Reconnaissance Study of Uranium Deposits in Arizona

GEOLOGICAL SURVEY BULLETIN 1147-A

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

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By H. C. GRANGER *and* R. B. RAUP

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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RECONNAISSANCE STUDY OF URANIUM DEPOSITS IN ARIZONA

By H. C. GRANGER and R. B. RAUP

ABSTRACT

Between 1950 and 1954 a large number of deposits in Arizona were examined in search of uranium-bearing minerals in minable concentrations. This report describes most of the localities at which anomalous radioactivity was detected.

Five of the localities are of particular interest, either because uranium is produced from them or because of their unusual geologic setting. The deposit on the Orphan claim, in Coconino County, contains material equivalent in radioactivity to as much as 12.5 percent U in a pipelike body, and the deposit exposed in Hack's mine in Mohave County is in a somewhat similar pipe. The deposits in the Dripping Spring quartzite of Precambrian age in Gila County are unusual in that they appear to be genetically related to diabase. A considerable quantity of uraninite-bearing ore has been produced from several of the many deposits in siltstone, and siltstone metamorphosed to hornfels, within the Dripping Spring. The economic possibilities of the Annie Laurie prospect in Santa Cruz County could be evaluated by exploratory drilling to the east of the eastward-dipping fault zone. Earlier drilling west of the faults gave negative results. Specimens of uranium ore found on the dumps of the Abe Lincoln mine in Yavapai County may indicate the presence of small but rich pockets of ore in the mine, but the workings are inaccessible because of caving and flooding.

The deposits in the Dripping Spring quartzite have received additional study by us, and the deposit on the Orphan claim recently has been extensively developed. Additional study of Hack's mine might be profitable, and the Annie Laurie and Abe Lincoln deposits might be worthy of further study and development.

INTRODUCTION

As interest in the uranium deposits of Arizona increased after World War II, owing to the immediate need for fissionable materials, the U.S. Geological Survey examined known and reported occurrences of uranium in Arizona and searched for new deposits on the basis of geologic evidence. The more notable uranium deposits examined by the authors between 1950 and 1954 are described in this paper.

Granger, accompanied at times by E. P. Kaiser and J. W. Adams, examined reported occurrences of uranium in Arizona during parts of 1950 and 1951. Raup, with D. V. Haines, looked for previously unknown occurrences of uranium in Arizona from late in 1952 until March 1954. The area in which he worked did not include Coconino, Apache, and Navajo Counties, nor the northern half of Mohave County. Granger and Raup made an extensive study of deposits in the Dripping Spring quartzite in 1954–57, and Granger examined the Orphan deposit in 1958 for the U.S. National Park Service. Summaries of these later investigations are included in this report. More recent studies of several of the deposits discussed have been made by other geologists, but, except for brief statements about samples, none of the results of this later work are cited in this report. Publications of some of these workers are, however, referred to in the text. Our work was done on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission.

Uranium minerals in Arizona occur in a wide variety of geologic settings. Deposits in sandstone are common in the northern part of the State, but not all these are of the "Plateau type," or layered, nearly concordant deposits that generally occur in continental sandstones. Aberrant occurrences are found at Hack's mine and on the Orphan claim. Veinlike deposits occur abundantly in altered siltstone in Gila County, near the center of the State, and others occur in various kinds of rock throughout the southern half of the State. Deposits of disseminated uranium minerals occur in Mohave, Pima, Graham, and Gila Counties. The mineralogy of the deposits is also diverse; for example, the principal uranium-bearing mineral is carnotite, metatorbernite, kasolite, pyromorphite, or uraninite at one or more of the deposits described in this report. Some rarer minerals that have been identified include bassetite, schoepite, dumontite and saleeite.

Figure 1 shows the locations of all deposits described in this report. In the text, descriptions of the geology and mineralogy of the individual deposits are arranged alphabetically according to the counties in which they occur. Uranium-assay data given in the text are from several laboratories, not all of which use the same system of reporting results. Therefore, some analyses are in terms of percent U or eU (uranium or equivalent uranium) whereas others are in terms of percent U_3O_8 or eU_3O_8 (uranium oxide or equivalent uranium oxide).

E. D. Wilson and J. W. Anthony of the Arizona Bureau of Mines, and Steven Malloy, LaMar Evans, and others at the Southwest Experimental Station of the U.S. Bureau of Mines extended many courtesies and gave us many helpful suggestions. R. J. Wright of

the U.S. Atomic Energy Commission conducted Granger to several deposits and supplied unpublished information. Many miners and prospectors were especially helpful.

DESCRIPTION OF DEPOSITS

The following descriptions of deposits are based on work that ranged from reconnaissance examinations to detailed field examinations accompanied by laboratory study. The information on the deposits therefore ranges widely in completeness. The amount of data given in the description of any deposit is not necessarily an indication of its relative economic importance. Deposits previously described in published reports have been described only briefly in the present report, and the reader should consult the articles listed under "References cited" for more details concerning these deposits.

COCHISE COUNTY

FLUORINE HILL DEPOSIT

The Fluorine Hill deposit is in secs. 33 and 34, T. 17 S., R. 25 E., 2½ miles east of Pearce. Fluorine Hill is mainly composed of partly silicified rhyolite cut by narrow and discontinuous fractures. Most of the fractures are stained with hydrous iron oxides and are partly filled with veins of calcite and hematite, rarely more than 2 or 3 inches wide.

The greatest amount of radioactivity was detected in a prospect pit on the south side of the hill, near its crest. A narrow carbonate vein exposed in this pit contains a small amount of dark-purple fluorite and flecks of a yellow uranium-bearing mineral that is probably uranophane or autunite. The vein can be traced for less than 25 feet on the surface, even with the aid of a scintillation meter. A grab sample of the vein material exposed in the prospect pit contained 0.11 percent uranium.

The other prospect pits and mine dumps on Fluorine Hill contained no material that was significantly more radioactive than the host rock, and no concentrations of uranium-bearing minerals were found in any of the fractures exposed at the surface. The rhyolite porphyry host rock, however, showed a slightly abnormal radioactivity in all the exposures checked on Fluorine Hill and the other hills nearby. A representative sample of the rhyolite porphyry contained 0.008 percent eU.

The secondary uranium minerals found in the prospect pit on Fluorine Hill may have been derived from the host rock and concentrated in the vein by circulating ground water, or they may have replaced primary uranium-bearing minerals that were deposited in

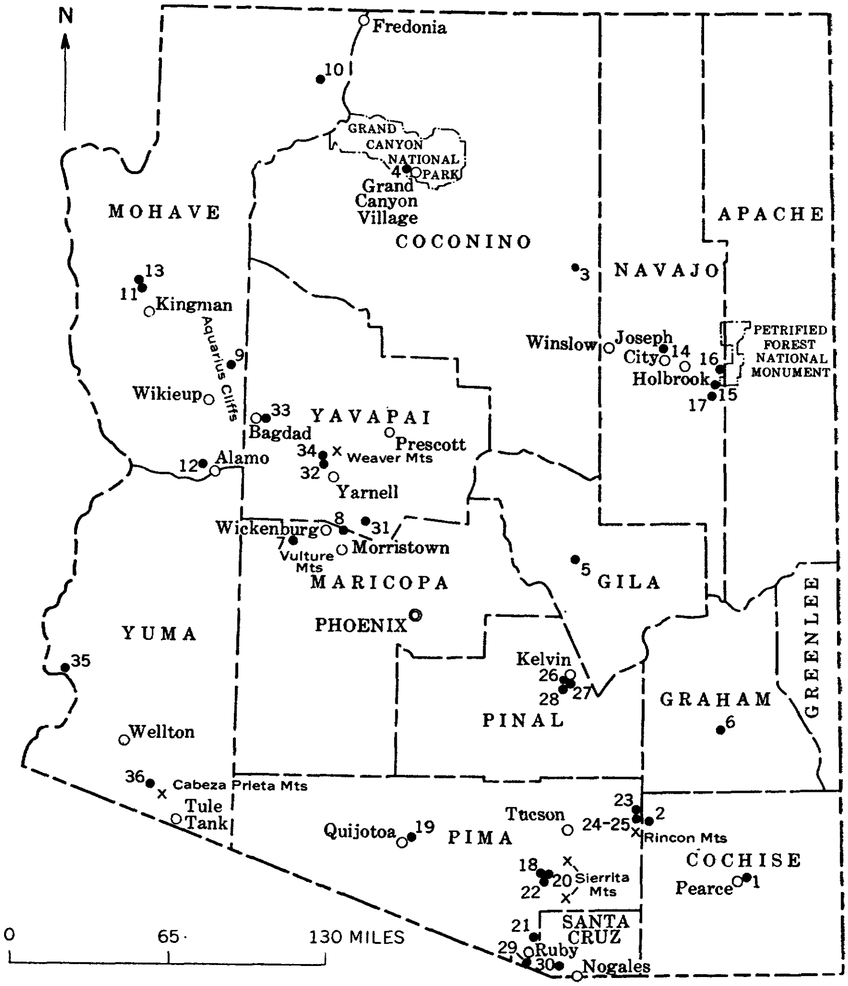


Figure 1.—Index map of Arizona, showing location of uranium deposits described in this report. (See table on facing page for names of deposits.)

the vein from hydrothermal solutions. The latter explanation seems the more probable, for fluorite and uranium-bearing minerals are commonly associated in hydrothermal deposits.

ROBLES SPRING DEPOSIT

The Robles Spring deposit is in the SW¼ sec. 30, T. 13 S., R. 19 E., about 30 miles east of Tucson. It is explored by a short adit and a shallow prospect pit. The adit follows a nearly vertical iron-stained shear zone that rolls and merges with the bedding below the adit level. The workings, which were probably dug in search of precious metals, *Uranium deposits shown on figure 1*

Cochise County

1. Fluorine Hill deposit
2. Robles Spring deposit

Coconino County

3. Hosteen Nez Mining Co. deposits
4. Orphan claim

Gila County

5. Dripping Spring quartzite

Graham County

6. Golondrina claims

Maricopa County

7. Black Mountain claims
8. Lucky Strike claim

Mohave County

9. Catherine and Michael claims
10. Hack's mine
11. Jim Kane mine
12. Red Hills prospect
13. Summit mine

Navajo County

14. Anna Bernice claims
15. Petrified Forest area
16. Tract No. 1
17. Tract No. 2

Pima County

18. Black Dike deposit
19. Copper Squaw mine
20. Glen claims
21. Iris and Natalia claims
22. Lena No. 1 and Genie No. 1 claims
23. Sure Fire No. 1 claim

24, 25. Van Hill
Nos. 5, 7, and 8 claims

Pinal County

26. Honey Bee No. 4 claim
27. Shorty claims
28. Wooley No. 1 claim

Santa Cruz County

29. Annie Laurie claims
30. White Oak property

Yavapai County

31. Abe Lincoln mine
32. Cuba and Independence claims
33. Kitten No. 1 claim
34. Peeples Valley mine

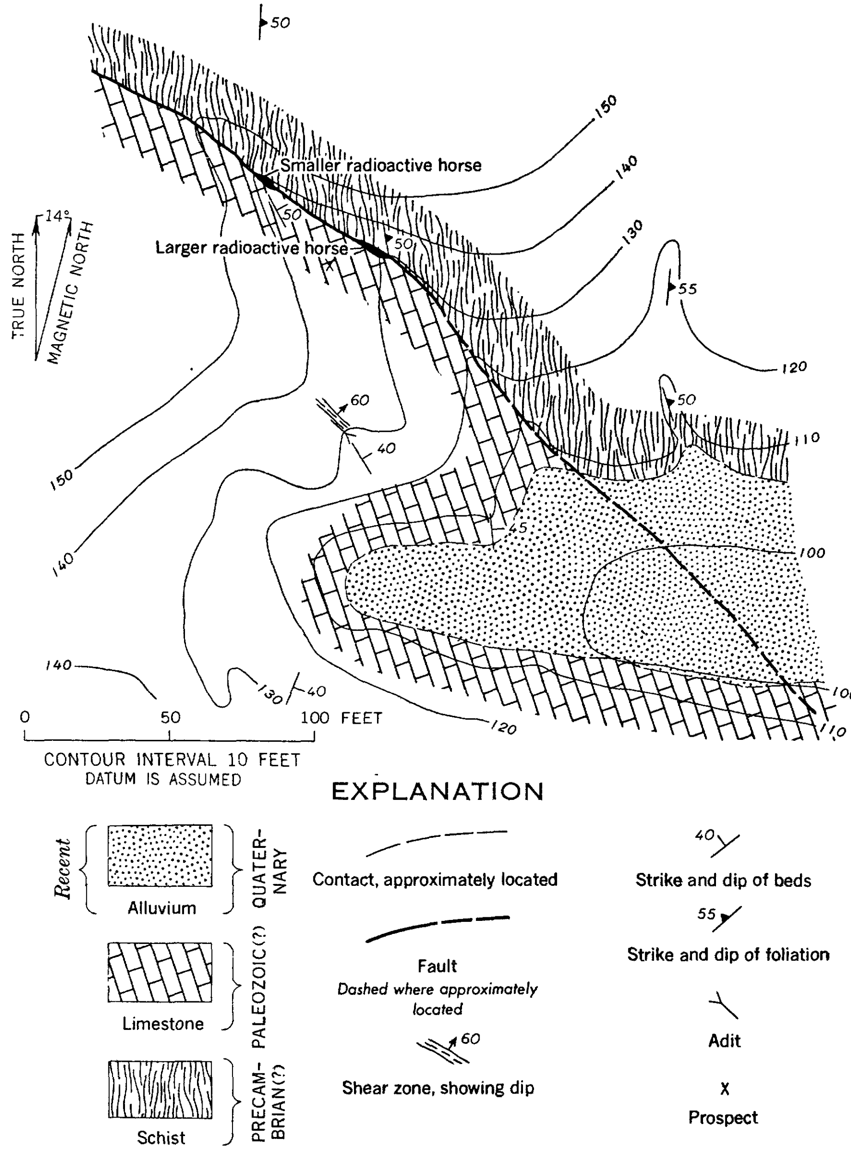
Yuma County

35. Atom claims
36. McMillan prospect

are not related to the structure that controlled the deposition of radioactive minerals.

The uranium-bearing material occurs north of the adit, along a nearly vertical northwest-trending fault which has placed limestone in contact with schist (fig. 2). The area has received little geologic study and the ages of the rocks are unknown; the limestone, however, is probably Paleozoic and the schist Precambrian. The former includes beds of fine crystalline limestone, shaly limestone, pebble conglomerate, and limestone-quartzite pebble conglomerate. The schist is fine grained, gray, and locally calcareous, and it contains numerous blebs of pegmatitic quartz. Its foliation trends slightly west of north and dips about 50° E.

The length and displacement of the fault were not determined but may be relatively large. The fault zone, which is characterized by local fractures, breccia, iron stain, and less resistance to erosion, is weakly radioactive along an outcrop length of 100 feet. The greatest radioactivity is in two fault blocks, or horses, of carbonaceous fractured and iron stained shale in the fault zone; the larger block is about 15 feet long and 5 feet wide, the other about 10 feet long and nearly 4 feet wide. Many of the fractures are filled with a powdery



Geology and topography by H. C. Granger, 1951

Figure 2.—Geologic sketch map of the Robles Spring deposit, Cochise County, Ariz.

yellow mineral, probably an iron sulfate. Iron stain and carbonaceous matter are less abundant in the smaller horse.

A channel sample across the larger horse contained 0.004 percent U and 0.078 percent eU. This suggests that some of the original uranium may have been removed by leaching.

The radioactivity may be from minerals deposited by solutions percolating in the fault zone or may be from material mechanically emplaced by the fault. The carbonaceous shale appears to have been favorable for precipitation of uranium, but its source is not known. Finding the source of the shale would be of great help in prospecting for more deposits of the Robles Spring type. If that were done, it could be determined whether all the shale is radioactive, or only the shale in the two horses in the fault zone.

COCONINO COUNTY

HOSTEEN NEZ MINING CO. DEPOSITS

The Hosteen Nez Mining Co. owns several deposits in T. 27 N., R. 12 E., on the Navajo Indian Reservation, about 40 miles north-northwest of Winslow.

Two deposits examined are in varicolored shale and sandstone tentatively assigned to the upper part of the Chinle formation of Late Triassic age. The northern deposit is exposed in the walls of a draw; the radioactive material is in the south edge of a lens composed of sandy shale, sandstone, and a few clay pebbles. A yellow uranium mineral partly replaces clay pebbles, coats fractures and bedding surfaces, and impregnates manganese-rich concretions and carbonized fossil wood. The manganese concretions are commonly very rich in uranium; one specimen contained 3.88 percent U_3O_8. An 8-foot sample across the radioactive lens, however, contained only 0.035 percent uranium.

Between the northern and the southern deposits the float contains uraniferous manganese nodules, which evidently weathered out of the very small, widely separated concretionary deposits.

The southern deposit caps the summit of a small knoll. Its uranium occurs chiefly in manganese-rich concretions and partly silicified fossil wood, but locally the sandstone itself is radioactive. About 4 tons of hand-picked ore from the surface of the knoll contained 0.20 percent U_3O_8. A selected sample collected by Granger contained 0.44 percent U.

ORPHAN CLAIM

The Orphan claim is a patented mining claim entirely within the Grand Canyon National Park, immediately west of Maricopa Point on the south rim of the Grand Canyon and approximately 6,500 feet northwest of the park headquarters at Grand Canyon, Ariz. The claim was located in 1893 and was patented before the establishment of the park. It was originally worked for the copper content of its ores, but mining activity since 1951 has been centered on uranium. Western Gold & Uranium, Inc., has been largely responsible for exploring, developing, and mining the uranium deposit.

The rocks on the Orphan claim are Pennsylvanian and Permian in age, although older rocks are exposed in the canyon wall below the claim. The rocks, from older to younger, are the Supai formation of Pennsylvanian and Permian age, and the Hermit shale, Coconino sandstone, Toroweap formation, and the Kaibab limestone, all of Permian age. The Kaibab limestone forms the rim of the canyon (fig. 3).

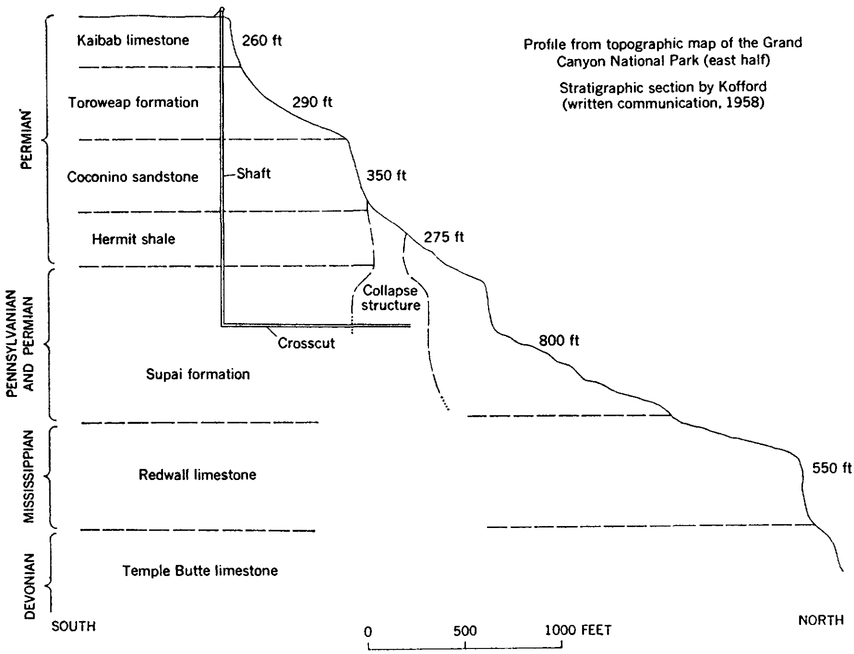


FIGURE 3.—Diagrammatic cross section of the south wall of the Grand Canyon through the collapse structure on the Orphan claim, Coconino County, Ariz.

The uranium deposit is in a nearly vertical, circular to elliptical pipelike body of collapse breccia. Exposed parts of the collapse structure at the surface cut both the Coconino sandstone and the Hermit shale; most of the rock exposed by mining within the structure is Coconino sandstone. The ultimate depth to which the structure extends is not known, but it may cut all the formations exposed in the walls of the Grand Canyon (fig. 3).

At the time of the original examination by Granger, in 1951, there were three small workings on the property, all dating from the early copper mining. The upper working was a small pit about 5 feet deep at the contact between the Coconino sandstone and the Hermit shale, about 35 feet southeast of the collapse structure. A small pool of water in it suggested that the pit may have been dug primarily as a source of water. A little efflorescent material on the walls was weakly radioactive.

The middle working, which was about 80 feet lower than the upper working, was in Coconino sandstone along the southeast margin of the collapse structure. The main adit trended S. 20° W. for about 25 feet, and a 15-foot working branched from the main adit near the portal. A fracture in the main adit contained malachite and iron oxides, but other nearby fractures were essentially barren. The sandstone contained blebs and streaks of copper sulfate minerals, chrysocolla, hematite, and some sulfide minerals. The walls of the adit were covered with efflorescent iron and copper minerals associated with gypsum. A composite sample composed of rock chips taken every 5 feet along the walls of the main adit contained 0.043 percent U and 0.064 percent eU.

The lower working was in the lowest outcropping part of the collapse structure, about 150 feet lower than the normal base of the Coconino sandstone. An adit extended S. 55°–50° W. for 45 feet, then turned sharply and extended S. 28° E. for 25 feet. Within the adit nearly all the sandstone was impregnated with pyrite, arsenopyrite, chalcopyrite, and hematite; secondary and efflorescent minerals were chrysocolla, chalcanthite or brochantite, and gypsum. At the portal of the adit was a vertical iron-stained shear zone about 5 feet wide that locally contained torbernite. The strike of this shear zone was about N. 25° W., nearly normal to the trend of the adit.

A composite sample composed of rock chips taken every 10 feet along the walls of the lower adit contained only 0.006 percent U. In sharp contrast, 3 channel samples cut across the torbernite-bearing shear zone near the portal contained 0.093 to 0.72 percent U, and 0.21 to 1.00 percent eU. A selected sample of iron-stained rock on a weathered wall of the shear zone contained only 0.039 percent U but 12.5 percent eU.

Since the original examination, Western Gold & Uranium, Inc., acquired the property and sank an underground shaft collared in a short adit near the portal of the lower working. From this shaft they have driven more than 1,500 feet of workings on several levels. In 1959, a 1600-foot shaft was sunk from the canyon rim and a crosscut more than 800 feet long was extended into the collapse structure.

The geologic setting of the Orphan deposit was not well understood until Western Gold & Uranium, Inc., had done extensive mining and drilling. This exploration has demonstrated that the collapse structure has a fairly abrupt shoulder near the contact between the Hermit shale and the underlying Supai formation. It has a diameter of about 175 feet at the outcrop and widens downward to about 400 feet in the upper part of the Supai. Evidence from drill holes suggests that the north wall of the structure may be deflected northward once more in the lower part of the Supai formation, but no information is available on the attitude of the south wall for more than about 100 feet below the shoulder.

The rocks in the collapse structure are highly fractured, bleached, and altered. Large blocks of sandstone, shale, and limestone are disoriented in relation to the stratification of the surrounding rocks. The blocks are displaced from their normal stratigraphic position but show remarkably little evidence of jumbling and mixing in some parts of the mine.

Blocks of Coconino sandstone are found at least 275 feet below their normal stratigraphic position. Hermit shale is rare in the upper mine workings and at the outcrop of the structure, but it is present in the lower workings as blocks of argillite and finely divided interstitial material between sandstone blocks. The limestone blocks are intermixed with the sandstone blocks and in some places replacement limestone forms a nearly homogeneous envelopelike mass as much as 60 feet thick at the margins of the structure. Much of the limestone probably results from a calcitic replacement of blocks and fragments of Hermit shale.

The rock immediately outside the structure is almost invariably bleached and altered for a few feet, but nowhere is it known to contain ore, nor is it replaced by calcite.

The ore seems to be entirely within the collapse structure. Mining and drilling have shown that most of the ore within 175 feet below the outcrop is in an arcuate body that generally parallels and locally touches the north wall of the collapse structure. Other ore bodies, probably smaller and perhaps more poorly defined and discontinuous, occur against the south wall and elsewhere within the collapse structure. Much of the rock between the ore bodies also contains abnormal amounts of uranium and sulfide minerals but of a lower grade.

The ore bodies are seemingly localized for the most part in the zone in which the collapse structure increases in diameter in passing downward from the Hermit shale into the Supai formation. The results of drilling strongly suggest that the periphery of the collapse structure is most favorable for ore and that this ringlike zone is thickest just below the shoulder of the structure and narrows downward. There is almost no ore in drill cores from parts of the structure more than 400 feet below the outcrop. The central part of the structure, enclosed by the favorable peripheral zone, is almost entirely devoid of ore. Within the favorable peripheral zone the rocks appear to be more shattered and the fragments of different rocks more mixed than elsewhere. The most favorable host for uranium ore seems to be shattered sandstone, although much of the limestone contains ore of good grade. Shattered Hermit shale or argillite, where not at least partly replaced by limestone, is generally a poor host rock.

The dominant ore mineral in the deposit is uraninite. It is generally disseminated in the host rock but locally forms lenses or veins several inches thick of relatively pure uraninite. It is associated with pyrite and other sulfide and sulfosalt minerals that contain copper, lead, zinc, cobalt, nickel, and molybdenum.

Secondary minerals of uranium, copper, and molybdenum are common on the surfaces of the mine workings but have little economic importance.

The geologic history of the collapse structure is uncertain. One concept is that it may have originated by a deep-seated explosion of gas of magmatic origin. Mr. Max Kofford, mine geologist at the Orphan claim (oral communication, 1958), considers that the explosion took place quite recently, probably in Quaternary time. No igneous rocks are known within the explored parts of the Orphan structure but possibly there may be some at depth.

The explosion shattered the rock and produced a megabreccia that settled into a position not far from the rock's original stratigraphic position. This megabreccia was indurated by pressure and cementation, forming a parallel-walled pipe nearly as competent as the surrounding sedimentary rocks, but sufficient open fractures remained to permit upward streaming of the fluids that possibly ascended from the source of the gas explosion. These fluids altered the rocks within and adjacent to the pipe and partly replaced them with calcium carbonate, which probably was derived from leaching of limestone strata below. Some of the altered and replaced rocks were again broken, probably as a result of continuing subsidence within the pipe after the solution and removal of the limestone below, and then further altered. Leaching of limestone adjacent to the pipe permitted collapse of the overlying Supai formation. This peripheral collapse zone worked upward until it reached the Hermit shale where it stopped, forming a shoulder or bottleneck. Solutions containing uranium, copper, and other constituents percolated through the altered and fractured rocks, depositing ore and gangue minerals wherever the chemical, pressure, and temperature conditions were favorable. Ore bodies were formed along the more open channelways, where conditions for precipitation were particularly favorable. Smaller amounts of ore minerals were also deposited in more restricted channelways and throughout the broken rock.

Another concept is that the collapse originated entirely by solution of underlying limestone, without any magmatic activity. The structure might then have developed somewhat in the way outlined above, except that the source of calcifying and mineralizing solutions would likely be ground water percolating through the Kaibab limestone and Coconino sandstone.

GILA COUNTY

DEPOSITS IN THE DRIPPING SPRING QUARTZITE

The Dripping Spring quartzite of Precambrian age is extensively exposed in southeastern Arizona, but economic uranium deposits in that formation have been found only in Gila County, particularly the north-central part. Uranium deposits in the Dripping Spring were first noted early in 1950, but they received little attention until late in 1953. Between 1954 and 1958, we conducted a detailed study of these deposits, and they are therefore described more fully than most of the other deposits. Several geologists have described the uranium deposits in the Dripping Spring quartzite, including Wright (1950), Kaiser (1951), Mead and Wells (1953), R. G. Gastil [1], Wells and Rambosek (1954), and Magleby and Mead (1955).

By 1956 about 100 uranium deposits had been found in the Dripping Spring quartzite. Less than 12 of these were being actively developed, but about 40 had been explored by drilling or drifting, in addition to the required assessment work.

The Dripping Spring quartzite is a formation in the relatively undisturbed and unmetamorphosed Apache group of younger Precambrian age, which consists of clastic, pyroclastic, and carbonate sedimentary rocks commonly capped by one or more flows of basalt. This group lies unconformably on older Precambrian gneiss, schist, and granitic rocks and is overlain disconformably by younger sedimentary rocks. The Apache group is extensively intruded by diabase, which occurs mainly in large sills but also forms dikes, gently crosscutting sheets, and irregular bodies.

The Dripping Spring consists of two members. The lower member is typically a reddish arkosic to orthoquartzitic sandstone. It is missing in the extreme northern part of Gila County, where the formation abruptly overlaps older rocks, but elsewhere in the county it

[1] Gastil, R. G., 1953. The geology of the eastern half of the Diamond Butte quadrangle, Gila County, Arizona: California Univ. doctoral thesis.

is 140 to 370 feet thick. The upper member, which contains all the known uranium deposits in the formation, is much finer grained and more thinly stratified than the lower member. It consists mainly of arenaceous siltstone but contains units that range in lithology from shale to coarse-grained orthoquartzite. Most of the uranium deposits are in gray siltstone strata near the middle of the upper member, but some deposits of secondary uranium minerals are lower in the member.

The siltstone favorable for uranium deposits is generally gray where unweathered; the color is due to 2 percent or less of extremely fine-grained carbon and a little disseminated pyrite. It is abnormally rich in potassium, containing about 10 to 14 percent K_2O, almost entirely in detrital and authigenic feldspar. Where cut by large diabase bodies, it is locally metamorphosed to hornfels and related rocks, which are even more favorable for uranium deposits than the unmetamorphosed siltstone.

The primary deposits are generally veinlike and nearly vertical. Their vertical extent is determined by favorable lithology and rarely exceeds 20 feet, but in some deposits it is 80 feet or more. Most of the veinlike deposits are less than 5 feet thick and about 100 to more than 300 feet long; their maximum length has not yet been determined. Favorable strata locally contain mantolike ore deposits extending laterally from the veinlike bodies.

Most of the veinlike deposits trend within a few degrees of either N. 70° W. or N. 20° E., parallel to joints. The outcrop of such a deposit is generally marked by a limonite-filled joint, but farther underground the joint is commonly unrecognizable or diverges from the trend of the deposit. However, most of the joints now visible are not the tight fractures along which the uranium minerals were deposited, but are postmineralization joints and were controlled in part by the deposits.

In some of the deposits in hornfels, the ore minerals are localized along breccia zones parallel to the principal joint system. These breccia zones are cemented by an aplitic rock.

The uranium minerals are generally disseminated in the host rock, but they also form short veinlets and irregular masses, particularly in the hornfels.

The primary uranium mineral in deposits adjacent to diabase is uraninite, largely in extremely small discrete grains. Some aggregates of these grains form masses that appear to be massive uraninite, but microscopic examination invariably discloses a multitude of rounded uraninite grains disseminated in a chlorite-rich matrix. Coffinite associated with uraninite was identified by X-ray methods in one specimen, but it is probably rare. No primary uranium minerals have been recognized in deposits not adjacent to diabase. Although extremely fine-grained uraninite may be disseminated in these deposits farther from diabase, it is probable that much of the uranium was adsorbed in the form of the uranyl ion on other minerals, such as clay, chlorite, and carbon.

Sulfide minerals, which probably formed later than the uranium minerals, are generally abundant in the deposits. The deposits in hornfels contain molybdenite, pyrrhotite, chalcopyrite, marcasite, galena, sphalerite, and pyrite, formed in approximately that order. Deposits in siltstone commonly contain all these minerals except molybdenite and pyrrhotite.

Weathered parts of deposits in hornfels contain abundant uranophane and sparse torbernite, associated with secondary copper and iron minerals, a little uraniferous hyalite, and gypsum. In the weathered parts of deposits in essentially unmetamorphosed siltstone, metatorbernite is the most abundant uranium mineral; but bassetite, saleeite, uranophane, meta-autunite, and uraniferous hyalite have also been identified, together with the same secondary nonuraniferous minerals that occur in the hornfels.

A genetic relationship between the uranium and diabase is suggested by the proximity of most of the deposits to diabase and by the association of uranium minerals with sulfide minerals, such as pyrrhotite and molybdenite, that are generally believed to have been formed at high temperatures.

Analyses of various facies of the diabase suggest that the diabase magma lost uranium as it cooled. The chilled borders of the diabase bodies contain more uranium than the inner parts, and they show no evidence of having been enriched in uranium from the enclosing sedimentary rocks. It therefore seems probable that the diabase magma, when injected, contained at least as much uranium as the borders do now but that the inner parts of the diabase intrusive bodies expelled uranium-bearing solutions during their slow crystallization. These solutions presumably moved outward through the surrounding rocks along permeable strata and tight joints until they came in contact with rocks rich in original carbon and pyrite or in carbon, pyrite, and clay where, under strongly reducing and adsorptive conditions, the uranium was deposited. Subsequent studies by Neuerburg and Granger (1960) substantiate the conclusion that the diabase lost uranium and that the uranium was incorporated in the deposits, but they indicate that the uranium was expelled from the diabase by late-stage deuteric solutions which also altered and probably added uranium to the chilled borders.

GRAHAM COUNTY

GOLONDRINA CLAIMS

The Golondrina property, in the S½ sec. 12, T. 11 S., R. 25 E., is a block of 21 claims held in 1951 by M. V. Lee of Dragoon. Fractures on the property are filled with radioactive pyromorphite associated with a little quartz and limonite. Deposits of pyromophite, lead chlorophosphate, apparently were localized, at least in part, by a 1- to 2-foot layer of agglomerate or flow breccia that separates 2 successive flows of porphyritic volcanic rocks. The pyromorphite occurs in cavities and fractures in the breccia, and also in fractures in the porphyritic rocks nearby. A short adit follows the breccia for about 20 feet, and 2 open pits expose what appears to be the basal part of the upper flow. In the larger pit the pyromorphite is associated with traces of chalcopyrite, chalcocite, and malachite.

The radioactivity is not everywhere in direct proportion to the quantity of pyromorphite, whose uranium content thus appears to be variable. Tests by the U.S. Atomic Energy Commission indicate that the pyromorphite contains as much as 0.6 percent U (R. J. Wright, written communication, 1950), probably as a constituent of the mineral. A sample tested by the U.S. Bureau of Mines contained 0.26 percent eU_3O_8 and 0.221 percent U_3O_8 (J. N. Faick, 1953, U.S. Defense Minerals Exploration Administration docket 2977). The radioactive material, though widespread, is mostly of very low grade.

MARICOPA COUNTY

BLACK MOUNTAIN CLAIMS

The Black Mountain claims and the Black Mountain Vanadium claims are on the west end of the Vulture Mountains, about 12 miles southeast of Aguila. In 1951 the claims were owned by Milton Ray of Aguila and contained several shallow prospect pits and trenches.

The uranium deposits occur in shaly beds of buff to white limy bentonitic tuff, from 100 to 200 feet thick. The tuff is exposed along a northwest-trending cuesta that is capped by a mafic lava flow. Underlying the tuff are gneiss and schist cut by pegmatite dikes. The tuff beds strike northwest and dip 60°–65° SW.; the steeper dips are caused by slumping. Bedding planes and fracture surfaces are thinly coated with gypsum and a yellow uranium mineral, probably carnotite (Hewett, 1925).

Although the tuff probably contains traces of carnotite for a distance of a mile or more, none of it is known to contain much more than a trace. A selected sample recorded by Hewett (1925) contained only 0.009 percent U_3O_8.

LUCKY STRIKE CLAIM

The Lucky Strike claim, about 13 miles by road north of Morristown, was owned in 1951 by John Richie and James Russell of Morristown. A 60-foot adit on the claim develops a narrow vein in Yavapai schist of Precambrian age.

On the dump was several tons of radioactive material containing galena, chalcopyrite, wulfenite, chrysocolla, chalcocite, willemite(?) and pyromorphite(?) in a quartz gangue, but no recognizable uranium minerals were found. A grab sample of this material contained 0.025 percent U. Although the size of the fragments indicates that they were mined from a fissure vein at least 8 inches thick, no remnant of any vein of this size and composition was found in the adit, and because the vein material on the dump has been broken clean of its wall-rock, its source is hard to determine. Perhaps the ore formed a pod or pocket in the schist or in an otherwise inconspicuous vein. Perhaps it was all mined out, or possibly it came from some other mine.

MOHAVE COUNTY

CATHERINE AND MICHAEL CLAIMS

The Catherine and Michael claims are near the west-facing escarpment of the Aquarius Cliffs, about 8 miles east of the road between Kingman and Wikieup and 50 miles southeast of Kingman. They were owned in 1951 by R. H. Carr and others of Los Angeles, Calif.

The Aquarius Cliffs, which are rugged slopes rather than cliffs, overlook a fault-trough valley underlain by a downthrown block. They consist mainly of Precambrian granite, gneiss, and schist, intruded by numerous dikes of aplite and pegmatite. The crest and parts of the escarpment are covered with lava and pyroclastic rocks; the lower slopes consist mainly of valley fill and terrace gravels.

The claims extend along a small valley sharply incised into the escarpment. On the east wall of the valley are exposed tilted strata of sandstone, shale, and limestone that overlie Precambrian granite on the west and are faulted against it on the east (fig. 4). On the west wall of the valley are exposed flat-lying arkosic grit and conglomerate strata, which are unconformable on steeply dipping strata beneath. Several hundred feet north of the claims a sheet of fine-grained mafic igneous rock containing limestone inclusions is exposed above the tilted sedimentary rocks; whether this is extrusive or intrusive was not determined.

Detailed study of the rocks in the Aquarius Cliffs was not made by the geologists who have visited this region in the past. Lee (1908) and Schrader (1909) briefly discuss the areal geology of the region, but they do not mention the tilted sedimentary rocks; nor does Wilson (1941), though he briefly describes the pegmatites and veins that contain tungsten minerals. Morrison (1940) mentions tilted "lake beds" that include concretionary limestone, volcanic ash, gypsum, analcite-bearing sandstone, diatomite, and bentonite, locally interbedded with basaltic lavas, but he does not give their age. These are

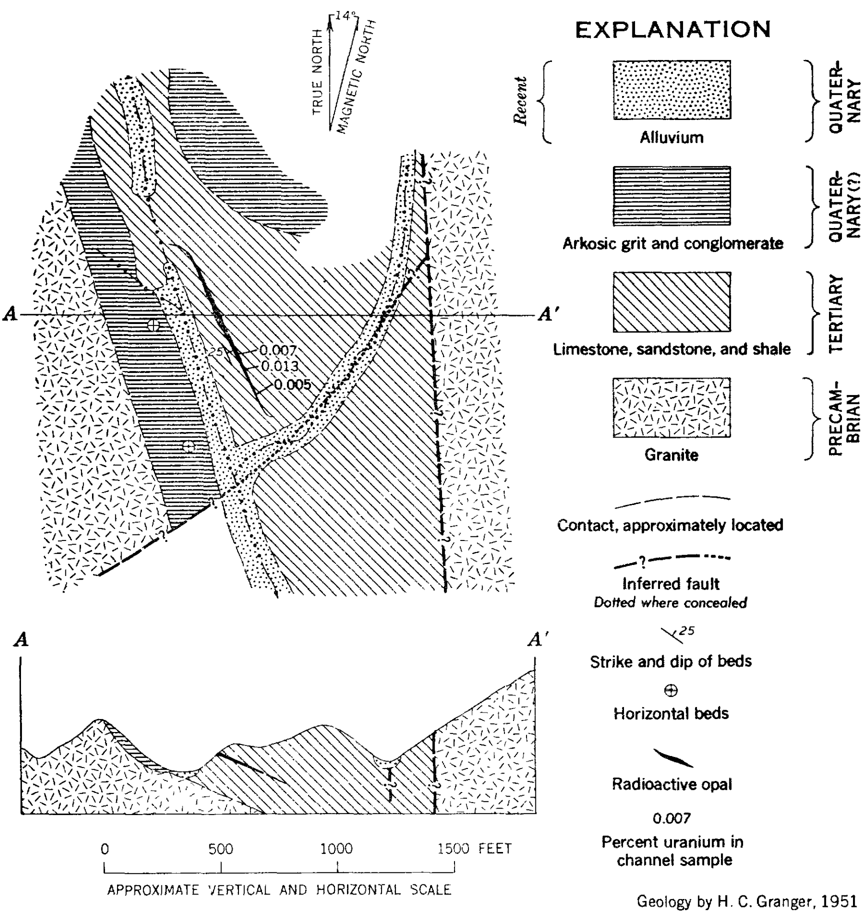


FIGURE 4.—Geologic sketch map, Catherine and Michael claims, Mohave County, Ariz.

evidently the rocks in which the uranium deposits occur on the Catherine and Michael claims, yet Morrison's map shows only the granitic basement rocks in the vicinity of the claims.

The uranium deposits occur on the east side of the small valley in a thinly laminated and poorly consolidated limestone unit, 20 to 30 feet thick, which strikes N. 20°–30° W. and dips 25°–30° NE. The limestone conformably overlies a series of sandstones and shales and is disconformably overlain by arkosic grit and conglomerate. The limestone is locally replaced by milky white and greenish opal; both are commonly stained with irregular patches of black manganese oxide and are fluorescent. The greenish opal is more brightly fluorescent and much more radioactive than the milky white opal, which is virtually nonradioactive. The greenish opal, through less common than the white, is scattered throughout a layer as much as 10 feet thick along the strike for nearly 800 feet in sufficient quantity to make almost the entire layer radioactive. Perhaps the uranium is held as ions within the molecular lattice of the opal, for no uranium minerals were identified in the radioactive material.

A small selected specimen of fluorescent green opal contained 0.2 percent U. This is much higher than the average uranium content of the deposit, but it shows how much uranium can be contained in opal that apparently contains no uranium minerals. Three channel samples believed to be representative of the uraniferous rock contained 0.005 to 0.013 percent U very near equilibrium.

HACK'S MINE

Hack's mine, also known as the Hack Canyon uranium mine, is on a group of five claims named Hack's and Hack's Nos. 2, 3, 4, and 5 claims. These claims are in Hack Canyon, in sec. 26(?), T. 37 N., R. 5 E., about 37 miles by road southwest of Fredonia. They were acquired in 1940 by Clair Pearson, A. E. Jenson, and three associates, all of Fredonia. Only the deposits on Hack's and Hack's No. 2 claims were examined.

The deposit at Hack's mine is explored by a 30-foot shaft, a 45-foot adit, 2 inclined shafts, and over 200 feet of drifts and crosscuts (fig. 5). Small amounts of copper ore have been produced from the mine at various times since 1920, and uranium minerals were discovered while the mine was being worked for copper late in World War II (Dunning, 1948).

Upper Hack Canyon is cut into a section of Permian sedimentary rocks from the Hermit shale to the Kaibab limestone. The copper-uranium deposit on Hack's claim crops out on a steep slope just below the contact between the cliff-forming Coconino sandstone and the underlying Hermit shale. At the surface, many fractures in broken, slumped Coconino sandstone are stained with green copper minerals and minor metatorbernite. The shaft is collared in Coconino sandstone talus. Beneath this are at least 15–20 feet of slumped Coconino sandstone in the throat of a pipelike collapse structure that seems to be similar to the structure on the Orphan claim. Underlying the

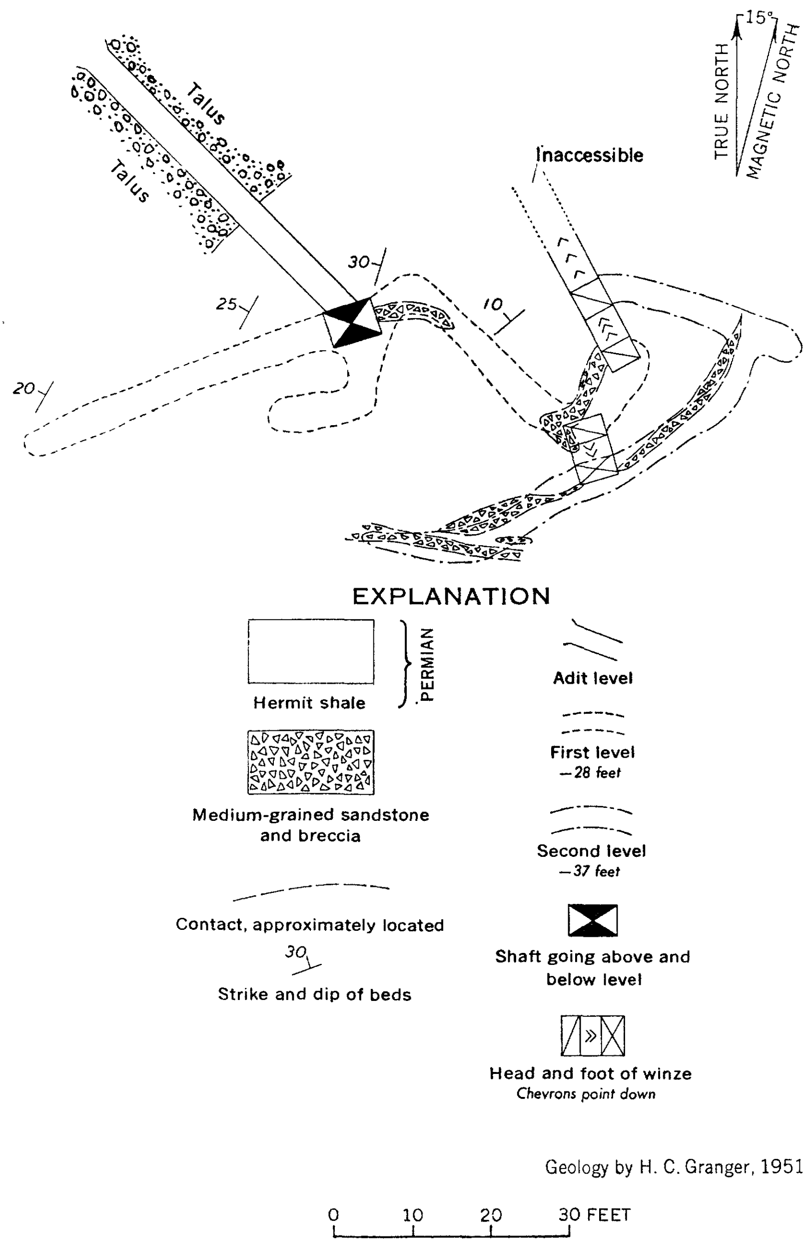


FIGURE 5.—Composite sketch of workings, Hack's mine, Mohave County, Ariz.

slumped sandstone is fractured bleached Hermit shale. Slumped coarse rock debris and talus at the outcrop of the deposit as well as in the upper workings had caused earlier investigators to believe that the deposit at Hack's mine is localized primarily in a surficial slump block of Coconino sandstone.

The rock within the mine is largely fine-grained indistinctly bedded dirty-gray altered sandstone of the Hermit shale. Near the southwest face of the first level this rock grades without any structural break into normal red unaltered Hermit shale.

Within the mine there are several elongate, ill-defined zones of breccia consisting of fragments of both fine- and medium-grained sandstone in a matrix of predominantly fine-grained sandstone. These zones generally dip steeply but locally follow bedding planes. In a thin section of the breccia it was found that many of the quartz grains were secondarily enlarged by overgrowths. Much of the medium-grained sandstone may therefore be silicified Hermit shale. As the breccia contains no cavities, it was probably cemented under considerable pressure.

The primary uranium minerals have been deposited in these brecciated zones and in some of the coarser grained sandstones. The breccia, which commonly is light red, owing to secondary iron oxides, contains black spots that are markedly radioactive. These spots probably consist of chalcocite mixed with a little pitchblende (J. W. Gruner, written communication, 1950.) No other metallic minerals were identified, but they were undoubtedly present before the rock was weathered, for the sides of fractures in the breccia are partly coated with chalcanthite, brochantite, erythrite or bieberite, and yellow uranium minerals, including zippeite(?). Farther out the altered fine-grained sandstone contains malachite and metatorbernite along fractures and bedding planes and as interstitial fillings.

Nine samples taken during this examination contained 0.004 to 0.28 percent U. The samples with a higher uranium content were mainly from the breccia zones. To mine the deposit efficiently, it would be necessary to know the extent and distribution of breccia zones.

About 500 tons of the rock on a dump near the portal of the tunnel in 1951 was radioactive. The radioactivity, as measured about 2 feet from the surface by means of a portable field meter with a 6-inch probe, averaged about 0.10 mr per hr (milliroentgens per hour), which is estimated to be equivalent to nearly 0.1 percent U. Ore containing 0.1 to 0.2 percent U could be recovered by hand-cobbing.

The Hack's mine deposit seems to be in a collapse structure very similar to that in which the Orphan deposit (p. A–7 to A–12) is localized. Hack's mine is probably on the southeast side of such a structure, as is indicated by the curvature of the breccia zones shown in figure 5. These breccia zones are quite likely the faults along which the collapse movements occurred. The talus above the mine workings probably resulted from slumping of fractured Coconino sandstone within the collapse structure after this rock was exposed by canyon cutting.

A small amount of a pale-yellow powdery uranium mineral was recovered from a prospect pit on Hack's No. 2 claim, about 500 to 600 yards northeast of Hack's mine. The mineral was not identified, but spectrographic analyses show that it contains significant amounts of uranium, silica, and phosphate. It occurs along joints and bedding planes in a shaly rock near the contact between the Coconino sandstone and the Hermit shale, probably in the Hermit shale. This pit has not uncovered an economically significant uranium deposit, but it demonstrates the possible widespread occurrence of uranium in the vicinity of Hack's mine.

JIM KANE MINE

The Jim Kane mine is in sec. 8, T. 22 N., R. 17 W., in the Wallapai district, about 10 miles north of Kingman (E. P. Kaiser, written communication, 1951). It was owned in 1951 by Jim Kane, who lived at the mine and had opened it in search of lead and zinc minerals.

The mine is in Precambrian gneiss. It has three adit levels, which follow a wide shear zone that strikes N. 60° W. and dips steeply northeast. Individual veins and shears within this zone contain scattered galena and sphalerite in a siderite gangue. One vein, about 3 feet wide, contains small amounts of radioactive material. Weak radioactivity is traceable for about 120 feet along the vein on the middle level, and stronger radioactivity for about 60 feet horizontally along the vein in a stope 23 feet above the level. The abnormal radioactivity coincides with a part of the vein that is reported to contain over 5 percent lead, whereas other parts contain 1 percent or less. No uranium minerals were recognized, although the U.S. Bureau of Mines has reported that the vein contains pitchblende (R. J. Wright, oral communication, 1950). Chalcedony and gypsum that locally coat the mine walls fluoresce yellow green and bright red, respectively.

Two samples taken by Kaiser, which probably represent the grade of the vein at the richest part of the ore shoot, contained 0.067 and 0.042 percent U. A. J. Rambosek (written communication, 1952), took two samples from unspecified localities in the mine that contained 0.003 and 0.006 percent U_3O_8.

RED HILLS PROSPECT

The Red Hills uranium prospect is in sec. 7, T. 11 N., R. 13 W., about 6 miles northwest of the old settlement at Alamo. In 1951 the claims were owned by E. W. Tate of Wenden.

The rocks at the Red Hills prospect belong chiefly to the Artillery formation, probably of Eocene age, which is underlain by Precambrian schist and gneiss (E. P. Kaiser, written communication, 1951). Nearby exposures indicate that the Artillery formation has been thrust over the Precambrian rocks at a low angle. The Artillery formation in the prospect area is represented by a breccia consisting of fragments of schist, felsitic material, conglomerate, and limestone cemented with silica, carbonates, and manganese oxide. This is probably a fault breccia related to the low-angle thrust fault, but it may be in part a sedimentary breccia at the base of the Artillery formation (Lasky and Webber, 1949).

A prospect pit was sunk on a radioactive shear zone that strikes N. 55° W., dips 70° SW., and is 305 feet wide. Three similar zones, two of which are radioactive, are exposed southwest of the pit. The brecciated rock in the shear zone exposed by the prospect pit is cemented with barite, fluorite, and secondary copper minerals. Much of it is radioactive, and two samples taken from the dump contained 0.12 and 0.14 percent U, although no uranium minerals were recognized.

Traverses made with a scintillation survey meter outlined a radioactive zone that trends eastward through the prospect pit for about 300 feet across the structural pattern defined by the shear zones. The most radioactive areas occur where the shear zones are crossed by the radioactive zone. Because the radioactive zone apparently crosses structural trends and the Artillery formation is presumably quite thin at the Red Hills prospect, the extent of the deposit cannot be reliably predicted.

SUMMIT MINE

The Summit mine is in sec. 32, T. 23 N., R. 17 W., about 15 miles north of Kingman. It exposes a composite vein zone, 20 to 30 feet wide, which strikes about N. 40° W. and dips steeply northeast. The host rock is gneissoid biotite granite intruded by a few narrow mafic dikes.

The mine workings include drifts on 3 levels, entered by a 300-foot shaft and 2 crosscut adits. The shaft connects with drifts on the 160- and 300-foot levels, and 1 of the adits intersects the 160-foot level near the shaft. The other adit intersects the vein on the 500-foot level of the mine and connects with a 350-foot drift from which there is a 30-foot raise.

Lead, zinc, copper, gold, and silver minerals are present in the vein, but no uranium minerals were identified. The highest radioactivity detected came from material containing sooty chalcocite, which may be mixed with finely divided uraninite.

Significant radioactivity was detected only on the 500-foot level and in the raise above it, where traverses with a scintillation survey meter indicated the presence of a small amount of radioactive material in the exposed vein. The most radioactive areas are at the top of the raise and in a 20-foot exposure of the vein 130 to 150 feet southeast of the adit. Geiger counter readings at these places were as much as 20 times background radioactivity.

The radioactivity measurements indicate that it is unlikely that minable quantities of uranium ore are exposed in the workings examined. Selected specimens of the sooty material on the 500-foot level of the mine may contain 0.2 percent U or more, but only a very small amount of this material is present.

NAVAJO COUNTY

ANNA BERNICE CLAIMS

The Anna Bernice claims, Nos. 1 to 5 are 6 miles north of Joseph City; they were owned in 1951 by D. O. Roller of Wickenburg and L. W. Kowalski of Phoenix. The claims contain two shallow prospect pits dug in a thin lens of jasper enclosed in flat-lying bentonitic shale in the Chinle formation of Late Triassic age. The lens is about 6 inches think and at least 150 feet in diameter. Most of it is exposed by the erosion of the overlying shale, so that it forms a small bench. The jasper is dark brown and shows relict fragmental structure. The darkest material seems to be the most radioactive. One specimen contained a few specks of a yellow uranium mineral on a fracture surface, but not enough of it is present to account for the uranium content of the deposit.

Three representative samples contained 0.025, 0.026, and 0.043 percent U, and a high-grade specimen contained 0.25 percent U.

Granger, who examined the property, believes that the uranium in the deposit may have been derived from the surrounding Chinle formation, a large part of which is now a montmorillonitic clay derived from volcanic ash. As the ash devitrified it lost silica, iron, uranium, and alkali metals; the silica and iron oxide selectively replaced a lens of conglomerate, forming an iron-rich jasper, and most of the uranium was redeposited in the jasper. The uranium, as determined from autoradiographs, occurs in extremely minute fractures invisible to the naked eye (T. G. Lovering, written communication, 1956).

PETRIFIED FOREST AREA

PETRIFIED FOREST NATIONAL MONUMENT

During routine traversing by Granger with a carborne Geiger counter in March 1951, a small low-grade uranium deposit was found inside the southern boundary of the Petrified Forest National Monument. The deposit is exposed in a road cut on both sides of U.S. Highway 260, 1.1 miles west of the south gate to the monument.

Although the geologic map of Arizona by Darton and others (1942) shows this locality as being underlain by the Moenkopi formation, the varicolored shales and abundant petrified wood exposed there are more characteristic of the Chinle formation than of the Moenkopi, and the deposit is believed to be in the lower part of the Chinle.

The radioactive material is localized in fragmented carbonized fossil plants in a lens of sandy shale about 5 feet thick and more than 125 feet across. Two representative channel samples contained 0.012 and 0.015 percent U, but no uranium minerals were identified. An abundant powdery yellow material associated with the carbonized fossil plants and impregnating the enclosing rock is nonradioactive and appears to be an iron sulfate.

TRACT NO. 1

Tract No. 1, which covers 21 acres, was owned in 1951 by the New Mexico and Arizona Land Co. and leased to Frank A. DoBell of Holbrook. It is outside the Petrified Forest National Monument and extends along the west boundary, in the SE ¼ sec. 1, T. 17 N., R. 23 E., about 3 miles west of the First Forest, in the northern part of the monument.

The uranium-bearing rock forms a lens about 125 feet long, exposed on both sides of a sharp ridge; it has a maximum thickness of about 8 feet but thins rapidly to less than 2 feet. It is in flat-lying buff-colored sandstone, clay, and conglomerate of the Chinle formation of Late Triassic age which contain abundant carbonized and petrified fossil plant debris. The petrified material, which is commonly in the form of buff-colored tree limbs and trunks, is nonradioactive. All the radioactivity comes from the carbonized material. This consists mainly of fragments or small flattened lenticular masses, but some of the petrified tree limbs have an outer shell of radioactive carbonized wood, as though the limbs had been charred before burial in sediment. Perhaps the fragments of carbonized material represent charred twigs and bits of charcoal broken from the surfaces of burnt logs and limbs during deposition.

Two channel samples contained 0.008 and 0.017 percent U, and individual fragments of carbonized material are much richer. In general, the radioactivity is roughly proportional to the amount of carbonized material. No uranium minerals were recognized.

TRACT NO. 2

Tract No. 2 covers 41 acres about 20 miles southeast of Holbrook. It is in the SE¼ sec. 33, T. 16 N., R. 23 E., about 3 miles south of the Petrified Forest National Monument. In 1951 it was owned by the New Mexico and Arizona Land Co. and was leased to Frank A. DoBell of Holbrook. The geologic map of Arizona by Darton and others (1924) indicates that Tract No. 2 is in the Moenkopi formation of Early and Middle(?) Triassic age, but its rocks are more like the sandy clay and sandstone of the overlying Chinle formation, as exposed in the Petrified Forest National Monument.

A yellow uranium-bearing mineral, probably carnotite, coats fracture surfaces in the dull-brown petrified logs scattered over much of the tract. Whether this mineral was derived from a primary uranium mineral enclosed in the petrified wood or whether it came from some other source is not known. As a rule, the more colorful the petrified material the less radioactive it is.

Representative samples from 2 of the logs contained 0.007 and 0.010 percent U, but their radioactivity was equivalent to 0.018 and 0.014 percent U, respectively, suggesting a significant amount of leaching.

PIMA COUNTY

BLACK DIKE DEPOSIT

The Black Dike deposit is on a group of five patented claims in secs. 23, 24, 25, and 26, T. 17 S., R. 10 E., on the west flank of the Sierrita Mountains and about 27 miles south-southwest of Tucson. The claims are on ranchland owned by Col. Moller of Tucson, who was leasing them in 1951 to Albert Ybarra, Glen Allen, and Bryce Wilson, all of Tucson.

The lower western slope of the Sierrita Mountains in the vicinity of the Black Dike claims is intricately cut by dry washes and has a rough rolling topography. Its average relief is less than 200 feet, but nearby hills and ridges rise as much as 400 feet above the surrounding surface.

The west flank of the Sierrita Mountains is composed of steeply dipping metamorphosed sandstone, limestone, shale, rhyolite, tuff, and conglomerate (Ransome, 1922). According to the geologic map of Arizona by Darton and others (1924), these metamorphosed sedimentary rocks consist largely of the Tornado limestone (Pennsylvanian and Mississippian) or Martin limestone (Devonian) and the Lower Cretaceous Comanche series. The core of the mountains is largely composed of granite and granite gneiss. The bedded rocks either were partly granitized by hot solutions or were invaded and partly assimilated by a granite magma.

The mineral deposits on the west side of the Sierrita Mountains are mostly in limestone. Many of the deposits were developed before World War I, and during the war unrecorded but probably small amounts of lead, silver, and copper were produced. The ore minerals are sporadic and rarely form continuous ore bodies. The primary minerals include pyrite, chalcopyrite, argentiferous galena, sphalerite, argentite, cerargyrite, native gold, and, near the north end of the district, fluorite. Secondary minerals, which are common near the surface, include chalcocite, malachite, azurite, cerussite, anglesite, wulfenite, and, locally, psilomelane and pyrolusite. Ransome (1922) states that the metallization has not been strong and that the area probably does not contain any large ore bodies. The Black Dike deposit is developed by a shaft originally put down in search of copper, probably just before World War I. The shaft was unused for several years and was then back filled with waste material. Early in 1950, however, the remaining waste rock around the collar of the shaft was found by Albert Ybarra to be radioactive. Later in that year, R. J. Wright of the U.S. Atomic Energy Commission made a brief examination of the property, and at his suggestion the lessees began to reopen the workings in order to look for uranium. In March 1951 the shaft had been cleared to a depth of about 75 feet, but still contained an undetermined amount of backfill.

The deposit was examined in February 1951 by Granger and J. W. Adams. The area immediately surrounding the Black Dike shaft was mapped (fig. 6); the cleared part of the shaft was sketched in vertical section, and two plan views of the shaft were prepared (fig. 7). The location and uranium content of several samples collected in the shaft are shown in figure 7.

The Black Dike deposit is near the contact between the gneissic granite and the metamorphosed sedimentary rocks. The metamorphic rocks strike N. 0°–20° W. and dip steeply eastward. The major structural and topographic features are related to the trend of these rocks. The more resistant strata, such as silicified limestone, form discontinuous north-trending ridges. The Black Dike claims were named for a low ridge of micaceous schist that crops out just east of the shaft. The schist, which is intensely stained with iron and manganese oxides, was mistaken for a dike.

The Black Dike mine is in gneissic granite that is cut by a small intensely bleached and altered basalt (?) dike. The shaft was sunk in a copper-stained fracture zone. About 40 feet below the surface

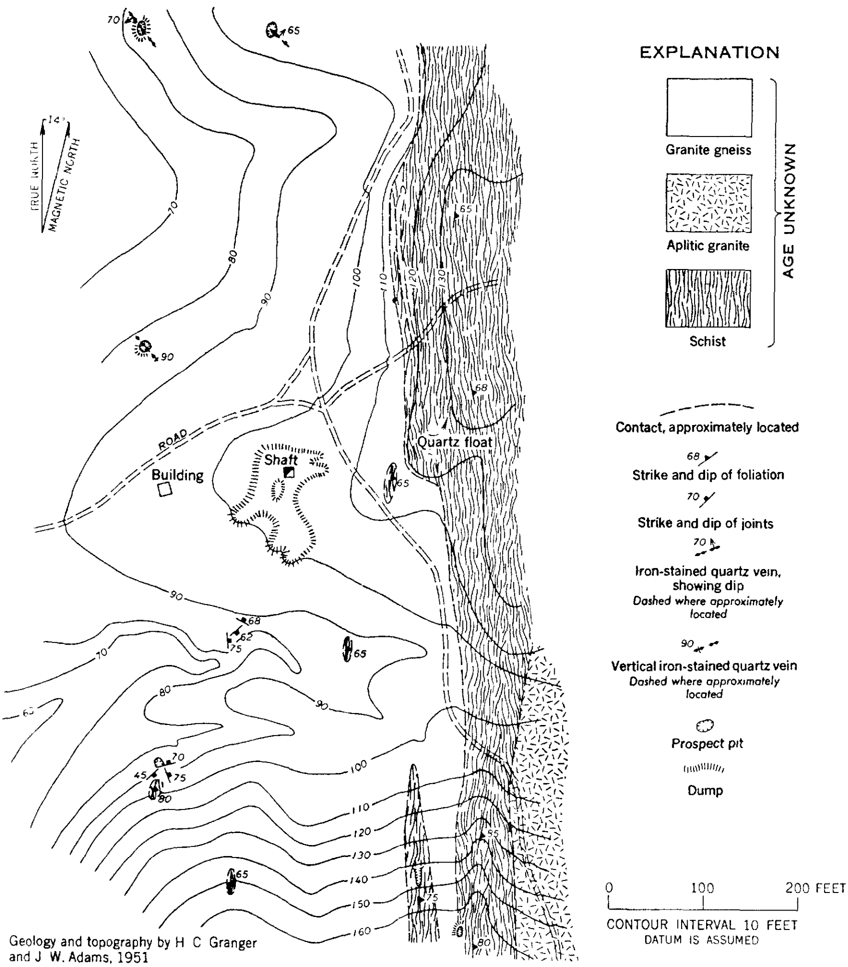


FIGURE 6.—Geologic sketch map of the Black Dike deposit, Pima County, Ariz.

the shaft intersected the altered dike; this dike was followed as far down as the shaft had been cleared at the time of our visit in 1951. Both the hanging wall and the footwall of the dike have been locally mineralized.

The basalt(?) dike is irregular in thickness but averages about 2 feet. Where observed underground, it strikes about N. 10° W. and dips 65° E., roughly parallel to the local foliation. The dike is highly altered and is concealed by rubble at the surface. In thin sections the dikerock shows a fine-grained texture similar to that of basalt. Most of the lath-shaped feldspar grains are altered to clay, and the ferro-magnesian phenocrysts are altered to chlorite. The dike locally contains calcite veinlets as much as an inch wide.

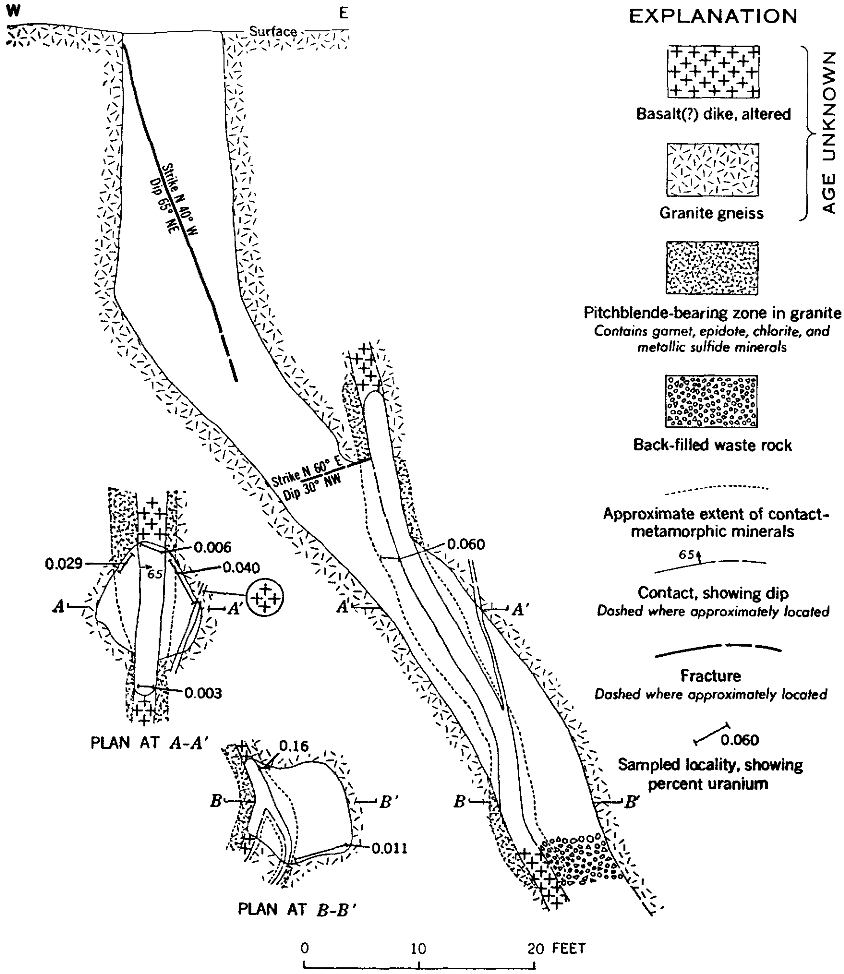


FIGURE 7.—Section and plans of the Black Dike shaft, Pima County, Ariz.

The dike is bordered by a very irregular contact-metamorphic zone in which the gneissic granite is altered to a finer grained schistose rock of greenstonelike appearance containing local concentrations of garnet, chlorite, and epidote, associated with pyrite, chalcopyrite, and magnetite (fig. 7). Fine-grained purple fluorite is disseminated through the greenstonelike rock and is commonly associated with the chalcopyrite. In some places the concentrations of garnet, chlorite, epidote, and sulfide minerals extend outward from the dike for several feet, but elsewhere the dike is in contact with the normal gneissic granite.

The radioactive material is in those parts of the contact-metamorphic zone that are richest in sulfide minerals and fluorite. Radioactivity is highest along irregular fractures coated with a black sooty material that is probably a mixture of manganese oxide and pitchblende (Lamar Evans, U.S. Bureau of Mines, oral communication, 1951). These fractures are mainly in the gneiss, but they extend, at most, only about 2 feet outward from the borders of the dike. In places they follow the contact, but none were observed within the dike.

Samples from the dike contained less than 0.006 percent U, but samples from the contact-metamorphic zone contained 0.011 to 0.16 percent U. The samples also contained 0.01 to 0.97 percent copper, the lowest amounts being in samples from the dike.

Local concentrations of uranium minerals would probably be found by further exploration in the rocks bordering the dike, but no large deposit of high-grade uranium ore is likely to be discovered. Ransome's statements (1922) regarding weak metallization of the district probably applies to the uranium deposits as well as to the base-metal deposits.

Since the examination of the Black Dike deposit in 1951, some further mining has been done on the property. We do not know the results of the more recent work.

COPPER SQUAW MINE

The Copper Squaw mine is in sec. 36, T. 14 S., R. 2 E., about 2 miles east of Quijotoa. The uranium deposit is in breccia of a fault zone in altered andesite that is probably Tertiary in age. The fault zone strikes N. 50° E., dips 30° NW., and is 6 to 36 inches wide.

The mine workings on the property consist of a 110-foot shaft, inclined 30° NW., and 4 prospect pits. About halfway down the shaft the fault zone widens to about 3 feet and is well exposed in a stope. At the bottom of the shaft the zone is less than 1 foot wide.

Radioactivity in the stope is quite low, but selected material stockpiled near the collar was probably taken from the stope and is in part uranium bearing. The predominant uranium minerals are uranophane and uraninite. Associated ore minerals are malachite and sparse azurite and chalcocite. The gangue minerals are quartz, calcite, hematite, and limonite.

A sample representative of the stockpile contained 0.12 percent eU_3O_8. Two selected chip samples, taken from the ore body in the stope before it was mined out, contained 0.76 and 1.40 percent U_3O_8 (R. L. Wells and H. E. Puttuck, written communication 1953). No other ore bodies have been found in the fault zone.

GLEN CLAIMS

The Glen claims are on the northwest flank of the Sierrita Mountains, in the NW¼ sec. 30, T. 17 S., R. 11 E., about 28 miles south-southwest of Tucson, and about 1 mile east-southeast of the Black Dike deposit. In 1951 they were under lease to Albert Ybarra and Glen Allen of Tucson. The property is underlain chiefly by granite but partly by quartz-biotite schist. The radioactive material occurs in and along a breccia zone that strikes N. 20° W. and dips about 80° SW. The breccia zone contains a silicified core about 6 feet wide, from which highly fractured rocks extend several feet on either side. The length of the zone was not determined, but it is radioactive for about 200 feet.

Near the northwest limit of radioactivity, an open cut about 15 feet long, 5 feet wide, and 6 feet in greatest depth exposes radioactive material along the hanging wall of the breccia zone. Most of the rock exposed in the cut is granite, but near the face there is a narrow vertical zone of light-colored intensely altered rock that contains much fine-grained muscovite or bleached biotite. The contacts of this rock with the granite are indistinct, and it is so easily weathered that it is not exposed at the surface. A 4-foot channel sample, which cuts 2 feet of the altered rock and 2 feet of granite, contained 0.015 percent U, and its radioactivity was equivalent to 0.035 percent U.

In an exposure nearly 200 feet southeast of the opencut, the breccia zone is more highly radioactive. There the rock is silicified and has the appearance of aplite. It is iron stained, and pyrite is scattered along some of the fractures. A sample of this rock contains 0.027 percent U, but its radioactivity is equivalent to 0.080 percent U. This lack of equilibrium indicates that the rock in the outcrops has been considerably leached and weathered and that uranium is probably more abundant in the fresh rock below.

IRIS AND NATALIA CLAIMS

The Iris and Natalia claims are in the SW¼ sec. 26, T. 21 S., R. 11 E., in the Oro Blanco mining district. They were owned in 1951 by Elmer and Lester Fernstrom of Tucson and Roman Encinas of Arivaca.

The several abandoned shafts and opencuts on the property explore three roughly parallel copper-bearing shear zones in rhyolite. Most of the mining was done on a shear zone several feet wide that strikes N. 80° E. and dips 34° N. Chalcocite nodules containing silver, gold, and uranium occur in gouge within the shear zone, especially along the footwall. These nodules may be related to the numerous iron-stained quartz veins, apparently crosscutting the shear zone, that are exposed at the surface.

Microscopic study of a specimen of radioactive material selected from the dump disclosed quartz, covellite, malachite, limonite, and a uranium mineral tentatively identified as kasolite. This specimen was reported (Wright, 1950) to contain 0.76 percent U_3O_8, but very little radioactive material could be found in the workings in 1951.

The owners reported that 2 diamond-drill holes collared north of the shaft intersected the low dipping shear zone at about 50 feet but that the drill cores contained no radioactive material and very little copper ore.

LENA NO. 1 AND GENIE NO. 1 CLAIMS

The Lena and Genie claims are in secs. 8 and 5, respectively, T. 18 S., R. 11 E., on the west flank of the Sierrita Mountains and about 25 airline miles southwest of Tucson. They are owned by Manuel Obregon of Tucson.

On the Lena No. 1 claim, a shaft about 16 feet deep follows a radioactive fissure vein in a light-colored slightly foliated granite. In some places the granite contains irregular xenoliths of impure quartzite and consists of steeply dipping layers, of northwestward trend, which suggests that the rock may have been formed by granitization of quartzose sediments. Widely scattered dark-colored fine-grained dikes cut the granite in various directions, but most of them trend northwestward and dip southwestward.

The fractures in and near the Lena No. 1 claim also trend northwestward for the most part and dip steeply southwestward (fig. 8). This trend is roughly parallel to the banding in the granite. Along one of these fractures is a narrow vein, traceable for about 25 feet, that contains disseminated magnetite, pyrite, chalcopyrite, galena, and possibly sphalerite in a dense quartz gangue. Sooty pitchblende and kasolite(?) coat fracture surfaces, chiefly along the footwall side of the vein. These relations are evident only near the bottom of the shaft (fig. 9); near the surface the vein narrows and becomes a nearly unmineralized fracture which forms the hanging wall of a shattered zone about 3 to 4 feet wide. The granite of the shattered zone is argillized, partly silicified, and stained with hydrous iron oxides, and it contains sparsely disseminated pyrite and green copper minerals. It is most intensely altered alongside the pitchblende- and sulfide-bearing vein, whose hanging wall is greenish tinged, possibly because of chlorite or serpentine, and silicified for about 3 inches from the vein.

The vein is about 1 to 2 inches wide at the bottom of the shaft and is apparently a fissure filling. The relative movement between opposite walls of the vein, if any, cannot be determined; therefore, the fracture may be a joint rather than a fault. Similar fractures nearby

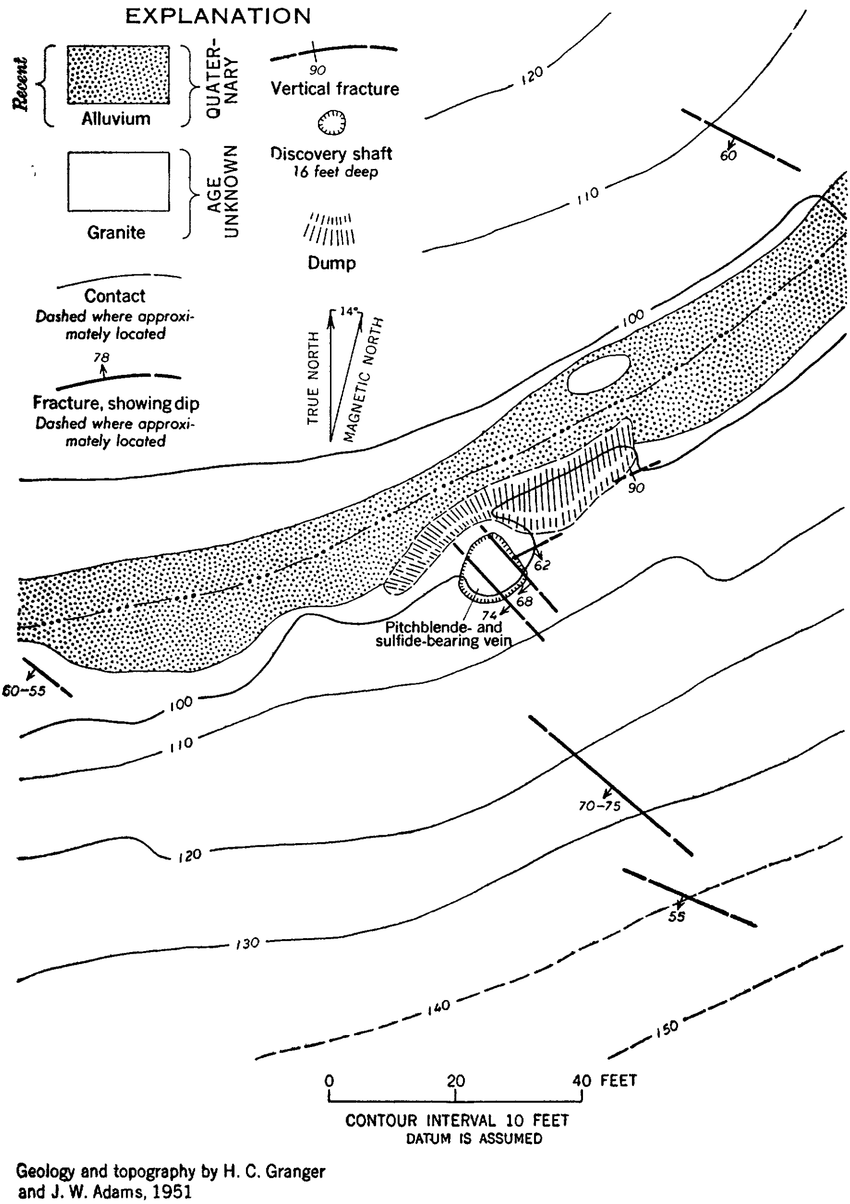


Figure 8.—Geologic sketch map of the Lena No. 1 claim, Pima County, Ariz., showing fracture pattern and uranium-bearing vein.

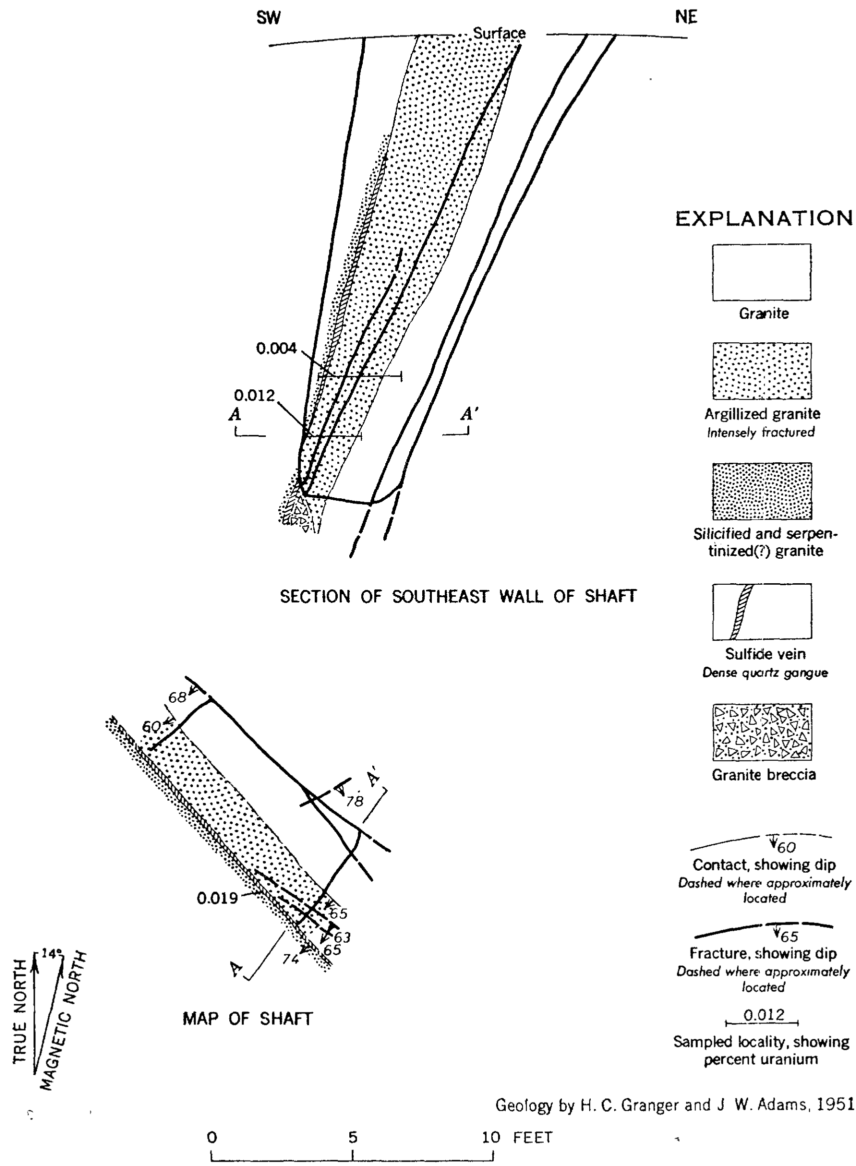


FIGURE 9.—Section and map of the discovery shaft, Lena No. 1 claim, Pima County, Ariz.

are tight and apparently contain no ore minerals. For these reasons it seems unlikely that the Lena claim contains any large ore body.

Two channel samples cut across the shattered zone near the bottom of the shaft contained 0.004 and 0.012 percent U, and a grab sample of the vein filling contained 0.019 percent U. These contrast sharply with a selected sample taken by the owner, which assayed over 2.0 percent U, and a sample selected by Faick and Romslo (J. N. Faick and T. M. Romslo, 1954, U.S. Defense Minerals Exploration Administration docket 3280) from the vein filling, which contained 0.25 percent U_3O_8.

On the Genie No. 1 claim, a few hundred yards east of the Lena No. 1, very little anomalous radioactivity can be noted. The Genie deposit is very similar to the Lena deposit, but it has been even less deeply explored. The country rock is a light-colored granite that contains disseminated pyrite and abundant tourmaline. The tourmaline forms clusters of radiating crystals in the granite, and some veins as much as 4 feet wide consist almost entirely of quartz and tourmaline. Most of these veins dip steeply southwestward.

Radioactivity is highest in the altered rock adjacent to a fracture in granite exposed along a draw, which crosses both claims. The fracture strikes about N. 40° W. and is nearly vertical. No uranium minerals or sulfide minerals were seen in this rock, but a sample contained 0.004 percent U and showed radioactivity equal to 0.008 percent U. A fracture along the southwest wall of one of the tourmaline-bearing veins also showed weak radioactivity, about 5 times the normal or background reading, but this radioactivity is apparently unrelated to the tourmaline.

SURE FIRE NO. 1 CLAIM

In August 1949, material of abnormal radioactivity was discovered on the Bar-LY Ranch in sec. 15, T. 13 S., R. 18 E., about 30 miles east-northeast of Tucson, and the Sure Fire No. 1 claim was located on the radioactive material by Dominick Oberto and others of Tucson. Four shallow prospect pits were sunk on the property, but no further work was done until 1954 when, after this report was written, there was renewed exploration.

The rocks on the Sure Fire No. 1 claim are believed to be of Precambrian and Cambrian ages. Apparently the oldest rock is a gray-green schist, consisting chiefly of quartz and chlorite interlaminated with dark minerals. The foliation dips 25°–55° NE. This rock may belong to the Pinal schist of Precambrian age. Probably intrusive into the schist, and nearly concordant with its foliation, is a gneissic granite that may be related to the Oracle granite, which is described by Moore, Tolman, and others (1949) as a coarse-grained nearly white rock with large feldspar phenocrysts that is locally crushed and contains schlieren. The granite and schist are successively overlain on the ridges by rocks that probably represent the Bolsa quartzite and the Abrigo limestone, both Cambrian in age. Fine-grained dark-colored dikes cut the Precambrian rocks on this claim and cut the younger rocks in nearby areas. The dikes are hard to trace on the surface, but where exposed they show both concordant and discordant relations to the foliation of the granite and schist.

All four shallow prospect pits on the Sure Fire No. 1 claim all are along an arroyo draining southward. These will be designated as pits A, B, C, and D.

Pit A, on the east side of the arroyo and about 30 feet above its floor, exposes weakly radioactive altered and iron-stained schist that contains a few veinlets of purple fluorite. A 14-foot chip sample of the schist just below pit A contained only 0.002 percent U, though its radioactivity would indicate 0.006 percent U.

Pit B, an opencut on the east wall of the arroyo about 60 feet northwest of pit A, exposes a bed of gray platy quartzose schist that is radioactive. The radioactive schist is locally crushed and altered and contains very small veinlets of quartz, fluorite, and calcite. It is overlain by dull gray-green schist that is soft and apparently chloritic.

A zone of abnormal but very weak radioactivity seems to be continuous between pits A and B. Across the arroyo from pits A and B is a small area of weakly radioactive schist that has not been explored by the owners. The radioactivity is largely in float; little bedrock can be seen.

Pit C, which lies north-northwest from pit B, is in a crushed and fractured zone, 8 feet wide, in altered gneissic granite. The Blue Rock shaft, sunk after our examination of the property, is probably in this zone. The granite contains veinlets and breccia fillings of quartz, calcite, purple fluorite, and an unidentified white claylike material. Some of the fractures contain yellow uranium minerals, identified as uranophane and autunite by the U.S. Bureau of Mines in Tucson. The crushed granite is iron stained, and pyrite and chalcocite are disseminated through slightly altered rock bordering the crushed zone. The radioactive material shows no continuity of trend. A 4-foot channel sample across the middle of the crushed zone showed radioactivity equivalent to 0.13 percent U but contained only 0.008 percent U by chemical assay.

Pit D, about 170 feet north of pit C, is in fractured schist along the west side of the arroyo. The two most prominent fractures strike N. 85° E. and N. 60° W., and dip 80° N. and 75° NE., respectively. They are about 4 feet apart in the face of the pit, and between them are veinlets filled with purple fluorite. The most radioactive material is a dull black coating on fracture surfaces. No uranium mineral has been identified in this material, which is far out of equilibrium; the radioactivity of 2 channel samples that contained only 0.004 and 0.006

percent U was equivalent to a uranium content of 0.069 and 0.038 percent.

The radioactive zones are weak and discontinuous, and all appear to be elongate parallel to the foliation. Weak abnormal radioactivity is traceable for the 60 feet between pits A and B, but pit C and pit D seem to be in 2 separate radioactive zones, both less than 25 feet long at the surface. All 3 radioactive zones contain minor amounts of purple fluorite, but the fluorite itself is not abnormally radioactive. The zones have been intensely leached, and their uranium content should increase downward for at least a few feet.

VAN HILL NO. 5 CLAIM

The Van Hill No. 5 claim is on the northeast flank of the Rincon Mountains, in sec. 15, T. 13 S., R. 18 E., about 30 miles east-northeast of Tucson. It was owned in 1951 by R. M. Vanover and others of Tucson.

Radioactive material is found in an altered quartzite, probably of Cambrian age, underlain by Precambrian metamorphic rocks and overlain by Paleozoic limestone. The quartzite is cut by a radioactive fracture zone, about 4 feet wide, that is traceable for about 50 feet; radioactivity is most intense where the fracture zone is exposed in an arroyo. In the fracture zone the quartzite is stained with iron and manganese minerals and contains fine-grained ferromagnesian minerals. A prospect pit in the bottom of the arroyo was almost completely filled with sand and gravel at the time of the examination. A few feet below the surface a yellow uranium mineral, probably autunite, is associated with purple fluorite in the fractures.

Analysis of a grab sample indicated that the uranium is not in equilibrium: the sample contained only 0.008 percent U, but contained 0.17 percent eU. The deposit has been strongly leached at the surface, and if the lack of equilibrium is the result of leaching, the uranium content may increase with depth.

VAN HILL NOS. 7 AND 8 CLAIMS

The Van Hill Nos. 7 and 8 claims are in the NW¼ sec. 24, T. 13 S., R. 18 E., about 30 miles east of Tucson and 1.5 miles south-southwest of the Bar-LY ranchhouse. (See U.S. Geological Survey 15-minute topographic map of the Redington, Ariz., quadrangle, 1943.) The No. 7 claim was located by R. M. Vanover and the No. 8 claim by L. D. Hill, both of Tucson.

The uranium concentration on these claims are in a conformable sequence of generally thin-bedded limestone, shale, and conglomerate strata that strike N. 40°–60° W. and dip 45°–70° NE. The rocks are probably of late Paleozoic age and may belong to the Naco limestone of Pennsylvanian age. The radioactive zone, exposed just below the crest of a short ridge formed by resistant limestone, follows a petroliferous limestone bed as much as 2 feet thick (fig. 10). Radioactivity commonly extends into the overlying fine-grained limestone and the underlying iron-stained shaly limestone, so that the maximum thickness of radioactive rock is about 6 feet. The radioactive zone is in 2 segments, one 115 and the other 190 feet long, separated by 28 feet of nonradioactive limestone. The northwest segment appears to be slightly higher stratigraphically than the southeast segment, possibly because of the lenticularity of the strata.

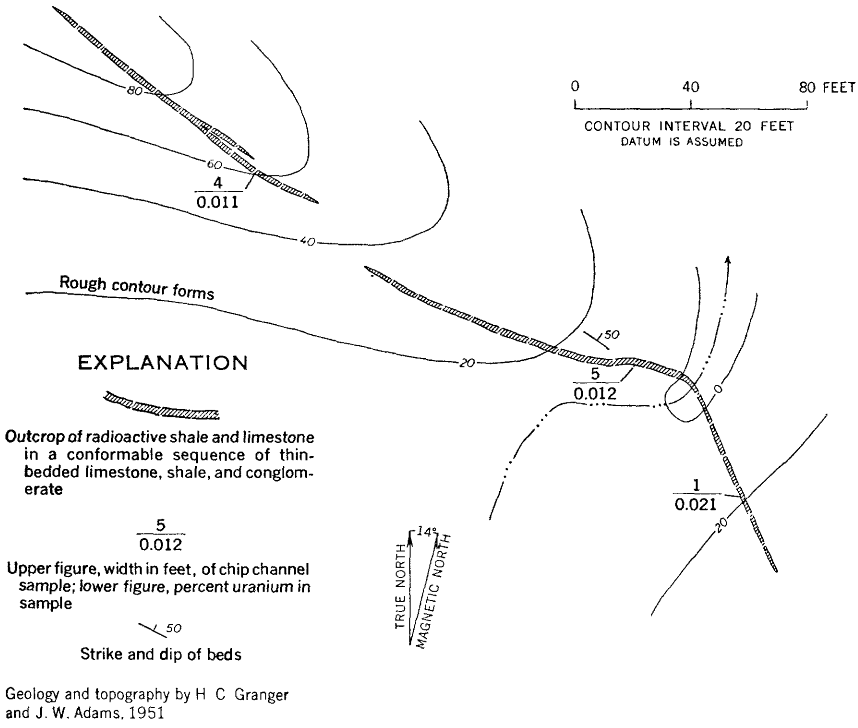


FIGURE 10.—Diagram outlining the radioactive rocks on the Van Hill Nos. 7 and 8 claims, Pima County, Ariz.

The uranium content of 3 samples taken across the radioactive zone ranged from 0.011 to 0.021 percent; it is not far out of equilibrium, which indicates that the limestone has not been appreciably leached. No uranium minerals were recognized, but the petroliferous material is the most radioactive.

PINAL COUNTY

HONEY BEE NO. 4 CLAIM

The Honey Bee No. 4 claim is about 2 miles southwest of Kelvin, in sec. 16, T. 4 S., R. 13 E., and was owned in 1951 by Leo Wall of Ray and I. D. Hollenbeck of Kelvin. It was originally worked for copper, but the copper deposits are not radioactive. Radioactivity is associated with a shattered fine-grained mafic dike, about 4 feet wide, and a nearby porphyry dike, each cutting the granite country rock. The petrographic classification of these dikes was not determined.

A 2-foot zone of iron-stained rock along the hanging wall of the mafic dike is radioactive in places for nearly 200 yards. A selected grab sample contained 0.021 percent U; the average uranium content is probably even lower.

The porphyry dike is radioactive in places for about 200 feet; one place indicated radioactivity of 0.4 mr per hr on a portable Geiger counter, where normal background was about 0.04 mr per hr. The dike is iron stained, and the uranium may be associated with the iron oxides.

SHORTY CLAIMS

The Shorty Nos. 1, 2, and 4 claims are in sec. 15, T. 4 S., R. 13 E., about 3 miles southwest of Kelvin. They were owned in 1951 by Leo Wall and Ray Adams of Ray and I. D. Hollenbeck of Kelvin. The country rock on the claims is a coarse-grained locally porphyritic granite. The radioactive material is associated with quartz stringers and oxides of iron and manganese in broad shear zones; the wallrocks commonly contain products of argillic alteration. The shear zones are about 3 feet to 100 feet wide and are traceable for several hundred yards, but the radioactivity is sporadic. The zones on the No. 1 and No. 2 claims strike N. 55°–85° W. and are nearly vertical; those on the No. 4 claim strike N. 45° W. and dip 65° NE. The radioactive parts of the shear zones are explored by several prospect pits and an adit about 15 feet long.

No samples were taken, but the radioactivity was about 2 to 5 times the normal background reading and probably equivalent to less than 0.01 percent U.

WOOLEY NO. 1 CLAIM

The Wooley No. 1 claim is about 5 miles southwest of Kelvin, in sec. 33, T. 4 S., R. 13 E., and was owned in 1951 by Leo Wall of Ray and I. D. Hollenbeck of Kelvin. It was originally explored for copper by a 250-foot shaft. An unknown tonnage has been mined, largely from a resistant quartz-filled breccia zone that contains malachite, chalcopyrite, and, perhaps, chalcocite. This material is not appreciably radioactive.

Although the material mined is not radioactive, the claim contains at least three veins that are radioactive. These cut the coarse- to fine-grained granite and are exposed within 150 yards of each other along a draw below the copper workings. They strike N. 63°–85° E. and dip 70°–90° SE. For convenience they will be termed veins 1, 2, and 3. Vein 1 is less than 1 inch wide but is bordered by a zone, up to 3 feet wide, that is characterized by argillic alteration products, a little silicified rock, and iron stains. It also is slightly copper stained. Its radioactivity is twice the normal background. Vein 2 is one-eighth to 3 inches wide, contains chrysocolla, and its radioactivity is 2 to 3 times more than the normal background. Vein 3 is developed by a 100-foot adit along a shear zone formed by a series of fractures and stringers 3 to 4 feet apart. Much of the rock in the shear zone is copper stained. A selected sample from the adit contained 0.017 percent U.

SANTA CRUZ COUNTY

ANNIE LAURIE CLAIMS

The Annie Laurie claims cover a lead-zinc-uranium prospect in the SE¼ sec. 1, T. 23 S., R. 11 E., about 25 miles west of Nogales and 3 miles south of the nearly abandoned mining town of Ruby. They were owned in 1951 by J. H. Bright, Jr., of Tucson, who discovered radioactive material on the Annie Laurie prospect (fig. 11) in the summer of 1948, when he tested a calcareous-tufa spring deposit with a Geiger counter (Wright, 1951). A small excavation, pit F on figure 11, failed to reveal any uranium minerals, but other pits on the hillside above the tufa disclosed two abnormally radioactive areas. Pit C contained some secondary uranium minerals; pit A exposed pitchblende and metallic sulfide minerals in a carbonate gangue. Other shallow prospect pits were dug, but all were in barren rock except pit B, which exposed minor amounts of sulfide minerals in a carbonate gangue. A 100-foot hole was diamond drilled in 1952, but no information about it is available because the core was not logged and was not properly saved.

The uranium deposits on the Annie Laurie claim are largely in granite, close to small bodies of porphyry, probably andesite, near the contact between granite and sedimentary rocks (figs. 11, 12). The granite, which appears to form a stock, is fine grained and is white to pink, owing to various proportions of white and red feldspar. The porphyry was injected along parts of the contact between the granite and the sedimentary rocks as an irregular dike, but dikes and sills of this rock also occur in the sedimentary strata, and lobes of it extend into the granite. The sedimentary rocks are interstratified shale, limestone, grit, and conglomerate, probably younger than Paleozoic in

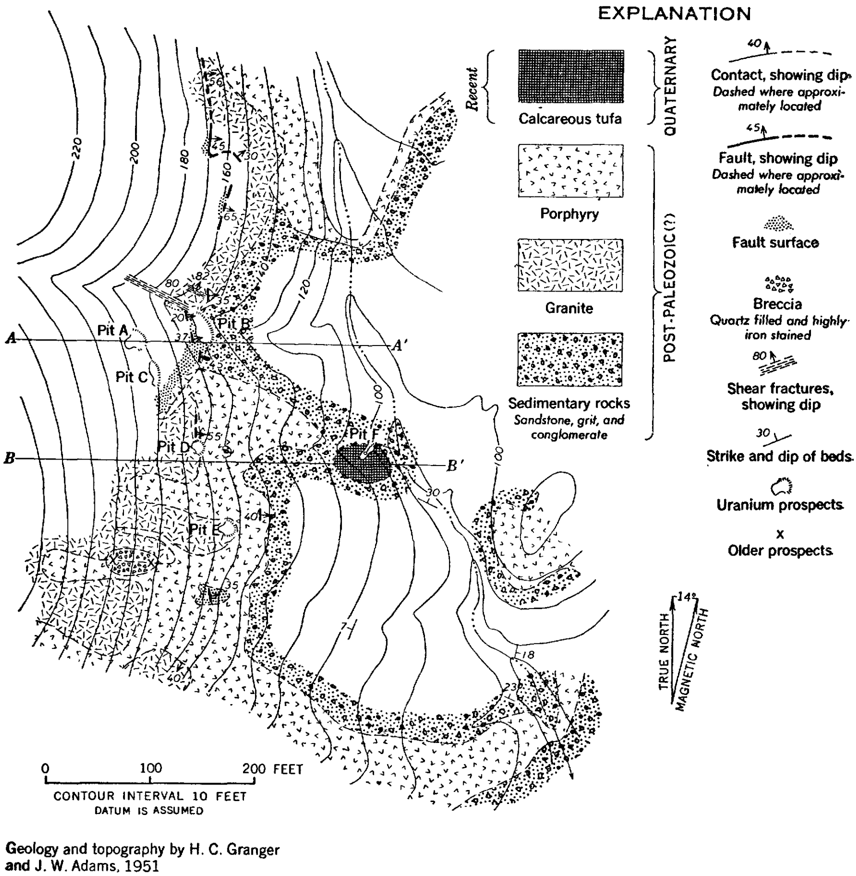


Figure 11.—Geologic map of the Annie Laurie prospect, Ruby district, Santa Cruz County, Ariz. Sections along lines *A-A'* and *B-B'* are shown in figure 12.

age. They are essentially flat lying, but near the intruded igneous rocks they are jumbled and are tilted as much as 20°.

The most significant feature related to the localization of the uranium is probably a system of north-trending east-dipping faults. These faults are roughly parallel to the margin of the granite and nearly parallel to the slope of the hillside; a large area of fault surface is exposed near pit B. Several of the fault fissures contain breccia cemented with porous quartz. The pores in the quartz probably once contained calcite, which has since been removed by weathering. Irregular zones of silicified breccia are exposed in the granite within the fault zone. The faults are younger than the porphyry.

North of pits A and B is a well-defined zone of shear fractures that strikes N. 60° W. and dips steeply northeast. Other fractures of

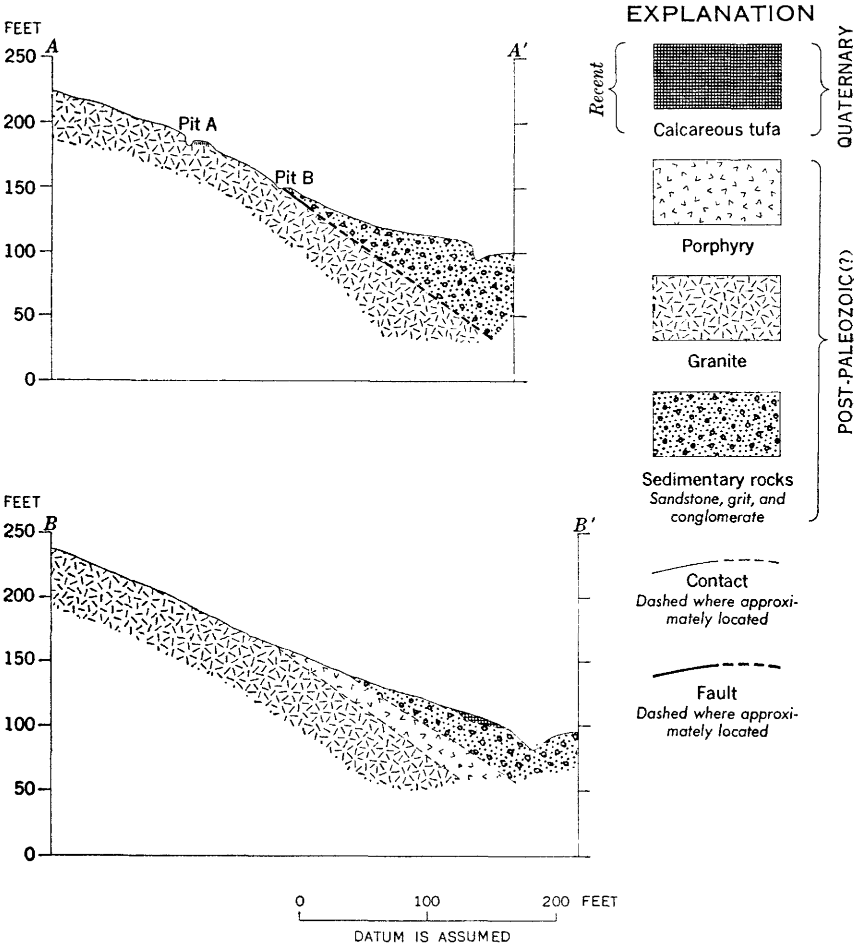


FIGURE 12.—Geologic sections, Annie Laurie prospect, Ruby district, Santa Cruz County, Ariz. Section lines are shown in figure 11.

similar attitude are common near the deposits but do not form such a prominent shear zone. Those exposed in the pits are locally filled with limonite.

Alteration in the vicinity of the uranium deposits was characterized by weak to strong silicification and by green coloration of the feldspar in the granite. Intense silicification commonly obscured the textures of the igneous rocks, so that the granite is nearly indistinguishable from the porphyry.

Within the alteration zone near the north-trending faults are many small variously oriented irregular veins, rarely more than 3 or 4 inches thick and 3 or 4 feet long. The walls of the veins are generally green, probably from chloritic alteration, and the original minerals are partly replaced by carbonate minerals, quartz, and a little pyrite. The vein filling is predominantly calcite but includes small amounts of sulfide minerals and quartz. Sphalerite, galena, chalcopyrite, pyrite, and purple fluorite form blebs and stringers in the calcite gangue. At some places in the wider veins the sulfide minerals, especially sphalerite, are concentrated in two layers within the calcite and parallel to the vein walls, as though the deposition of calcite had been interrupted by a period of sulfide deposition. Uraninite locally occurs disseminated and in hairline fractures in the walls of the veins, but none was noted within the vein filling.

Samples taken at pits A, B, and C contained 0.010, 0.015, and 0.010 percent U, respectively. Two samples taken at pit F contained 0.015 and 0.010 percent U, nearly in equilibrium with its daughter products; the first of these 2 samples consisted of a calcareous tufa and the second of underlying pyrite-rich sedimentary rocks. Wright (1951) lists assays as high as 0.79 percent U, but these were of selected material on the dumps.

The pitchblende and sulfide minerals appear to have been deposited by hydrothermal solutions that circulated along the north-trending, east-dipping fault fissures. Only quartz and calcite are now found in these fissures; the ore minerals occur only in and near related fractures bordering the faults. It is possible, however, that pitchblende and sulfide minerals were deposited in the fault fissures but were leached from them near the surface. If this is true, ore minerals might be found in the fissures by further exploration below the zone of weathering. The radioactive calcareous tufa at pit F was probably formed by leaching of the breccia and movement of ground water along the N. 60° W. set of fractures.

An article by Anderson and Kurtz (1955) describing a biogeochemical reconnaissance of the Annie Laurie prospect was published after our examination was made.

WHITE OAK PROPERTY

The White Oak property is in the NE¼ sec. 2, T. 24 S., R. 12 E., 15 miles northwest of Nogales. The host rock of the deposit is rhyolitic volcanic rock of Cretaceous or Tertiary age. The deposit is in a mineralized shear zone from which oxidized lead ore was mined.

The mine workings all follow or intersect the shear zone and consist of the White Oak adit, the White Oak No. 1 adit (fig. 13), 4 smaller adits, and several surface cuts and pits. The drift entered by the White Oak adit has been stoped for almost the entire length of the part that is accessible; the adit has been blocked by caved rock about

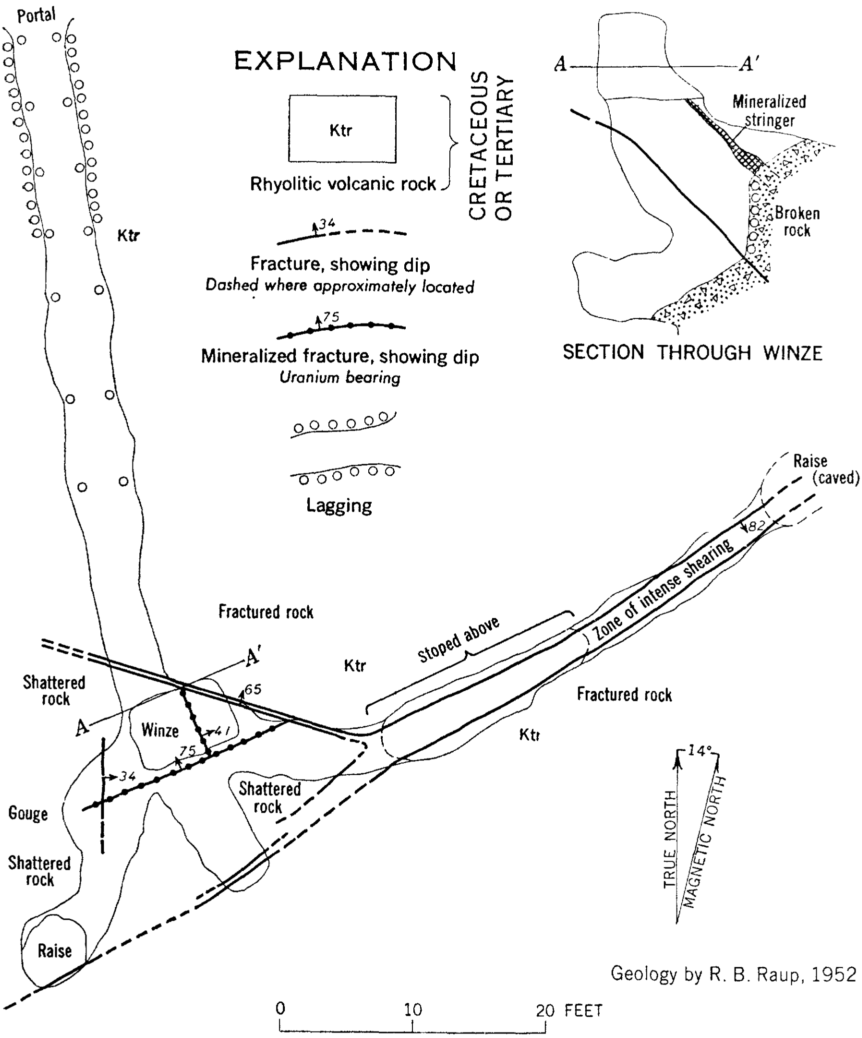


Figure 13.—Map of part of the White Oak No. 1 adit, Santa Cruz County, Ariz.

350 feet from the portal. The White Oak No. 1 adit cuts across to the shear zone beyond the caved area. Raises and winzes connect the various workings of the mine.

The mineralized shear zone on the White Oak property strikes about N. 55° E.; its dip ranges from 70° SE. to vertical and averages 80° SE. The few exposures on the surface and in the mine workings indicate that this shear zone extends for at least 1,500 feet across the property. It is a complex zone, as much as 30 feet wide, consisting of sheared, fractured, and locally shattered rock. In places it contains as much as 3 feet of breccia and gouge in a zone of intense shearing near the middle. Cerussite, the mineral originally sought by the owners of the property, fills fissures and partly replaces the breccia and gouge.

Uranium minerals have been found in the White Oak No. 1 adit (fig. 13), principally at its intersection with the mineralized shear zone. They are most abundant in 2 narrow intersecting zones of fractures, which are as much as 10 inches wide, within the shear zone; the rock between the fracture zones contains very little uranium. The uranium minerals are chiefly kasolite and uranophane, but they include small amounts of dumontite, autunite, and, perhaps, uranium-bearing pyromorphite. These minerals, all dark-yellow or orange, commonly occur as earthy or hard incrustations on the walls of fractures.

Selected samples from the uranium-bearing fractures in the White Oak No. 1 adit contained as much as 0.82 percent U, and a chip sample across a 10-inch fracture zone contained 0.47 percent U. Concentrations of such "high-grade" material, however, are small, discontinuous, and rare.

YAVAPAI COUNTY

ABE LINCOLN MINE

The Abe Lincoln mine is in the SE¼ sec. 11, T. 8 N., R. 3 W., about 14 miles by road northeast of Wickenburg. A limited partnership known as The Abe Lincoln Mines owned the property in 1952. The mine was opened in 1917 as a copper prospect and has produced a small amount of copper ore.

The mine has 2 vertical shafts and 2 adits, connected with 3,150 feet of drifts and crosscuts. Although both shafts are inaccessible because of water and caved rock, Elsing and Faick (M. J. Elsing and J. N. Faick, 1952 Defense Minerals Production Administration docket 2331) report that mine records indicate that 1 shaft was sunk 660 feet and gave access to workings on the 145-, 175-, 350-, and 660-foot levels and that another was sunk 175 feet to connect with the 350-foot level. One adit follows the Abe Lincoln vein system on the 175-foot level for at least 350 feet to a point beyond which it is caved. The other adit cuts across to the drift on the 145-foot level but is partly caved at the portal and is completely blocked 160 feet from the portal.

The country rock is a gneiss and schist complex of Precambrian age, locally intruded by Precambrian tourmaline granite and by younger dikes of both felsic and mafic composition, which cut both the metamorphic rocks and the granite. As indicated by the strikes of the dikes, the predominant structural trends in the vicinity of the mine are N. 50° E. and N. 32°–45° W.

The Abe Lincoln vein system consists of two veins separated by a narrow basalt dike; all three are on the hanging-wall side of a trachyte porphyry dike, and they, together with the trachyte porphyry dike, occupy a fault zone that strikes approximately N. 50° E. and dips 78°–89° NW. The vein on the footwall side of the basalt dike ranges in width from a few inches to 5 feet; the other vein, on its hanging-wall side, is narrower. Slickensided gouge, from 1 to 18 inches thick, is common between the basalt dike and the footwall vein. The dikes are older than the ore, for they contain sparsely disseminated ore minerals.

The veins contain chalcopyrite and smaller amounts of azurite, chalcocite, and malachite, in a gangue of quartz, calcite, pyrite, and limonite. On the dump there is some purple fluorite associated with calcite, but no fluorite was noted in place in the exposed vein system.

No radioactive material was found in place in the 510 feet of accessible mine workings, but uranium minerals were found in small amounts on the dumps of the 660-foot shaft and the 145-foot level adit. Selected samples from the dumps contained as much as 0.46 percent U. The material from the shaft dump included trachyte porphyry containing fractures coated with malachite, limonite, and secondary uranium minerals; it also included vein material consisting of chalcopyrite, malachite, secondary uranium minerals, and fluorite in a gangue of pyrite, quartz, calcite, sanidine, and black altered gouge. The gouge contains disseminated grains of pyrite and chalcopyrite in a fine-grained aggregate of chlorite, sericite, altered feldspar, quartz, apatite, and leucoxene(?). The material from the adit dump included a large specimen of banded vein filling that consisted of quartz, black altered gouge, sanidine, pyrite, chalcopyrite, and secondary uranium minerals. The principal secondary uranium mineral in this specimen was identified by X-ray methods as schoepite. It formed a coating on pyrite grains.

Although no primary uranium minerals were identified, the presence of uraninite is suggested by the secondary uranium minerals, especially schoepite, for schoepite occurs as an alteration product of uraninite in the Belgian Congo (Palache, Berman, and Frondel, 1944, p. 628) and at Beryl Mountain, N.H. (Rabbitt, 1953). Finely divided uraninite may be present in the black altered gouge, which is weakly radioactive in many specimens from the dumps.

As no significant radioactivity was detected in the accessible mine workings, the source of the radioactive material on the dumps could not be determined. This material is unlike that known to come from the Abe Lincoln vein system, the most noticeable difference being the fluorite in the calcite gangue. Perhaps the uranium-bearing rock on the dumps came either from local fluorine-rich pockets in the Abe Lincoln vein system, or from some other vein, separate from or intersecting the main system.

Samples from a vein on a property about a mile west of the Abe Lincoln mine contained 0.006 and 0.012 percent U and a sample that contained 0.012 percent U was taken from an exposure of the metamorphic rocks in a road cut a little less than a mile west of the mine. Although these samples do not in themselves contain much uranium, they indicate that the area around the Abe Lincoln mine may contain minable deposits of low-grade uranium ore.

CUBA AND INDEPENDENCE CLAIMS

The Cuba and Independence claims are adjacent to one another in T. 11 N., R. 5 W., approximately 7 miles north-northwest of Yarnell. On the Cuba claim there is an 18-inch quartz vein, striking N. 52° W. and dipping 25° NE., in a coarse-grained buff-colored granite. The mine workings comprise a 125-foot inclined shaft connecting with a 150-foot adit drift. For about 25 feet along the drift, flecks of what seems to be torbernite occur sparingly in a narrow zone on the footwall side of the vein. A chip sample across this zone contained 0.009 percent U.

Within a hundred yards of the Cuba workings and on the Independence claim, a thin coating of uranophane(?) was found on an exfoliation surface in the coarse-grained granite country rock. A selected sample of the material contained 0.016 percent U. The country rock in the vicinity is abnormally radioactive, though not uniformly so. As measured with a scintillation survey meter, the background radioactivity was 0.015 to 0.020 mr per hr and the radioactivity of the granite ranged from 0.035 to 0.140 mr per hr. The highest readings were obtained at the exfoliation surface; the average reading was between 0.040 and 0.050 mr per hr. A representative sample of the granite contained 0.004 percent eU.

KITTEN NO. 1 CLAIM

The Kitten No. 1 claim is in the SW¼ sec 27, T. 15 N., R. 9 W., about 155 feet west of the Hillside mine road and 4.3 miles from Bagdad. It was owned in 1951 by W. D. Moore of Bagdad. The country rock in the area is a coarse-grained porphyritic granite, of Precambrian age, cut by many narrow pegmatite and aplite dikes. Most of the dikes are roughly parallel to the most prominent joints, which strike N. 23° W. and dip 85° NE. Development in 1951 consisted only of one shallow prospect pit.

The uranium deposit extends along a fracture that strikes N. 88° W. and dips 60° N., at a large angle to the regional structural trend, and that forms a well-defined footwall for the deposit. Metatorbernite, pyrite, and fluorite are disseminated in a zone of intensely altered rock 3 to 4 feet wide. Within this zone most of the feldspar is changed to clay, yet most of the biotite retains its original form and luster. Much of the altered material, and the minor fractures bordering the hanging wall, are intensely iron stained. The deposit is only about 15 feet long at the surface, and probably is shallow. The footwall fracture is traceable for about 50 feet, being marked by a narrow quartz filling and limonite stain. Several nearby fractures have the same attitude and contain minor amounts of quartz and limonite, but they are not radioactive.

Two channel samples across the most radioactive part of the deposit contained 0.094 and 0.013 percent U. The first sample seems to have been strongly leached, for its radioactivity was equivalent to 0.20 percent U.

The relation of this deposit to other uranium deposits in the area is not known. The deposit is only about 3 miles from the Hillside mine from which uraninite has been identified, but there is no reason to believe that the two occurrences are closely related.

PEEPLES VALLEY MINE

The Peeples Valley mine is in the Weaver Mountains, about 20 miles southwest of Prescott. Its workings consist of a 20-foot shaft and several opencuts. The deposit is in a lenticular mass of quartz-feldspar pegmatite in coarse-grained granite. The pegmatite strikes about N. 40° E. and dips from 70° NW to nearly vertical. Its outcrop is about 300 feet long and 150 feet wide.

In 1953 a small amount of scrap mica was produced from the mine. In addition to numerous though small books of muscovite, the pegmatite contains small quantities of beryl and probably niobium-tantalum minerals. Although assays indicate the presence of uranium and thorium, no primary radioactive minerals were identified. The uranium occurs in yellow secondary minerals, predominantly uranophane, and possibly also in niobium-tantalum minerals.

Three samples obtained from the few small concentrations of radioactive material in the mine contained 0.004 to 0.13 percent U and 0.032 to 0.078 percent Th. A selected sample from the most radioactive spot in the mine contained both the most uranium and the most thorium.

YUMA COUNTY

ATOM CLAIMS

The Atom Nos. 1, 2, and 3 claims were located for uranium by Richard Peters of Yuma in the fall of 1948. They are near the intersection of the U.S. Coast and Geodetic Survey coordinates 1099100 N. and 83900 E. on the Picacho 15-minute quadrangle map.

The country rock is a medium-grained foliated Precambrian granite containing lenticular inclusions of mica schist, the largest of them several hundred feet long. The elongation of the inclusions, like the regional foliation, strikes about N. 55° W. and dips 55° SW., but the strike and dip show extreme local variations. The principal joints strike N. 15° W. and dip steeply eastward. The schist inclusions commonly have hematite veins along their footwall contact, and parts of these veins are very weakly radioactive. Barren quartz veins occur in small swarms and locally follow the principal joints.

A 25-foot inclined shaft on the Atom No. 1 claim follows the foliation, which there strikes N. 40°–45° W. and dips 40°–60° SW. The shaft was sunk in fractured rock that appears to be schist partly assimilated by the enclosing granite. Along the foliation are stringers of quartz, hematite, and calcite. Some weak radioactivity, probably associated with the hematite, was found in the shaft.

Other radioactive zones on the Atom claims are exposed in shallow prospect pits. There also the radioactivity is commonly associated with hematite-rich stringers, which follow either the foliation in schist inclusions or the principal joints. No uranium minerals were recognized in either the shaft or the pits.

Samples taken by the owner contained 0.01 to 0.04 percent U. As the samples indicate that the uranium is in equilibrium and there is no evidence of strong mineralization, it seems unlikely that the deposits will improve in grade at greater depth.

McMILLAN PROSPECT

The McMillan prospect is on the northwest flank of the Cabeza Prieta Mountains, 25.5 miles southeast of Wellton on the road between Wellton and Tule Tank. The deposit is in a fracture zone that strikes N. 34° W. and dips 68° SW., in biotite granite. The zone is traceable for 210 feet up a 30° slope and along the crest of a ridge. Adjacent to the fracture zone is a quartz-feldspar pegmatite dike that roughly parallels the zone on the hanging wall side. Two short adits and an opencut have been driven into the fracture zone where it is exposed on the slope. The lower adit is about 10 feet long and the upper adit, 90 feet up the slope, is about 20 feet long. The opencut, which is 110 feet above the upper adit and near the top of the slope, is only 5 feet long. At the lower adit stringers of pegmatite are about 2 feet above the hanging wall of the fracture zone. These stringers merge upward into a pegmatite dike 4 to 5 feet wide. The distance between the fracture zone and the pegmatite gradually decreases upward, and from the upper adit to the opencut the pegmatite forms the hanging wall of the zone. The fracture zone is about 1½ feet wide at the lower adit, but it narrows upward, being only about 2½ inches wide at the opencut.

Where exposed in the lower adit, the fracture zone is stained along the cracks by copper and iron minerals, and there are seams of malachite and chrysocolla along major fractures. Chrysocolla and malachite occur in a similar way at the upper adit and in the opencut, but in those openings the copper and iron stains are stronger than in the lower adit. The pegmatite is fractured and copper- and iron-stained where exposed in the opencut, but not in the two adits. Apparently the metalliferous solutions followed the fracture zone and are not related genetically to the pegmatite.

A 50-foot vertical shaft a short distance northwest of the adits does not seem to be in this fracture zone, even though it is in highly fractured and iron-stained granite whose larger fractures are coated with secondary copper minerals.

At some places in the mine workings and on the dumps, radioactivity is as much as five times the background radioactivity. A stockpile of copper-stained material presumably mined from one of the adits gave readings of nearly 0.5 mr per hr on a scintillation meter. A selected sample of this material contained 0.034 percent U and 7.69 percent copper. Although it is possible that the McMillan prospect contains local concentrations of uranium ore, most of the radioactive rock on the property is below commercial grade.

CONCLUSIONS

Some of the deposits described in this report deserve more detailed geologic study and physical exploration. Further work has in fact been done on the deposits in the Dripping Spring quartzite since the completion of fieldwork on which this report is based, and some exploration has been conducted on the Annie Laurie claims. The Orphan claim and Hack's mine contain deposits of the same type, and the similarity in geologic setting seems too great to be accidental; further study of these would increase the possibility of finding other similar deposits on the Colorado Plateau. In fact, since this part of the report was originally written, Western Gold and Uranium, Inc., has extensively mined the Orphan claim, has explored the Hack Canyon deposit, and has discovered similar structural features in the Grand Canyon region.

The source of the uranium-bearing rock on the dumps of the Abe Lincoln mine cannot be determined until the caved workings have been, at least in part, reopened. The dumps on which radioactive material was found are at the collar of the 660-foot shaft and the portal of the 145-foot-level adit. As the shaft is caved for 175 feet below the surface (M. J. Elsing and J. N. Faick, 1952, Defense Minerals Production Administration docket 2331), the 145-foot-level adit, though now partly caved at the portal and completely caved 160 feet beyond it, might be the more economical way to reenter the mine. Although only a little uranium-bearing rock was found on the dumps, it was on the top, suggesting that the source rock may still be exposed in a heading. As the uranium occurs with fluorite in a calcite gangue, a mineral association not typical of the Abe Lincoln vein system, the uranium-bearing areas may be in workings away from the main veins or they may be veins that intersect the Abe Lincoln vein system.

The Annie Laurie deposit has been examined by Wright (1951), who made a study of the geology and radioactivity, and by Anderson and Kurtz (1955), who did a biogeochemical reconnaissance of the prospect. Both of the resulting papers state that the deposit dips westward, and drilling has therefore been done west of the prospect pits. If the deposit dips eastward, however, as we believe that it does, the deposit might be explored from the hillside to the east below pits A to E, or from the bottom of the gully shown in figure 11.

As in other metallogenic provinces, small amounts of uranium minerals are present in many deposits in Arizona exploited for their base or precious metals, but most of the deposits described in this report probably have too little uranium exposed to merit further examination or exploration. With few exceptions, the concentrations of uranium appear to be small and do not necessarily indicate that there are greater concentrations elsewhere in the deposit or in the surrounding area.

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