CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
3550 N. Central Ave, 2nd floor
Phoenix, AZ, 85012
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

5.1 GEOLOGICAL REPORT

5.1.1 REGIONAL GEOLOGY

The Anderson Mine Property is located along the northeast margin of the Date Creek Basin in west-central Arizona. The basin is bordered by the Black Mountains on the north and northeast, by the Rawhide, Buckskin, and McCracken Mountains on the west, and by the Harcuvar Mountains on the south. To the east and southeast it is bordered by a low drainage divide governed in part by the Harcuvar Mountains and/or the Black Mountains. The basin has a gently sloping topography to the west and northwest.

Surface Flow across the basin is accomplished by three drainages; the Santa Maria River, Date Creek and Bullard Wash. The south-flowing Big Sandy River joins the Santa Maria River in the northwest portion of the basin just west of the confluence of Date Creek and the Santa Maria. This combined drainage flows southward into Alamo River Reservoir becoming the Bill Williams River.

The area has been on the margin of several regional deformations. It was on the northwestern margin of Mazatzal Land, the southeastern margin of the Cordillarian Geosyncline, deformed by the Laramide Orogeny, and is presently on the margin of the Basin and Range Physiographic Province.

The area around Anderson Mine exhibits structures typical of the Basin and Range and it is the Basin and Range deformation which is evident in the area today. The structural trends of this deformation are a dominant northwest-southeast trend of parallel to subparallel hinged block faults and a less dominant westnorthwest-eastsoutheast fault system. Many of these faults exhibit recurrent movements.

The regional stratigraphy may be briefly summarized by 1) a Precombrian or Jurassic granitic basement complex, 2) the lacustrian, clastic and volcanic members of the Paleocene-Eocene Artillery Peak Formation, 3) the Arrastra Volcanic Complex including dacitic intrusions, andesitic flows and volcaniclastic members of early to mid Tertiary age, 4) the Chapin Wash Formation - Anderson Mine Lacustrian sediments of miocene age, 5) a conglomeritic-sandstone unit possibly equivelent to upper Chapin Wash, 6) a Miocene basalt, 7) a Plio-Pleistocene Conglomerate, and 8) Quaternary Alluvium.

5.1.2 GEOLOGY OF MINE AREA

All the drainage on the Anderson Mine Property is to the north and northwest into the Santa Maria River. The headward erosion of these tributaries southward into the Date Creek Basin surface has resulted in a series of subparallel gullies and ridges trending north to northwest. Maximum topographic relief at Anderson Mine is 700 feet.

Faulting in the area trends northwest-southeast and many of the tributaries are developed partially along fault traces. The southerly dip and resistance to erosion of the stratigraphic section have tended to inhibit the headward migration of the tributaries.

Three major faults, the East Boundary Fault System, Fault 1878, and the West Boundary Fault System are present in the area. In addition to these are many parallel faults which have less displacement than the major faults. All of these faults trend between N30^{o}W and N55^{o}W. Another set of faults trending more westerly (N65^{o}W) are present at least in the south-central portion of the property. A set trending northeast has been conjectured by Urangesellschaft and others but has not been observed in the field.

Within the boundaries of the Anderson Mine claims nine (9) informal stratigraphic units have been recognized by Minerals Exploration Company. From oldest to youngest these are: 1) Crystalline Intrusive Rocks, 2) Felsic to Intermediate Intrusions and Flows, 3) Felsic to Intermediate Volcaniclastic Sediments, 4) Andesitic Volcanic Flows, 5) Lacustrian Sediments, 6) Lower Conglomerate, 7) Basaltic Volcanic Flows and Dikes, 8) Upper Conglomerate, and 9) Alluvium.

As the Lacustrian Sediments are the only mineralized unit on the property only they are described in detail. The lacustrian sediments unconformably overlie the andesitic volcanics over most of the Anderson Mine Property. However, to the east-central they overlie the volcaniclastic sediments and further to the east they onlap the felsic to intermediate volcanics. Several drill holes in the center of the mine area have encountered the felsic to intermediate volcanics or the tuffaceous part of the volcaniclastic sediments immediately below the lacustrine sediments.

Evidence now suggests that deposition of the lacustrine sediments occurred in a restricted basin. Therefore, these sediments represent time-transgressive facies deposited within a narrow, probably shallow, basinal feature. This type of depositional environment exhibits complex relationships between individual facies; lensing out, vertical and horizontal gradation, interfingering, etc.

The lake sediments include green silstones and mudstones, white calcareous siltstones, and silty limestone or calcareous tuffaceous material. Much of this material is silicified to varying extents and was derived in part, from volcanic ashes and tuffs common throughout the lake beds. Also present in the lacustrine sequence are zones of carbonaceous siltstone and lignitic material. Along the southern boundary with Urangesellschaft, drill holes encounter the basal arkosic sandstone. To the south and southwest the "typical" lake beds interfinger with and eventually are replaced by a thick, medium to coarse-grained, arkosic sandstone unit.

In addition to the organic material in the carbonaceous zones, abundant plant remains (including twigs, reeds, and small roots) are present in the lacustrine sediments. Reyner et al (1956) recognized abundant silicified palm type wood. Fresh water mollusks, up to 1½ inches in length, are locally common. Thin laminated calcareous siltstone near the top of the lake beds contain small fresh water fish fossils. A jaw of a rhinoceros reportedly found at Anderson Mine is on display at the Wickenburg Museum. The leg bone of a duck found in the unit has been dated as Miocene by the Los Angeles County Museum. William Breed (1977) of the Museum of Northern Arizona and his associates collected fossils at Anderson Mine in April of 1977. Included in their finds were fresh water fish (Eocene to Recent), a camel bone, and a rhinoceros tooth (Miocene).

All of the lake beds facies may exhibit some uranium mineralization. However, the highest grade and most consistent mineralization is located in the carbonaceous siltstones and lignitic materials.

Occasional mineralization has also been noted in the basal sandstone of the lacustrine sediments and in the lower conglomerate. Carbonaceous material is known to interfinger with the basal sandstone and carbon has been noted in the lower conglomerate. Remobilization of the uranium has resulted in the deposition of mineral as fracture fillings around and below the main mineralized zones.

The mineralization is syngenetic as evidenced by the continuation and offset of mineralization across faults. Carbon tends to immediately fix uranium when soluble uranium comes in contact with it. Much of the mineralization is at the top or bottom of the carbonaceous facies, however, mineralization does occur in the middle of some carbonaceous zones. This later relationship implies that mineralization occurred during the deposition of the carbonaceous material.

Silicification of various parts of the Anderson Lake sediments probably occurred soon after deposition. Devitrification of the tuffaceous and ashy lake bed sediments and/or the felsic volcanics were probably the primary sources of silica. This silicification would tend to lock the uranium mineralization and protect it from remobilization.

The following origins have been suggested for the uranium mineralization at Anderson Mine.

1) Leaching of volcanic tuffs
2) Solution, mobilization and deposition from granites in the area
3) Combination of 1 and 2
4) Hypogene
5) Hot springs

Whatever the origin it was the reducing environment of the lake or swamp that provided the structural and stratigraphic trap necessary for the retension of the uranium.

CIRC. 753

GEOLOGICAL SURVEY CIRCULAR 753

Short Papers of the U.S. Geological Survey Uranium-Thorium Symposium, 1977

URANIUM MINERALIZATION DURING EARLY BURIAL, NEWARK BASIN, PENNSYLVANIA-NEW JERSEY

By C. E. Turner-Peterson, U.S. Geological Survey, Denver, Colo.

Sedimentation in the Triassic-Jurassic Newark basin was the result of infilling of a rift basin formed prior to continental breakup. Asymmetrical development of facies resulted from differential tectonism in an internally-drained lake basin. The Stockton Formation, which crops out along the southern margin, consists of conglomerate, gray fine-grained sandstone, red siltstone, and red mudstone. The Lockatong Formation, which crops out in the central part of the basin, contains analcimic black mudstone and carbonate rocks. The Brunswick Formation, which crops out along the northern margin of the basin, is composed predominantly of red siltstone and mudstone, and local conglomerate.

The Lockatong Formation has a lacustrine origin, as documented by Van Houten (1962). The presence of carbonate rocks, black mudstone, sedimentary analcime, fish remains, and conchostracans suggests that a perennial alkaline lake existed in the basin. The Stockton and Brunswick Formations, long considered fluvial, are here considered largely marginal lacustrine deposits, based on facies relations, sedimentary structures, and a newly found fossil.

Laterally coalescing fans of conglomerate, derived from a crystalline highland to the south, compose the base of the Stockton Formation. Basinward from the southern margin, the next facies consists of thick beds of gray, fine-grained, flat-bedded, well-sorted sandstone of the Stockton, interpreted to be nearshore lacustrine in origin. A conspicuous lack of trough crossbeds, foresets, ripples, and other typical current features indicates that there was no fluvial plain between the aprons of coarse material on the fans and the fine-grained sandstone in the lake. Fine-grained detritus settled out of suspension farther from shore to form the red siltstone and burrowed red mudstone facies of the Stockton. Black mudstone included in the Lockatong Formation was deposited in the central euxinic part of the lake. Locally the red, fine-grained facies of the Stockton is absent and the offshore black mudstone is interbedded with the nearshore lacustrine sandstone. Thus, facies distribution along the southern border reflects a fan-to-lake transition with development of thick, well-sorted nearshore sandstone beds.

Facies development along the northern border was notably different. The fans in the Brunswick Formation are not coalesced, are restricted in areal extent, and are dominated by debris flow units. An abrupt fan-to-lake transition, without development of a nearshore sandstone, is indicated by interfingering of fanglomerate with green and black mudstone, conchostracan-bearing red mudstone, and mollusk-bearing limestone in the Brunswick Formation.

The differences in the facies along the two margins of the basin, as reflected in the Stockton and Brunswick Formations, are explained by the tectonic model proposed for the basin. Geophysical data suggest that en echelon normal faults occur near the northern border with their downthrown sides towards the basin (Sumner, written commun., 1975). Faulting is also present along the southern border but sedimentary overlap is more common. The tectonic differences that characterize the two borders directly affected facies distribution in the basin. The development of a nearshore lacustrine sandstone facies in the Stockton may be attributed to a gentle slope of the basin floor along the southern margin which permitted sorting of detritus delivered to the basin. In contrast, the interfingering of low-energy lake beds and coarse debris-flow units in the Brunswick Formation can be attributed to poor sorting on a steep slope, maintained by recurrent faulting, along the northern margin of the basin. A similar situation was documented in Death Valley (Denny, 1965), where a playa, flanked on the east and west by fans, occupies a graben. Renewed faulting along the east side causes greater tilting and subsidence along that margin. The west side fans, in response, have been extended and the playas have encroached upon the more restricted fans on the east side.

Uranium mineralization in the Newark basin occurred in the offshore lacustrine black mudstones of the Lockatong Formation and the nearshore lacustrine sandstones of the Stockton Formation. Mineralization occurred during or shortly after deposition of the host rock, as indicated by geochemical considerations discussed below.

Two agents (humic acids and aqueous sulfide) capable of fixing uranium were forming in the offshore black muds at the time of deposition. The bottom sediments of the central part of the lake were anaerobic, as indicated by the black color of the mudstones and the presence of pyrite. Ferroan dolomite in the offshore mudstone facies also indicates anoxic conditions because ferrous ions substitute for magnesium in dolomite only in reducing conditions. Sedimentary analcime indicates a high pH, perhaps as high as 9.4, in the pore waters of the black muds. Humates are soluble in basic solutions and thus the solubilization of humic acids was favored in the pore fluids of the black muds. Simultaneously, bacterial anaerobic respiration resulted in the reduction of sulfate to bisulfide within the bottom sediments. Uranium was fixed near the sediment-water interface in the black muds, resulting in widespread medium-grade (0.01-0.02 percent U_3O_8) uranium deposits in the Lockatong.

Mineralization in the nearshore sandstone beds of the Stockton occurred shortly after deposition. The proximity of mineralized sandstone to black mudstone units suggests that the black mudstones played an important role in uranium mineralization. It is proposed that the reducing agents generated within the black muds (humic acids and aqueous sulfide) were expelled during compaction into the adjacent, more permeable nearshore sands, providing the reductants necessary for uranium fixation in those sands. Uranyl ions were carried into the basin by ground water from uranium-rich crystalline rocks south of the basin. Recent studies (McBride and Pfannkuch, 1975) on ground water movement on the periphery of modern lakes demonstrate that seepage into a lake occurs largely in the nearshore zone. In a similar manner, uranium-bearing ground water passed into the nearshore sands and then upward into the lake. In this manner, large amounts of uranium-bearing ground water may have passed through the nearshore sands, where reductants expelled from the black muds would have caused the uranium to precipitate, resulting in localized mineralization (as much as 1.28 percent U_3O_8) in the Stockton.

If the reductants were provided by expulsion of fluids from the compacting black muds, as is proposed here, certain time constraints are imposed on the model. The generation of aqueous sulfide in sediments is greatest at shallow depths, restricting its availability as a reductant to early burial stages. Further limitations are imposed on the depth and timing of fluid expulsion, because clays compact readily during early burial and expel most of the pore fluids at that time. Thus, compaction-induced lateral movement of the fluids containing aqueous sulfide and humic acids from the black muds into the adjacent, more permeable nearshore sands, and the resulting uranium mineralization, occurred during early burial.

The model proposed here for uranium mineralization in the Newark basin has several important implications: (1) black mudstones associated with uranium deposits in the Newark basin played an active geochemical role during mineralization, and (2) mineralization in the Stockton Formation occurred shortly after deposition of the host sandstone because agents necessary for fixing uranium were generated in the pore fluids only during early burial.

Denny, C. S., 1965, Alluvial fans in the Death Valley region, California and Nevada: U.S. Geol. Survey Prof. Paper 466, 62 p.

McBride, M. S., and Pfannkuch, H. O., 1975, The distribution of seepage within lakebeds: U.S. Geol. Survey Jour. Research, v. 3, no. 5, p. 505-512.

Van Houten, F. B., 1962, Cyclic sedimentation and the origin analcime-rich Upper Triassic Lockatong Formation, west-central New Jersey and adjacent Pennsylvania: Am. Jour. Sci., v. 260, no. 8, p. 561-576.

April 27, 1977

MEMORANDUM

URANIUM - EXPLORATION

"Uranium mineralization during early burial, Newark Basin, Pennsylvania-New Jersey". U.S.G.S. Uranium Symposium at Golden, Colorado by Charlene E. Turner - Peterson.

* Developed a model for uranium deposits within a lacustrine basin.

* Newark Basin is lacustrine, has 4000 feet of black lake-deposited mudstones in center of the basin. Feels that basin was not "passive" but actually contributed uranium to system as pore water chemistry and hydrology were favorable.

* Mineralization occurred shortly after deposition of host rocks at interface of sandstone and mudstones.

* Anerobic bacteria were present in the black mudstones

* pH of ground water was about 94 (alkaline) - Humic acid and acqueous sulfides were present in the water in mudstones, then this water seeped laterally into the lake.

* SO_4 "highs" may represent oxidization of FeS_2 - some "highs" 10X background are in south fault block of Lockatong Formation.

* May have applications in fault basins of Basin and Range Uranium-bearing ground water in near shore. ~~Sandstones could have seeped up into the lake~~.

* Compaction of acqueous sulfides and bacteria occurred and then uranium was precipitated by sulfides (which had migrated laterally and up).

(Notes taken during oral presentation by O. Jay Gatten

HWP

GEOLOGICAL SURVEY CIRCULAR 753

Short Papers of the U.S. Geological Survey Uranium-Thorium Symposium, 1977

GEOLOGY OF URANIFEROUS TERTIARY ROCKS IN THE ARTILLERY PEAK-DATE CREEK BASIN, WEST-CENTRAL ARIZONA

By James K. Otton, U.S. Geological Survey, Denver, Colo.

Uranium occurs in Tertiary rocks of the Artillery Peak-Date Creek basin 150 km northwest of Phoenix, Arizona. Although the original size and shape of the basin is unknown, it presently underlies an area 30 km wide that extends 80 km from the southern end of the McCracken Mountains southeast of an area of low hills near the intersection of U.S. Highway 93 and State Highway 71 (fig. 1).

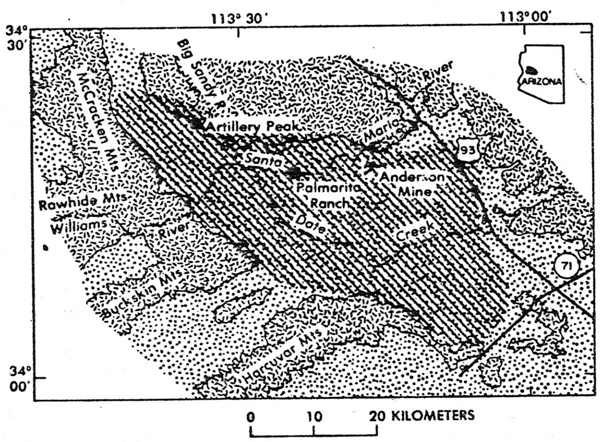


Figure 1.--Index and generalized geologic map of the Artillery Peak-Date Creek basin area. Pattern, outline of present basin; light stipple, Tertiary to Holocene basin fill; dark stipple, Precambrian and Mesozoic basement rocks.

Lasky and Webber (1944, 1949) first mapped and described Tertiary rocks in the Artillery Mountains manganese district in the western part of the basin. More recently, Shackelford (1976), J. S. Gassaway (written commun., 1972, 1976), I. Lucchita (oral commun., 1976) and the author have studied the rocks of the basin and adjacent areas.

The Tertiary rocks within the basin consist of Eocene(?) sedimentary and intermediate to mafic volcanic rocks belonging to the Artillery Formation named by Lasky and Webber (1944) who had assigned an Eocene(?) age to it and its probable lateral equivalents; lower Miocene silicic volcanic and tuffaceous sedimentary rocks; upper lower to middle Miocene(?) mafic to intermediate volcanic rocks, coarse clastic sedimentary rocks and tectonic breccias belonging to the Chapin Wash Formation named by Lasky and Webber (1944) who assigned a Pliocene(?) age to it; upper Miocene(?) basalt; and upper Miocene(?) to Holocene sedimentary rocks. Facies relations within these units are complex, unconformities are common, and no unit can be traced continuously throughout the basin.

The Eocene(?) rocks of the basin are best exposed at the northwestern end and along the northeastern margin of the basin. The rest of the basin is largely covered by the Holocene sedimentary rocks. The maximum thickness ot the Tertiary section is about 2,500 m near the confluence of the Big Sandy River and the Santa Maria River (J. S. Gassaway, written commun., 1977). One drill hole 8 km south of the Anderson mine encountered 1,700 m of Tertiary sedimentary and volcanic rocks.

The rocks of the basin are generally tilted to the south or southwest and have been cut by normal faults. The predominant faults have a northwesterly trend, although east-west and northeast-trending faults have also been observed. Movement on the northwest-trending faults seems to have been recurrent throughout most of the history of the basin. Greatest offsets occur in the upper part of the Artillery Formation of the eastern part of the basin. Offsets are progressively smaller in younger rocks. Low-angle normal(?) faulting, interpreted as gravity glide faulting with a probable source in the Rawhide Mountains (Shackelford, 1976), has occurred at least once in the western part of the basin during deposition of the Chapin Wash Formation and may also have occurred during deposition of the upper part of the Artillery Formation. The sedimentary rocks of the basin have also been gently folded periodically.

A thin sheet of arkose and arkosic conglomerate of Eocene(?) age was the first Tertiary sediment deposited in the basin. This arkose is the lowermost unit of the Artillery Formation, and is generally well preserved in the western part of the basin but in the eastern part it is exposed only in isolated patches unconformably overlain by younger rocks. At the type locality in the Artillery Mountains in the western part of the basin, the Artillery consists of fine-grained calcareous sandstone and siltstone, successively overlain by volcanic pebble conglomerate, limestone, metavolcanic breccia, and limestone and basalt. Although exposures are not continuous to the east, the calcareous siltstone and limestone of the Artillery appear to intertongue with sandstone which, in turn, intertongues with andesitic(?) flows and agglomerates and other volcanic rocks.

An age of 43.3 m.y. has been obtained for the basalt in the upper part of the formation near Artillery Peak (J. S. Gassaway, written commun., 1976).

Unconformably overlying the Artillery Formation are unnamed lower Miocene rocks. At the far western end of the basin these are silicic volcanics which have been dated at 17.1 m.y. (J. S. Gassaway, written commun., 1977). In the vicinity of Artillery Peak, the lower Miocene unit consists of tuffs interbedded with sandstone. Throughout its western exposures the unit is thin. North of the mouth of Date Creek and east of the Big Sandy River, the tuffs and relatively fine-grained fluvial rocks grade into a thick section of gray calcareous boulder to sandy conglomerate and tan sandy conglomerate and sandstone which, in turn, grades into a red-brown Fe- and Mn-rich sandy conglomerate and sandstone near Palmerita Ranch. East of Palmerita Ranch these rocks intertongue with tuffaceous mudstones and siltstones and other rocks which form the mineralized unit at the Anderson Mine.

Overlying this lower Miocene unit is the Chapin Wash Formation. West of the Big Sandy River, the formation consists of basalt, conglomerate, a massive megabreccia and manganiferous conglomerate and sandstone. The base of the Chapin Wash appears to have been intruded by andesitic bodies near the confluence of the Big Sandy and Santa Maria Rivers. East of the Big Sandy River, the megabreccia and manganiferous clastic facies are absent. The basalt at or near the base of the formation has been dated at 15.9 m.y. (J. S. Gassaway, written commun., 1976).

The younger basin-fill rocks overlying these three units include an upper Miocene(?) basalt that locally caps a few mesas in the western end of the basin; upper Miocene(?) to Holocene fanglomerate that is several hundred feet thick in the central and southeastern part of the basin, but apparently has been largely removed by erosion in the western part of the basin; and Holocene alluvium.

At the Anderson Mine in the eastern part of the basin, uranium occurs in silicified, tuffaceous, locally carbonaceous lacustrine mudstones, calcareous mudstones, and siltstones. These lacustrine and overlying fluvial rocks compose a unit that ranges in thickness from 60 to 120 m in surface exposures, and thickens considerably downdip to the south in the subsurface. This unit is here correlated with the unnamed lower Miocene silicic volcanic and tuffaceous sedimentary rocks in the western part of the basin.

Fossil plant material, consisting of thin beds of lignitic(?) material and silicified twigs, leaves, and roots, is abundant. Uranium occurs principally in thinly bedded siltstones rich in carbonaceous or silicified plant material. In many places these siltstones are highly stained by Fe- and Mn-oxides. Carnotite is the only uranium mineral yet recognized, and is probably secondary. The primary uranium phase has yet to be identified: in the mineralized carbonaceous rock it may be a urano-organic complex; and in the silicified rock it may be a urano-silica or urano-iron hydroxide complex.

Interbedded with the mineralized tuffaceous siltstones are unmineralized, thickly bedded, greenish-gray tuffaceous mudstones, white to light-gray tuffaceous calcareous mudstones with abundant calcareous microfossils, and sparse sandstone and siltstone. A thin conglomerate is observed locally at the base. The overlying fluvial rocks consist of upward coarsening gray to greenish-gray sandstones and sandy conglomerates. Virtually the entire unnamed lower Miocene unit is rich in tuffaceous material and is anomalous in uranium content.

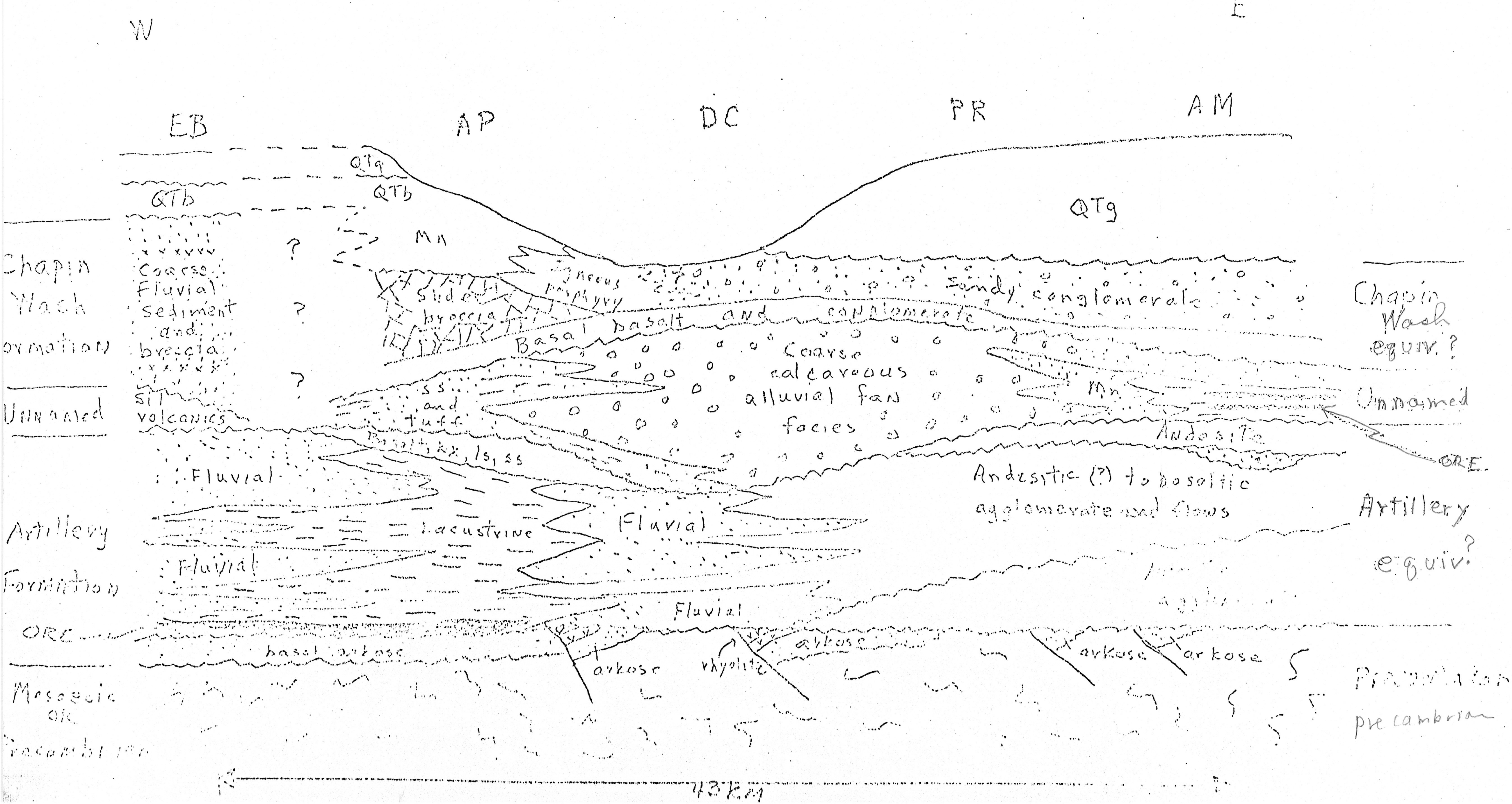
Approximately 2 km west of Artillery Peak, uranium occurs in carbonaceous, calcareous siltstones and fine-grained sandstones immediately overlying the basal arkose of the Artillery Formation. The arkose overlies basement rocks which are rich in uranium and thorium in the Artillery Peak area.

Lasky, S. G., and Webber, B. N., 1944, Manganese deposits in the Artillery Mountains region, Mohave County, Arizona: U.S. Geol. Survey Bull. 936-R, p. 417-448.

______1949, Manganese resources of the Artillery Mountains region, Mohave County, Arizona: U.S. Geol. Survey Bull. 961, 86 p.

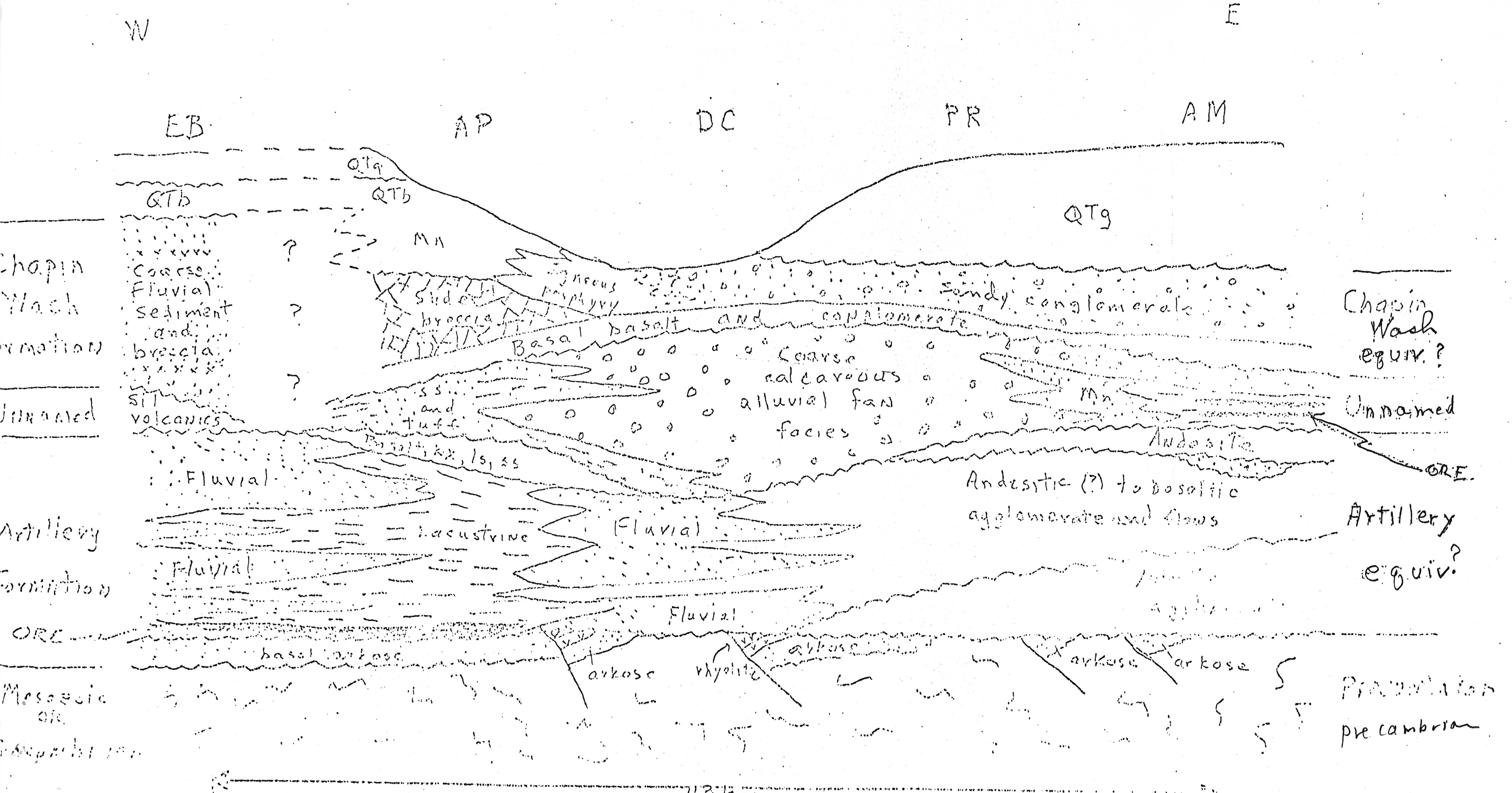
Shackelford, T. J., 1976, Structural geology of the Rawhide Mountains, Mohave County, Arizona: Univ. Southern Calif. Ph.D. thesis, 176 p.

Schematic Stratigraphy of the
Artillery Peak - Date Creek Basin
from Jim Otton 4-77



Schematic Stratigraphy of the Artillery Peak - Date Creek Basin

from Jim Otton 4-77



G. Dohm

Union Oil Company of California

In Reply Give No.

union 76

December 18, 1975

To: G. E. Marrall

From: E. H. Lindsey

Subject: Anderson Mine, Arizona

As we discussed at Golden during the week of December 8, there appears to be no reason, or need, to carry on immediately with the development drilling at Anderson Mine at the close of the present exploration drilling.

We should have the field map and drill sections in preparation currently with the drilling so that at the close of the planned drilling, fill-in drilling can be done, as dictated by the surface mapping and completed drill holes. To do this, I think you will need two teams of two geologists tending the drills and rotating with each other on the ten-day schedule. John Ljung should be free to concentrate on surface mapping and drill section correlation. John should probably plan on staying with the project more or less continuously after the Christmas-New Year break to the completion of the project.

It appears that about 15 holes will be cored at Anderson and these should be analyzed for $CaCO_3$ content as well as chemical analyses for uranium.

We would like to get your formal report on Anderson in late March or early April so that we can approach the Executive Committee in the spring. Assuming a favorable response from the Committee, we will have the summer months to put together the development program. In the interim, we need a written recommendation from you on Section 16 at least two weeks in advance of the February 3 payment deadline.

I have searched our files here and I cannot find any geologic or drill hole location maps on Anderson. Would you have Dee put together a set of the pertinent Anderson maps for me? As I said, while at Anderson, my memory is not all that good and I rely heavily on surface maps, cross sections and drill logs to stay current with the various projects.

EHL:mm

cc: G. Dohm ✓

Form 402 (Rev. 9/67)

To File
From Chris Hill

Regional Geology: Date Creek Basin, Arizona

The Regional Geology Maps (RGM) of the Northern Margin of the Date Creek Basin (Fig. 1) were compiled by the Casper Exploration Group of Minerals Exploration Company and are included with this report. The maps were made by Bill Buckovic in 1975 from air-photo interpretation and several days of field checking. The project was initiated to provide regional geologic relationships for the Anderson Mine Project and to evaluate the Uranium potential of the area around Anderson Mine. Although recent work in the area has shown that some of the interpretations are invalid, the maps do form a good base for further detailed work.

This memorandum will 1) compare the stratigraphic columns of the Anderson Mine area with those of the regional maps, 2) briefly discuss the structural relationships of the area, 3) discuss the correlative units of the maps and 4) delineate some inconsistencies, problems, problem areas.

The Anderson Mine Geology Map is the work of John Ljung, Steve Paulak, Chris Hill and others. The map included with this report is taken from the MX Develoment Group, Anderson Mine Geology Report August 1977. This report and two others Ljung et al Geology and Uranium Resources of the Anderson Mine Project Yavapai County Arizona MX-76-2 June 1976 and Sherborne et al A Major Uranium Dicovery in a Frontier Area- The Anderson Mine, Yavapai County, Arizona March 10, 1978, are included with this Report.

STRATIGRAPHY

A Comparison of the stratigraphic columns of the units mapped in detail at Anderson Mine with the units used on the Regional Geology maps exhibits basic agreement (figure 2).

The units at Anderson Mine are described as follows in the MX Development Group Anderson Mine Geology Report (AMGR), August 1977:

Memorandum
Union Oil Company of California

27 June 1977

TO: Ayax Alba
H. S. Jacobson
C.A. Oakley
R.L.Sherer

FROM: R.D.McNeil

SUBJ: Exploration Guides - Lake Sediment Uranium, Arizona-New Mexico

I have enclosed a copy of J. Ljung's memo titled Exploration Guides Based on Observations at Anderson Mine, Yavapai County, Arizona. If you wish to comment or add to John's observations and conclusions, please forward comments to me in writing.

RDM:sg

cc: C.Hill (Development)

Memorandum

Union Oil Company of California

UNION 76

TO: R. D. McNeil
FROM: J. R. Ljung

DATE: June 17, 1977
RE: Exploration guides based on observations at Anderson Mine, Yavapai Co., Arizona

This memo is in response to the suggestion that a compilation of our observations at the Anderson Mine be assimilated into a report. These observations are weighted according to their relative importance as exploration guides in locating Anderson Mine type ore bodies in both the Basin and Range geographic province and the intermontane basins of the Rocky Mountains.

DEFINITE EXPLORATION GUIDES

Uranium
- a. uranium minerals in outcrop
- b. subsurface gamma anomalies

Reducing Environment + Lign[illegible]
- a. the major portion of mineralization is associated with carbonaceous siltstones and mudstones in close stratigraphic proximity to:
  1. green mudstones and siltstones
  2. fetid limestone

Lacustrine Depositional Environment
- a. limestone, siltstone, mudstone, marlstone
- b. remnant plant material
- c. gastropod fossils in limestone
- d. fish fossils in marlstone
- e. fossil bird remains (leg bone of duck)
- f. fossil mammal remains (lower jaw bone of rhinoceros) Camel Bone

PROBABLE EXPLORATION GUIDES

Acid Volcanic Component of Lacustrine Sequence (uranium source?)
- a. Tuffs
- b. Tuffaceous siltstones
- c. Tuffaceous mudstones

Alteration (of acid volcanic material)
- a. silica as vein filling, nodules, organic replacement, and cement
- b. white clays (bentonite?)

Paleotopographic control of paludal deposition
- a. lake beds were deposited on an eroded volcanic terrain

Pathfinder elements

minerals possibly accumulated under similar conditions as uranium but distributed differently and more widely due to varying geochemical properties i.e. solubility
- a. vanadium, lithium, manganese, copper, cobalt, strontium, molybdenum

(Rev. 7 67)

POSSIBLE EXPLORATION GUIDES

Fluvial/Lacustrine contact mineralization (cgrn/fgrn contact)
- a. minor mineralization within limonite stained arkose at base of lacustrine sequence
- b. possible minor mineralization where carbonaceous sandstones interfinger with green mudstones

Stratigraphic Position
- a. overlain by a coarsening upward clastic sequence containing a basaltic flow
- b. underlain by an andesitic volcanic sequence that contains clastic units

Age
- a. leg bone of duck dated Miocene
- b. basalt flow within overlying coarse clastic unti dated 13-14 million years (late Miocene) by Arizona Bureau of Mines

Geochemical Alteration (?)
- a. limonite stain within basal arkose unit

OBSERVATIONS DEFINING EXPLORATION PHILOSOPHY

Present Topographic Basin not necessarily basin configuration at time of Lacustrine deposition
- a. rocks dip 5°- 15°SW
- b. NW-SE normal faulting offsets mineralized zones

Exposure of mineralized lake beds
- a. If erosion by Santa Maria River drainage system had not exposed the lake bed sequence and uranium mineralization to uranium hunters in the 1950's, the mineralization would very probably be unknown today.

Distribution of Lacustrine Rocks
- a. thickness - maximum known, 385 feet
- b. lateral dimensions - minimum 2 mile X 5 mile, maximum not determined
- c. facies changes
  1. the limestone, siltstone, mudstone sequence changes to a mudstone, siltstone, sandstone sequence to the west
  2. the limestones thin to the southwest
- d. thin to north east
- e. absent in outcrop to north - eroded or not deposited
- f. present in oil well 5 miles to the southeast, T10N R10W Sec 3

Distribution of Reducing (Paludal) Environment
- a. thickness - up to 170' of carbonaceous mudstones and siltstones interbedded with limestones, chert
- b. lateral dimensions - minimum 6000' X 20,000', maximum not determined

Distribution of Mineralization
- a. major portion conforms with the reducing environment as a tabular body of stacked mineral zones
- b. a minor amount occurs in the mudstone/siltstone/limestone unit overlying the carbonaceous mudstone siltstone unit
- c. a minor amount occurs in the basal arkose unit

Potential Clastic Units Within Underlying Volcanics
a. These zones potentially grade to lacustrine strata - a possible example is the Artillery Peak lacustrine sequence to the west.

MISCELLANEOUS OBSERVATIONS

Presence of Sulfides
a. pyrite has been identified only in the basal arkose unit

Boundary Fault Zones
a. two major NW-SE trending fault zones mark the east and west extent of the thickest portion of the lacustrine sediments

Limonite Coloration
a. yellow and orange siltstones, mudstones, and chert have been observed locally in outcrop, drill cuttings, and cores

The information used in this outline was derived from input by Minerals Exploration Company geologists who in some way have been associated with the project over the past three years either as project geologists working on the project or as geologists directly and indirectly involved.

This memo is not intended to suggest that Anderson Mine type situations provide the only potential geologic settings for economic uranium deposits in the Basin and Range province and Intermontane Basins of the Rocky Mountains. Sandstone type uranium deposits and contact type (Midnite and Pitch Mine) uranium deposits are two potential exploration targets that should not be ignored.

JRL:cm

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INTRODUCTION

The Anderson Mine Property, located in Yavapai County, Arizona, is 45 miles northwest of Wickenburg. The area is located along the northeast margin of Date Creek Basin and is bordered on the north by the Black Mountains and the Santa Maria River. The properties held by Minerals Exploration Company are mining claims and state mineral leases in Section 2-5, 8-11, 15 and 16, T11N, R10W and in Section 34 T12N, R10W.

In 1974 Minerals Exploration Company took an option on the properties, and then purchased them in 1975. Drilling has proceeded from 800 foot centers to 400 foot centers, to 200 foot centers. To date, 513 holes including 32 core holes and two geotechnical holes have been drilled.

The latest drilling program (a 306 hole, 120,000 foot program on 200 foot centers) was completed in April, 1977. This program further delineated the edge of the orebody, extended the known orebody in the northeast corner of Section 16, and confirmed the sheet-like nature of the mineralization. Data from this drilling will provide ore reserve projections and structural, hydrological and metallurgical information imperative to future developmental planning.

This report summarizes the geologic information obtained from drilling programs, field reconnaissance and other sources. The report is not a final statement on the geology of the Anderson Mine area, but is a generalized summary of a very complex geologic area.

SURFACE DRAINAGE & TOPOGRAPHIC EXPRESSION

In the vicinity of Anderson Mine the topography and drainage are primarily controlled by the Santa Maria River. However, stratigraphy, dip and faulting play an important modifying role on the topographic expression and drainage of the area.

Date Creek Basin (Figure 1) is bordered by the Black Mountains on the north and northeast, by the Rawhide, Buckskin, and McCracken Mountains on the west, and by the Harcuvar Mountains on the south. To the east and southeast it is bordered by a low drainage divide governed in part by the Harcuvar Mountains and/or the Black Mountains. The basin has a gently sloping topography to the west and northwest.

Surface Flow across the basin is accomplished by three drainages; the Santa Maria River, Date Creek and Bullard Wash. The south-flowing Big Sandy River joins the Santa Maria River in the northwest portion of the basin just west of the confluence of Date Creek and the Santa Maria. This combined drainage flows southward into Alamo River Reservoir becoming the Bill Williams River.

Tributaries of Bullard Wash are almost exclusively from drainage of the northern flank of the Harcuvar Mountains. The wash is developed along the southern margin of the basin and drainage is due west to Alamo Reservoir.

Date Creek heads in the Date Creek Mountains and courses west-southwesterly across the nearly buried southern end of the Black Mountains, and into Date Creek Basin. Near the center of the basin the drainage shifts to the northwest and empties into the Santa Maria River. Most of the surface drainage of Date Creek Basin is into Date Creek. The Date Creek Flood Plain is approximately 200 feet below the basin surface.

The Santa Maria River heads in the mountains above Bagdad, Arizona, and has a very large catchment area. The river cuts through the Black Mountains' volcanics and granite or granite gneiss "core". It then trends westerly along the southern edge of the Black Mountains on the north side of Date Creek Basin. Drainage in this northern portion of the basin is to the Santa Maria. Approximately 10 miles west of Anderson Mine, the Big Sandy joins the Santa Maria and they flow south along the western margin of the basin into Alamo Reservoir. The Santa Maria Flood Plain is cut 400 feet beneath the Date Creek Basin surface at Anderson Mine.

All of the drainage on the Anderson Mine Property is to the north and northwest into the Santa Maria River. The headward erosion of these tributaries southward into the Date Creek Basin surface has resulted in a series of subparallel gullies and ridges trending north to northwest. Maximum topographic relief at Anderson Mine is 700 feet.

Faulting (see Structure below) in the area trends northwest-southeast and many of the tributaries are developed partially along fault traces. The southerly dip and resistance to erosion of the stratigraphic section have tended to inhibit the headward migration of the tributaries.

STRATIGRAPHY

Within the boundaries of the Anderson Mine claims nine (9) informal stratigraphic units have been recognized by Minerals Exploration Company. From oldest to youngest these are: 1) Crystalline Intrusive Rocks, 2) Felsic to Intermediate Intrusions and Flows, 3) Felsic to Intermediate Volcaniclastic Sediments, 4) Andesitic Volcanic Flows, 5) Lacustrian Sediments, 6) Lower Conglomerate, 7) Basaltic Volcanic Flows and Dikes, 8) Upper Conglomerate, and 9) Alluvium (figures 2 and 3).

Crystalline Instrusive Rocks (Precambrian) ~~pe~~ J

In the extreme northeast portion of the claims group, the Santa Maria River and its tributaries have cut into a crystalline basement complex. These rocks are low in quartz content but are granitic. This granitic rock is purplish-grey in color, medium to coarse crystalline to pegmatitic and is intruded by veins of quartz and plagioclase feldspar with large crystals of hornblende and black biotite. A sample of the ~~This~~ crystalline basement complex has been dated by the Geochron Laboratories, Division of Kruger Enterprises for Bendix Field Engineering Corporation by the K-Ar method to be Jurassic (157.5+-3MY). ~~is believed to be of Precambrian age~~. In drill hole AM515 (NW¼ Sec 2 T11N R10W), 35 feet of this granite was encountered. Gamma radiation is two to three times the normal background radiation (figure 4).

Felsic to Intermediate Volcanics (Tertiary) Tvf

Unconformably overlying the crystalline basement or in fault contact with it is a series of felsic to intermediate volcanics. This series includes intrusive necks, flows, lahar breccias and tuffs. These volcanic rocks appear to be rhyolitic to andesitic in composition and are generally white to light gray in color.

Volcaniclastic Sediments (Tertiary) Tvs

Interbedded with and unconformably overlying the felsic to intermediate volcanics are tuffs, ashes and volcaniclastic sediments. All of these appear to be of felsic to intermediate composition and are, therefore, believed to be contemporaneous with the felsic to intermediate volcanics. However, deposition of this unit continued after the felsic to intermediate volcanic activity ceased, as they are also interbedded with the overlying andesitic volcanics.

The most complete section of this unit in the area is located in the northeast portion of the claims group. Here the basal part of the section is composed of white felsic to intermediate tuffs, thin ash flows or volcaniclastic sediments, lahar breccias and volcanic bombs. Volcaniclastic sediments increase upward in the section and the color changes from white to yellow tan to tan. These sediments include felsic volcanic material and arkosic sandstone.

Many aspects of these sediments (crossbedding, thin continuous beds, etc.) lead to the conclusion that they were deposited in a lake bed ancestral to the overlying lacustrian sediments.

Where exposed on the surface or encountered in drill holes, these volcaniclastic sediments exhibit no anomalous gamma activity.

Andesitic Volcanics (Tertiary) Tva

A series of andesitic volcanic flows unconformably overlies the felsic to intermediate volcanics or the volcaniclastic sediments. Reyner (1956) described the unit as a fine-grained, vesicular augite andesite locally containing calcite-filled amygdules. The flows are generally purple, red brown, gray brown, or gray. In several areas of outcrop they are interbedded by volcaniclastic sediments composed of felsic volcanic pebbles and arkosic sands. The andesitic flows have been considered "basement" at Anderson Mine, as no mineralization has been observed in or below them. Before deposition of the lacustrian sediments, erosion and faulting developed a complex paleotopography and locally thick red brown paleosols on the top of the andesitic volcanics.

Lacustrian Sediments (Miocene) Tml

The lacustrian sediments unconformably overlie the andesitic volcanics over most of the Anderson Mine Property. However, to the east-central they overlie the volcaniclastic sediments and farther to the east they onlap the fesic to intermediate volcanics. One drill hole, AM 341, encountered the felsic to intermediate volcanics or the tuffaceous part of the volcaniclastic sediments immediately below the lacustrian sediments.

Evidence now suggests that deposition of the lacustrian sediments occurred in a restricted basin (see Geologic History). Therefore, these sediments represent time-transgressive facies deposited along this margin. This type of depositional environment exhibits complex relationships between individual facies; lensing out, vertical and horizontal gradation, interfingering, etc.

Ljung et al (1976) simplify dividing these complexities by the lake bed sequence into four (4) subunits: 1) a basal coarse clastic unit, 2) a mudstone-siltstone unit containing intercolated carbonaceous zones, 3) a succession of interbedded limestones, silicified limestones, chets, mudstones and siltstones, and 4) a thin fissile, fossiliferous marker bed which has been designated the top of the lacustrine unit.

The lake sediments include green siltstones and mudstones, white calcareous siltstones, and silty limestone or calcareous tuffaceous material. Much of this material is silicified to varying extents and was derived in part, from volcanic ashes and tuffs common throughout the lake beds. Also present in the lacustrian sequence are zones of carbonaceous siltstone and lignitic material. Along the southern boundary with Urangesellschaft, drill holes encounter the basal arkosic sandstone. To the south and southwest the "typical" lake beds interfinger with and eventually are replaced by a thick, medium to coarse-grained, arkosic sandstone unit.

All of the lake beds facies exhibit some uranium mineralization. However, the highest grade and most consistent mineralization is located in the carbonaceous siltstones and lignitic materials.

In addition to the organic material in the carbonaceous zones, abundant plant remains (including twigs, reeds, and small roots) are present in the lacustrian sediments. Reyer et al (1956) recognized abundant silicified palm type wood. Fresh water mollusks, up to 1½ inches in length, are locally common. Thin laminated calcareous siltstone near the top of the lake beds contain small fresh water fish fossils. A jaw of a rhinoceros reportedly found at Anderson Mine is on display at the Wickenburg Museum. The leg bone of a duck found in the unit has been dated as Miocene by the Los Angeles County Museum. William Breed of the Museum of Northern Arizona and his associates collected fossils at Anderson Mine in April of 1977. Included in their finds were fresh water fish (Eocene to Recent), a camel bone, and a rhinoceros tooth (Miocene).

Lower Conglomerate (Miocene) Tmc

Immediately above the lacustrian sediments a tan to brown siltstone usually is present. This siltstone grades upward into arkosic sandstones and then into the conglomerate. The unit is composed primarily of arkosic sands and granitic and metamorphic clasts. Minor amounts of rhyolitic and andesitic volcanic materials are present throughout the unit. The sandstone and conglomerated may either be locally well cemented by calcite or relatively unindurated. To the southwest where the lake beds interfinger with sandstones the lower conglomerate is indistinguishable from these sandstones.

Basaltic Volcanics (Miocene) Tmb

Basaltic volcanic flows unconformably overlie the lower conglomerate forming erosionally resistant caps on many of the mesas and eroding cliffs. Ljung et al (1976) describes the basalt as "black fine-grained to aphanitic, containing calcite-filled amygdules, and commonly jointed parallel to the flow surface". The basalt attains a maximum thickness of 120 feet southeast of Flat Top Mesa and thins to the east where eventually it is no longer present. At least two flows are present in the western portion of the property. To the north east of Flat Top Mesa (NE¼ Sec 9 T11N R10W) several dikes, possibly basaltic, have been noted. These dikes cut the felsic to intermediate and andesitic volcanics, however, no direct pipe has been observed to the basaltic flows from these dikes. Wes Peirce (1977a) of the Arizona Bureau of Mines, reports that a sample of basalt taken at Anderson Mine near AM 368 (SE¼ Sec 10 T11N R10W) has been dated by Paul Damon of the University of Arizona, using the Potassium Argon Method, as being 13 to 14 million years old or Miocene in age.

Upper Conglomerate (Quaternery Tertiary) QTcgl

The upper conglomerate unconformably overlies either the basaltic volcanics or the lower conglomerate. The unit is composed of cobbles and boulders of felsic to mafic volcanics, and granite and metamorphics in a matrix of medium to coarse-grained arkosic sandstone. The unit is weakly to moderately indurated and is locally well cemented by calcite.

Alluvium (Quaternery) Qal

Unconsolidatd sands and gravels are present in most of the drainages at Anderson Mine. At least one older alluvial terrace is present in the northeast portion of the claims group. Remnants of several older alluvial deposits are present along some of the deeper drainages. Most of these older alluvial deposits have well developed caliche zones within them.

GEOLOGIC HISTORY

The geologic history of the southwest United States has been extremely complex. This complexity arises from the area's situation along the southwestern margin of the North American Plate. The area has been subjected to repeated orogenies and crustal deformations.

During the Older Precambrian era, a broad northeast trending geosyncline was dominate across central Arizona. At the end of this time the Mazatzal Orogeny transformed central Arizona into roughly northeast trending mountain ranges. Accompanying this orogeny was extensive volcanism and the implacement of many grantitic plutonic bodies.

Erosion greatly reduced this mountainous area during Middle Precambrian time. However, central Arizona remained a positive area throughout the remainder of the Precambrian, and during most of Paleozoic and Mesozoic Eras. At the end of the Precambrian the Grand Canyon Disturbance resulted in deformation and intrusion of diabase to the northwest and southwest of the positive area.

During the Paleozoic Era, the positive area (Mazatzal Land) remained relatively stable. The Cordillaran Geosyncline to the northwest and the Sonoran Geosyncline to the southeast of Mazatzal Land became very active and were the sites of deposition of thousands of feet of Paleozoic sediments. Deposition in these geosynclines continued into the Mesozoic.

In the Mesozoic the relative movement of the North American Plate westward or northwestward increased the compressional forces on western North America. A trench or subduction zone formed along the North American Plate margin and the small plate(s) between this plate and Pacific Plate were subducted. This activity initiated a series of orogenies that generally progressed eastward deforming the cordillarian geosyncline. Although parts of this general activity have been separate names, many workers now apply the name Laramide Orogeny to the entire series of deformations. The Laramide Orogeny also affected the Sonoran Geosyncline. Orogenic activity continued into the Cenozoic Era.

In the middle of the Cenozoic, in the Late Oligocene, the East Pacific Rise was subducted in the California trench system or passed eastward under the North American Plate. Whichever occurred, the trench system ceased, transform movement between the North American and Pacific Plates was initiated, compression forces were released, and tensional forces began. With the transform movement and related tensional forces, western North America was literally pulled apart. The basin and range block faulting is the result of this activity. Commonly associated with this activity are basaltic volcanic occurrances.

The geology at Anderson Mine reflects many of these regional geologic trends. The mine is located in an area that has been marginal or is marginal to every regional deformation. It was on the northwestern margin of Mazatzal Land, the southeastern margin of the Cordillarian Geosyncline, deformed by the Laramide Orogeny, and is presently on the margin of the Basin and Range Physiographic Province.

The granites at Anderson Mine are probably of Precambrian origin. As such, they may represent a plutonic intrusion implaced during the Mazatzal Orogeny.

The lack of Paleozoic and Mesozoic rocks in the area is the result of the area's position on the margin of Mazatzal Land. Rocks of these ages were eiher not deposited or were eroded from the area.

After this long period of relative quiescence, the Laramide Orogeny began in the Mesozoic. The California trench system was actively subducting the small plates between the Pacific and North American Plates. Subduction is normally associated with felsic to intermediate volcanic activity behind the trench on the non-subducted plate. The felsic volcanics at Anderson Mine appear to conform to this general pattern. It is expected that dating of these volcanics would provide dates falling in the late Cretaceous to Middle Tertiary.

With the cessation of the trench system at the end of the Oligocene, basin and range block, transform, and normal faulting began. The lacustrian sediments have been dated Paleontologically as Miocene and ~~with~~ a geochemical date of Miocene (13 - 14 M.Y.) for the basalt. The lake beds are probably early or middle Miocene. During this time volcanism was waining, however, ashes and tuffs would still have been common ~~as the last gasps of volcanism.~~

Drill hole data from the Anderson Mine, shared information with Urangesellschaft and information obtained from Exxon, Public Service of Oklahoma and Sohio lead to the conclusion that deposition of the lacustrian sediments occurred in a very restricted area. To the north of Anderson Mine in Section 4, T11N, R10W, the basalt caps Hill 2826 and is underlain by the lower conglomerate. This in turn rest unconformably on the "basement volcanics". Two possibilities arise: 1) the lake beds were never deposited here, or 2) they were deposited and subsequently eroded. Since the lake beds are thinning rapidly northward, it is felt that the lake beds were never deposited here. The intertongueing and interfingering of the "typical" lake beds with clastic siltstones and medium to coarse grained sandstones to the southwest and south limits the lake in this direction. The relationship of coarse-grained lithologies in this direction and the lack of them to the north in the "typical" lake bed sequence implies that the sediments source was from the west or south. Urangesellschaft drilling has traced the lake beds and mineralization to the southeast. Public Service of Oklahoma drilling to the southeast of Urangesellschaft has encountered interbedded green siltstones and sandstones and little mineralization. Thus it appears that the lacustrian sediments were deposited in an area less than three miles wide and only about five or six miles long. The lake trended roughly northwest-southeast, generally parallel to the dominate Post-Oligocene faulting trend of the area. One further lithologic implication is of interest. The northern and northeastern margin of the lake was probably the Black Mountains, however, they must have been topographically lower, only a slight bit above the lake beds, as there are no coarse clastics in the lake sediments along this margin.

The lower conglomerate overlying the lake beds attests to the continuation of basin and range faulting and development. Erosion from nearby sources, possibly from the north or northeast, is indicated. Near the end of Miocene the basaltic volcanics flowed across the area, possibly marking the passage of the East Pacific Rise beneath the area. Normal faulting continued and the upper conglomerate was deposited. Its very coarse ~~aspect~~ texture implies very near sediments sources and a very high energy environment of deposition. The inclusion of fresh basaltic boulders suggest the source was to the north and that the transporting agent may have been the Santa Maria River.

STRUCTURE

The Anderson Mine Property is located in the Basin and Range Physoigraphic Province and exhibits the general structural pattern common to the province. Parallel to subparallel fault blocks with usually normal bounding faults predominate. These faults are often rotational or hinged and may have experienced some logitudinal movement. While much of the basin and range faulting is on the magnitude of thousands of feet of displacement, displacement along faults at Anderson Mine are measured in tens and hundreds of feet.

At Anderson Mine faulting was active prior to and during the deposition of the Miocene section (lake beds, lower conglomerate and basalt). The general 5° to 15° to the south appears to be the result of the recurrent nature of the faulting and may be in part the result of fault hinging and rotation of fault blocks. Drag folds are common along many of the faults and in these areas dips may surpass 20°. Many of the onlap, pinchout and lens relationships in the lake beds are probably due to or related to recurrent faulting.

The recurrent and hinging nature of the faulting makes it extremely difficult to predict how a specific fault will affect the individual units along it. At one point along a fault there may be only a few feet of vertical displacement while two hundred feet beyond that point portions of the section may be displaced several tens of feet. Many of the faults that displace the lake beds show diminished or no movement in the basalt and most of the faults die out before or in the upper conglomerate.

Three major faults, the East Boundary Fault System, Fault 1878, and the West Boundary Fault System are present in the area. In addition to these are many parallel faults which have less displacement than the major faults.

All of these faults trend between N30°W and N55°W. Another set of faults trending more westerly (N65°W) are present at least in the south-central portion of the property. A set trending northeast has been conjectured by Urangesellschaft and others but has not been observed in the field.

The West Boundary Fault System includes at least two distinct normal faults. Movement on these faults is down to the southwest. Vertical offset of the volcanic basement across the two faults is approximately 400 feet. Another fault is indicated to the southwest which vertically offsets the volcanic basement about 250 feet. While total vertical offset of the basement volcanics across the West Boundary Fault System is over 700 feet, vertical offset of the basalt is less than 200 feet.

Fault 1878 in the east-central portion of the properties exhibits 200 feet of vertical displacement near the boundary with Urangeshellschaft. To the northwest along the fault displacement appears to decrease and movements appear to be distributed across a zone of faults. The movement along this normal fault has been down to the southwest. Along the zone of faults, movement (while generally down to the southwest) has produced horst and graben features.

The East Bountary Fault System consists of several large faults along the eastern and northern portion of the porperties. These faults are beyond the limits of mineralization and therefore, very little is known about them. In general they are downthrown to the southwest and several of them probably have displacements approaching a thousand feet.

MINERALIZATION

Uranium mineralization at Anderson Mine is primarily associated with carbon. In the "typical" lake beds ~~carbon is present in the~~ carbonaceous siltstone and lignitic facies are present. These facies are the primary mineralized zones at Anderson Mine, and it is suspected that mineralization that appears to be unassociated with carbonaceous material, may in fact, be associated with such material. This association may be around the pinch out of carbonaceous material or with very thin carbonaceous laminae.

Occasional mineralization has also been noted in the basal sandstone of the lacustrian sediments and in the lower conglomerate. Carbonacesou material is known to interfinger with the basal sandstone and carbon has been noted in the lower conglomerate. Remobilization of the uranium has resulted in the deposition of mineral as fracture fillings around and below the main mineralized zones.

The mineralization is syngentic ~~or nearly so~~ as evidenced by the continuation and offset of mineralization across faults. Carbon tends to immediately fix uranium when soluble uranium comes in contact with it. Much of the mineralization is at the top or bottom of the carbonaceous facies,however, mienralization does occur in the middle of some carbonaceous zones. This later relationship implies that mineralization occurred during the deposition of the carbonaceous material.

Silicification of various parts of the Anderson Lake Sediments probably occurred soon after deposition. Devitrification of the tuffaceous and ashy lake bed sediments and/or the felsic volcanics was probably the primary sources of silica. This silicification would tend to lock the uranium mineralization and protect it from remobilization.

The ~~source~~ origin of the uranium at Anderson Mine presents some interesting possibilities.

Reyner and others (1956) suggest three possible origins for the uranium at the Anderson Mine property: hypogene, ash leach, and bog deposition. A fourth possible origin, mobilization across Date Creek Basin is discussed at the end of this section.

"Reyner et al (1956) cites field evidence in favor of a hypogene source and state 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; 4) calcite, chalcedony, sepiolite, and manganese are found associated with the west bounding fault. This field evidence can be interpreted differently. Drilling data indicates that the carbonaceous sediments also have not been observed beyond the boundary faults. This may explain why the mineral is localized within the boundary faults. Further, if uraniferous solutions migrated up faults, one would expect mineral and grade to be concentrated along the faults. Subsurface interpretations indicate no such association. Data indicates that faulting offsets mineralization. Intense silicification is ~~most~~ probably a result of devitrification of silicic volcaniclastic sediments. Bentonite, common in the area, is also an alteration product of tufface-ous material. Hematite and limonite stain on bedding and fracture planes was possibly derived from pyrite associated with carbonaceous material. Calcite, sepiolite, chalcedony, and manganese deposited along the western fault may indicate movement of fluids along this zone; but without associated uranium, such deposits cannot significantly be cited as evidence that uraniferous solutions migrated up the fault zone.

"Reyner et al (1956) speculate that two other types of origin are possible: ash leach and bog type deposition. Both leaching of ash and deposition in bog type reduction traps are conceivable. Reyner further alludes to a vitrophyric andesite source. Andesite is not commonly a uranium source. Silicic volcanic rocks are known to contain anomalous amounts of uranium (Love, 1961; Turekian and Wedepohl, Table 2, 1961)... The presence and diagenesis of the tuffaceous component of the lacustrine sediments in combination with adjacent geochemically favorable paludal sediments, provides a possible ash leach-bog deposition model for the origin and deposition of uranium at the Anderson Mine property... The known affinity of uranium for carbonaceous material (Bredger, 1974) accounts for the fixation of uranium within the paludal unit." (Ljung, et al, 1976)

A fourth possibility is that the uranium was mobilized from the western Date Creek Basin, carried by ground water across the basin and deposited in the reducing environment of the lacustrain sediments. It is interesting to note that uranium mineralization in the western Date Creek Basin is limited to the Artillery Peak Formation of Oligocene Age. Overlying the Artillery Peak Formation is the Chapin Wash Formation which is composed of altered (red) arkosic sandstones. Pierce (1977) suggests correlation of the Chapin Wash and the Anderson Lake Sediments. Sedimentation at Anderson Mine suggests a western or southern source. Groundwater movement during the Miocene, therefore, may have been easterly across the basin from the west. Uranium, remobilized from the Artillery Peak Formation or derived from the same but later source, could have been carried in soluble form across the basin to the lacustrian sediments where the reducing environment of the carbonaceous facies precipitated its deposition. Other sources (ashes, tuffs, and granites) may have contributed to some extent to the mineralization of the lacustrian sediments.

Support for this source, over devitrification, is implied by mineralization throughout the carbonaceous materials. If the source had been from overlying sediments containing volcanic fragments, mineralization would be expected only at the top of the carbonaceous zones. Further if mineralization had been tied with devitrification, uranium should be present in all of the partings and fractures where silica was deposited. This is not the case at Anderson Mine.

HYDROLOGY

Groundwater in the Anderson Mine area appears to be controlled by structure. Groundwater movement appears to be along fault blocks and to the northwest. Catchment and recharge is possibly along the Black Mountains in the Aso Pass-Tres Alamos area. Groundwater movement may be directed and restricted by faults; and fault zones at Anderson Mines, if continuous, would be exposed in this area of the Black Mountains. Restriction of groundwater reservoirs by faults at Anderson Mine is indicated in several areas. For instance, water table levels vary nearly 150 feet between drill holes AM 405 and AM 424 (SE 1/4, Sec 10, T11N, R10W) which are only 300 feet apart.

Water Development Corporation is compiling an in depth study of the hydrology and information from Dames & Moore's report on pit slop stabilities may provide more detail on groundwater in the area.

~~Walt Johnson~~

~~Mon 9:45~~

~~at 11:00~~

Pt or J

~~On the Regional Maps the Tvb and Tap unit~~

In the immediate ~~area~~ vicinity of Anderson Mine the Tvb and Tap (. and Tertiary Artillery peak Formations) have not been observed. It is possible that these units are present at depth beneath the Tertiary Andesitic Volcanics. Tvc Tvs Tva = Ta

The largest problem with the regional maps is that they lump under the Ta (Tertiary Anderson) the Anderson Lacustrian sediments (Tml) the Chapper Wash Formation and ~~the~~ many of the occurrences of the Tertiary Volcaniclastic Unit (Tvs). In the case of the Chapper Wash Formation and the Anderson Lacustrian Unit this is not misleading as the two units appear to interfingure. However as the Lacustrian unit is very distinctive, with its Limestones, green siltstones and silicified nature, it should be mapped as a separate unit. In the Case of the the Tertiary Volcaniclastic Unit (Tvs) it is very misleading to incorporate it with the Lacustrian Unit (Tml). The Tvs unit is light colored and on air photos and from a distance appears ~~to~~ very similar to ~~the~~ the lake beds. Most of the Ta exposures labeled on the north side of the Santa Maria River are actually the Volcaniclastic unit. Future field work should determine the proper nature of these three units and make the needed Connections on the maps. Tmc = Tt, Tmb = QTv, QTcgl = Tt

Notes for Regional Geology Maps

Background Bukavic Did Work, Year
From Aerial Photos + 2? Field Days
Modified by Cyh in Anderson Mine Area.

QLS .
QTv = Tmb
Tft May include Tmc Tmb and QTcgl

Ta (red Beds) Chappen Wash Fm
Ta = Tml Lake Beds includes Volcaniclastics
Ti ?? Tvs
Tvfi intrusive
Tap Artillery Peak Fm Eocene or Cret.
Trb
PЄ
STRATIGRAPHY Tynnasin

Describe Units inclusions Probabilities Problems

STRUCTURE

Suggested Further Work
Reasons Knowledge

Pe

TVS Because of their light (Gray to Wht) Color this unit has been improperly map across the area. Most often it was incorrectly mapped as Ta however in some cases it may be incorrectly mapped as Tap.

Tap Artillery Peak Formation

Trb? Base Red to Red Brn Arkosic SS.

Sh Ls SS (Diabase? Dikes) Ash flow Tuff.

Ta: At Anderson Mine ~~[illegible]~~ the Unit labled Ta consists of the Tertiary Miocene Lacustrian sediments. These may include the Lower Conglomerate. To the West of Anderson Mine to Palmerita Ranch Units Lable Ta ~~between An~~ include Chapper Wash red bed SS and Conglom and Lacustrian sediments as at Anderson but lacking carbonaceous facies. Along and to the north of the Santa Maria River Units Lable Ta are in most cases if not all cases actually the Tertiary Volcaniclastic Unit (TVS)

~~[illegible]~~ Problem's (Areas)

Philite in Sec 21 + 22 T12N R13W an in Sec 33 T12N R12W

~~Artillery Peak Fm? in Sec 33 T12N R12W~~

~~Artillery Peak Fm? in Sec 16 + 21 T11N R12W~~

~~Massive Conglomerate in Sec 8 T11N R11W~~

~~Artillery Peak FM???? in Sec 13 T10N R9W~~

Hugh Harris

PROBLEMS and PROBLEM AREAS

Phyllite or Schist. A phyllite or schist has been noted in the Artillery Peak Formation in Sections 21 and 22, T12N, R 13W and in Section 33 T12N R12W or Sections 3 and 4 T11N, R12W. ~~At~~ the last location the Tap? is in contact with a volcanic that may have been exposed to hydrothermal alteration.

An interesting problem is if the above out crop is the Artillery Peak Formation. Also are the beds outcroping in Sections 16 and 21 T11N, R12W Artillery Peak. Further are all the patches of Artillery Peak Formation to the east of the Big Sandy river really the Artillery Peak Formation. If all

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