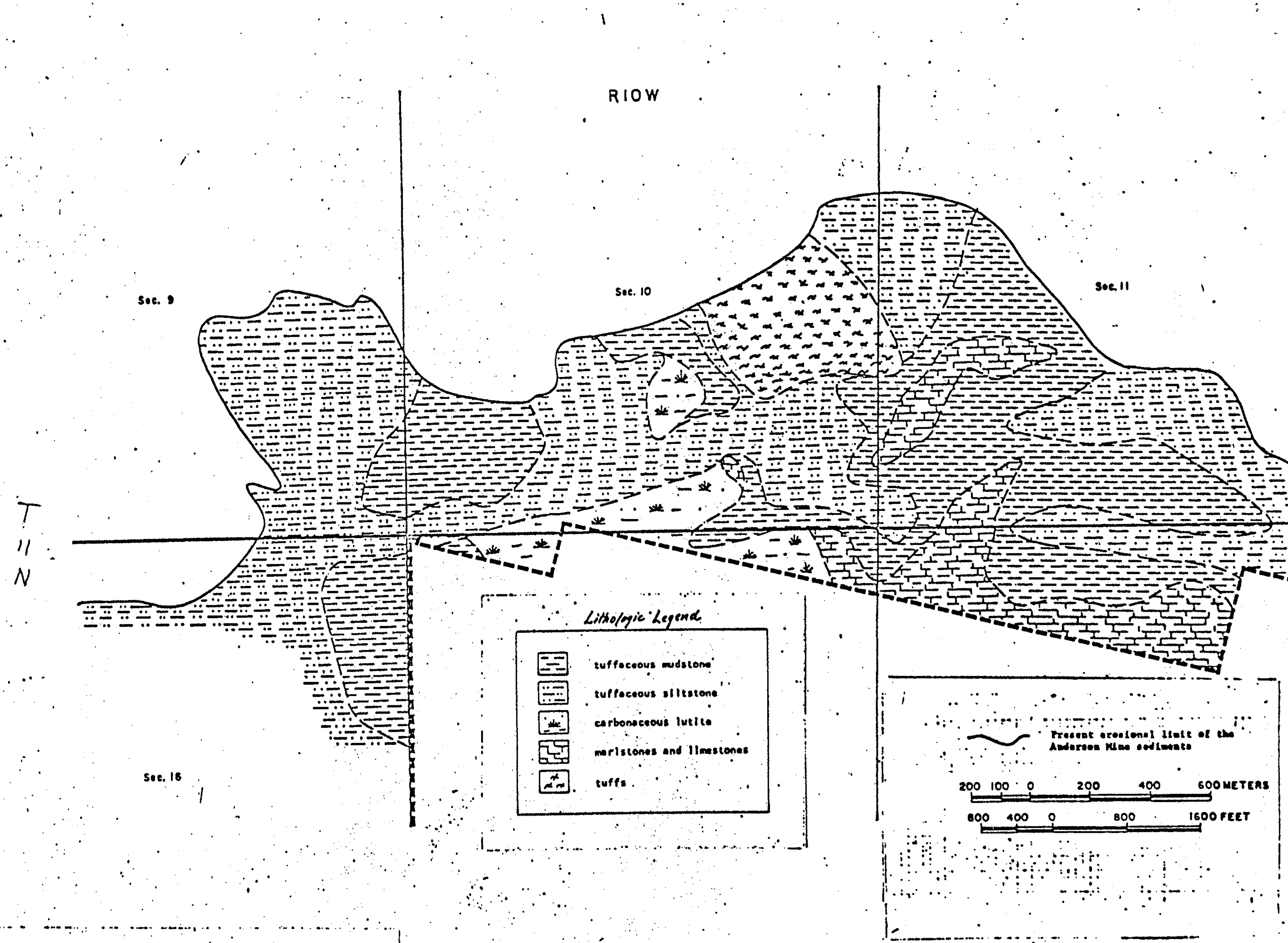
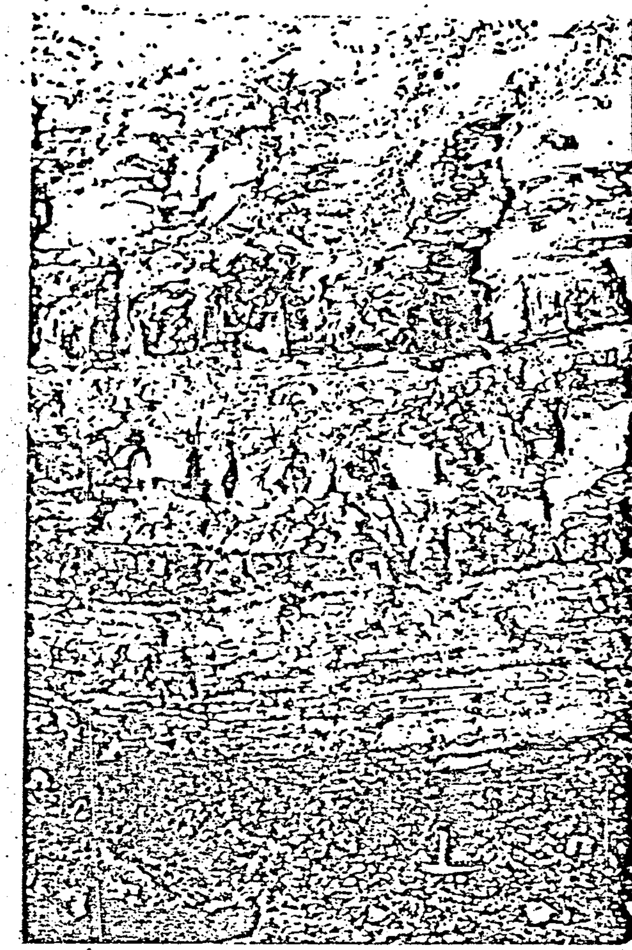
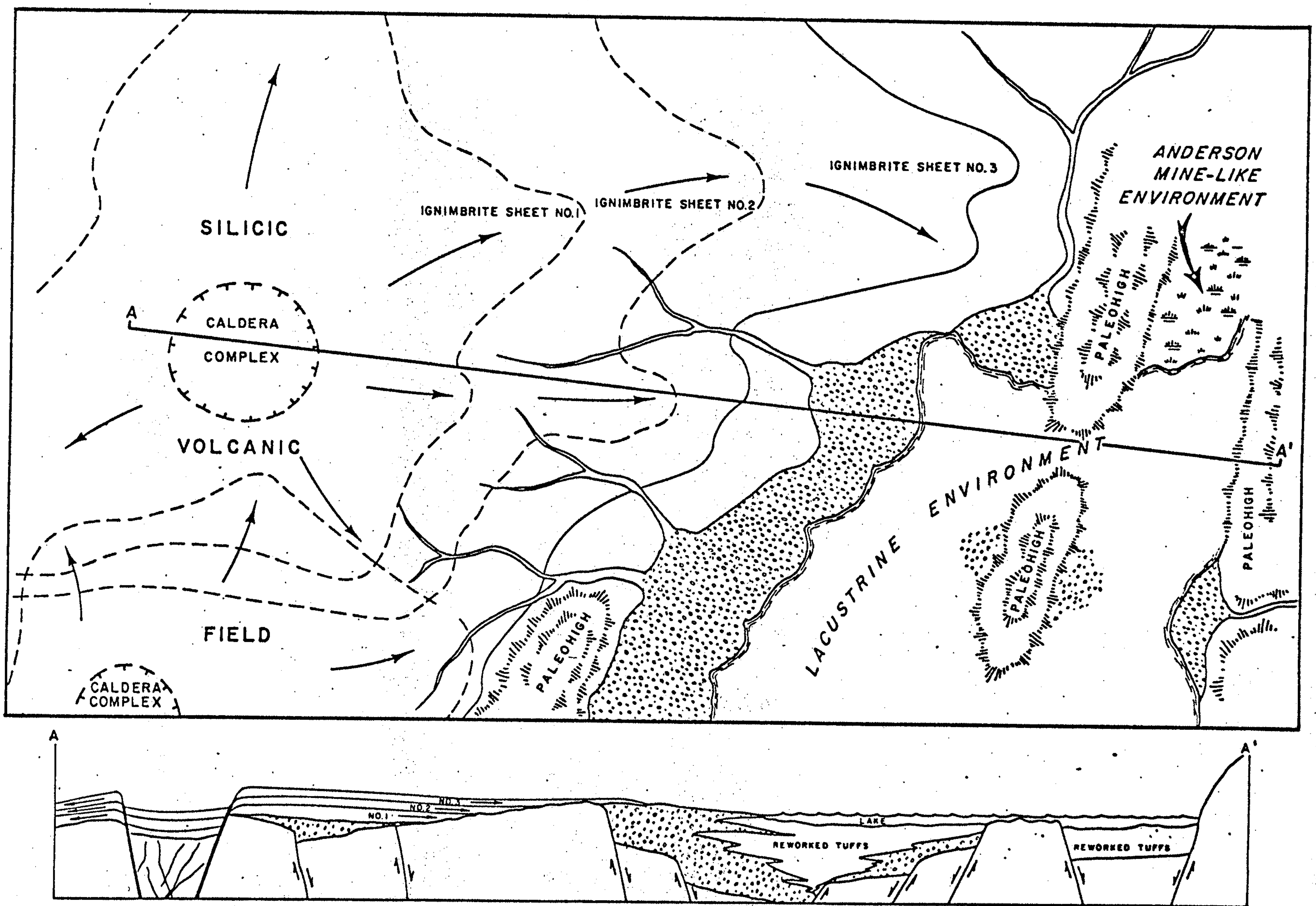


FIG. 10- Lithofacies and paleotopographic map of the upper tuff and carbonate unit of the upper Anderson Mine member. The map is drawn near the base of the unit as indicated by T_4 in Figure 6.

FIG. 11 - Highly silicified and altered lacustrine sediments of the upper Anderson Mine member. These sediments are part of the upper tuff and carbonate unit exposed in the north-central part of the mine area.

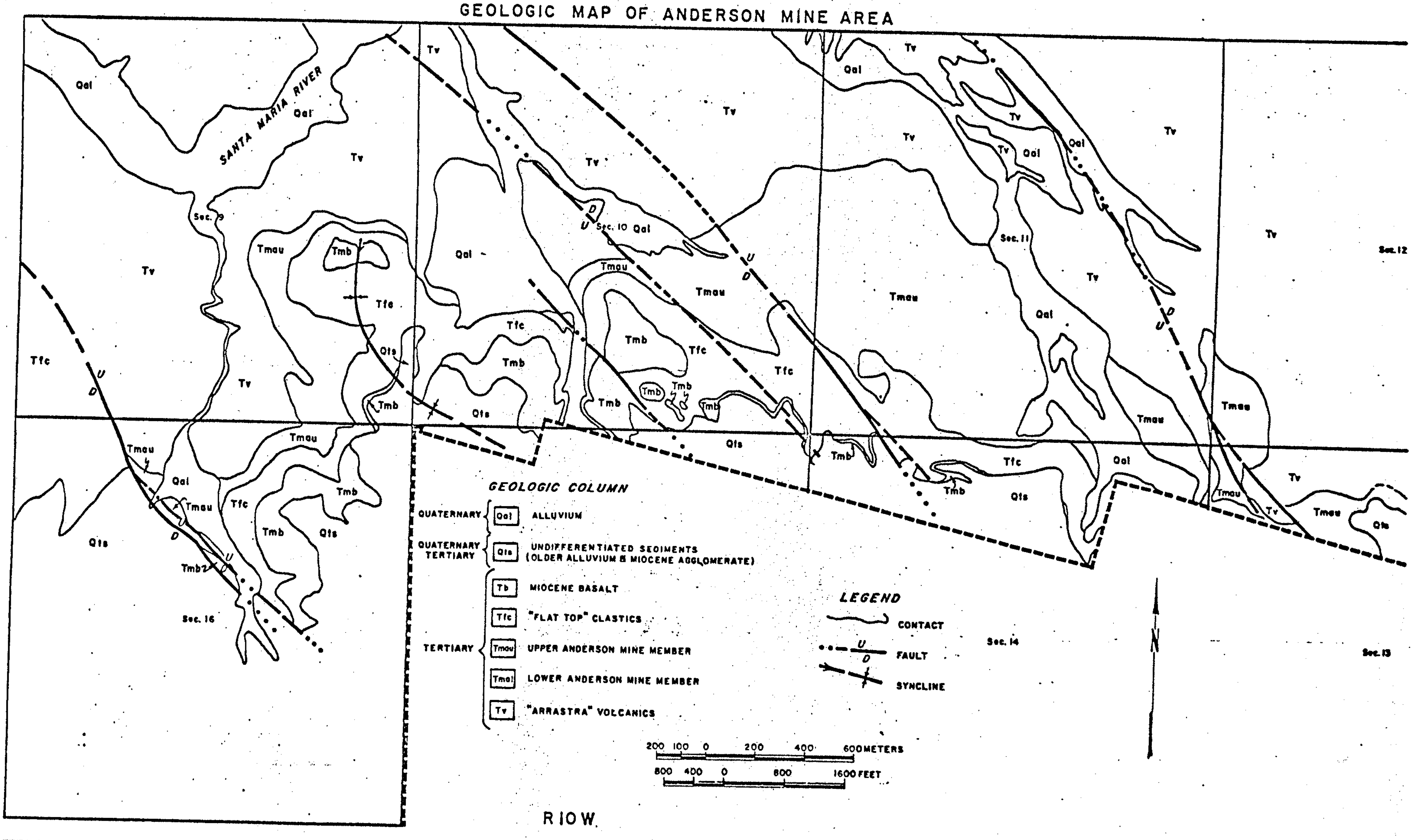




ANDERSON MINE-LIKE ENVIRONMENT
IGNIMBRITE SHEET NO.3
IGNIMBRITE SHEET NO.2
IGNIMBRITE SHEET NO.1
SILICIC
CALDERA COMPLEX
VOLCANIC
FIELD
CALDERA COMPLEX
PALEOHIGH
PALEOHIGH
PALEOHIGH
PALEOHIGH
LACUSTRINE ENVIRONMENT
A
A'
NO.1
NO.2
NO.3
LAKE
REWORKED TUFFS
REWORKED TUFFS

Fig. 12

GEOLOGIC MAP OF ANDERSON MINE AREA



g 13

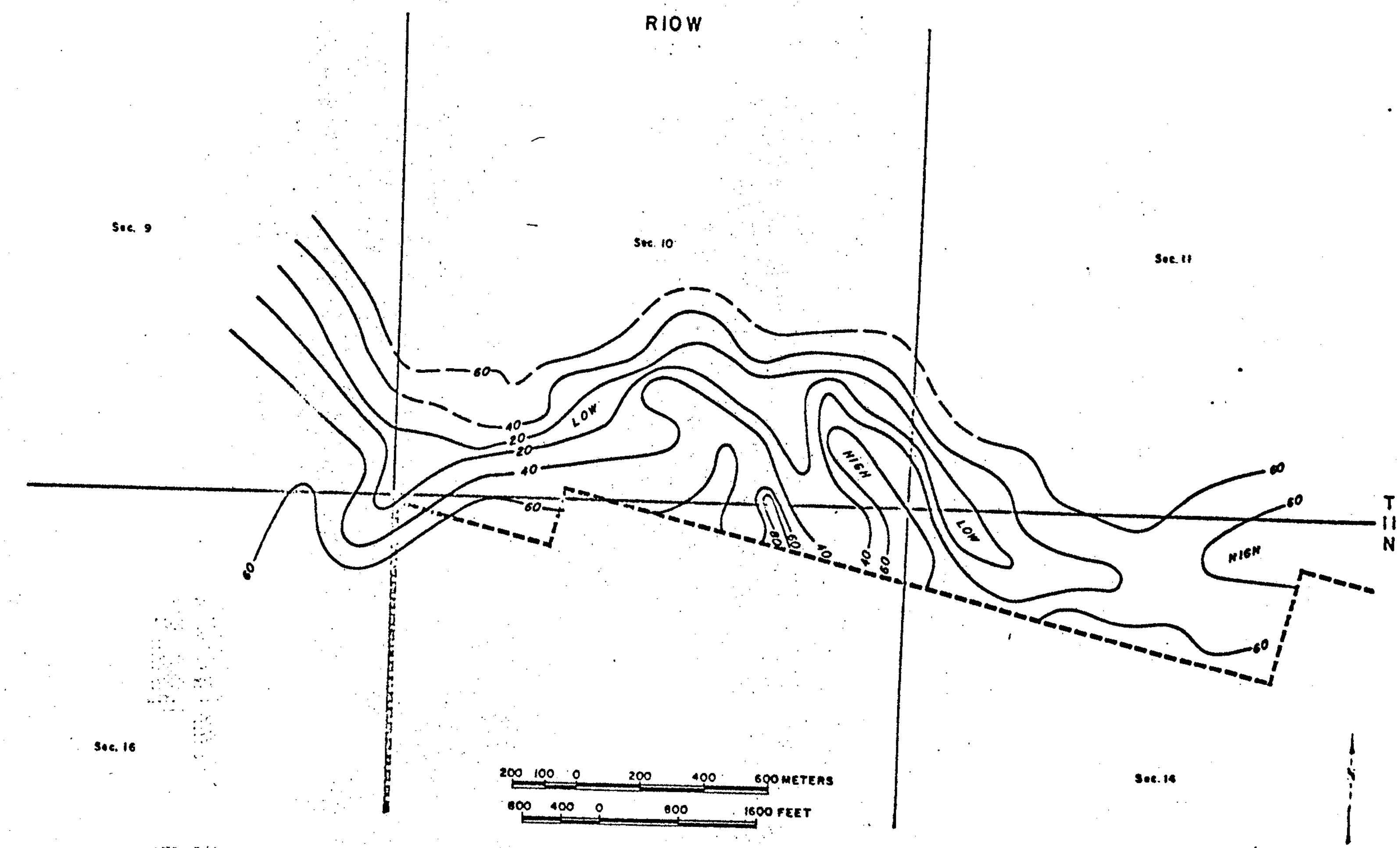

R10W
Sec. 9
Sec. 10
Sec. 11
Sec. 16
Sec. 14
T
11
N
LOW
HIGH
LOW
HIGH
60
40
20
20
40
60
80
60
40
40
60
60
60
60
200 100 0 200 400 600 METERS
800 400 0 800 1600 FEET

Fig. 14

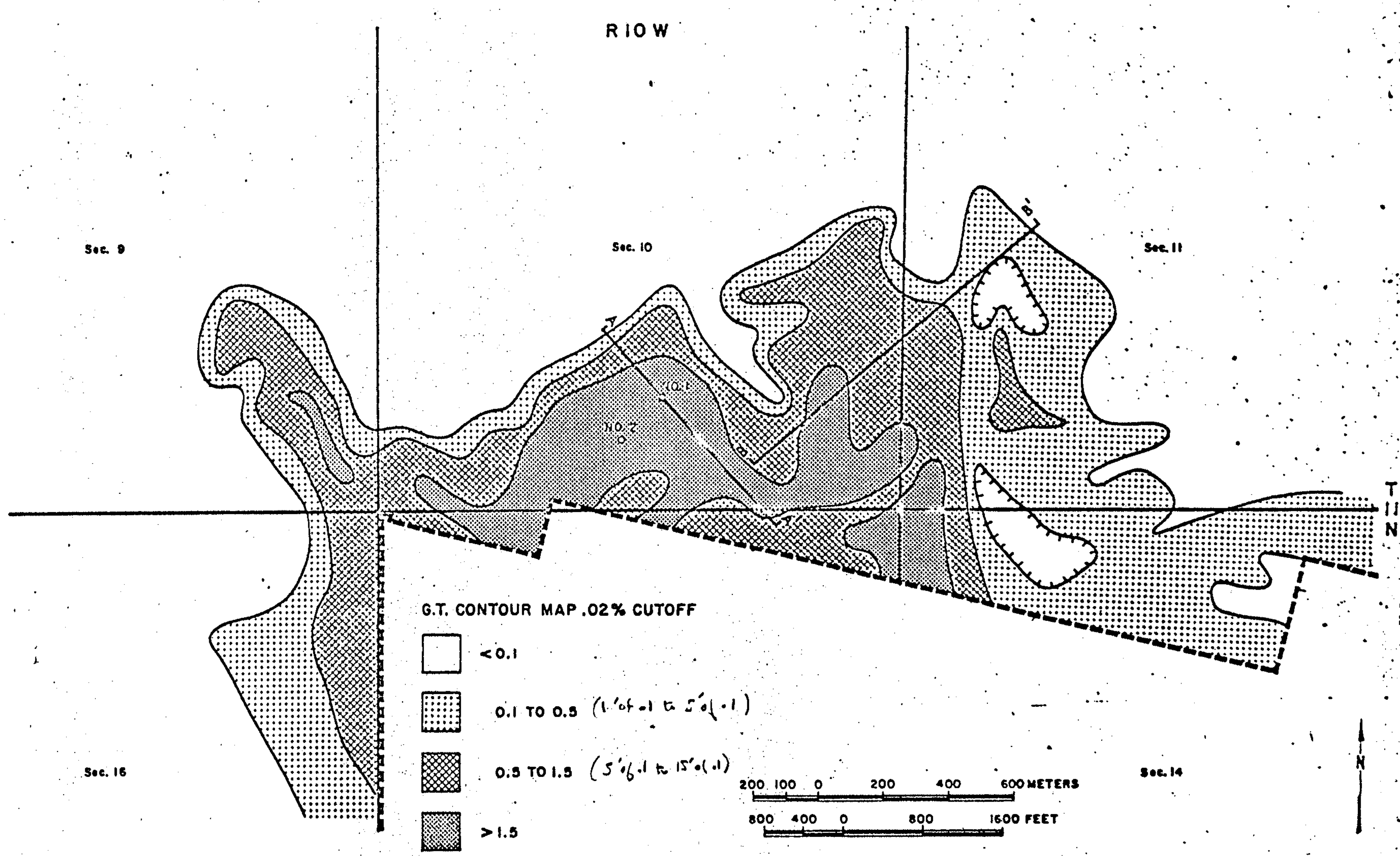

R10W
T11N
Sec. 9
Sec. 10
Sec. 11
Sec. 16
Sec. 14
No. 1
No. 2
A
B
B'
G.T. CONTOUR MAP .02% CUTOFF
<0.1
0.1 TO 0.5 (1' of .1 to 5' of .1)
0.5 TO 1.5 (5' of .1 to 15' of .1)
>1.5
200 100 0 200 400 600 METERS
800 400 0 800 1600 FEET
N

Fig. 15

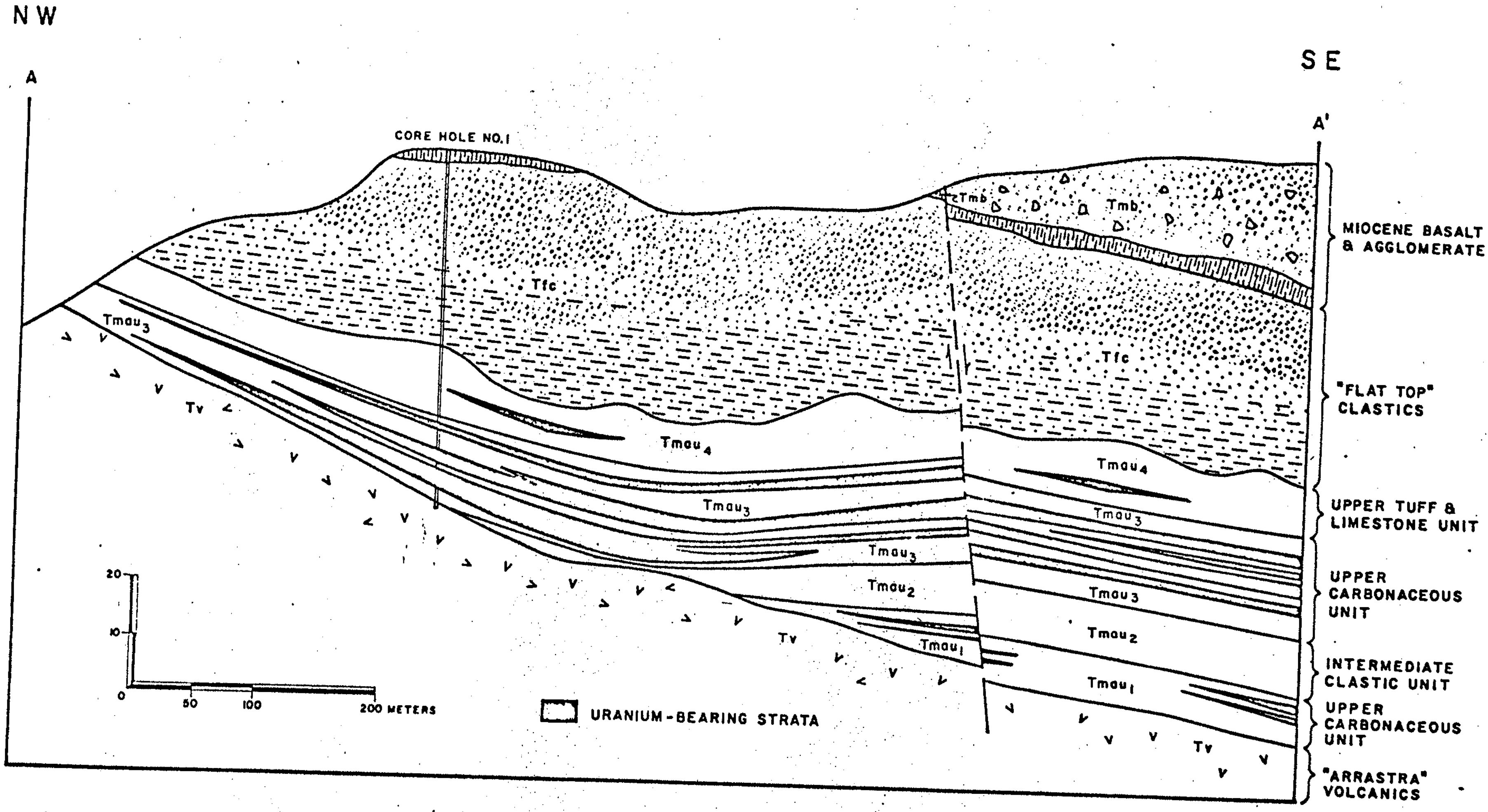

NW
SE
A
A'
CORE HOLE NO.1
Tmb
Tfc
Tmau4
Tmau3
Tmau2
Tmau1
Tv
MIOCENE BASALT & AGGLOMERATE
"FLAT TOP" CLASTICS
UPPER TUFF & LIMESTONE UNIT
UPPER CARBONACEOUS UNIT
INTERMEDIATE CLASTIC UNIT
UPPER CARBONACEOUS UNIT
"ARRASTRA" VOLCANICS
URANIUM-BEARING STRATA
0
10
20
50
100
200 METERS

Fig. 16

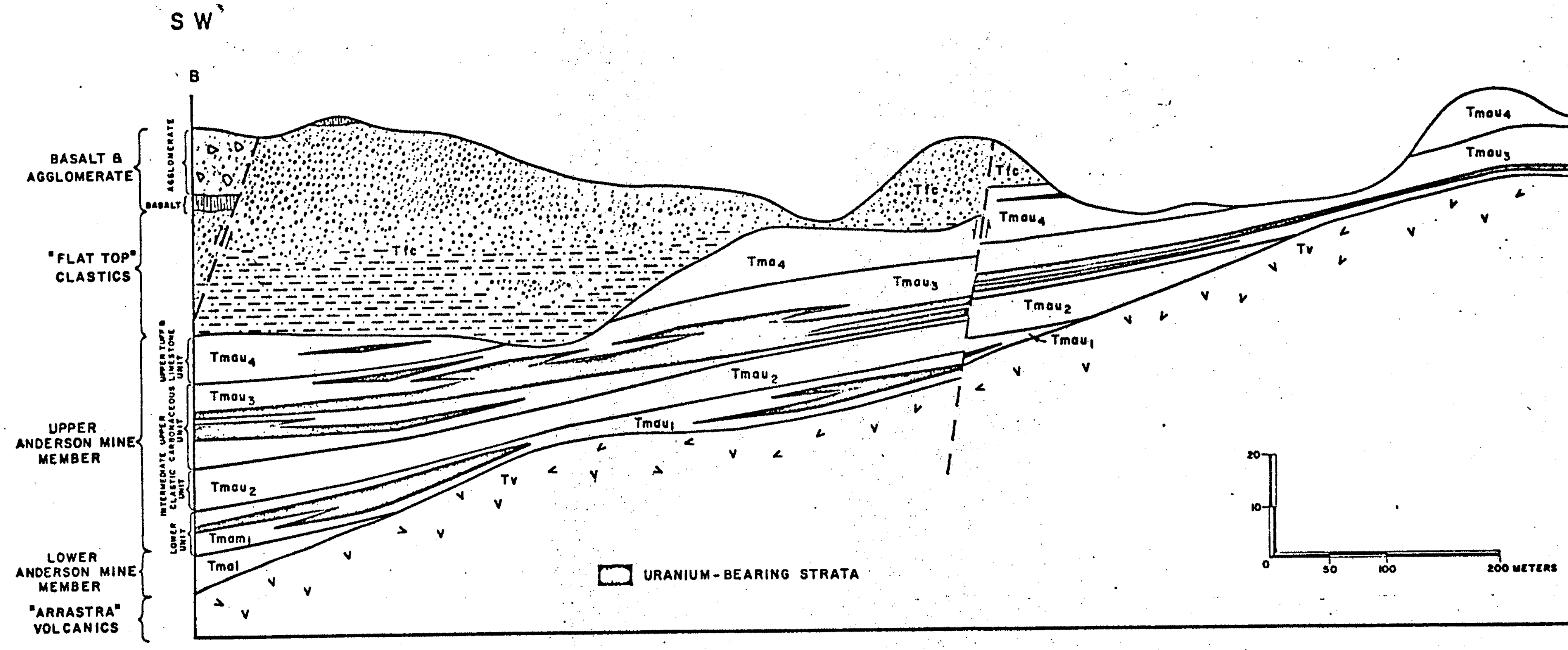
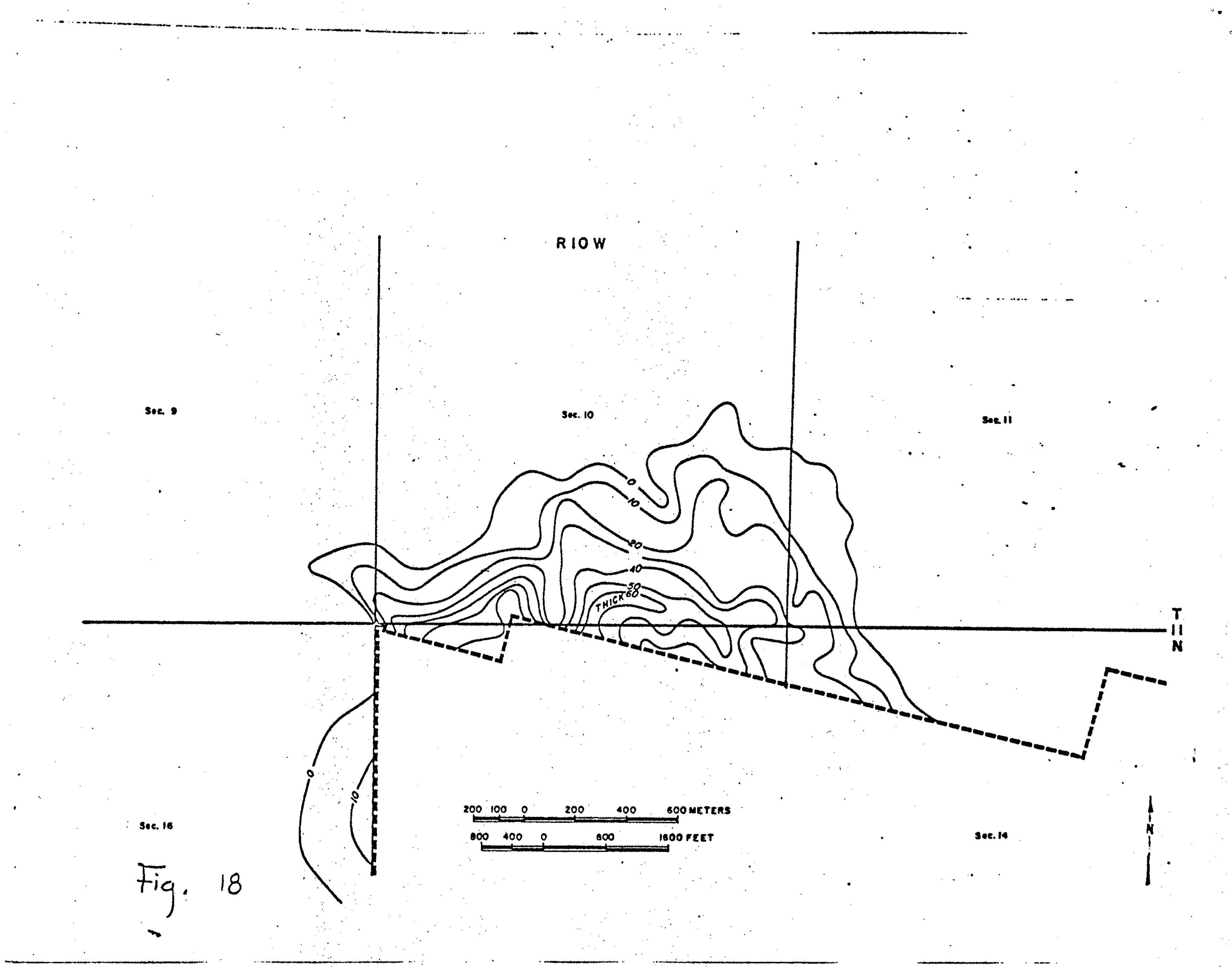

S W
B
BASALT & AGGLOMERATE
AGGLOMERATE
BASALT
"FLAT TOP" CLASTICS
UPPER ANDERSON MINE MEMBER
UPPER TUFF & LIMESTONE UNIT
INTERMEDIATE UPPER CLASTIC CARBONACEOUS UNIT
LOWER UNIT
LOWER ANDERSON MINE MEMBER
"ARRASTRA" VOLCANICS
Tfc
Tma4
Tmau4
Tmau3
Tmau2
Tmau1
Tmam1
Tmal
Tv
URANIUM-BEARING STRATA
20
10
0
50
100
200 METERS

Fig. 17



R10W
Sec. 9
Sec. 10
Sec. 11
Sec. 16
Sec. 14
T 11 N
0
10
20
40
50
THICK 60
200 100 0 200 400 600 METERS
800 400 0 800 1600 FEET
N

Fig. 18

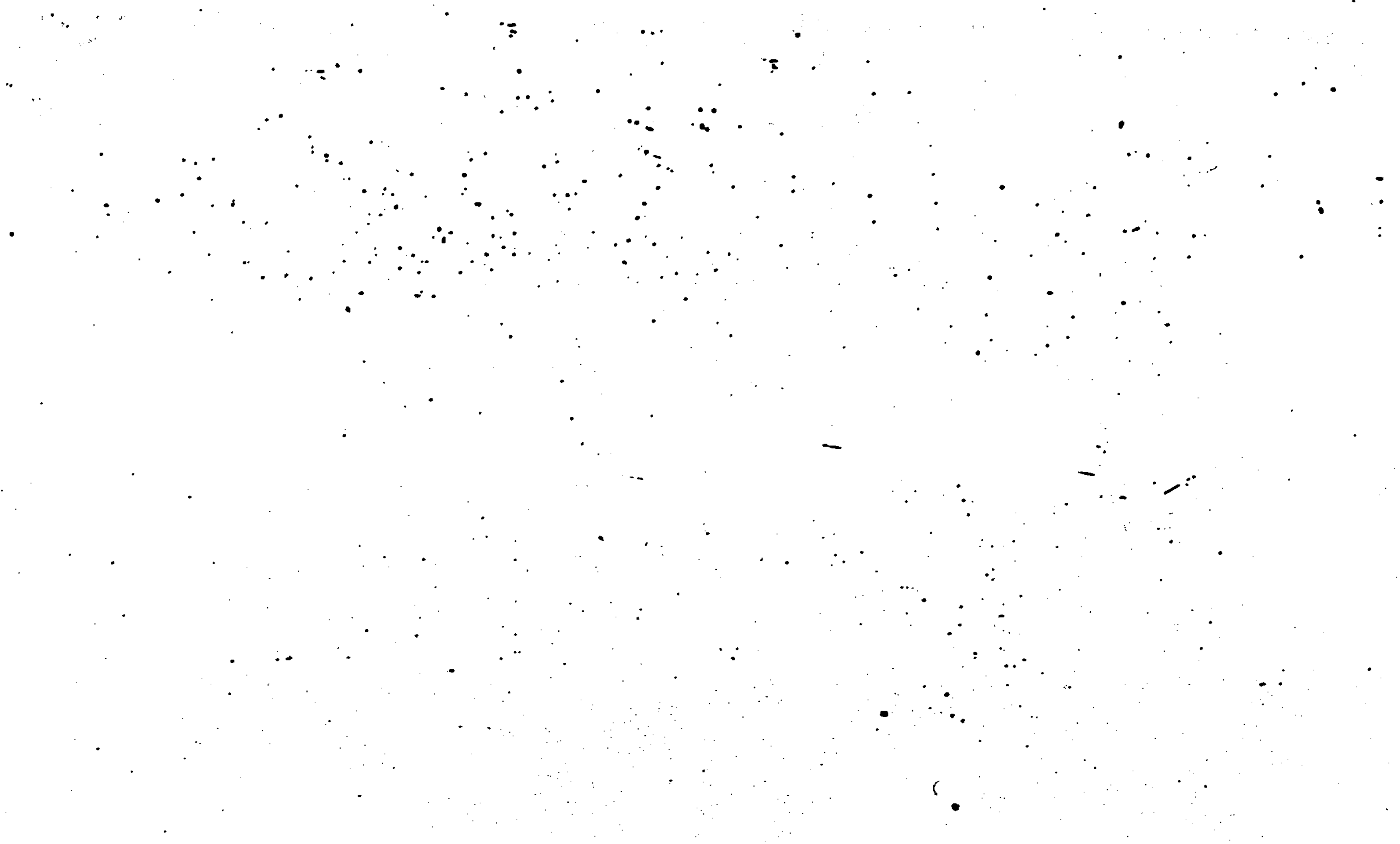


Fig. 19. Autoradiograph of carbonaceous lutite from the upper carbonaceous unit ($Tmau_3$), Anderson Mine.

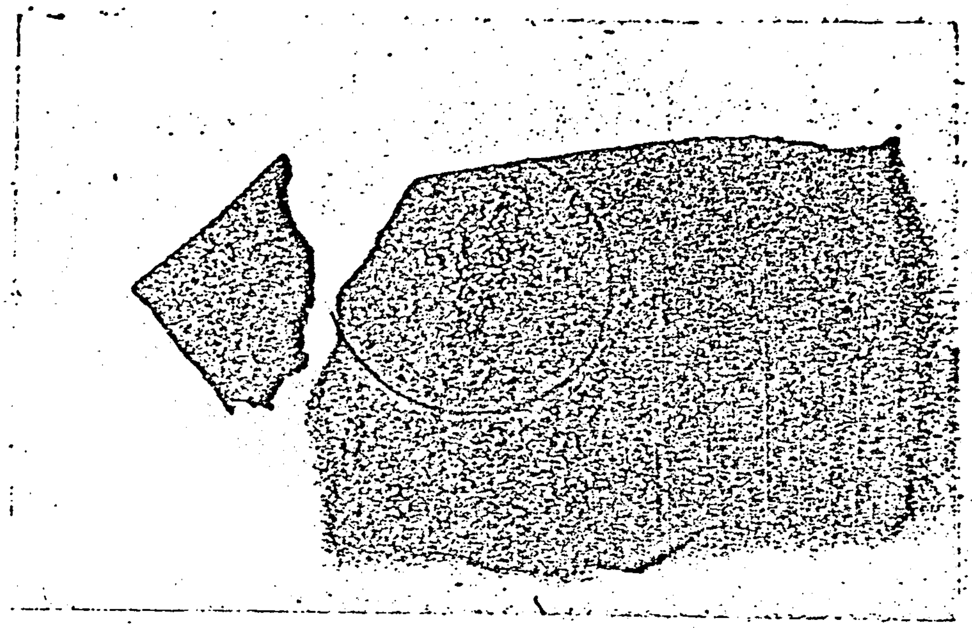


Fig. 19

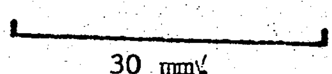


Fig. 20. Photomicrograph of mineralized carbonaceous lutite: a) Carbonaceous material, both as cellular structure and as veinlets, is shown in light gray. Pyrite appears as white spots in the photograph. b) Microprobe scans of uranium and silica from the outlined area in 20a (light color indicates the presence of the element).

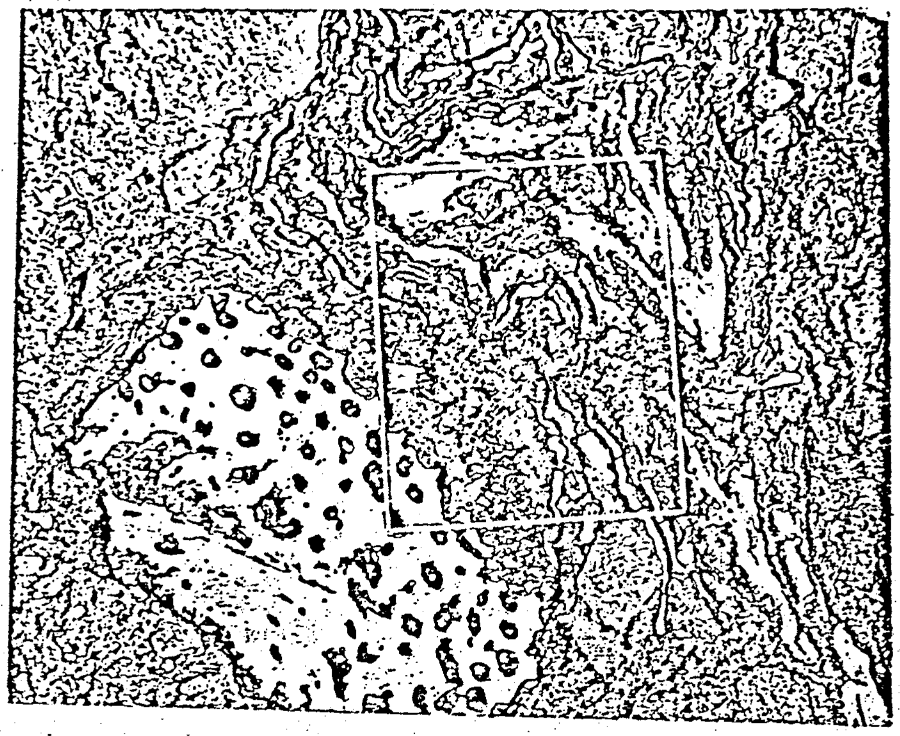
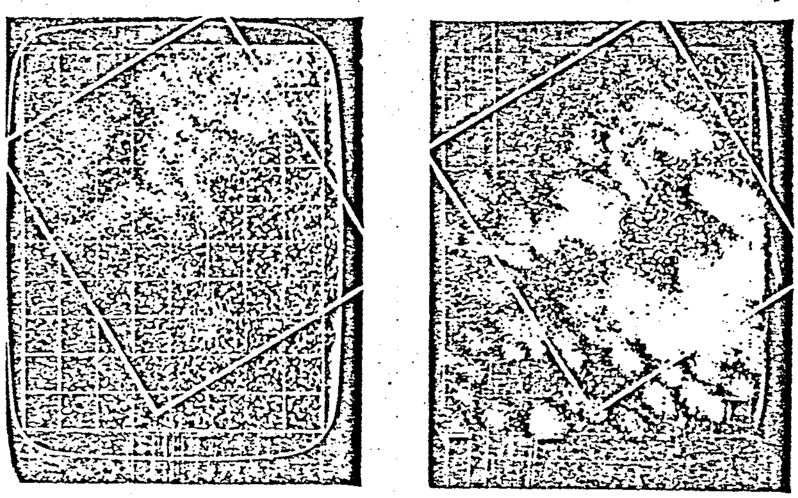


Fig. 20a

0.2 mm



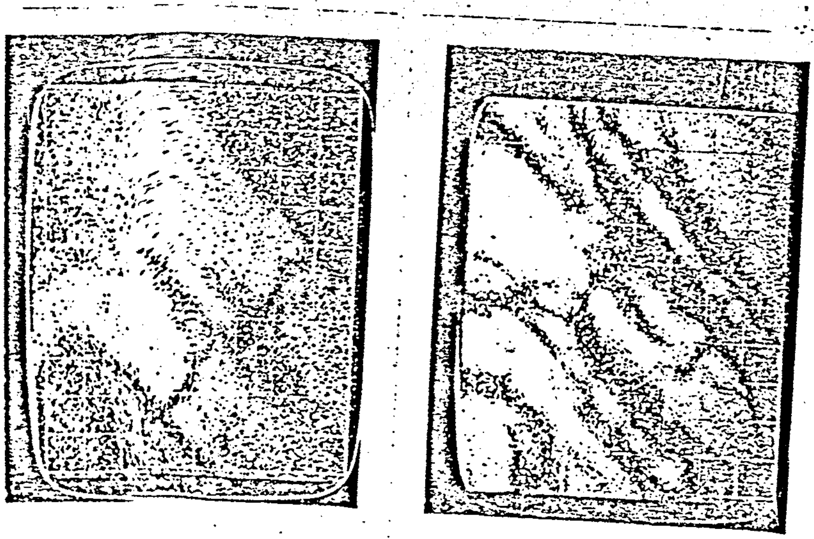
U Si

Fig. 20b

Fig. 21. Photomicrograph of mineralized carbonaceous lutite: a) Carbonaceous material is shown in light gray along with siliceous material shown in dark gray. Pyrite appears as white spots in the photograph. b) Microprobe scans of uranium and silica from the outlined area in 21a (light color indicates the presence of the element).

Fig. 21a

0.2 mm

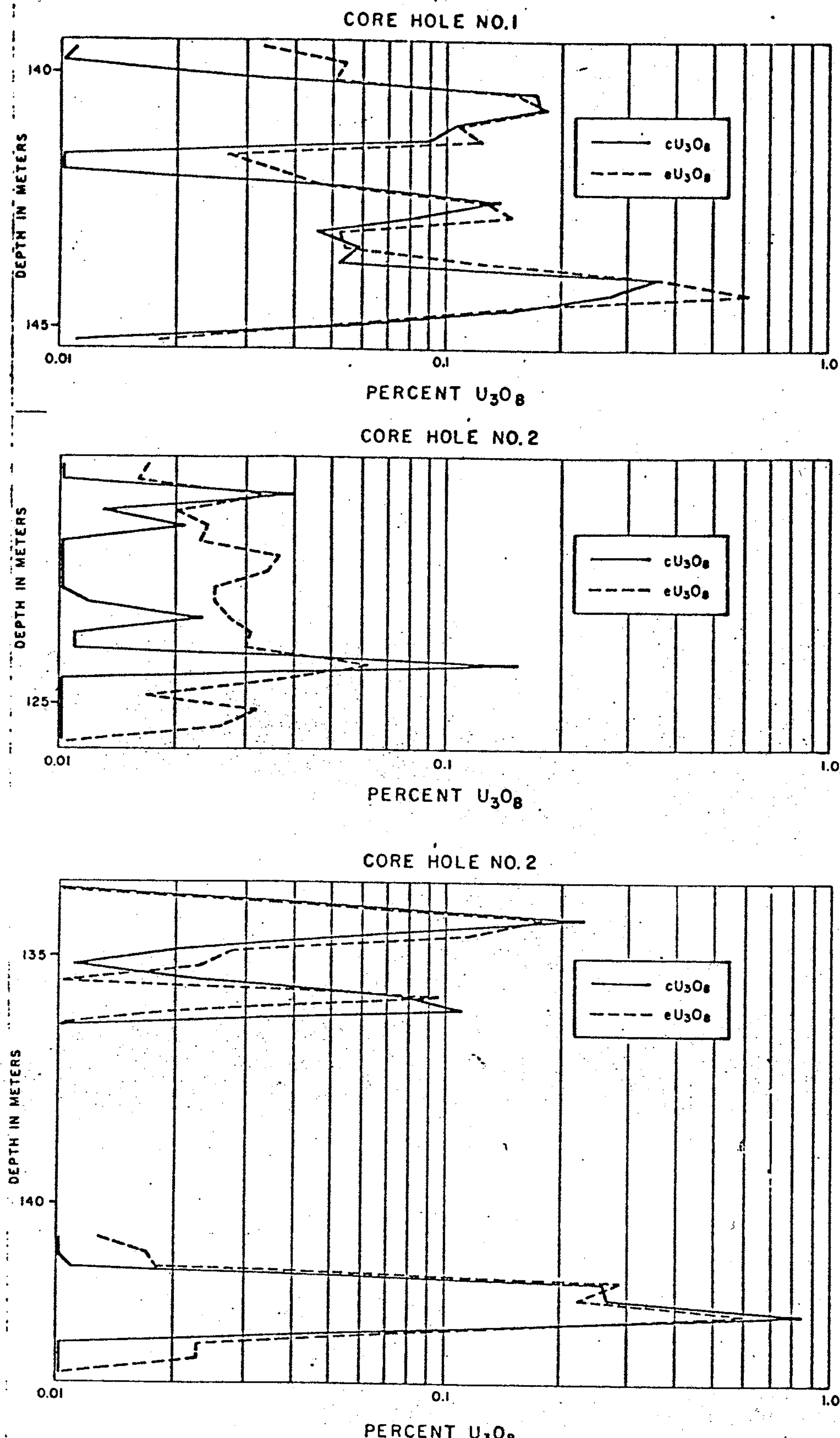


U

Si

Fig. 21b

FIG. 22 - Uranium disequilibrium diagrams for core holes. a) Core hole #1. b) Upper interval of core hole #2. c) Lower interval of core hole #2.



CORE HOLE NO. I
DEPTH IN METERS
140
145
0.01
0.1
1.0
PERCENT U_3O_8
cU_3O_8
eU_3O_8
CORE HOLE NO. 2
DEPTH IN METERS
125
0.01
0.1
1.0
PERCENT U_3O_8
cU_3O_8
eU_3O_8
CORE HOLE NO. 2
DEPTH IN METERS
135
140
0.01
0.1
1.0
PERCENT U_3O_8
cU_3O_8
eU_3O_8

FIG. 22

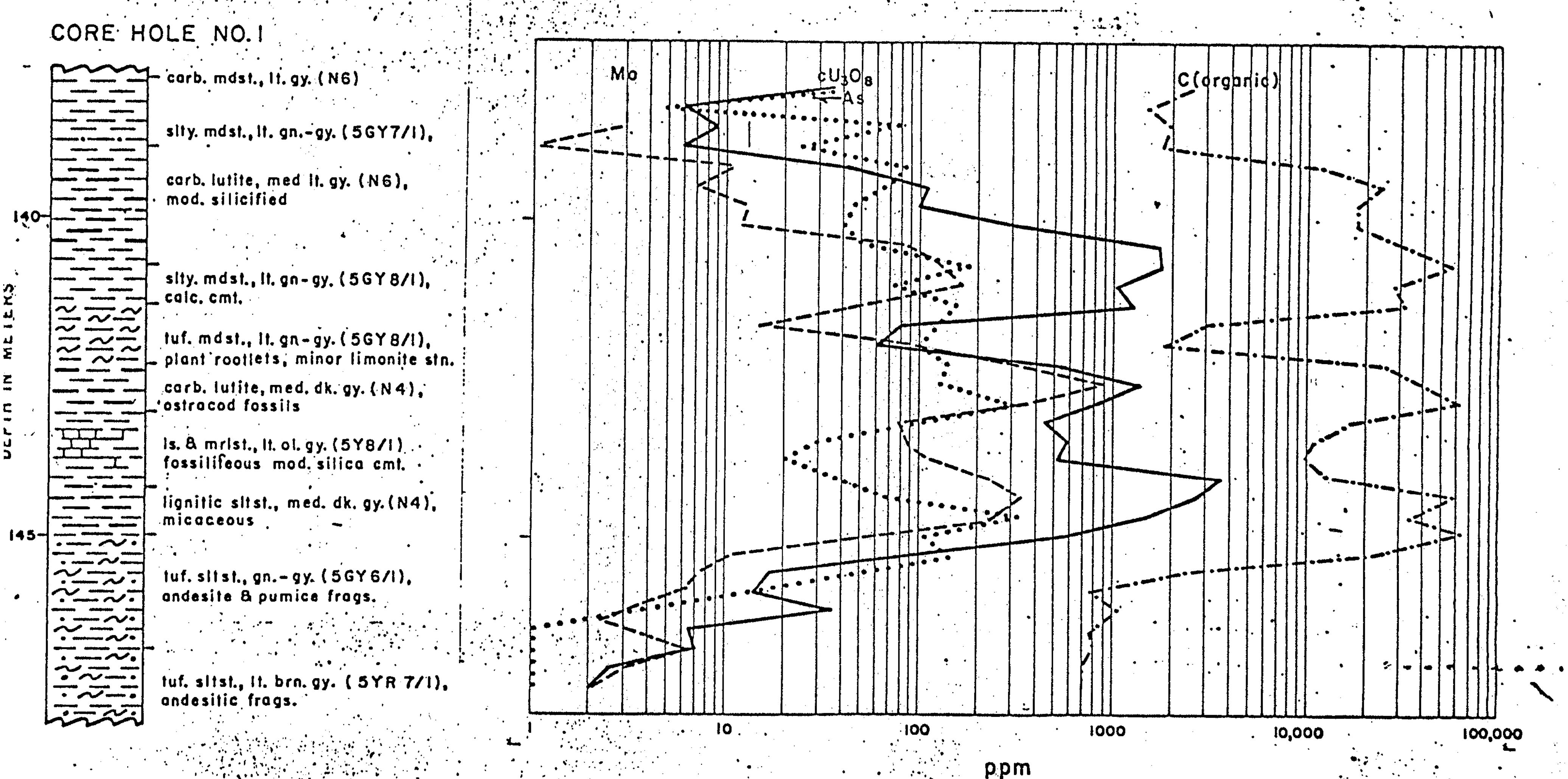


Figure 23a. Lithologic description and distribution of U_3O_8, C(organic), A_S, and Mo in a portion of the upper carbonaceous unit (Tmavo), core hole #1. The core hole location is given ...

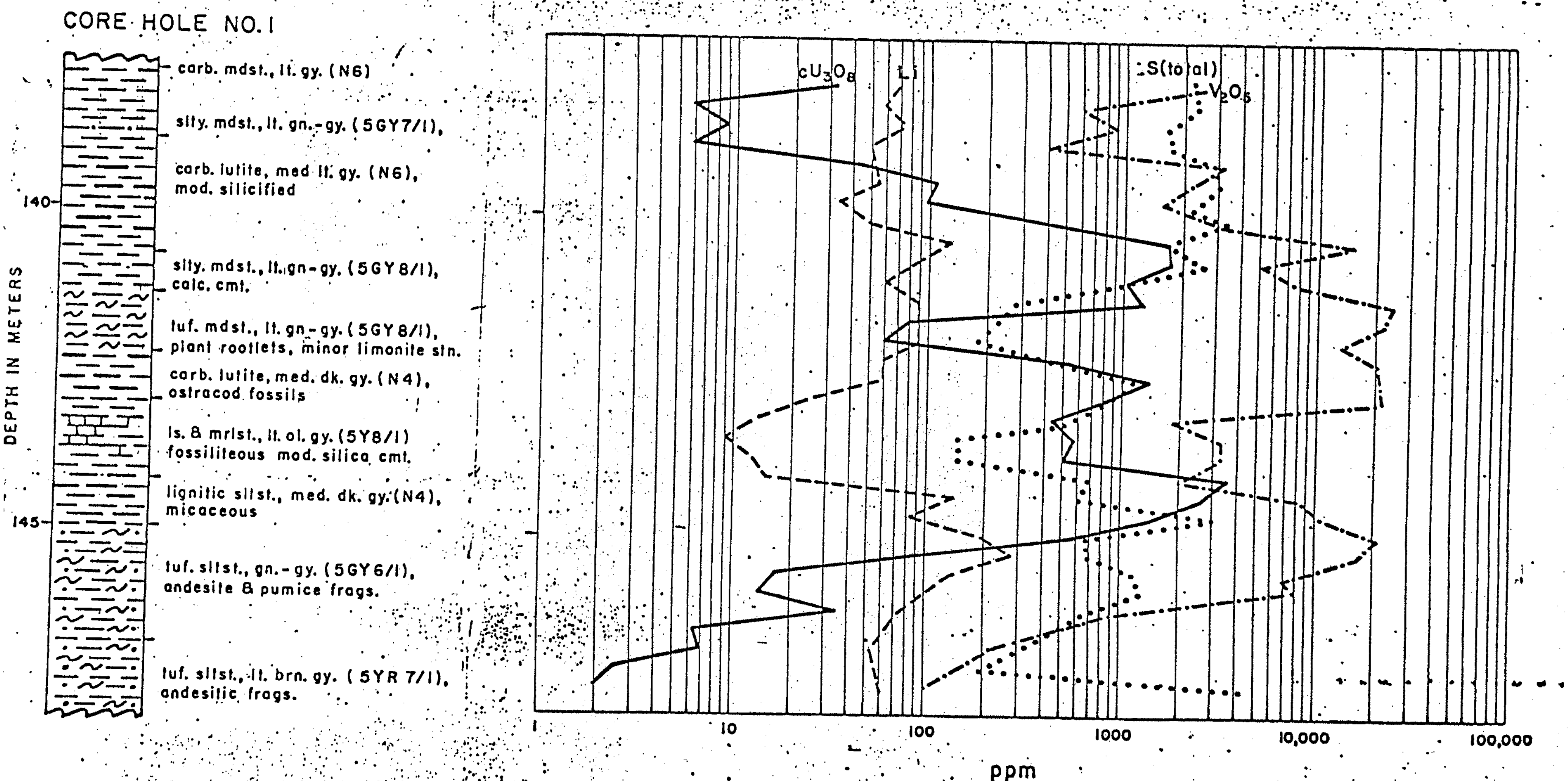


Figure 23b. Lithologic description and distribution of U_3O_8, V_2O_5, total S, and Li in the same interval given in Figure 23a

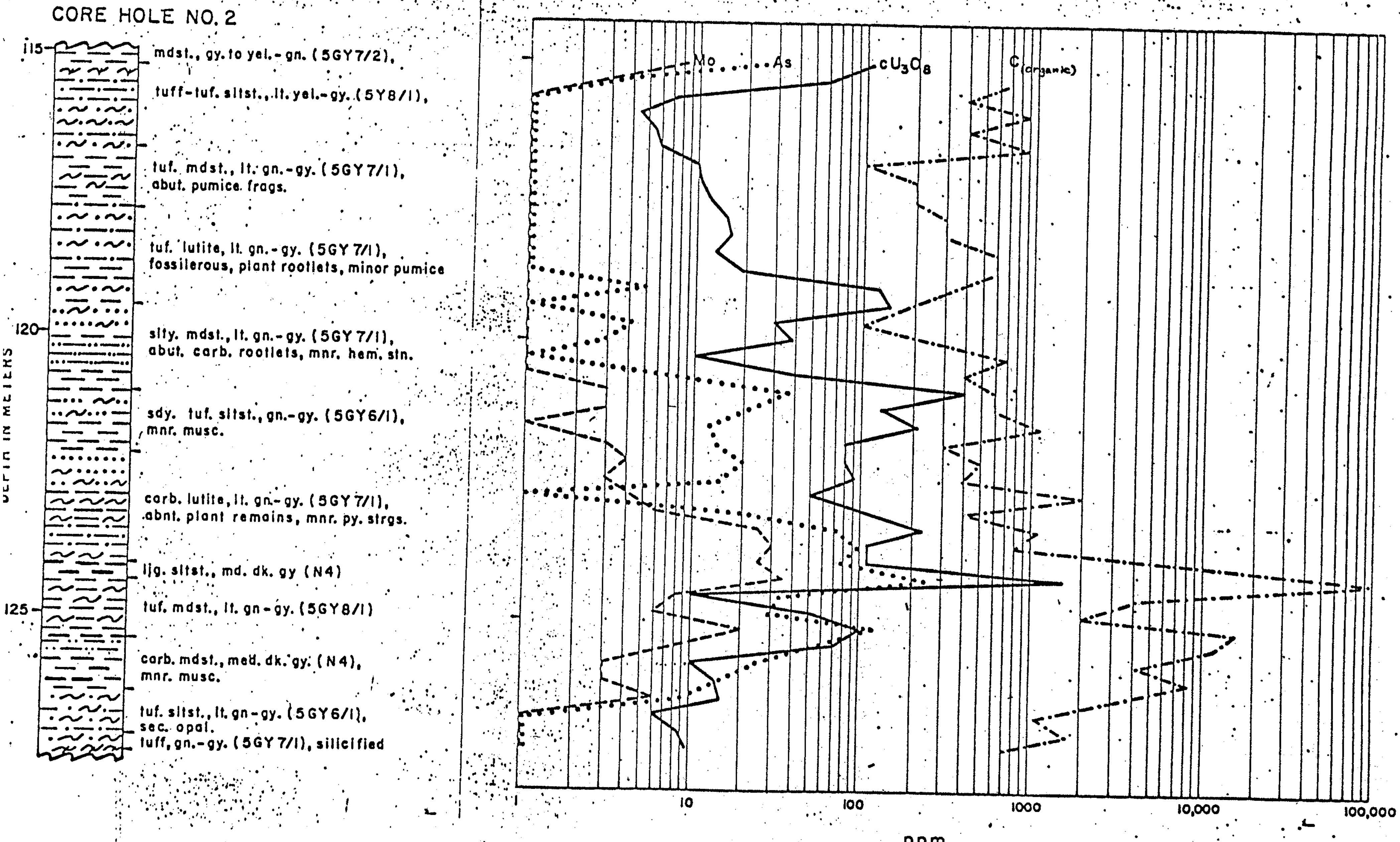


Figure 24a. Lithologic description and distribution of U_3O_8, C(organic), A_S, and Mo in the upper portion of the upper carbonaceous unit (Tmau3), core hole #2. The core-hole location is given in Figure 15.

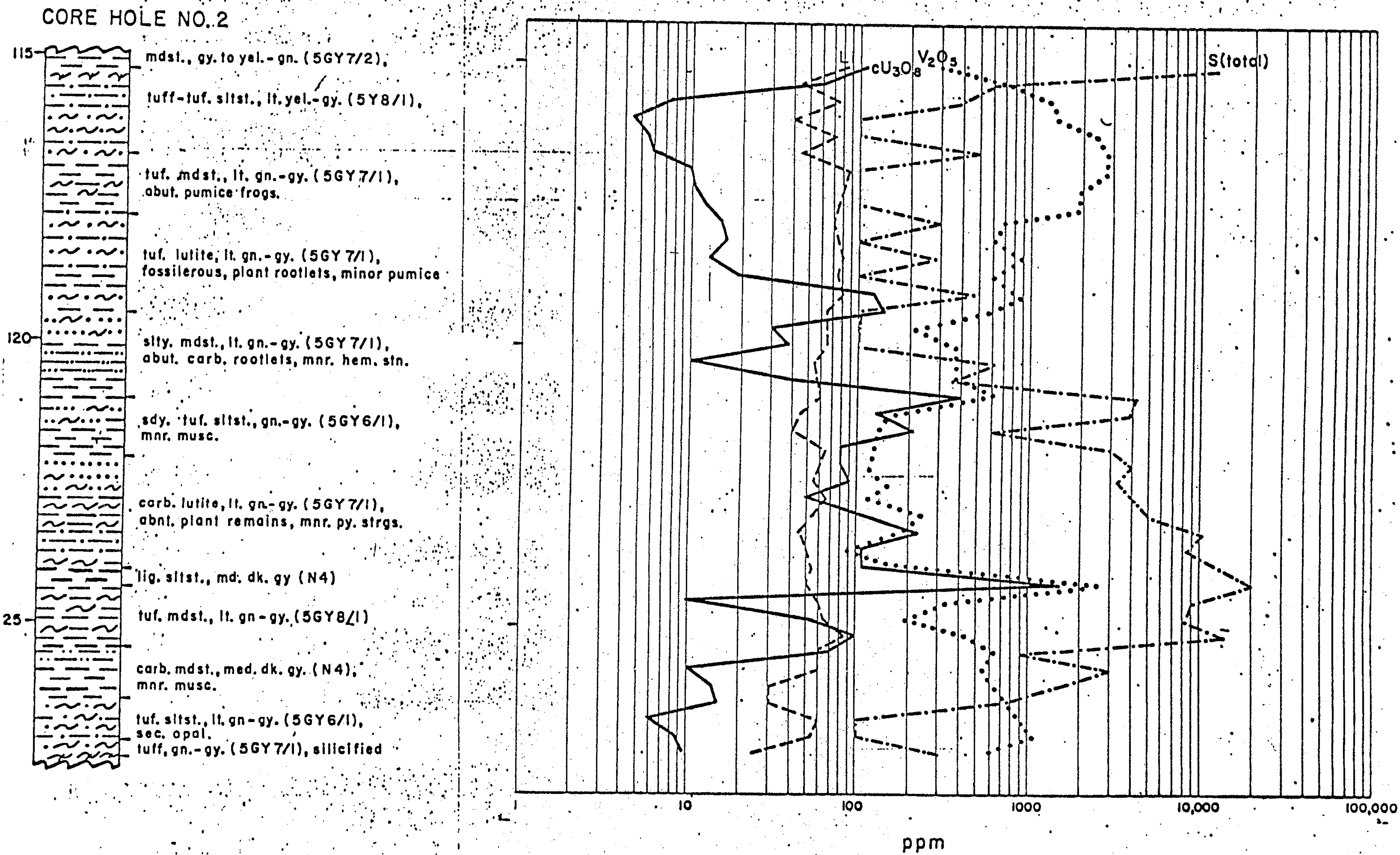


Figure 24b. Lithologic description and distribution of U_3O_8, V_2O_5, total S,

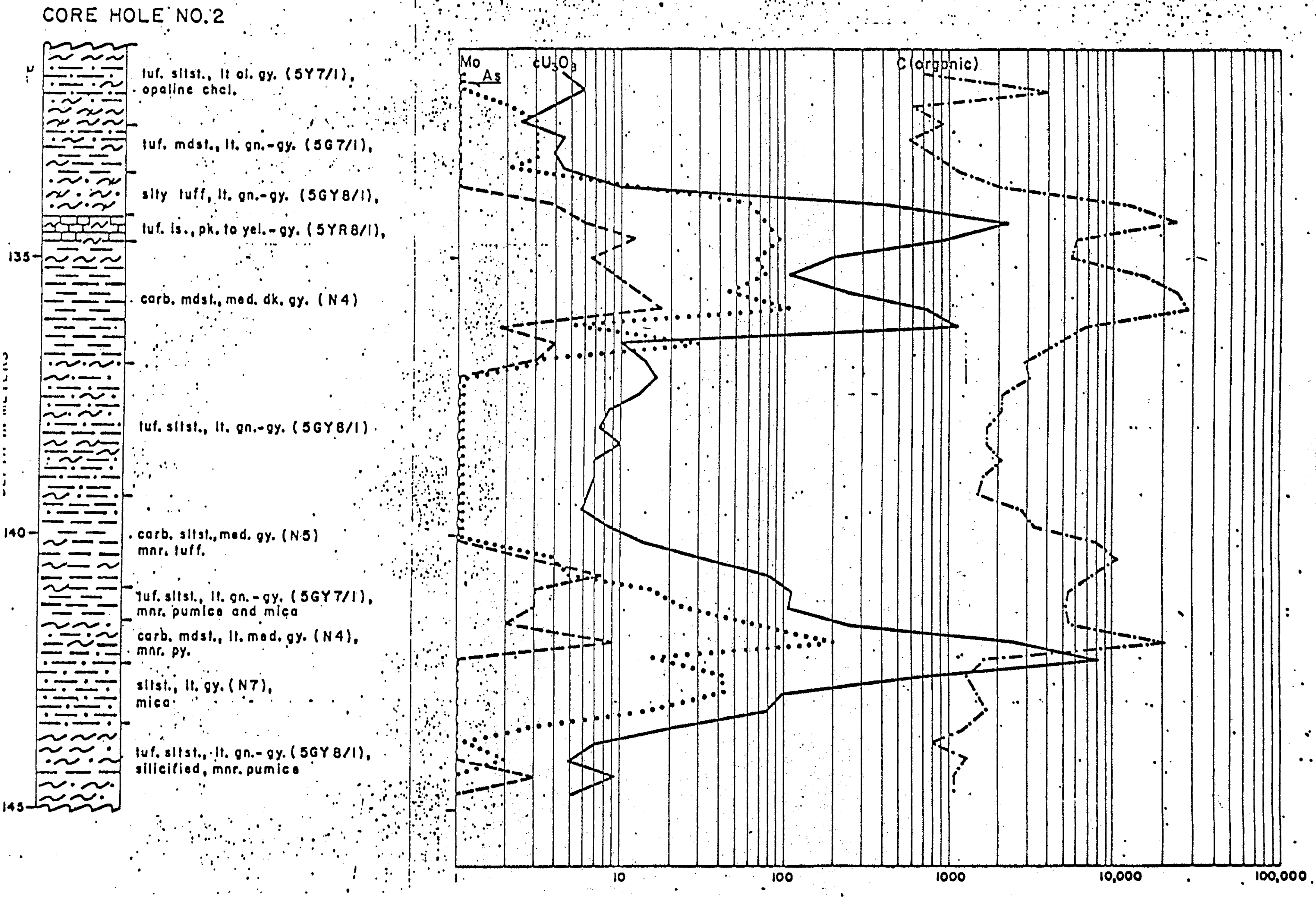


Figure 25a. Lithologic description and distribution of U_3O_8 C(organic), As, and Mo in the lower portion of the upper carbonaceous

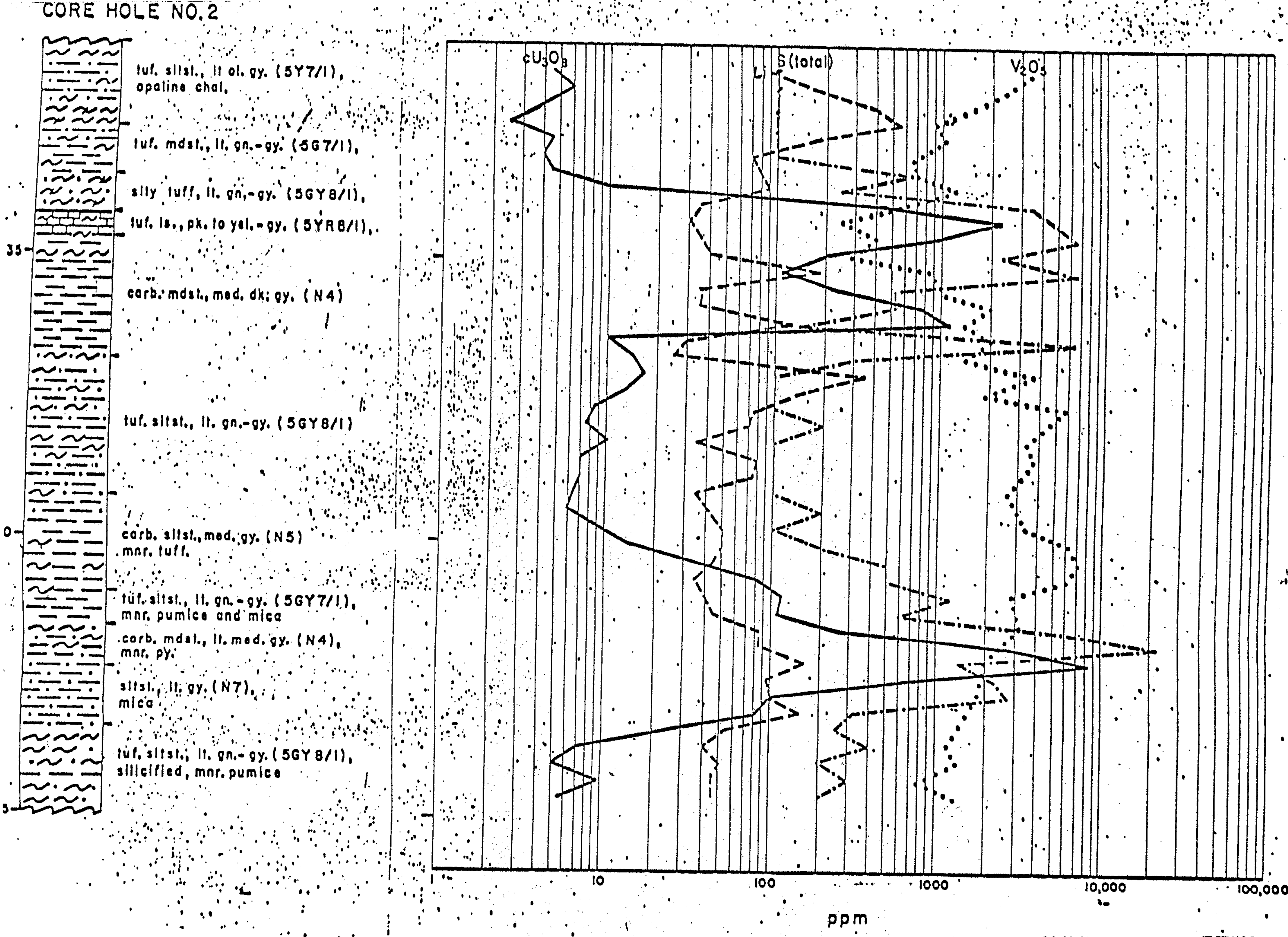
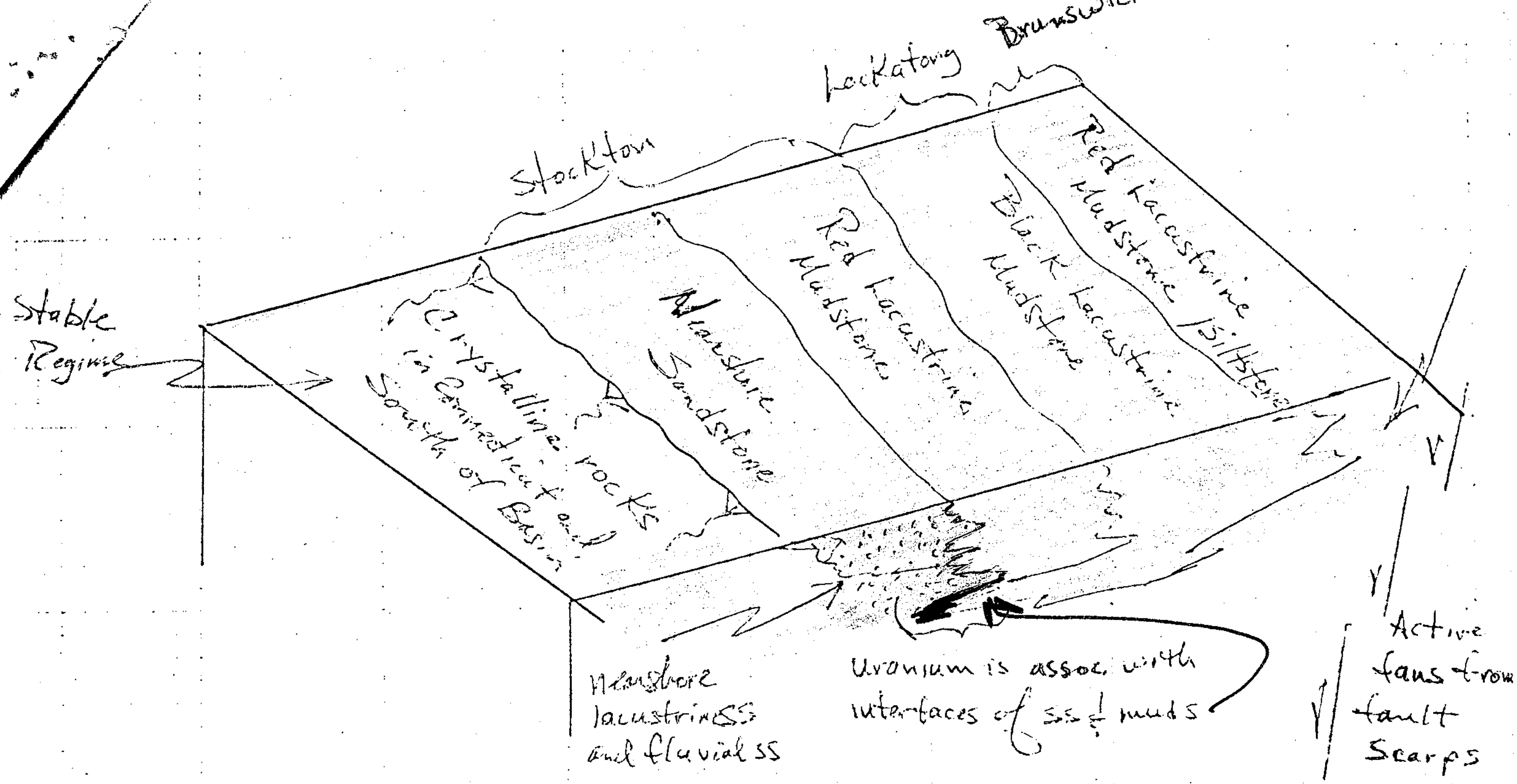
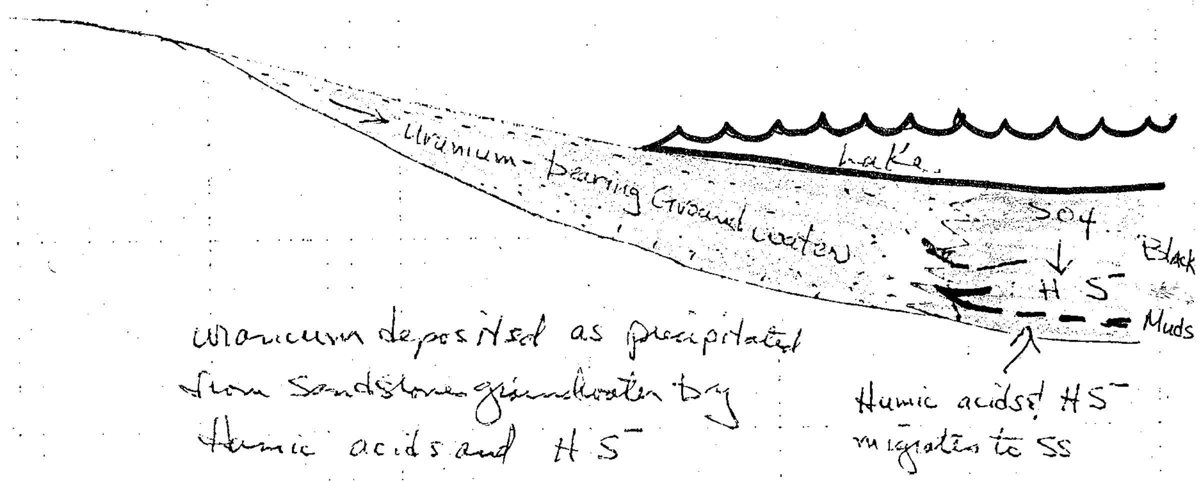


Figure 25b. Lithologic description and distribution of U_3O_8, V_2O_5, total S, and Li in the same interval given in Figure 25a.





NEWARK BASIN - SKETCH DATA

GENERAL GEOLOGY OF THE AREA

The geology of the area is relatively complex and futher complicated by numerous northwest-southeast trending structural features generally downfaulted to the southwest. A regional detailed geologic map of the area is not available but the geologic units exposed within and near the area of interest are all of the Cenozoic age.

In brief these units include recent alluvium primarily along the course of the Santa Maria River; a conglomerate which is exposed in a portion of the Minerals Exploration claim area, and which is at or near land surface in most of the Urangesellschaft claim area; the mineralized fine grained "lake bed" type of sediments underlying the conglomerate; an agglomerate which has been encountered beneath the mineralized section, and andesitic volcanics underlying this.

Detailed surface mapping has been done by personnel of Minerals Exploration Company within their claim area and the above mentioned conglomerate has been separated into two units, with the upper unit described as a "Capping conglomerate and the lower unit described as "Sandstone and conglomerate". Generally, but not always, the two units are separated by a basalt flow. Cross-sections prepared by Urangesellschaft personnel show the existence of this same basalt flow in parts of their claim area with the overlying unit being more conglomeratic and the underlying unit sandier.

Within the mineralized fine-grained sediments is a unit referred to by Urangesellschaft as the "Barren sand" with mineralization occuring above and below the coarser grained Barren sand. This unit occurs in the southern portion of the Minerals Exploration claim area and in the northern and central portion of the Urangesellschaft claim area. Based on information furnished by David Hertzke, Urangesellschaft Project Geologist, the Barren sand pinches or lenses out in the southern portion of their claim area.

Within the claims areas the sediments are dipping to the south and land surface rises to the south from the Santa Maria River to the central portion of the Urangesellschaft claim area, thus depth below land surface to a given unit becomes progressively greater in a southerly direction. The mineralized section has been exposed at land surface in a portion of the Minerals Exploration area by erosion of the overlying conglomerate and occurs at depths in excess of 1,000 feet below land surface in the southern portion of the Urangesellschaft claim area.

To the north and east of the general potential mine area the volcanics are exposed at land surface. These same volcanics also occur for several miles in a westward direction along both sides of the Santa Maria River. Beginning along the west side of Section 18, T. 11 N., R. 10 W., surface exposures of the volcanics are not apparent along the south side of the Santa Maria River for a distance of about four miles downstream to the vicinity of the Palmerita Ranch (see Plate 1) and the Capping conglomerate outcrops in this area along the south edges of Sections 13, 14, 15, and 16, T.11 N., R.11 W., and Section 18, T.11 N., R.10 W. During the course of field work this conglomerate was observed in the vicinity of Sections 19, 20, and 27, T.11 N., R.11 W., dipping southward under fine grained younger sediments similar to those exposed along Date Creek.

Minerals Exploration Company has drilled several exploration holes in the vicinity of Sections 16, 17, 18, and 19, T.11 N., R.10 W., and encountered a thick section of materials generally described as conglomerates, sands, and gravels. Maximum thickness penetrated to date has been 1,640 feet for hole 11-10-19-2 located in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 19. Volcanics, probably equivalent to the basalt flow observed and mapped in the Minerals Exploration claim area, were encountered at a depth of 200 to 255 feet, thus the thickness of the underlying Sandstone and conglomerate unit is in excess of 1,385 feet at this site.

A major fault, downdropped to the southwest has been mapped in this area trending northwest-southeast across the northeast 1/4 of Section 16 (see Plate 1). Hole AM-507, located about 1,500 feet southwest of this fault encountered bedrock at a depth of 1,495 feet. With the exception of a basalt flow between depths of 285 to 365 feet the materials encountered in AM-507 appear to be relatively unconsolidated and were generally described as ranging from silty sand to sand to gravel with a siltstone from 410 to 485 feet and a silty clay layer from 1,150 to 1,220 feet. Materials encountered above the basalt layer should be equivalent to the Capping conglomerate and those below to the Sandstone and conglomerate unit as mapped by Minerals Exploration personnel.

Of the geologic units discussed in the preceding paragraphs the recent alluvium along the Santa Maria River, the Capping conglomerate, the Sandstone and conglomerate, the Barren sand, and the agglomerate contain ground water. Thus, from a hydrologic standpoint these are the units of primary interest and are discussed in greater detail in subsequent sections of this report.

THE ARIZONA GEOLOGICAL SOCIETY SPRING FIELD TRIP

THE ANDERSON MINE AREA

MAY 27, 1978

THE ARIZONA GEOLOGICAL SOCIETY SPRING FIELD TRIP

Welcome to the Arizona Geological Society Spring Field Trip.

Minerals Exploration Company and its parent firm, Union Oil Company, have graciously arranged for the AGS and its guests to visit the Anderson Mine area. This prospect has a potential of developing into a major uranium producer and we are pleased to be able to visit this prospect at such an early stage in its development.

The visit today is intended to permit viewing of some of the features discussed by Bill Buckovic in his address to the Society on May 2nd. Much of the substance of this address was taken from a paper on the area by J. E. Sherborne, Jr., W. A. Buckovic, D. B. DeWitt and S. J. Pavlak of Minerals Exploration Company, Casper, Wyoming; and T. S. Hellinger, Minerals Exploration Company, Tucson, Arizona. The paper will soon be published in the American Association of Petroleum Geologists (AAPG) Journal. Some of the text and figures in that article have been excerpted for the purpose of your field guide. We are indebted to the editors of the AAPG Journal for permission to use this material.

Travel directions from Wickenburg to the Anderson Mine are shown in Table 1. Since most of you joined the trip at the intersection of Highway 93 and Alamo Road, you may follow the road log from that point.

Minerals Exploration has laid out a parking site in the general mine area near Flat Top Hill. We have been asked to keep vehicle usage within the mine to a minimum, therefore, all points of interest will be visited on foot. Please stay with the Minerals Exploration Company Guides.

On arrival at the mine site, the guides will point out your location on Figure 1D. This figure can be used as a general guide to the geology of the area. Some of the features are explained in the summary. Notes on the geology of each stop and the proposed mining and milling plan are also included, and have been provided by Minerals Exploration Company.

SUMMARY

The Anderson Mine has been a known Uranium resource area for some time. Limited production occurred prior to the major exploration in the area. This production is summarized in Table 2. With the kind permission of Minerals Exploration Company and the AAPG editors, the following material has been excerpted from J. E. Sherborne, Jr., W. A. Buckovic, D. B. DeWitt, T. S. Hellinger, and S. J. Pavlak's (of Minerals Exploration Company) paper on the geology of the Anderson Mine soon to be published in the AAPG Journal. As a regional guide, we present a generalized geologic map of the northeastern Date Creek Basin as Figure 2. A more detailed geologic map of the Anderson Mine area is shown in Figures 1D and 3.

From the assembly point near Flat Top Hill, some of the general geology can be viewed and it is also possible to see a section containing the lake sediments at Anderson Mine. Particular emphasis is placed on these sediments since they are the principal uranium bearing hosts in the northeastern Date Creek Basin. The view, and an explanation thereof, are shown in Figure 3 and the section is shown in considerably more detail in Figure 4. Comments on the stratigraphy have been taken directly from Sherborne, et. al's paper.

Several stops have been scheduled in the mine area to permit study of the detailed geology, the uranium mineralization and some of the factors relevant to mining. At the end of these scheduled stops, there will be an opportunity to walk the entire Tertiary section.

The Tertiary section is divisible into two stratigraphic sequences characterized by complex assemblage of arkosic sediments overlain by silicic volcaniclastics. Within these two sequences, five stratigraphic units are recognized. The lower sequence includes the basal Tertiary and Arrastra Volcanics; the upper sequence contains the Miocene "Anderson Mine" Formation, the Flat Top and Upper Miocene Basalt Conglomerate. The Tertiary section is overlain by Plio-Pleistocene older alluvium.

The various units of interest are identified on the geological maps and your field guides will point out certain relevant features. Particular attention is directed to the Anderson Mine Formation.

GENERAL

Uranium mineralization occurs near the northern margin of the present Date Creek Basin in a gently-dipping sequence of Miocene lacustrine volcaniclastic sediments. The uranium is associated with lignites, carbonaceous and silicified tuffaceous mudstones, calcareous mudstones, and impure limestones and marlstones. The mineralized units are interbedded with green tuffaceous mudstones, light-colored calcareous, fossiliferous and tuffaceous mudstones and tuffs, and a few thin sandstone and sandy siltstone beds.

The uranium deposit has a tabular blanket-type configuration with minimum dimensions of approximately 1,000 m by 1,500 m. The mineralization extends at least an additional 1,000 m down-dip. The zone is comprised of several mineralized beds which are generally from 1 to 3 m thick but occasionally ranges up to 11 m. The mineralization is stacked in most areas and aggregate thicknesses in excess of 15 m are not uncommon. Most of the mineralization has grades ranging from 0.03 to 0.10% U_3O_8 with an average grade of approximately 0.06%. Elements which appear to be concentrated with the uranium mineralization include arsenic, molybdenum, organic carbon, total sulfur, and vanadium. Other elements which are anomalous in the Anderson Mine sediments include manganese, lithium, and flourine. In portions of the ore body, there are considerable variations in the disequilibrium factor; however, the overall factor is close to one.

During compaction and dewatering of uranium-rich volcanic lake sediments, the derived fluids probably came into contact with a strongly reducing paludal environment causing precipitation and fixation of the uranium. This would indicate an early diagenetic origin for the primary mineralization. Some remobilization into fractures has occurred in more recent geologic time.

The Anderson Mine area is located in the Basin and Range physiographic province approximately 72 kilometers northwest of Wickenburg, Arizona (Fig.1). The uranium deposit occurs in Tertiary rocks in the northern portion of an area designated by Otton (1977b) as the Date Creek Basin. This basin, which encompasses an area in excess of 900 km^2, has recently gained national interest as the result of considerable land acquisition and exploration drilling by a number of companies. The main stimulus to this exploration activity was the discovery that uranium mineralization at the old Anderson Mine was considerably more extensive than had previously been thought. This is illustrated in a recent publication by the United States Energy Research and Development Administration (1976) which states that the $30 per pound uranium reserves for the entire Basin and Range Province is 2,800,000 pounds U_3O_8 (Table 1). Exploration drilling at the Anderson Mine indicates that the reserves in this area alone are considerably in excess of this figure. This is significant in that it lends credence to the high uranium resource estimates for this province made by U.S.E.R.D.A in the same publication.

Anomalous radioactivity was first discovered in the Anderson Mine area by T. R. Anderson of Sacramento, California while conducting an airborne scintillometer survey in early 1955. Several hundred claims were located after a ground check of the anomaly revealed surface uranium mineralization. A limited drilling program indicated sufficient mineralization to justify a small mining operation. This resulted in the production of 33,230 pounds of U_3O_8 between 1955 and 1959 from ore that averaged 0.15% U_3O_8 (W. L. Chenoweth, personal communication, 1977). The production figures are summarized in Table 2. After this period, however, the property remained essentially idle until 1967 when the claims were optioned to a major oil company. This option was terminated in 1968 even though exploration drilling outlined several areas of uranium mineralization. This decision was probably influenced by the low price of uranium at that time and the remote location of the deposit. Prompted by the increasing price of uranium in 1974, Minerals Exploration Company, a wholly-owned subsidiary of Union Oil Company of California, obtained an option on the Anderson Mine property. The claims were purchased in 1975 following a drilling program on a 244 m (800 foot) grid which showed the uranium mineralization to be considerably more widespread than had previously been suspected. Subsequent drilling on a 122 m (400 foot) grid has indicated that the uranium mineralization is laterally continuous. The data generated from this program has served as the basis for this study. More recently, drilling on a 61 m (200 foot) grid has further substantiated the lateral continuity of the uranium mineralization. At present, the company is completing the first phase of development drilling and is undertaking mine and mill design and feasibility studies. In addition, consultants have been retained to conduct extensive studies of the potential physical impacts the project will have on native wildlife, plantlife, water quality and availability, air quality, and socio-economic impacts on neighboring communities.

If all the studies now underway indicate the project is feasible, mine preparation and mill construction could begin in 1979 and continue for approximately 18 months. Mining would begin concurrently, with mill start-up to follow late in 1980. The mill would operate continuously over an expected minimum life of 15 years at a designed throughput rate of between 2,000 and 2,500 tons of ore per day. The ore would be mined initially by open-pit methods with an underground mining operation to follow.

"Anderson Mine" Formation (Tma)

The "Anderson Mine" Formation ranges from 80 to 150 m thick and includes a lower arkosic member and an upper uranium-bearing tuffaceous lutite member. In the vicinity of the Anderson Mine workings, the sediments thicken gradually to the south and west and thin to the north and east where they onlap the "Arrastra" paleohigh (Fig.6). The section at Anderson Mine has been tentatively correlated with fanglomerates of the Chapin Wash Formation by Reyner, et. al. (1956), Peirce (1977), and Otton (1977b). The Chapin Wash Formation, which may grade into and intertongue with the Anderson Mine sediments, is formed of arkosic sandstones and conglomerates interbedded with silicic and basic volcanic rocks in the western Date Creek Basin (Laskey and Webber, 1949; Shackelford, 1976; Gassaway, 1977).

Lower Member (Tma_1)

The lower arkosic member consists of up to 120 m of coarse, poorly-sorted reddish to yellowish gray arkosic sediments and locally developed volcanic sandstones and conglomerates. This succession appears to represent the distal portion of a subaerial fan complex that coarsens and thickens to the west and south of the Anderson Mine. Due to the paleotopography developed on the Arrastra Volcanics, the lower member thins rapidly and pinches out in the northern portion of the Anderson Mine area. In the southern portion of this area the lower member consists predominantly of volcanic and arkosic sandstones and conglomerates which grade vertically into the finer-grained sediments of the upper member. Elsewhere, the lower member is formed principally of conglomerates and sandstones derived from a Precambrian (?) crystalline terrain.

Upper Member (Tmau)

The upper or tuffaceous lutite member is the principal uranium-bearing host rock in the northeastern Date Creek Basin. This member represents a paludal-lacustrine succession consisting of tuffaceous mudstones and siltstones interbedded with vitric tuffs, micritic limestones, marlstones, carbonaceous lutites, and a smaller proportion of tuffaceous and arkosic sandstones. In the southern portion of the area, the upper member is 140 m thick and thins to 80 m where the member onlaps the volcanics to the north (Fig.6). Four general stratigraphic units are recognized in this member: a lower carbonaceous unit, an intermediate clastic unit, an upper carbonaceous unit, and an upper tuff and limestone unit.

Lower Carbonaceous Unit ($Tmau_1$)

The lower unit infills local depressions and channels and averages 25 m in thickness. Massive green-gray micaceous tuffaceous lutite beds averaging 1 m thick constitute a major portion of the unit. The remainder consists of approximately equal proportions of micritic limestone, marlstone, carbonaceous lutite, and arkosic sandstone. The limestones and marlstones, which are found mainly in the western and southeastern parts of the area, are massive, light greenish-gray to off-white, and occur mainly in the upper 15 m of this unit. The thickest and most abundant limestones are found in the southeastern portion of the area where they have an aggregate thickness of up to 8 m. These limestones commonly contain comminuted carbonaceous material and grade laterally into carbonaceous lutites to the west.

Upper Carbonaceous Unit ($Tmau_3$)

The upper carbonaceous unit is the most laterally continuous unit in the upper member with individual beds extending for over 500 m. This unit is approximately 20 m thick and consists mainly of tuffaceous mudstones interbedded with subordinate amounts of carbonaceous lutites, tuffaceous siltstones, and micritic limestones. The remainder of this unit is formed of tuffaceous siltstones, marlstones, vitric tuffs, and a minor fraction of sandstones. The middle portion of the unit contains the wide distribution of carbonaceous lutites and limestones and an abundance of tuffaceous clastic sediments are in the northern part of the area.

The tuffaceous mudstone beds are massive, light greenish-gray in color, and contain carbonaceous rootlets and remnant pumice fragments. These beds, which average less than 1 m thick, form up to one-third of the unit in the southwestern part of the area. The abundance of organic structures and the massive character of the mudstones is indicative of the gradual influx of mainly air-fall tuffs washed in from surrounding uplands. Carbonaceous and lignitic lutites form about one-third of the carbonaceous interval in the central mine area.

Commonly interstratified with the carbonaceous beds are tan, gastropod-rich, tuffaceous marlstones that locally form up to one-third of the carbonaceous interval. The tan marlstones in the carbonaceous units are characterized by a strong fetid odor when broken. Analyses of the gas derived from these marlstones in the upper carbonaceous unit show an abundance of hydrogen sulfide and carbon dioxide. To the east these marlstones and carbonaceous beds grade and intertongue into micritic limestones (Fig.6). The limestone beds are up to 1.5 m thick and are very light greenish-gray to off-white in color. Varying amounts of tuffaceous and pumiceous material are interspersed in these limestones. Fossils commonly found in these beds include fresh-water pelecypods, gastropods, small fish, and rush-like plant material. Locally, these massive limestones are difficult to distinguish from massive calcareous vitric tuffs.

Upper Tuff and Carbonate Unit ($Tmau_4$)

Up to 80 m of this upper unit are preserved in the Anderson Mine area. It is formed largely of tuffaceous lutites, reworked vitric tuffs, marlstones, and micritic limestones. The tuffaceous lutites are greenish-gray and massive, comprising the largest part of this unit. The tuffs are similar to those in the underlying carbonaceous unit, except that some are yellowish to pinkish-gray in color. A few thin lapilli-bearing pumice tuffs are recognized in the north-eastern mine area. The marlstones and limestones are massive and off-white in color, and occur mainly in the eastern and southern mine area. Reyner, et al. (1956) recognized a relatively persistent, thin-bedded marlstone that occurs near the top of the section. In much of the subsurface this marlstone is not preserved due to post "Anderson Mine" erosion. A few thin carbonaceous beds which are rare and laterally discontinuous occur in this unit (Fig. 6). The remainder of the unit consists of minor poorly-sorted tuffaceous sandstones.

Replacing limestones and lutites in this unit are beds of chalcedony up to 1 m thick. These beds and the associated carnotite fracture-fillings are prevalent features in the old pits exposed at Anderson Mine. The carnotite, though the most conspicuous type of surface mineralization, forms only a small proportion of the total uranium mineralization at Anderson Mine.

A Lower to Middle Miocene age is suggested for the Anderson Mine sediments by the presence of Hemingfordian-aged (17-21 m.y.) vertebrates and the relative stratigraphic position of the unit. An abundance of palm remains is indicative of tropical or subtropical conditions during the deposition of the Anderson Mine Formation.

"Flat Top" Formation (Tfc)

Unconformably overlying the Anderson Mine sediments is a thick upward coarsening succession of arkosic sediments up to 170 m thick in the Anderson Mine area (Fig. 6). This unit is composed largely of grayish-orange to yellowish-brown locally calcite-cemented arkosic siltstones, sandstones, and conglomerates, interbedded with minor reworked greenish-gray siltstones that are well exposed near Flat Top (Figs. 1, 1D). The finer-grained clastics fill an east-west trending channel that was scoured as much as 100 m into the Anderson Mine section. Elsewhere in the vicinity of the Anderson Mine area, this phase of sub-"Flat Top" erosion appears to have eliminated much of the Miocene lacustrine section.

The "Flat Top" section includes brown to buff siltstones interbedded locally with fine to coarse-grained arkosic sandstones that grade upward into pebble sandstones and conglomerates. Most of the coarser clastics that fill local channels in the section were derived from the Precambrian (?) crystalline complex. A minor amount of material was also derived from the older volcanic highlands as recognized by Reyner, et al. (1956).

The "Flat Top" Formation may be correlative to part of the Chapin Wash Formation of Lasky and Webber (1949). Based on the relative stratigraphic position, and associated structural events, the age of the "Flat Top" section is likely Middle to Late (?) Miocene.

URANIUM MINERALIZATION

The uranium deposit at the Anderson Mine is a stratiform, blanket-type deposit occurring within and in proximity to carbonaceous lacustrine sediments. The deposit, as presently drilled out, has minimum dimensions of approximately 1,000 by 1,500 m and extends at least another 1,000 m down-dip into the subsurface to the south. Most of the mineralization occurs in 1 to 3 m thick zones which, in highly mineralized areas, have composite thicknesses in excess of 15 m. The average grade and thickness of the uranium resources at the Anderson Mine are summarized in Table 3. It should be emphasized that these figures do not constitute average ore grades and thicknesses for the deposit since detailed mining feasibility studies have not yet been completed.

The majority of the uranium mineralization is associated with carbonaceous lutite beds in the two carbonaceous units of the Upper Anderson Mine member. It also occurs in the marlstones, limestones, and tuffaceous lutite strata interbedded with or laterally adjacent to the carbonaceous lutites. Many of these interstratified beds contain finely comminuted carbonaceous plant material and abundant silicified rush-like plant remains and gastropods.

The areal distribution of the mineralization is illustrated in Figure 8 which is a grade-thickness product contour map. The tabular configuration of the deposit is evident. A simplified cross-section (Fig. 8B) shows the lateral continuity of the uranium mineralization. It was not possible to show details of the lithology on these sections, but the mineralization is continuous across facies boundaries and locally crosscuts bedding. A comparison of the grade-thickness map and an isopach map of the carbonaceous sediments suggests a close spatial relationship between the carbonaceous sediments and the uranium mineralization. In addition, the most significant areas of uranium mineralization appear to coincide with the greatest thickness of carbonaceous material. These features indicate the importance of the paludal environment in the localization of the uranium mineralization at Anderson Mine.

Both oxidized and unoxidized uranium mineralization are recognized at the Anderson Mine. The unoxidized mineralization chiefly occurs in the upper and lower carbonaceous units and is rarely exposed in the study area. It ranges in grade from 0.03% to 0.10% U_3O_8 and probably averages 0.06% U_3O_8. The oxidized uranium mineralization, which is the mineralization previously identified by Reyner et al. (1958), Otton (1977a) and Peirce (1977), is found mainly in the northern part of the mine area. It occurs principally in silicified limestones, marlstones, and tuffaceous lutites overlying and laterally adjacent to the unoxidized mineralization. The oxidized uranium, which usually occurs in small irregular masses or as minor late-stage fracture fillings, probably has an average grade of greater than 0.10% U_3O_8. Select samples of this carnotite mineralization have assayed greater than 30% U_3O_8.

MINERALOGY

Several analytical methods were used to identify the unoxidized and oxidized uranium minerals at the Anderson Mine. Initially, the distribution of the radioactive minerals in all the unoxidized samples was determined by autoradiography. The autoradiographs showed finely disseminated radioactive mineralization which was judged to be too fine-grained to obtain suitable samples for X-ray diffraction analysis, therefore electron microprobe analyses and microscopic studies were initiated. These studies indicated that the unoxidized uranium mineralization consists of uranium silicate with a highly variable uranium to silicon ratio occurring in intimate association with carbonaceous material. The uranium content of this uranium silicate mineral was found to range from 4% to 20%. The chemical composition of this material suggests the mineral coffinite and an attempt was made to reconfirm this by X-ray analysis. One sample of black, sooty material with a high uranium content (determined from microprobe analyses) was isolated from a carbonaceous tuffaceous mudstone unit. The X-ray analysis of this uraniferous material showed no evidence of any uranium mineral. This indicates that the uranium minerals are very poorly crystallized to amorphous or too finely dispersed for conventional X-ray techniques (Breger, 1974).

ALTERATION

Anderson Mine member sediments have undergone extensive diagenetic silicification, calcification, zeolitization, and argillic alteration. The alteration which has affected the entire lacustrine unit varies in both intensity and type across the study area.

Silicification is the most common form of alteration and is found in all units except the lower Anderson Mine member. It appears to have begun early and continued throughout the diagenetic history of the sediments. The initial stage of silicification resulted in the dissemination of fine-grained multicolored chalcedony in the sediments, the replacement and preservation of delicate fossil forms (chiefly gastropods and ostracods), and the association of silica with disseminated uranium in carbonaceous plant material. Most of the carbonaceous beds have been partially to completely silicified. In general, the strong silicification has penetrated a few tens of centimeters into the carbonaceous beds at the upper and lower contacts of these beds with the enclosing sediments. Occasionally, entire beds of carbonaceous mudstone and siltstone have been completely silicified, but there seems to be no direct correlation between degree of silicification and intensity of uranium mineralization.

Diagenetic calcification has affected both members of the Anderson Mine sediments and has resulted in both the cementation and replacement of the sediments by calcite. Specifically, calcite replaces feldspars and cements the arkosic sandstones in the southern portion of the area and replaces and indurates tuffaceous and carbonaceous lutites and reworked tuffs. In addition, sparry calcite has replaced micrite in some of the marlstones and limestones of the upper Anderson Mine member. In thin-section studies, both calcite and silica can be found in cross-cutting relationships in veinlets indicating that the later phases of both may have occurred concurrently. However, in outcrop studies on the upper unit of the Anderson Mine member, calcification generally appears to be slightly younger than the silicification, particularly in the filling of voids and fractures.

The formation of clays and zeolites early in the diagenesis of the sediments may have been of some importance during the initial phase of uranium mineralization. Clinoptilolite-heulandite group zeolites, and to a lesser extent, montmorillonite-group clays can act as effective adsorbents of uranium from solution (Katayama, et al. 1974). Although this type of mineralization has not yet been recognized at Anderson Mine, it is possible that uranium could have been adsorbed in the early stages of mineralization and subsequently remobilized and reduced in proximity to the carbonaceous sediments. Katayama et al. (1974) report that uranium preferentially forms coffinite (or uranium silicates) when excess silica and strongly reducing conditions prevail as was likely the case in the paludal portion of the lake sediments at Anderson Mine.

Pyrite occurs in the carbonaceous sediments as finely-disseminated crystals and more commonly as fracture fillings. The disseminated pyrite is likely of syngenetic origin while the mineralization in veinlets was possibly formed during the diagenesis of the sediments. Pyrite is also found in portions of the arkosic sandstones in the southern part of the study area. Much of this pyrite occurs as a cementing agent around sand grains and resembles the "matrix" pyrite commonly found in unaltered sandstones in many Wyoming uranium districts. Interestingly, portions of these sandstones are limonite-stained and the pyrite, where present, is highly pitted and tarnished. It is conceivable that these limonite-stained sandstones are "altered" which suggests the possibility of "rollfront" type mineralization in these units. Minor quantities of medium-grade uranium mineralization have been found in these sands in general proximity to "altered-unaltered" contacts, but this mineralization has not been evaluated in any detail.

GEOCHEMISTRY

Quantitative analyses for U_3O_8, V_2O_5, CO_2, and total S were performed on samples representing 0.3 m (1 ft.) intervals throughout the mineralized sections of 14 widely-spaced core holes. In addition, the entire cored intervals from two holes were analyzed for U_3O_8, V_2O_5, As, Mo, Li, Mn, F, organic C, and total S. This latter study was primarily concerned with the geochemistry of the unoxidized mineralization and the respective underlying and overlying unmineralized sediments. Two commercial analytical laboratories were employed to cross-check analyses.

Disequilibrium studies were undertaken to ascertain the relationship between chemical and radiometric uranium. Chemical and radiometric values from all of the core holes were plotted as in Figure 9, and disequilibrium values were calculated. These values ranged from 0.48 to 1.18, with a weighted average disequilibrium factor approaching 1.00 for the deposit. Values ranging from 0.90 to 1.10 were obtained for mineralized intervals from the unoxidized zone suggesting only minor uranium migration in these portions of the deposit. In contrast, the oxidized uranium mineralization shows erratic disequilibrium factors, generally less than 0.90 or greater than 1.10. These erratic values indicate probable remobilization of uranium in the oxidized sediments, at least until fairly recent times.

Uranium mineralization appears to be closely related to the organic carbon content of the Anderson Mine sediments. The possibility that tuffaceous rocks are the source of uranium in many ore deposits has been considered for some time by Waters and Granger (1953) in the Colorado Plateau, Denson and

Gill (1956) in the northern Great Plains, and Weeks and Eargle (1963) in the Texas coastal plain. It is a good possibility that the tuffaceous sediments in the Anderson Mine sequence were the source of much of the uranium in the deposit.

DIRECTIONS TO THE ANDERSON MINE

0	Wickenburg
6.2	Highway 93
16.6	Highway 93 and 71
21.0	Alamo Road
26.9	Road fork - stay right
27.5	Cattle guard
30.6	Road to left - stay right
	Yellow cattle guard
31.5	Ranch
38.2	Stay left
	Cattle guard - Anderson Mine sign at left
38.4	Turn right
41.7	Stay right

Minerals Exploration Office
784 Whipple Street #3 - #5
Box 2246
Wickenburg, Arizona 85258
(602) 684 5155

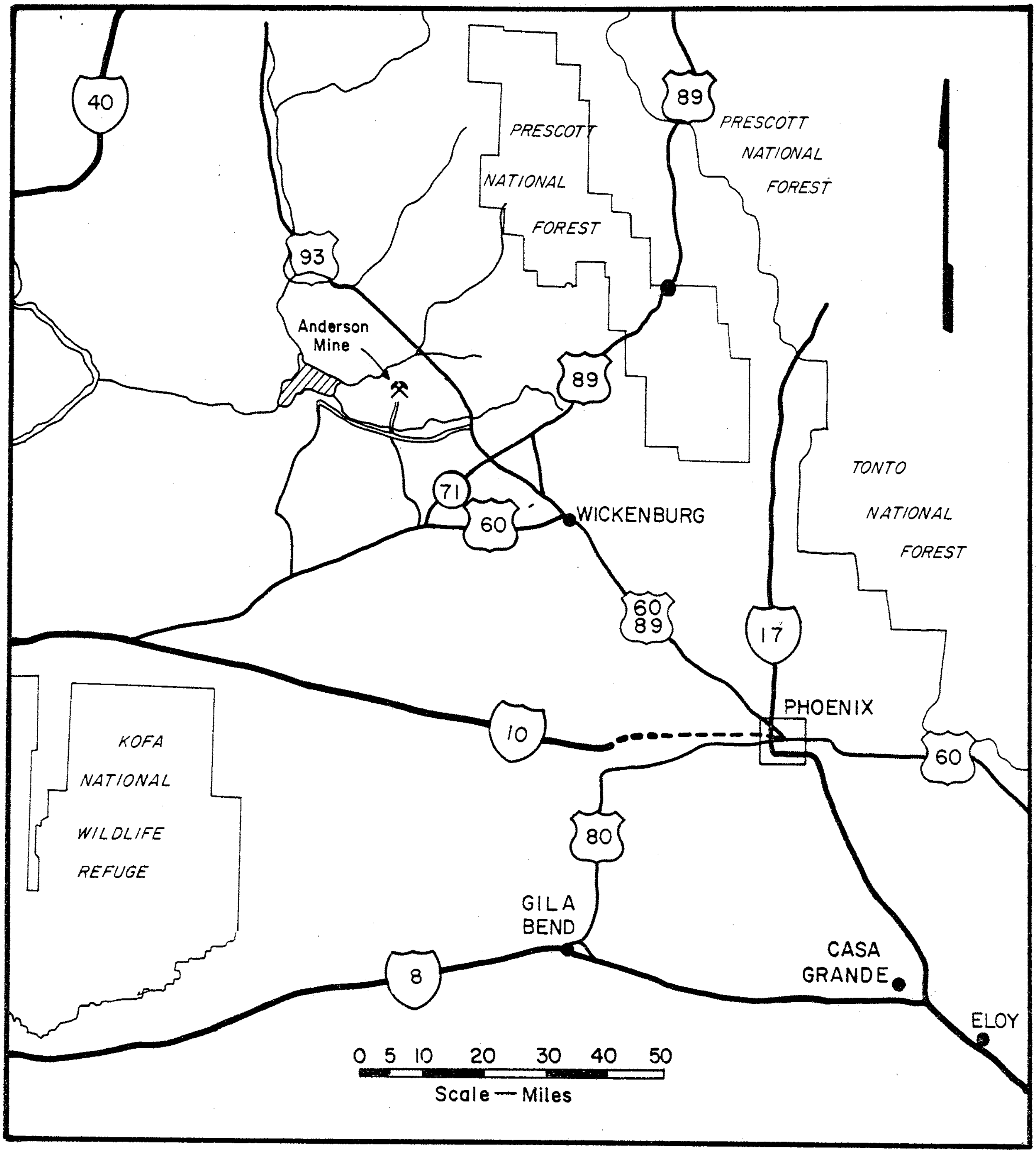
TABLE 1

TABLE 2: Production Figures from Anderson Mine

Year	Tons of Ore	Grade (%) U_3O_8	Lbs. of Ore
1955	9	0.56	101
1956	31	0.21	130
1957	3,614	0.19	14,043
1958	725	0.27	3,928
1959	6,379	0.12	15,028
TOTAL	10,758	Ave. 0.15% U_3O_8	33,230

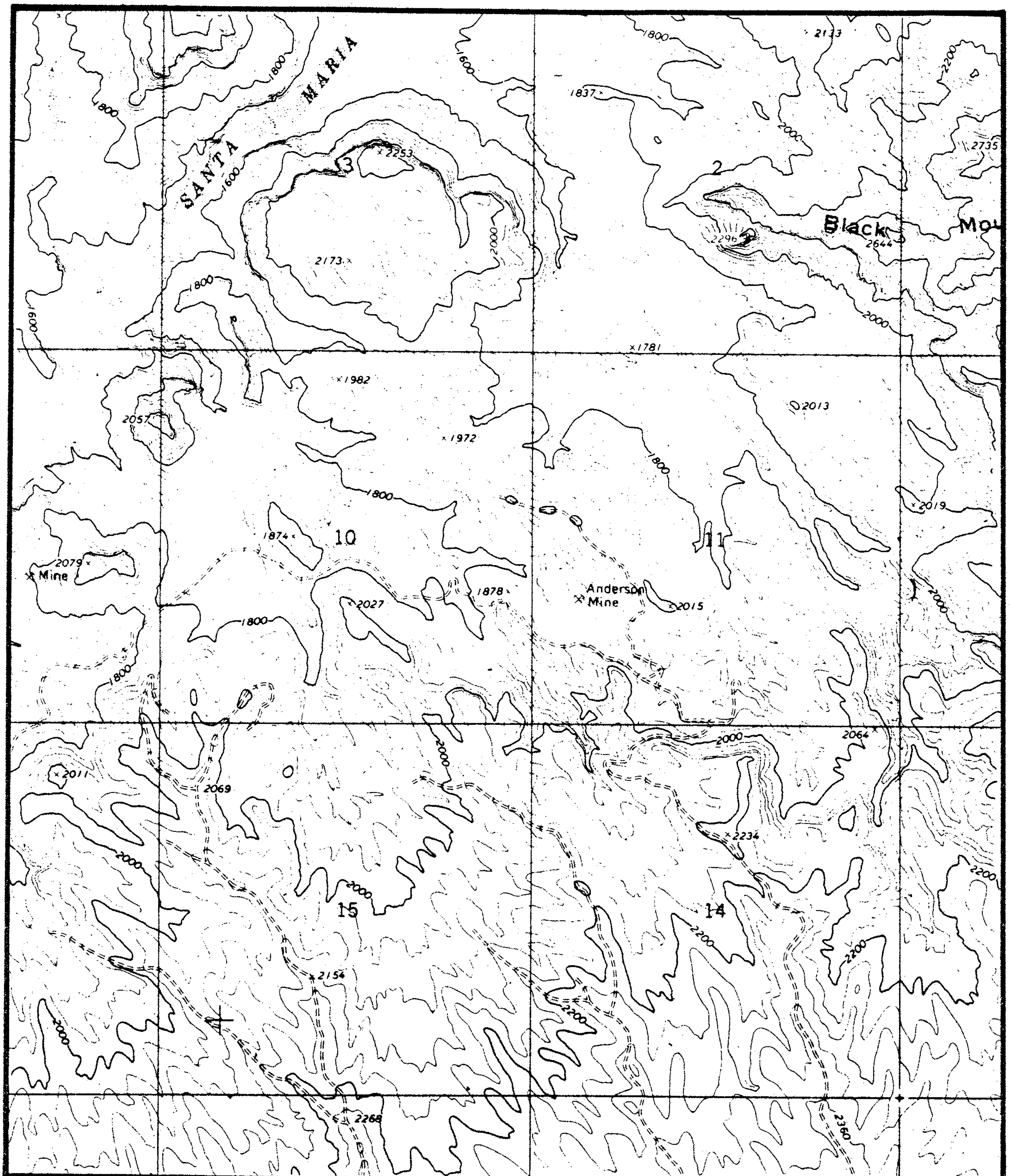
TABLE 3: Uranium Resources from Anderson Mine

Cutoff (% U_3O_8)	Average Grade (% U_3O_8)	Average Thickness (m)	Uranium Mineralization (%)
.02	.05	6.3	100%
.03	.06	4.2	83.1%
.05	.09	2.6	60.6%
.07	.12	2.0	47.9%

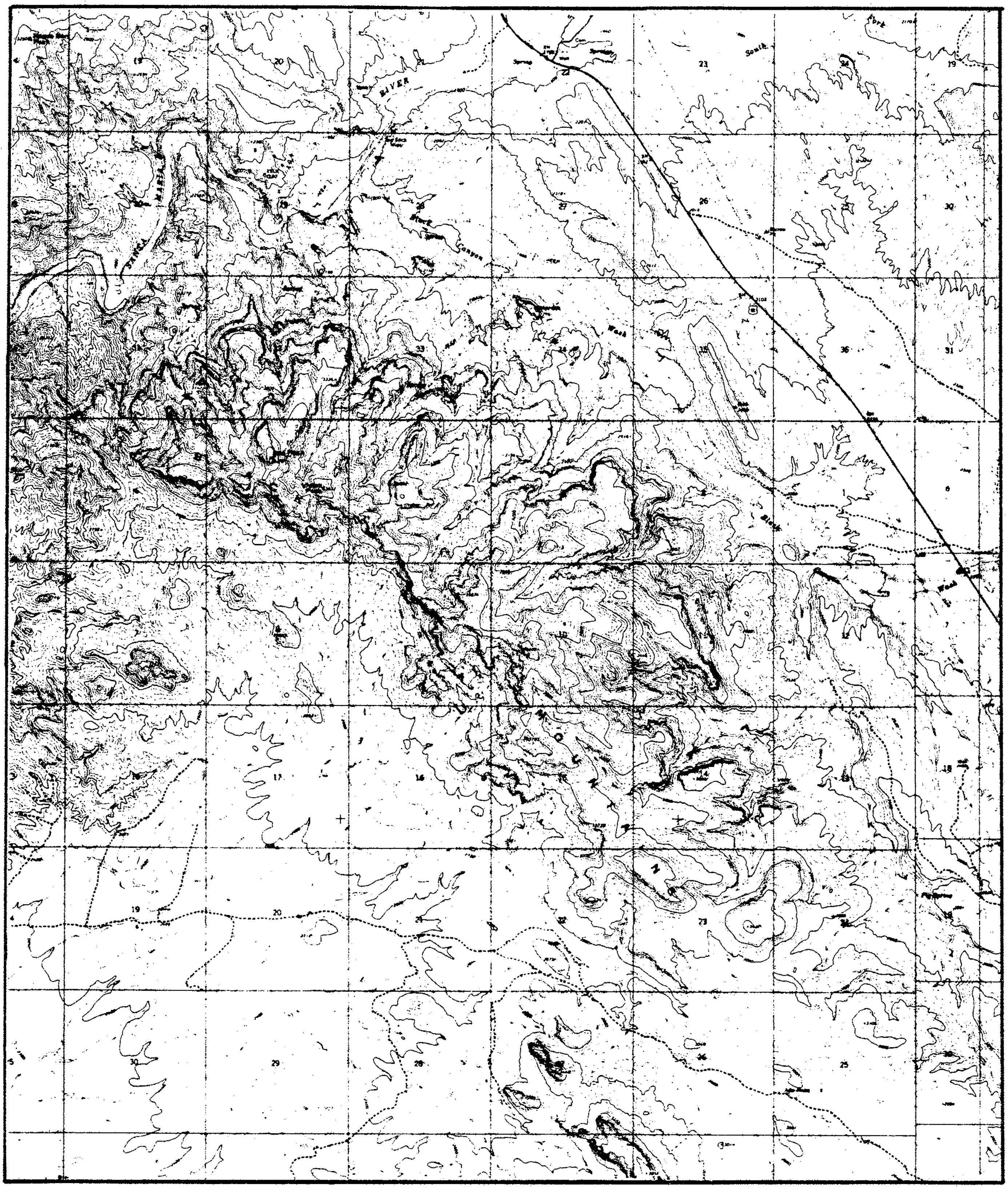


LOCATION MAP
ANDERSON MINE-
DATE CREEK BASIN AREA
Yavapai County, Arizona

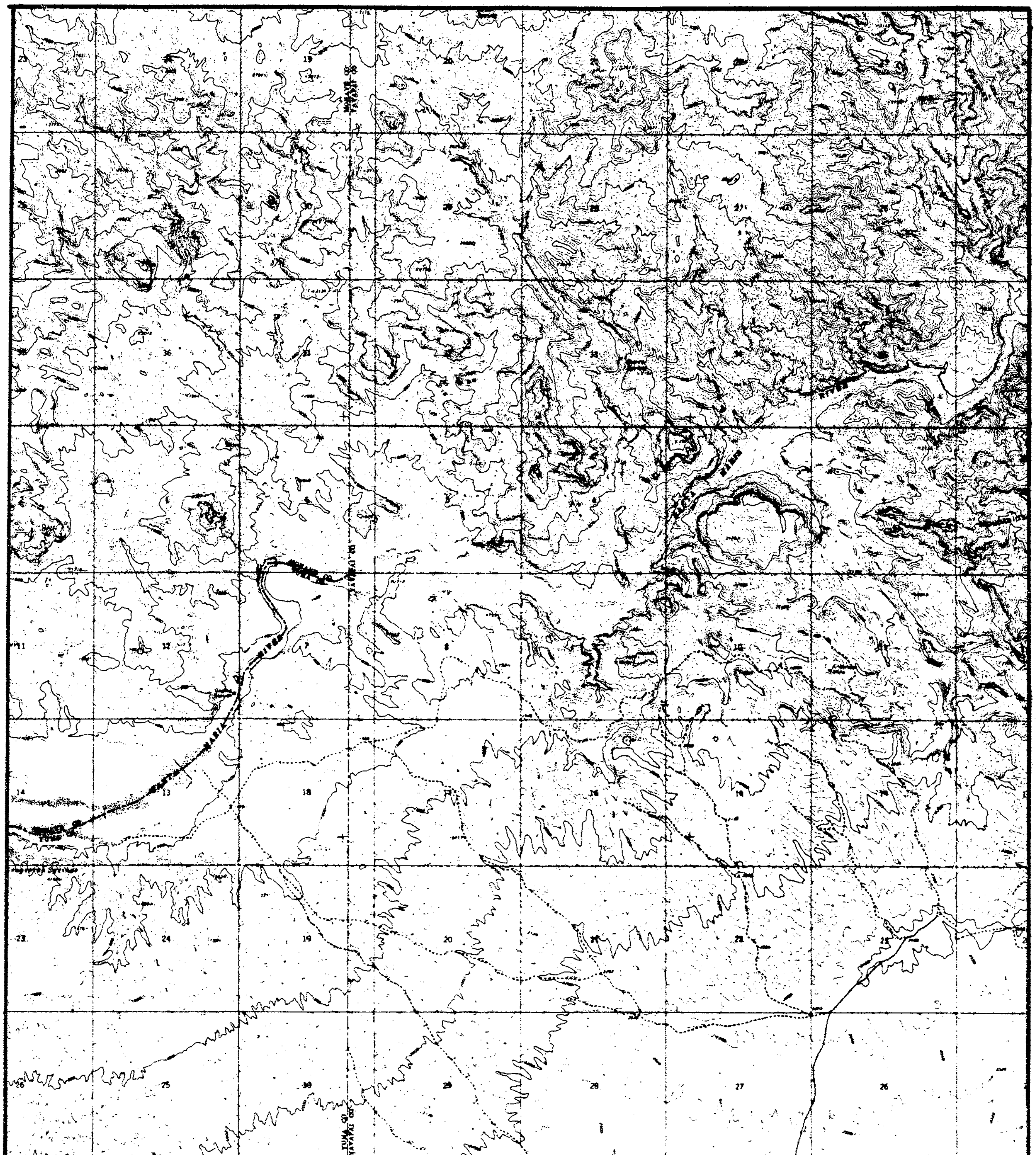
Fig. 1-A



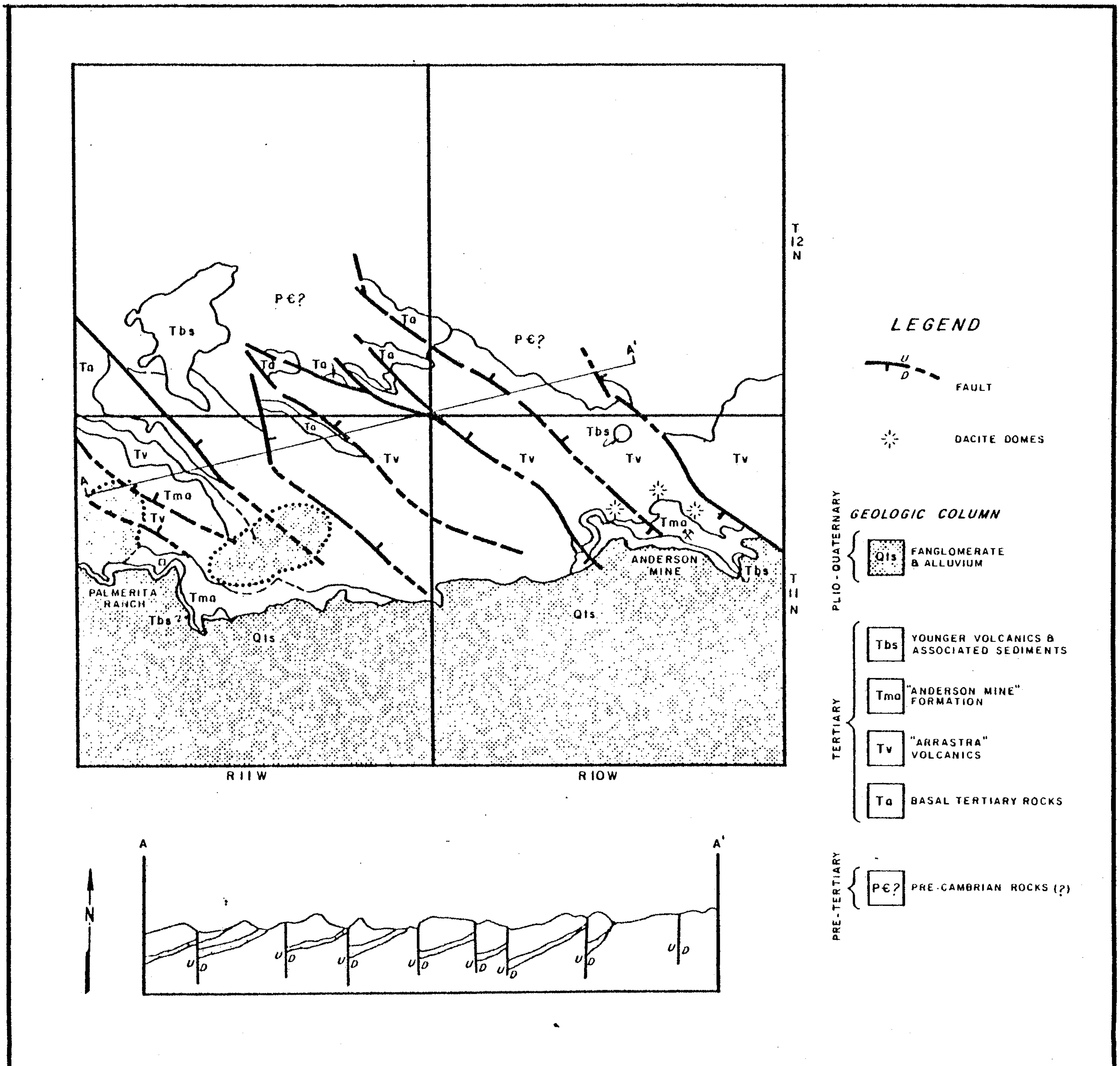
LOCATION MAP
ANDERSON MINE–
DATE CREEK BASIN AREA
Yavapai County, Arizona
Scale 1:24,000
Fig. 1-B



LOCATION MAP
ANDERSON MINE–
DATE CREEK BASIN AREA
Scale 1:62,500
Fig. 1–C



LOCATION MAP
ANDERSON MINE—
DATE CREEK BASIN AREA
Scale 1:62,500
Fig. 1-D



LEGEND
FAULT
DACITE DOMES
GEOLOGIC COLUMN
PLIO-QUATERNARY
Qls FANGLOMERATE & ALLUVIUM
TERTIARY
Tbs YOUNGER VOLCANICS & ASSOCIATED SEDIMENTS
Tma "ANDERSON MINE" FORMATION
Tv "ARRASTRA" VOLCANICS
Ta BASAL TERTIARY ROCKS
PRE-TERTIARY
P€? PRE-CAMBRIAN ROCKS (?)
T 12 N
T 11 N
R11W
R10W
ANDERSON MINE
PALMERITA RANCH
A
A'
N

FIGURE 2

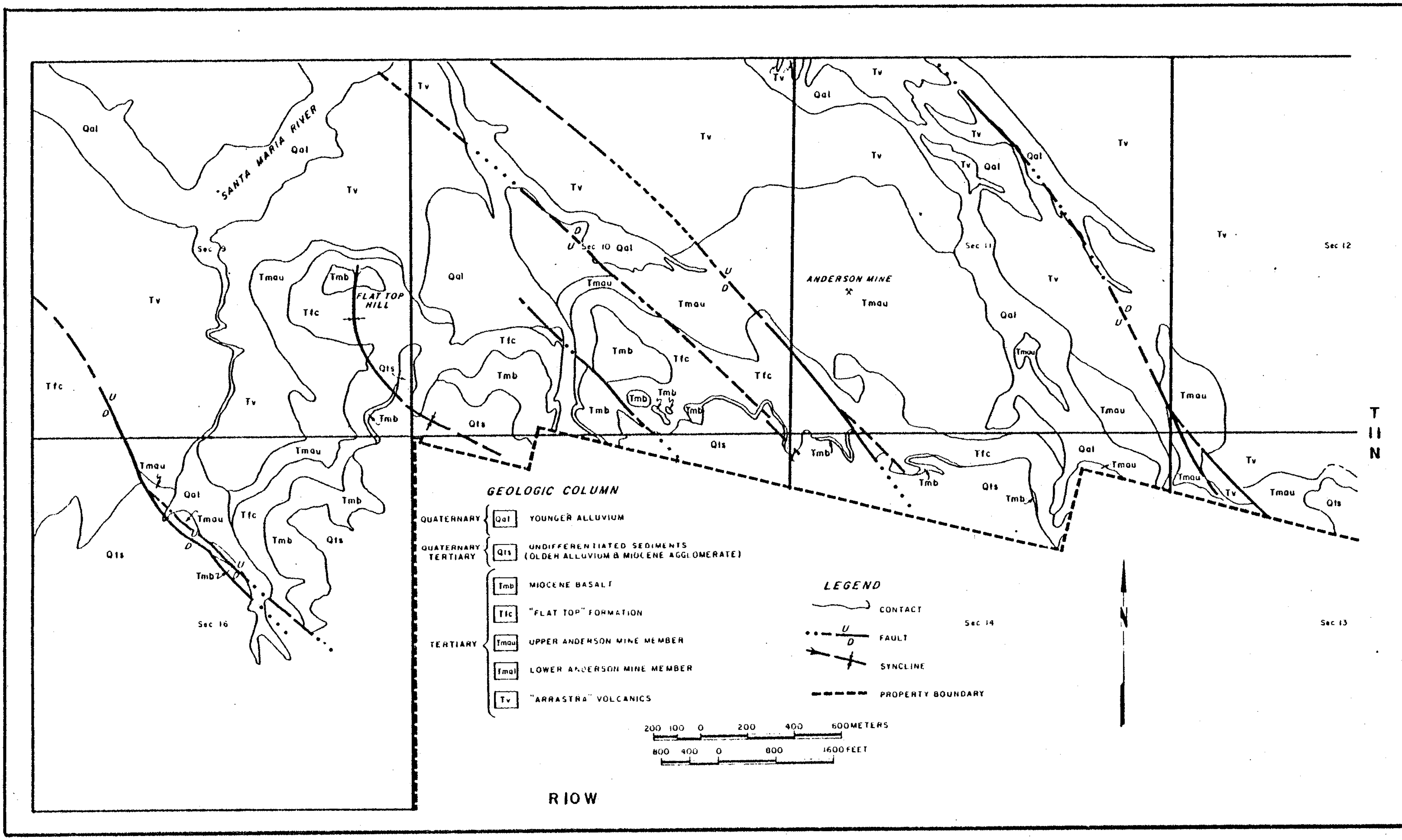
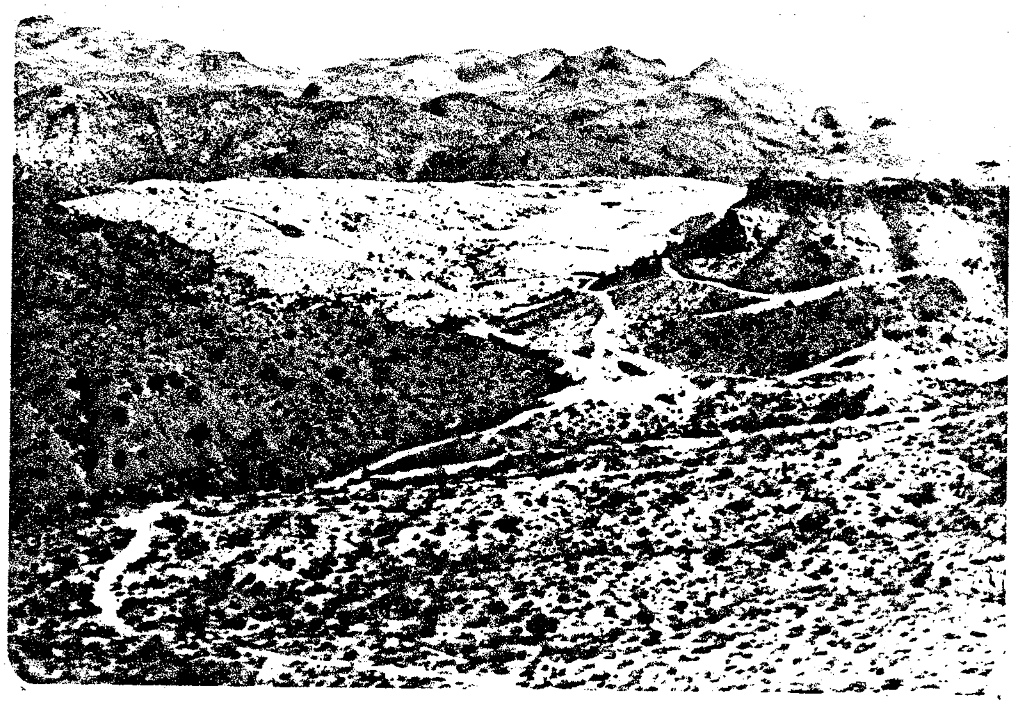
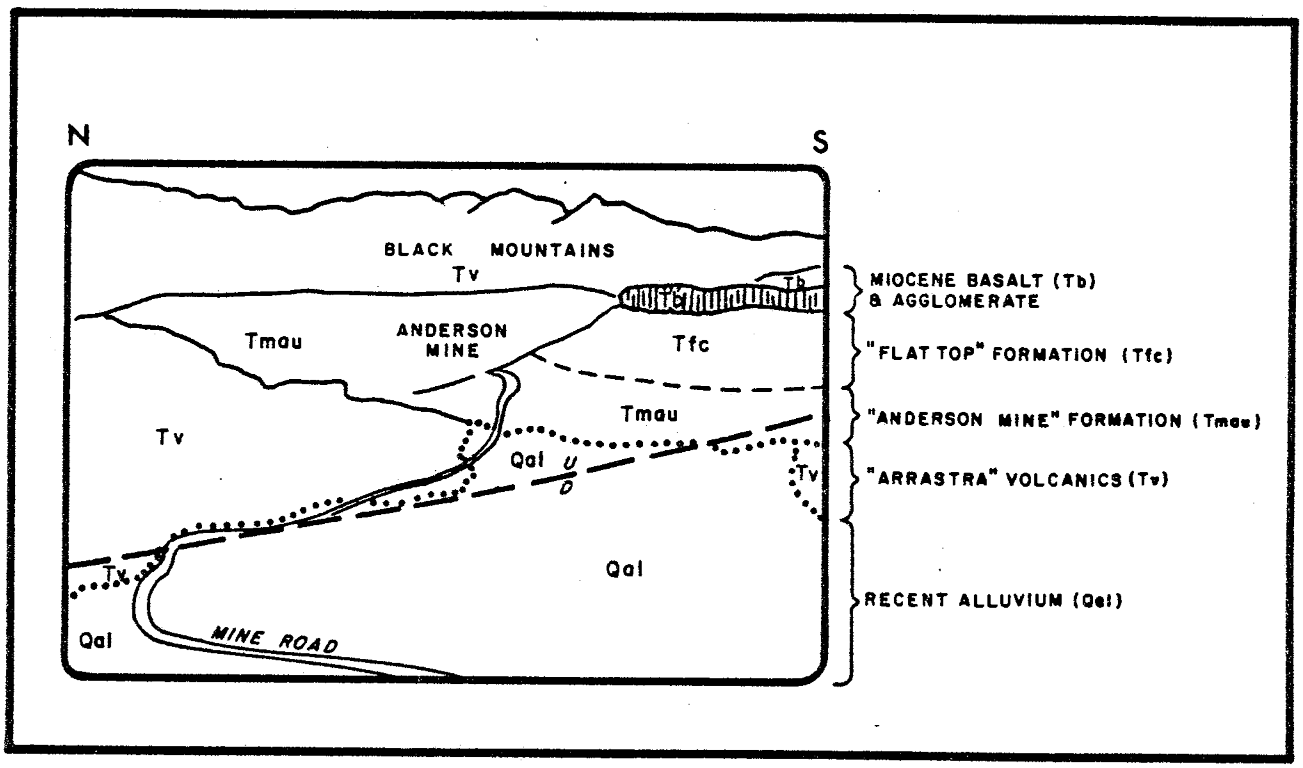

SANTA MARIA RIVER
FLAT TOP HILL
ANDERSON MINE
Sec 9
Sec 10
Sec 11
Sec 12
Sec 13
Sec 14
Sec 16
T 11 N
R 10 W
GEOLOGIC COLUMN
QUATERNARY
Qal YOUNGER ALLUVIUM
QUATERNARY TERTIARY
Qts UNDIFFERENTIATED SEDIMENTS (OLDER ALLUVIUM & MIOCENE AGGLOMERATE)
TERTIARY
Tmb MIOCENE BASALT
Tfc "FLAT TOP" FORMATION
Tmau UPPER ANDERSON MINE MEMBER
Tmal LOWER ANDERSON MINE MEMBER
Tv "ARRASTRA" VOLCANICS
LEGEND
CONTACT
FAULT
SYNCLINE
PROPERTY BOUNDARY
200 100 0 200 400 600 METERS
800 400 0 800 1600 FEET
N

FIGURE 3





N
S
BLACK MOUNTAINS
Tv
Tb
Tfc
Tmau
ANDERSON MINE
Tfc
Tmau
Tv
Qal
U
D
Tv
Tv
Qal
Qal
MINE ROAD
MIOCENE BASALT (Tb) & AGGLOMERATE
"FLAT TOP" FORMATION (Tfc)
"ANDERSON MINE" FORMATION (Tmau)
"ARRASTRA" VOLCANICS (Tv)
RECENT ALLUVIUM (Qal)

FIGURE 4

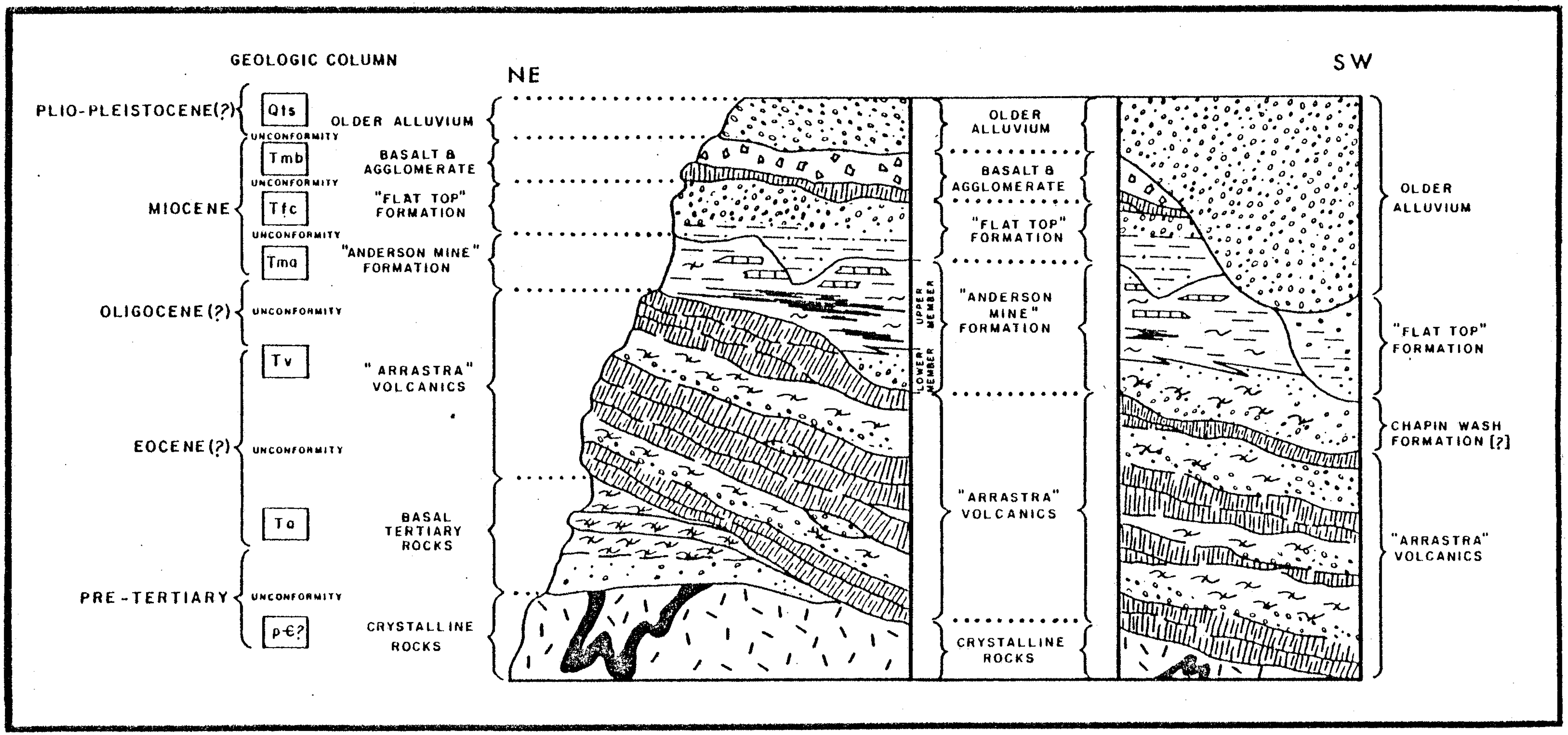

GEOLOGIC COLUMN
NE
SW
PLIO-PLEISTOCENE(?)
MIOCENE
OLIGOCENE(?)
EOCENE(?)
PRE-TERTIARY
Qts
Tmb
Tfc
Tma
Tv
Ta
p-€?
UNCONFORMITY
OLDER ALLUVIUM
BASALT & AGGLOMERATE
"FLAT TOP" FORMATION
"ANDERSON MINE" FORMATION
"ARRASTRA" VOLCANICS
BASAL TERTIARY ROCKS
CRYSTALLINE ROCKS
UPPER MEMBER
LOWER MEMBER
"ANDERSON MINE" FORMATION
CHAPIN WASH FORMATION [?]

FIGURE 5

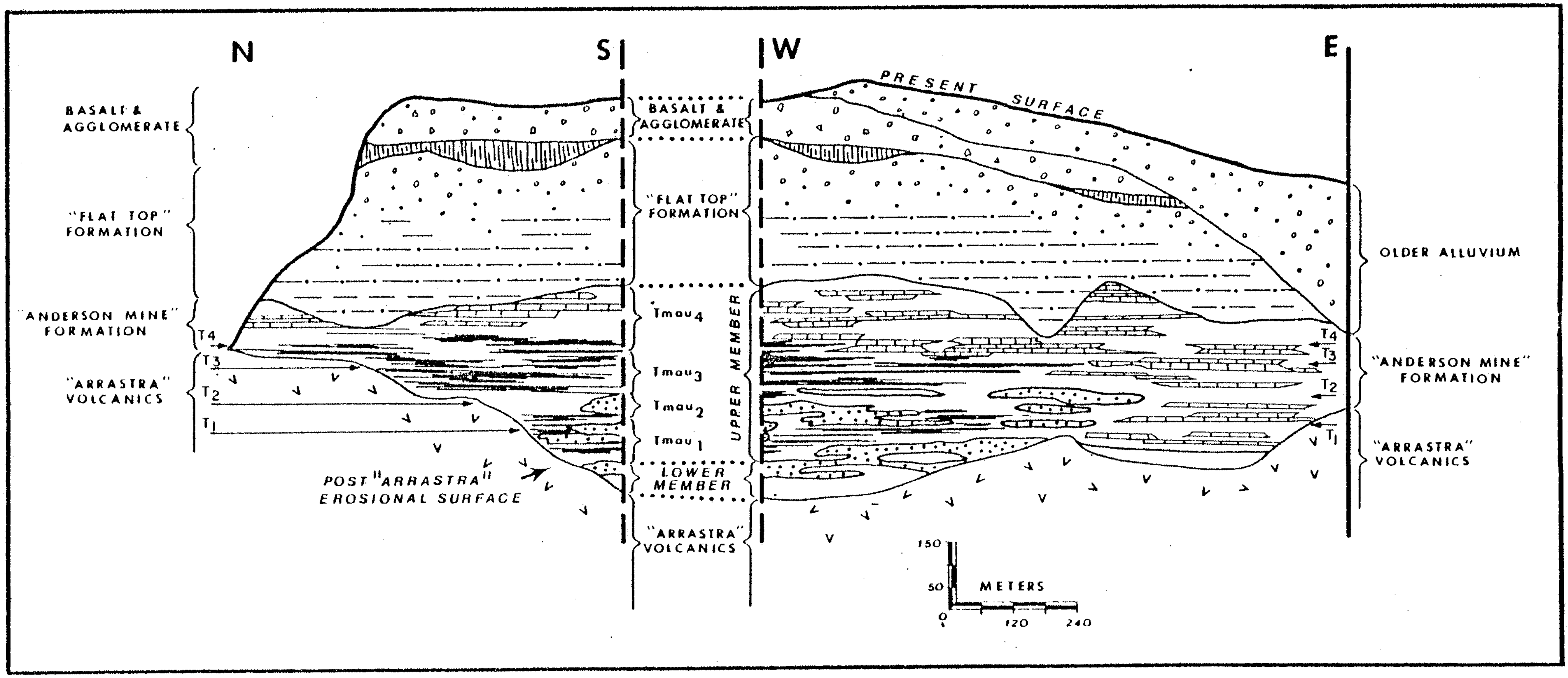

N
S
W
E
PRESENT SURFACE
BASALT & AGGLOMERATE
"FLAT TOP" FORMATION
"ANDERSON MINE" FORMATION
"ARRASTRA" VOLCANICS
T4
T3
T2
T1
BASALT & AGGLOMERATE
"FLAT TOP" FORMATION
Tmau4
Tmau3
Tmau2
Tmau1
UPPER MEMBER
LOWER MEMBER
"ARRASTRA" VOLCANICS
OLDER ALLUVIUM
"ANDERSON MINE" FORMATION
"ARRASTRA" VOLCANICS
POST "ARRASTRA" EROSIONAL SURFACE
150
50
0
METERS
120
240

FIGURE 6

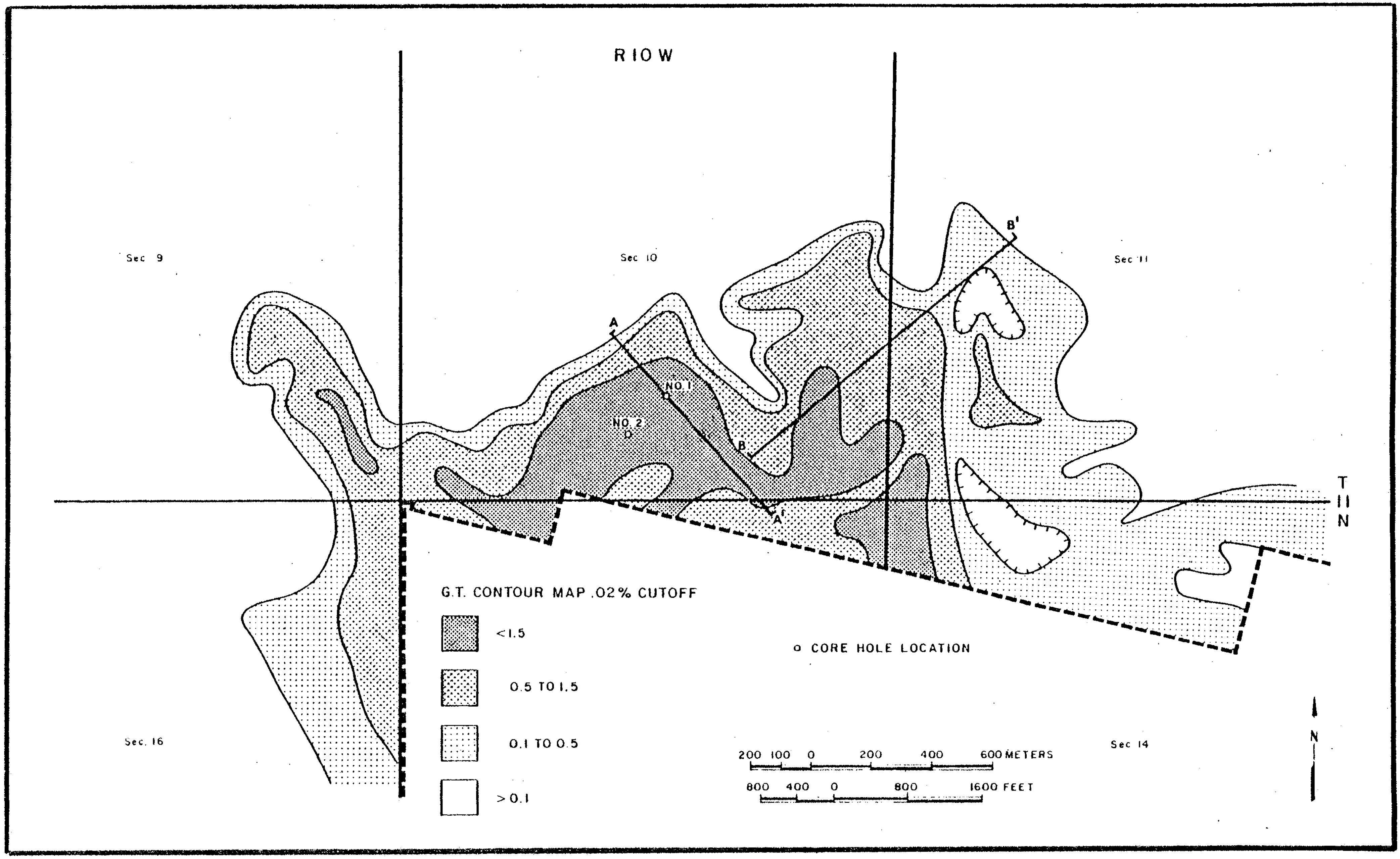

R10W
Sec 9
Sec 10
Sec 11
Sec 16
Sec 14
T 11 N
A
A'
B
B'
NO. 1
NO. 2
G.T. CONTOUR MAP .02% CUTOFF
<1.5
0.5 TO 1.5
0.1 TO 0.5
>0.1
o CORE HOLE LOCATION
200 100 0 200 400 600 METERS
800 400 0 800 1600 FEET
N

FIGURE 8

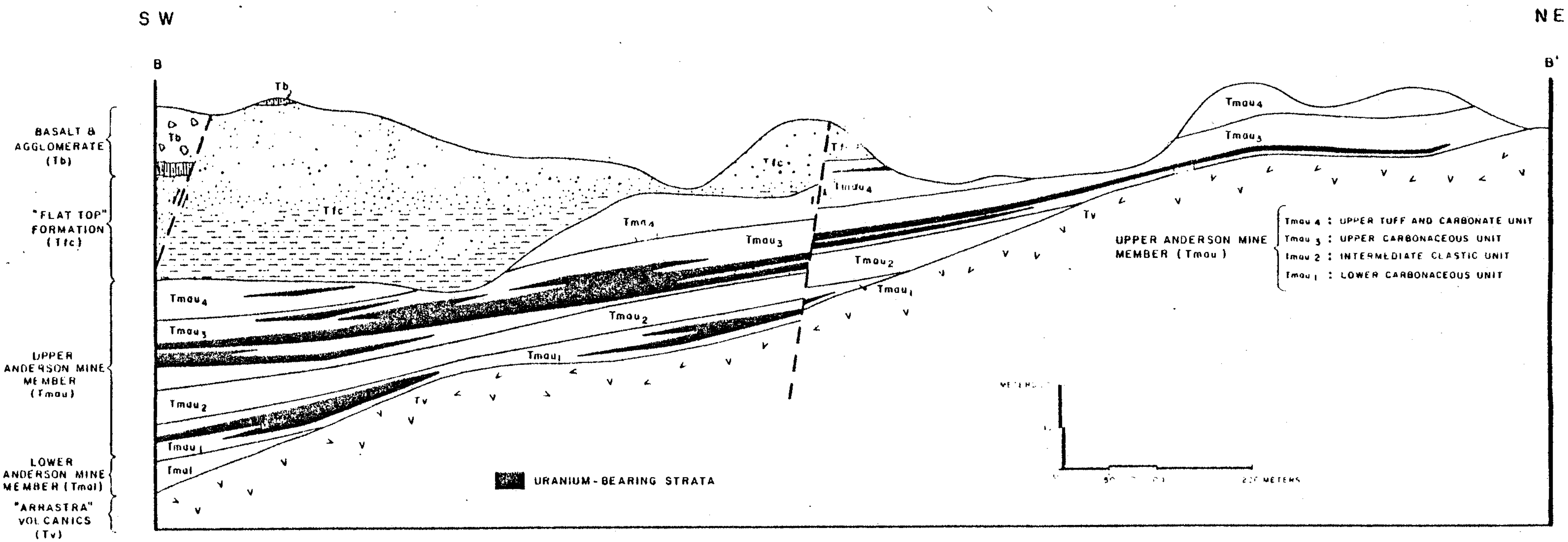
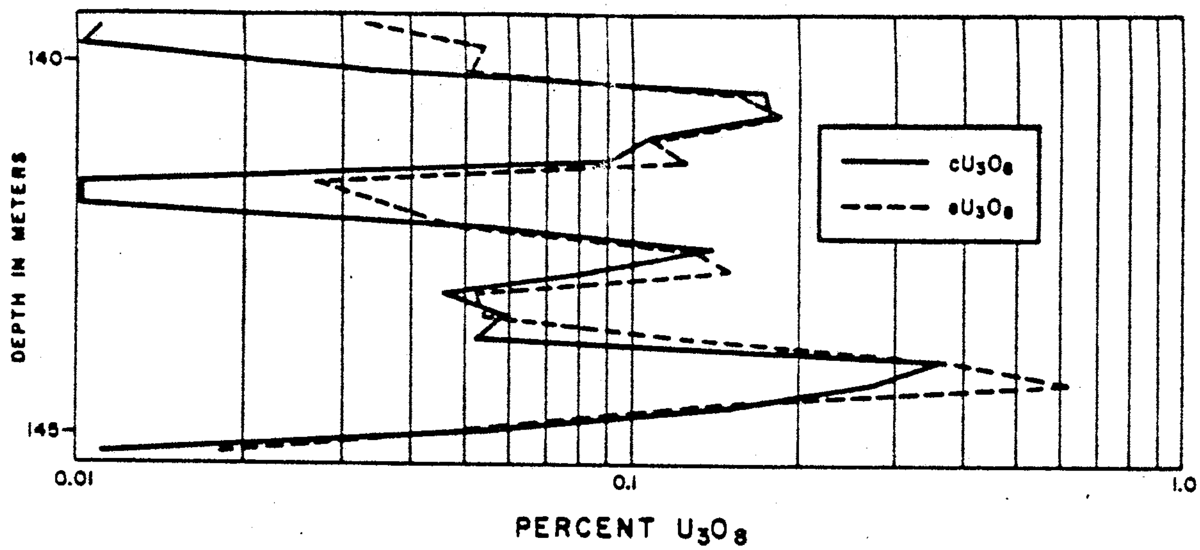
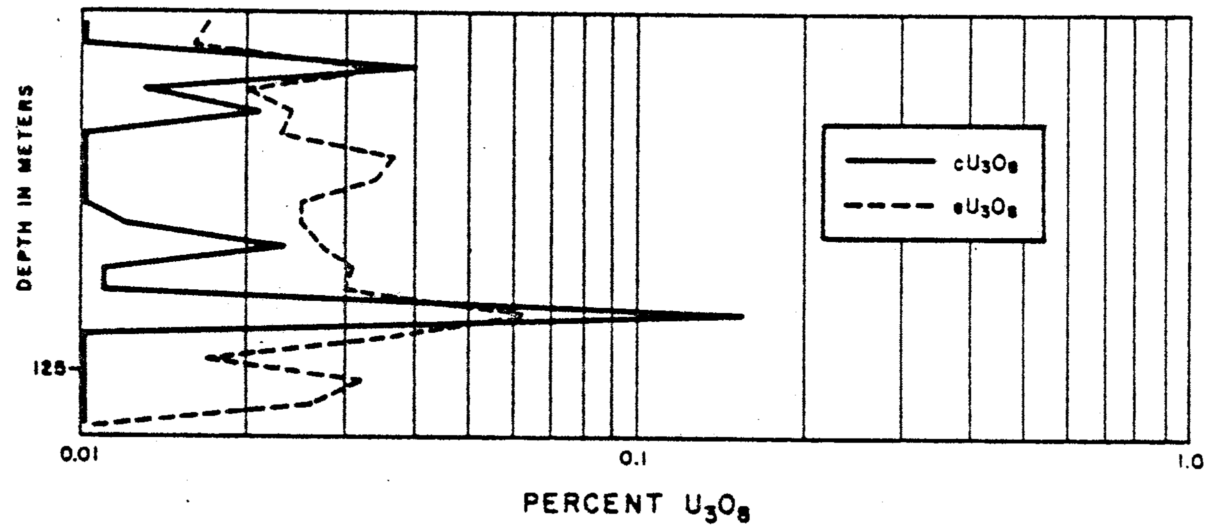

SW
NE
B
B'
BASALT & AGGLOMERATE (Tb)
"FLAT TOP" FORMATION (Tfc)
UPPER ANDERSON MINE MEMBER (Tmau)
LOWER ANDERSON MINE MEMBER (Tmal)
"ARRASTRA" VOLCANICS (Tv)
Tb
Tfc
Tmau4
Tmau3
Tmau2
Tmau1
Tmal
Tv
UPPER ANDERSON MINE MEMBER (Tmau)
Tmau 4 : UPPER TUFF AND CARBONATE UNIT
Tmau 3 : UPPER CARBONACEOUS UNIT
Tmau 2 : INTERMEDIATE CLASTIC UNIT
Tmau 1 : LOWER CARBONACEOUS UNIT
URANIUM-BEARING STRATA

FIGURE 8b

CORE HOLE NO. 1



CORE HOLE NO. 2



CORE HOLE NO. 2

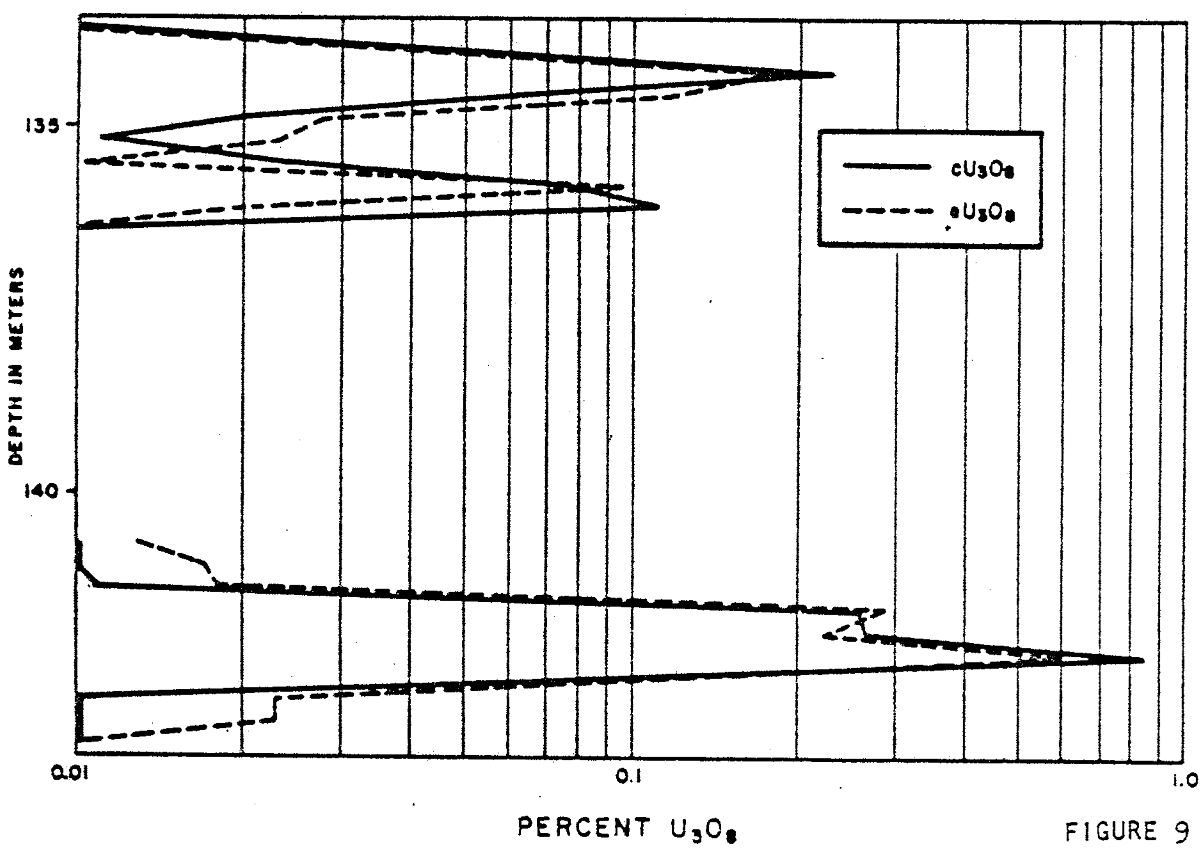


FIGURE 9

MEETING AREA - Route 93 and Alamo Road Junction.

The meeting area is slightly east of the eastern edge of the Date Creek Basin. To the northeast, across the highway are the granite gneiss' and schists of the Date Creek Mountains. To the northwest the Black Mountains composed of tertiary volcanics are apparent. To the west-southwest the Harcuvar Mountains composed of granite gneiss may be visable.

As we continue we will enter the date creek basin at approximately the first cattle guard we cross. As we continue into the basin, note the curvature of the Black Mountains (northeast) northwestward into the Poachie range. The Harcuvar Mountains are to the southwest.

The large drainage cutting the Date Creek Basin surface is Date Creek. As we come up out of Date Creek and continue west, the Artillery, Rawhide and Buckskin mountain ranges are seen on the western horizon.

STOP NO 1. ASSEMBLY.

This stop is made to let everyone catch up. We are on the approximate drainage divide between Date Creek to the south, and the Santa Maria River to the north. The lowest point on the skyline to the north-northeast is the Santa Maria River Canyon which delineates the boundry of the Black Mountains and the Poachie Range. To the north, note the onlap of the Tertiary volcanics onto and against the granitic portions of the Poachie Range. To the west note the dip of the Miocene Basalt into the Date Creek Basin as noted in the mesas along the flank of the Poachie Range. The general structural fabric of the area is northwest-southeast hinge faulting. Several major faults may be noted in the Poachie Range.

STOP No. 2

As we drive to this stop the Santa Maria River Channel will be seen to the west. We are drilling on the upper conglomeritic unit of Plio-Pleistocene age. As we approach our second stop we will drive onto a Miocene basalt. Vehicles will be parked at this point and the tour will continue on foot.

From this high vantage point on the basalt note the onlap of the lacustrian sediments on the underlying andesitic volcanics to the northeast.

Immediately beneath the basalt is the lower conglomerate which overlies the lacustrian sediments. To the northwest across the river note the pyramid-like peak. The lower conglomerate may be seen overlying the Arrastva Volcanics and in turn capped by the basalt. No lacustrian sediments are present there between the lower conglomèrate and the Arrastra Volcanics. Note the fault zone beneath us to the northwest in the Arrastra Volcanics. From here we will proceed downslope to the stop no. 3.

STOP No. 3.

At this location is one of the only out-crops of the carbonaceous material on the property. Note that the unit here is exposed only due to the bulldozer cut made for bulk sampling purposes. This is the middle carbonaceous zone which is the thickest and most continuous mineralized unit across the area. The unit thickens rapidly to the south (down dip) beneath the hill. The carnotite mineralization noted above the carbonaceous unit was not observable when the cut was made but "bloomed" two weeks later after a rain. Note the small tare zones and the close proximity of the fault zone to the north and the differences in elevation of the Arrastra volcanics.

STOP No. 4

This is the area of the old Anderson Mine. During the late 1950's, 33,230 pounds of U_3O_8 were produced from this area. In this cut a resistant tuffaceous siltstone with large silicified pods overlies a green tuffaceous siltstone. Near the base of the cut is a thin slightly carbonaceous zone which carries most of the uranium. Beneath these beds are varicolored siltstones exhibiting various degrees of silicification. This will be our lunch break.

STOP No. 5.

This stop will provide a look at the volcanics, volcaniclastics and intrusives older than the lacustrian sediments and thus unmineralized. Therefore those who wish to poke around in the lake beds longer or who wish to return to the vehicles may. At Stop No. 5, we are standing on the andesitic volcanic flows which forms the drilling basement as no mineralization has been noted in or below this unit. To the east the onlap and different thickenss of the lacustrian sediments overlying the andesite can be seen. In various outcrops in the valley to the northeast the volcaniclastic unit can be observed beneath the andesite. In general the basal portions of this unit are very tuffaceous and waterlain while the unit coarsens upwards becoming less tuffaceous and more sandy and conglomeritic. To the north and to the west are two light gray intrusive bodies. Flow structures may be noted and on close inspection can be clearly seen. Note the thick section of Tertiary volcanics northeastward in the Black Mountains and the granites to the north in the Poachie Range. This concludes the tour and we will proceed back to the vehicles. Union Oil thanks you for your participation and hopes that the tour has been enjoyable and informative for you.

MINERALS EXPLORATION COMPANY

A.G.S. ANDERSON MINE PROPERTY TOUR

Stop #2

The Anderson Mine Project is envisioned as a uranium mine-mill complex with a milling capacity of 2,000 TPD throughput. The mill will utilize a conventional acid leach, solvent extraction circuit.

Mine waste stripping will be accomplished using 17 YD^3 electric shovels and 120 Ton trucks. Mining of ore intervals will use more selective backhoe-front shovels and 35 Ton trucks. Waste material not backfilled into mined out increments will be placed into surface waste dumps to the north and northeast of the mine area. Maximum depth of the envisioned pit is about 700'.

Access to the mine will be via a paved road using a route north of that used today. Total employment at the mine site is expected to be in the neighborhood of 300 persons.

The mill site is situated on the nearest rhyolite outcrop to the north. Tailings from the mill will flow into a tailings pond which will be located below us and to the northeast. The tailings pond utilizes the first mined out pit increments as its site. Mining will extend from this point approximately 1,555' to the south, east and west, and approximately 500' to the north.

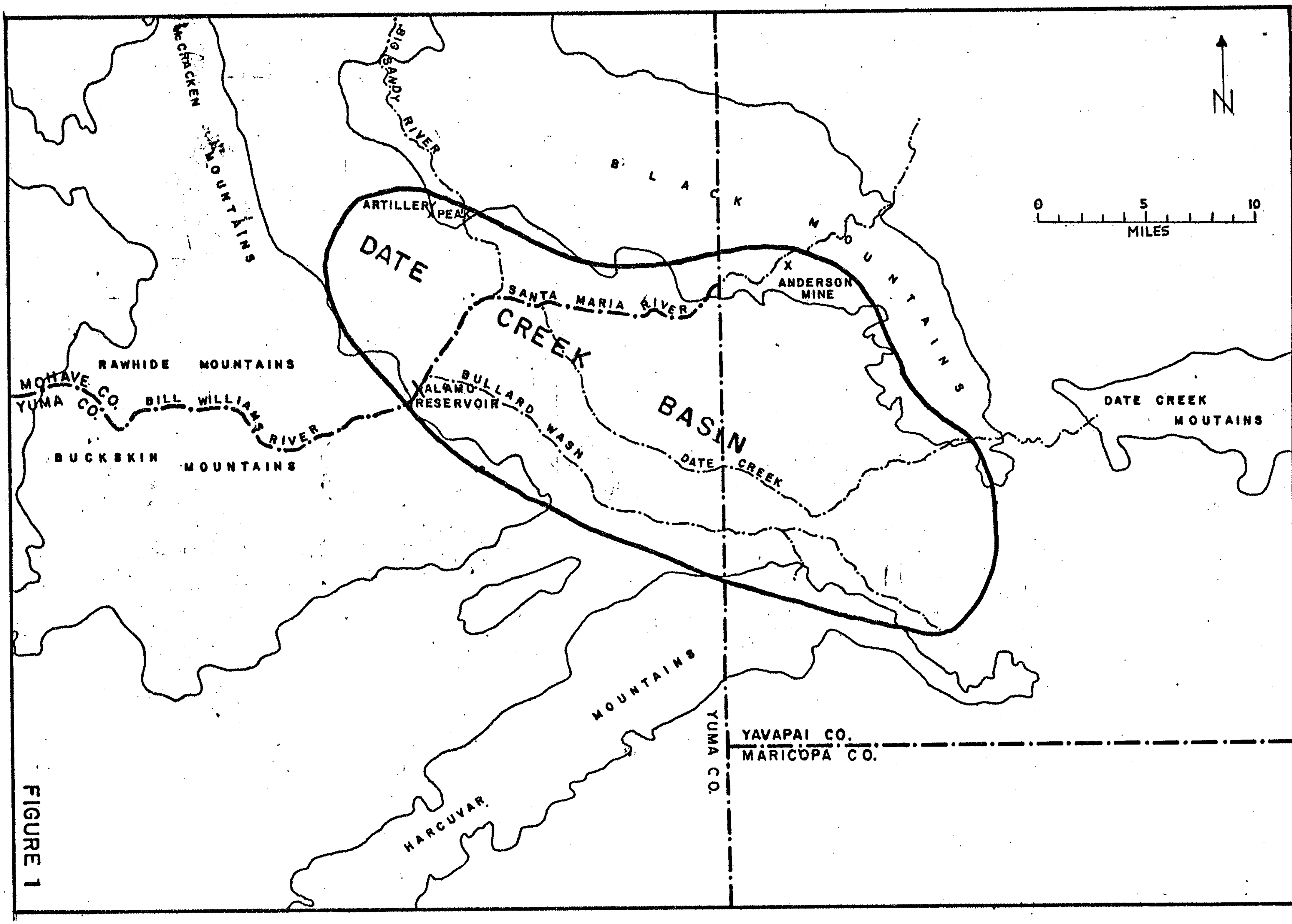
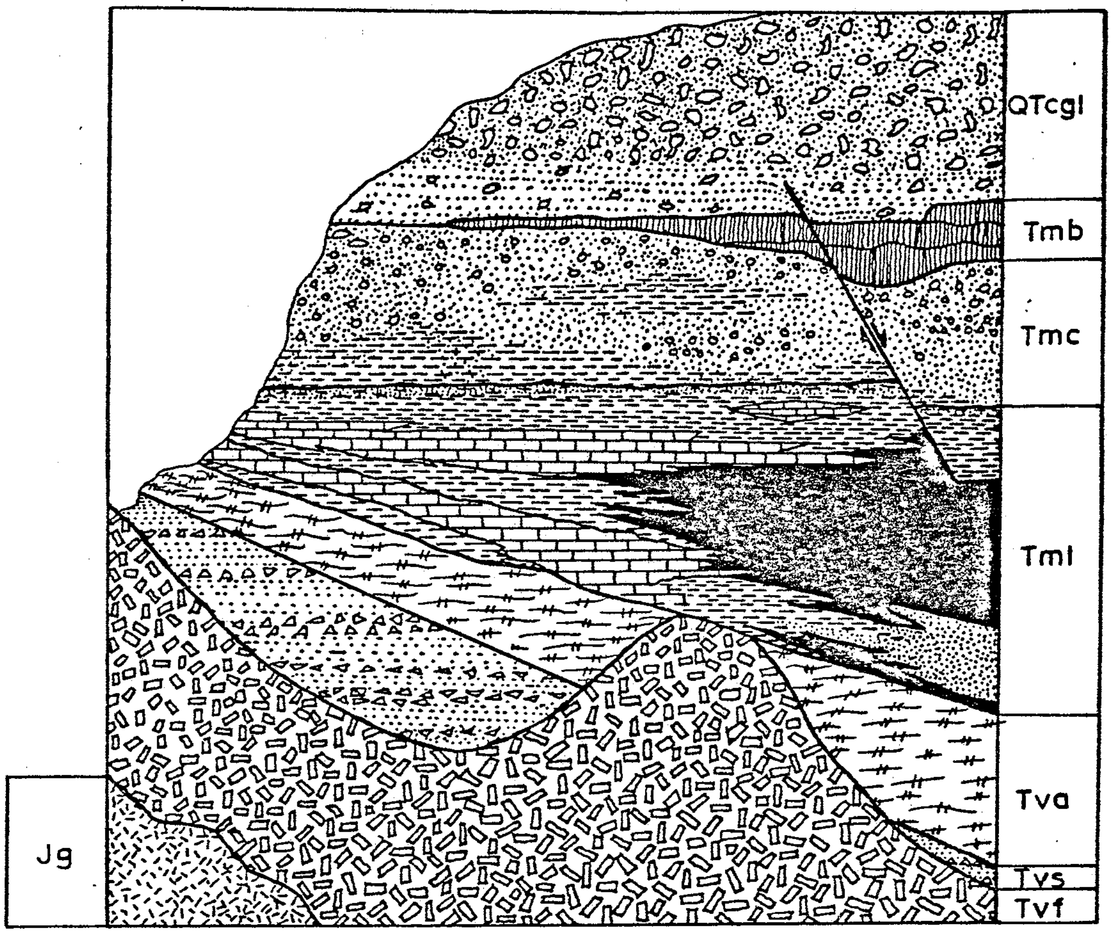
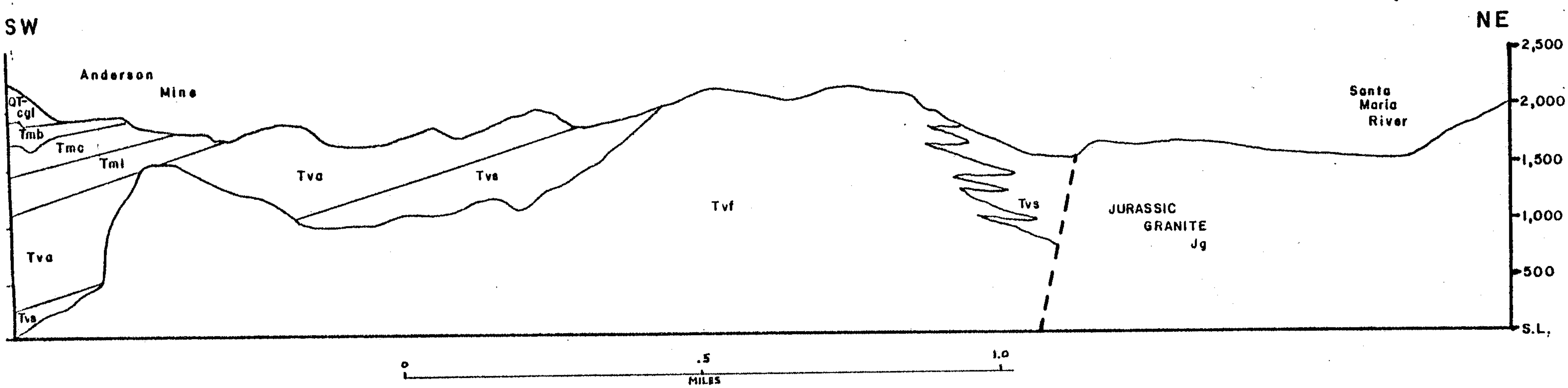

N
0 5 10
MILES
DATE CREEK BASIN
BLACK MOUNTAINS
DATE CREEK MOUTAINS
ARTILLERY PEAK
ANDERSON MINE
SANTA MARIA RIVER
BULLARD WASH
DATE CREEK
ALAMO RESERVOIR
BIG SANDY RIVER
McCRACKEN MOUNTAINS
RAWHIDE MOUNTAINS
BUCKSKIN MOUNTAINS
BILL WILLIAMS RIVER
MOHAVE CO.
YUMA CO.
HARCUVAR MOUNTAINS
YUMA CO.
YAVAPAI CO.
MARICOPA CO.

FIGURE 1


QTcgl
Tmb
Tmc
Tml
Tva
Tvs
Tvf
Jg



- **QTcgl** Quaternary–Tertiary conglomerate, 0–400', tan to white, sandy to very coarse, locally calcite cemented, granitic metamorphic felsic & basaltic clasts
- **Tmb** Tertiary Miocene basalt, black fine-grained to aphanitic, calcite–filled amygdules, commonly jointed parallel to flow surface, 0'–120'
- **Tmc** Tertiary Miocene conglomerate, tan to brown siltstone grades upward into arkosic sandstone & then into conglomerate with granitic & felsic clasts, 200'–450'
- **Tml** Tertiary Miocene lacustrine sediments, basal arkosic sandstone, carbonaceous siltstone & lignite, silty limestone, limy siltstone, green siltstones & mudstones, tuffaceous material throughout, 0'–400'
- **Tva** Tertiary volcanic andesite, gray, gray brown, brown, red brown, fine–grained, vesicular augite andesite, locally containing calcite–filled amygdules
- **Tvs** Tertiary volcaniclastic sediments, gray to white, felsic to intermediate tuffs, ash flows, lahar breccias, upper section yellow tan to tan, sandy
- **Tvf** Tertiary felsic to intermediate volcanics, white to gray, pink-gray, nuchy flows & tuffs
- **Jg** Jurassic granite, brown, purple-gray, biotite granite

GENERALIZED CROSS SECTION ANDERSON MINE

FIGURE 2