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STRUCTURAL CONTROL OF URANIUM DEPOSITS, SIERRA ANCHA REGION, GILA COUNTY, ARIZONA

By
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ABSTRACT

The discovery and exploitation of primary uranium mineralization in the Sierra Anchas of east-central Arizona made possible an analysis of the structural ore controls.

An older Precambrian metamorphic and granite complex is covered by the younger Precambrian Apache group of sediments and the Cambrian Troy formation. The sediments are generally flat-lying and broken by steep-dipping normal faults. Extensive, thick, diabase sills have penetrated several thinly bedded horizons. Although the region is within the mountain belt of Arizona, the structural framework is similar to that of the Colorado Plateau, which is expressed physiographically by the Magollon Plateau 20 miles to the north.

The investigation was carried out in four phases: (a) detailed mapping of uranium occurrences, (b) field measurement and analysis of jointing over the region, (c) analysis of fractures taken from aerial photographs, and (d) petrographic and chemical investigation of the sediments, diabase intrusives, and uranium ores.

Results of the work indicate three types of structural controls which are responsible for localization of the uranium deposits:

(a) Fracture Control The primary uranium ore is located adjacent to steep-dipping fractures with strikes oriented either north-northeast or west-northwest. These fractures are part of a pre-ore system which has a consistent pattern over the entire region.

(b) Sedimentary Control All primary deposits occur within the upper Dripping Spring quartzite, which is an ancient potassium-rich tuff within the Apache group.

(c) Diabase Intrusives Hydrothermal activity accompanying the intrusion of diabase dikes and sills has concentrated the uranium to form the ore deposits. Thus, the position of these intrusives with respect to the favorable stratigraphic interval is an essential structural control.

It is not likely that the diabase magma was the source of the uranium. Rather, it appears that as the diabase magma penetrated, engulfed, and metasomatized the upper Dripping Spring quartzite, associated gases and hydrothermal solutions removed and transported much of the syngenetic uranium from the sediment to the ore deposits.

I. INTRODUCTION

A. Geography

The Sierra Anchas are a prominent mountain-range located in east-central Arizona at approximately 34° north latitude and 111° west longitude. (See index map, Plate 1). The region is covered in large part by the McFadden Peak and the Rockinstraw Mountain quadrangles, and is situated between Globe and Young in Gila County. These mountains are bounded by the Salt River and Roosevelt Reservoir on the south, by Tonto Creek on the west, by Pleasant Valley on the north, and by Cherry Creek on the east. From an elevation of 2200 ft at Roosevelt Reservoir, the range rises in bold steps up to an elevation of over 7700 ft in the central portion. Access into the region is by highway 88 to Roosevelt Reservoir and northward via the Young highway. Improved and unimproved dirt roads allow automobile travel around the north and south ends of the range and for some distance up and down Cherry Creek. Roads extend up Pocket Creek, Workman Creek, and Reynolds Creek from the Globe-Young highway (Plate 25).

B. History of Exploration and Mining

Uranium was discovered at the Red Bluff property (Plate 2) in the souther Sierra Anchas in January, 1950, by Mr. Carl Larsen. In early 1953, Messrs. Melvin Stockman and O. H. Shepp reported a uranium discovery on Wilson Creek in the northeastern Sierra Anchas. Both of these early discoveries were found in the upper Dripping Spring quartzite of the late Precambrian group. (i)

During 1953, the writer and other geologists of the U. S. Atomic Energy Commission carried out field investigations and planned an airborne uranium exploration project for this region. In the spring of 1954, the Commission conducted for three months a low-level airborne survey utilizing scintillation, gamma-ray detection equipment. Anomalous radio-activity was discovered at more than twenty locations, most of which are in the Sierra Anchas. Although considerable flying was done over various formations, nearly all of the anomalies were discovered within the upper DS.

The public announcement of these discoveries stimulated claim staking and mining activity. By the summer of 1955, enough uranium ore was mined and developed that a government ore buying station was established on a railhead near Globe.

C. Purpose of the Research Project

The earlier geological investigations of these deposits had been limited to a very few uranium occurrences, and only the Red Bluff property had been studied in any detail. Concepts of structural controls

(i) The Dripping Spring quartzite will occasionally be abbreviated DS in the remaining portion of this report.

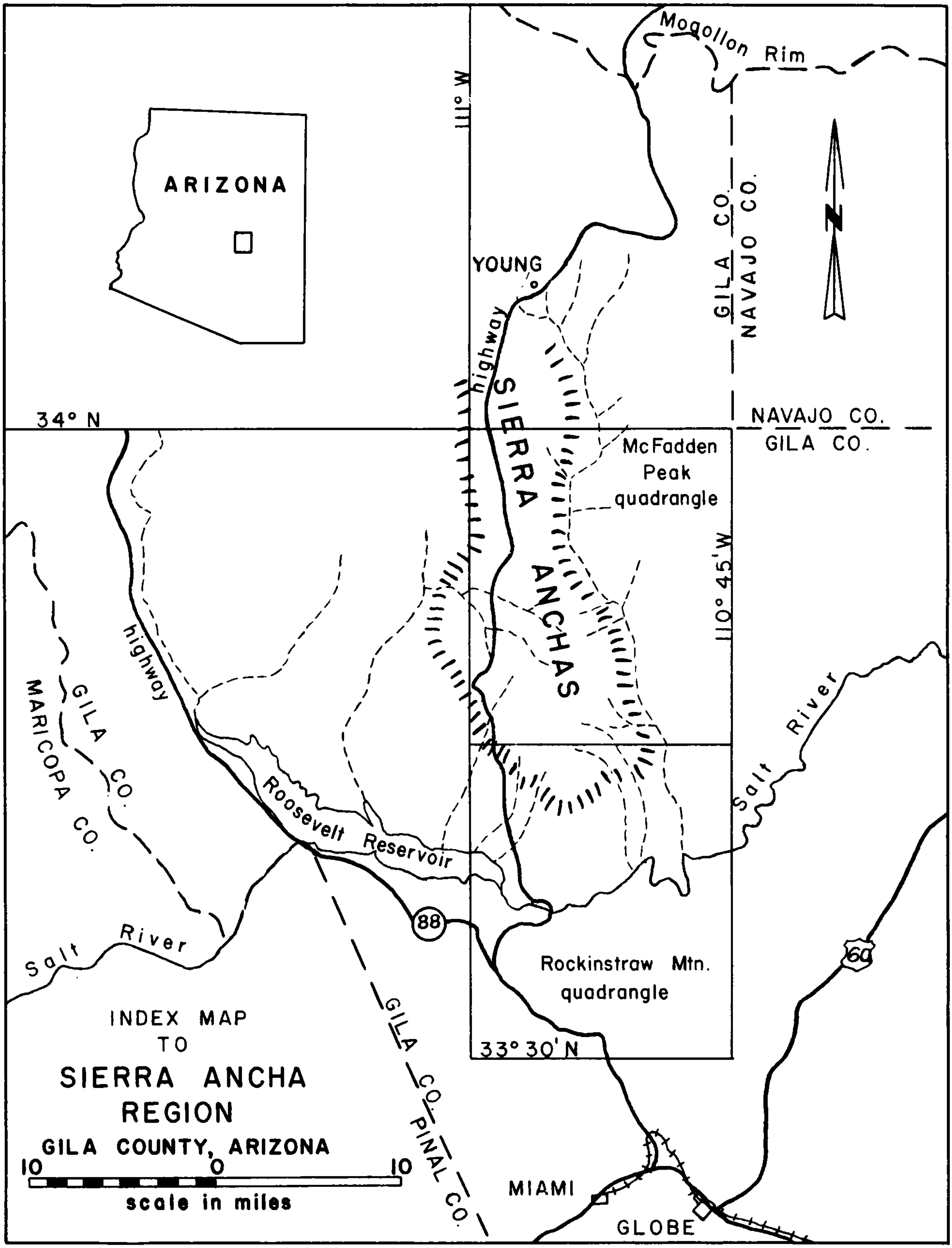


PLATE I. Index map to Sierra Ancha Region, Gila County, Arizona

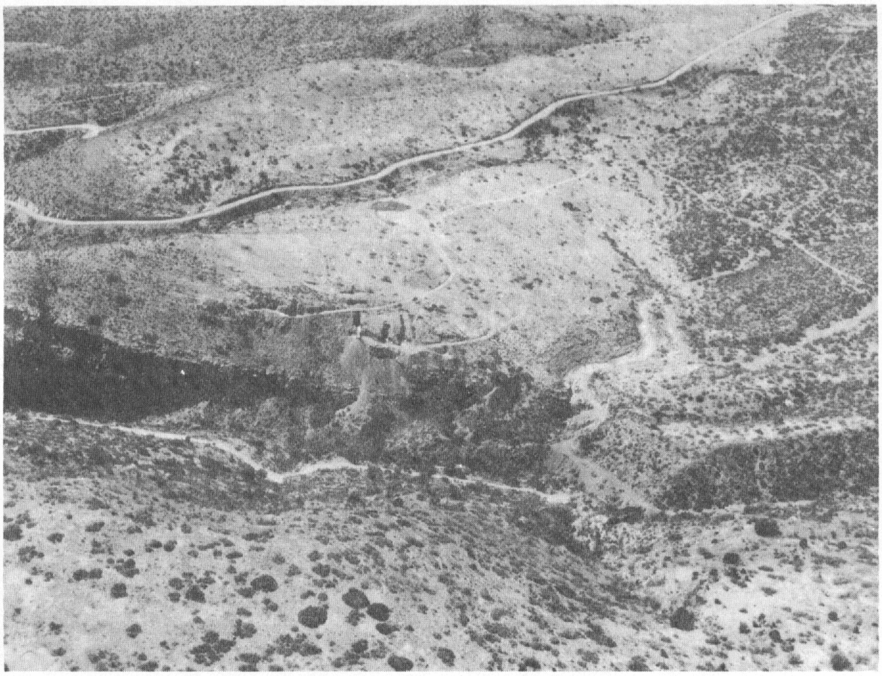


Plate 2. Photograph of the Red Bluff Property, looking NW across Warm Creek. Portals and trenches are in the upper Dripping Spring quartzite. A dike of the less resistant diabase crops out in the bottom of the creek. The narrow, light-colored ridge at the right end of the canyon and parallel with it is a plagioclase-rich segregate within the thick diabase sill. Mescal limestone is in the foreground. The Globe-Young highway crosses the top of the picture.

of the ore were varied and generally vague. However, these earlier investigations pointed out the problems involved, and thus gave guidance to the planning of this work. Kaiser (1951), in his report on the Red Bluff property, reports two favorable stratigraphic layers in the upper DS and fracture-controlled ore within these layers. He believed the structural relationship to an adjacent diabase dike to be significant. Wright (1950) accepted stratigraphic control of the ore at the Red Bluff property, and thought the intrusive contact of the diabase dike was important due to decreasing radioactivity away from the dike. Mead and Wells (1953) recognized the generally higher radioactivity of the DS quartzite, and that the two most noteworthy uranium deposits are in the same stratigraphic horizon of the upper DS. They suggested a genetic association of the uranium deposits with diabase dikes and sills. A study of the anomalous radioactive occurrences in the Wilson Creek area by Wells and Rambosek (1953) indicated that all the anomalies were from 100 to 130 ft stratigraphically below the DS-Mescal limestone contact. They found some evidence of fracture control of uranium. Gastil (1953) states that the siltstones of the upper DS and the tuff of the Pioneer formation are anomalously radioactive throughout. He found both stratigraphic and fracture controls of ore, and believes the ore to have been introduced hydrothermally into a favorable argillaceous siltstone bed.

The writer undertook this investigation in an attempt to answer several fundamental questions related to the localization of the uranium ores: What fractures localize the ore, and what is their pattern? Are they identical with the main joint system of the region? Are the joints in the host rock unique to that formation? How do the joint patterns compare with those in the younger and older granites, the diabase intrusives, and in the younger flow rocks? Over what area are the fracture patterns consistent? Were the joint systems in the upper DS created by the diabase intrusions or were they already in existence when the intrusion took place? What was the interplay of the process of intrusion and fracturing?

Is the ore actually restricted to certain horizons in the DS or not? Can the ore be correlated with localization or concentration of joints in certain horizons, with porosity, or with precipitating agents?

Was the ore derived from the diabase magma, or did the intruding magma act as a concentrating agent to collect uranium from the invaded rocks? Did the diabase contacts act as favorable channelways for ore transport? Did the uranium-bearing solutions come through the diabase from sources lower down?

An attempt to answer these questions gave purpose and direction to the investigation.

D. Initiation of the Research

The research was sponsored and financed for two years by the Raw Materials Division of the U. S. Atomic Energy Commission. Dr. Walter H. Bucher, Newberry Professor of Geology, Columbia University, has been director of the project.

Field investigations were started June 1, 1954, at a time when many newly discovered uranium deposits were being opened up by surface trenching, underground mining, and core drilling. At this time, a meeting was held with Mr. A. F. Shride and Dr. Nels P. Peterson, geologists of the U. S. Geological Survey in Globe. The current work of these two was discussed, and since Shride was conducting a program of quadrangle mapping in the Sierra Anchas, it was decided that the writer would do no mapping which would duplicate the work of the Survey, but would concentrate particularly on the uranium deposits and the problems related to them.

Field work was concluded in September, 1955 and laboratory study was completed in September, 1956.

E. Acknowledgments

The ranchers, claim owners, and mine operators were always friendly and helpful during property examinations. The practical exploration problems which confronted these people were a day-to-day stimulus to the writer. Messrs. Ernest E. Thurlow, Donald L. Everhart, Millard Reyner, and Roland Schwartz, geologists of the Raw Materials Division, U. S. Atomic Energy Commission, gave their support and interest throughout the investigation.

Professor Walter H. Bucher, Director of the Project, has been a constant guide, inspiration, and friend. Professor Arie Poldervaart gave invaluable help and encouragement to the writer in the planning and execution of the petrographic and geochemical phases both in the field and in the laboratory. Professor Paul F.Kerr helped with special mineralogical problems. Professors Marshall Kay, Charles H. Behre, Jr. and Arthur N. Strahler gave helpful advice on certain problems.

Mr. Gordon Gastil willingly shared his knowledge of the geology of the Sierra Anchas. Messrs. John Crawford, Paul Damon, and Bruno Giletti shared their views of the problems through many hours of discussion.

Chemical analyses of rocks were made by Mr. H. B. Wiik. Spectrochemical analyses were made by Dr. Karl Turekian and Dr. S. Sen at Lamont Geological Observatory of Columbia University.

II. GEOLOGIC SUMMARY

The Sierra Anchas are composed essentially of the Apache group, which was named and described by Ransome (1903; 1904; 1916; 1919; 1923) as a result of his work in the Globe and Ray copper districts. The Apache group and the structure of the Sierra Anchas were discussed by Darton (1925). Wilson (1939) wrote on the Precambrian Mazatzal Revolution in central Arizona. Gastil (1953) made a study of the eastern half of the Diamond Butte quadrangle, which includes the NW portion of the Sierra Anchas. Other reports of an economic nature concerned with asbestos deposits have been written - Bateman, 1923; Wilson, 1928; and Stewart, 1955.

A crystalline basement of older Precambrian rocks is overlain by the later Precambrian, mid-Cambrian, and Devonian sediments. The Cambrian Troy quartzite is the youngest formation with any significant geographical extent in the Sierra Anchas. The younger Paleozoic and Mesozoic sediments of the Colorado Plateau presumably once covered the area, but they have been eroded back to the Mogollon Rim twenty miles northward.

A. Older Precambrian Rocks

Several thousand feet of interbedded sedimentary and volcanic rocks of an early Precambrian age have been mapped by Gastil in the Diamond Butte quadrangle, which joins the McFadden Peak quadrangle at the northwest corner. Most of the sediments were derived from the volcanic rocks in the area, and the extent of the individual formations is limited. Granites which were emplaced during the Mazatzal Revolution, are well exposed in the foothills around the Sierra Anchas. They are coarse-grained with unusually large feldspar phenocrysts.

This older metamorphic and granite complex has a strong northeast-southwest structural orientation. Axial planes of folds, planes of schistosity in the metamorphics, and prominent jointing in the granites, have this orientation in the Diamond Butte quadrangle.

B. Younger Precambrian Rocks

The Apache group of central Arizona includes the following formations as described by Ransome (1903):

Formation	Character	Thickness (feet)
Troy quartzite	Largely quartzite, light colored, cross-bedded, pebbly streaks.	160-1000
Basalt flow	Vesicular lava, present at many places.	0-75
Mescal limestone	Thin-bedded, hard, with intercalated cherty layers.	225-300

Formation	Character	Thickness (feet)
Dripping Spring quartzite	Fine-grained arkosic quartzite and sandstone mostly massive, and reddish-brown, locally thin-bedded.	450-700
Barnes conglomerate	Smooth, mostly rounded pebbles in hard arkosic matrix.	5-50
Pioneer shale	Shale, mostly brownish-red and hard.	150-250
Scanlan conglomerate Pebbles	Mostly local, generally grades up into arkosic sandstone.	0-30

Ransome originally classified the Apache group as Cambrian, but Darton (1925), and later Ransome, restricted the group to exclude the Troy and considered it to be Precambrian.

Given below is a portion of Wilson's (1939) stratigraphic tabulation of the rocks of central Arizona:

Age	Group and Formation	Character	Thickness in Feet
	disconformity		
Cambrian (middle)	Sandstone	Red-brown cross-bedded pebbly Troy sandstone in northern Sierra Ancha and southern Mazatzal Mtn areas; dark red-brown bedded friable Tapeats sandstone, 75-100 ft thick, in north-western portion of region.	75-400
	unconformity		
Younger PreCambrian	Apache group (in eastern Tonto Basin and southwestern portion of Mazatzal mts.)		
	basalt	Vesicular, epidotized basalt, present at most places.	0-75
	Mescal limestone	Thin-bedded cherty dolomitic limestone, intruded by diabase.	225-300
	Dripping Spring quartzite	Reddish-brown, generally massive, fine-grained arkosic quartzite; intruded by diabase	450-700

Age	Group and Formation		Character	Thickness in Feet
Younger Pre-Cambrian	Apache group (in eastern Tonto Basin and southwestern portion of Mazatzal mts.)	Barnes conglomerate	Smooth, rounded pebbles in sandy arkosic cement; intruded by diabase.	5-50
		Pioneer shale	Brownish-red, hard shale; intruded by diabase.	150-250
		Scanlan conglomerate	Imperfectly rounded pebbles in sandy arkosic cement; intruded by diabase.	0-30
		unconformity		

The characteristics of these formations as they appear in the Sierra Anchas will be discussed below in more detail.

1. Scanlan Conglomerate This formation is a basal conglomerate which overlies the older granites unconformably. Thickness varies from zero to several tens of feet, depending largely upon the relative relief of the old erosion surface. It is composed of locally derived, poorly sorted, angular gravel in a pink, arkosic, coarse, sandstone matrix. For this reason, its color and texture commonly blend with the underlying rock. However, in some exposures there is a large portion of transported material which usually consists of well-rounded quartzite pebbles and cobbles. The outcrops of the locally derived gravel and sandstone are not particularly resistant, but the quartzite conglomerate forms ledges and overhanging cliffs. The matrix is sufficiently silicified that many fractures break through the pebbles and cobbles.

2. Pioneer Shale This shale is gradational and conformable with the underlying Scanlan. A section of Pioneer at Bull Canyon (Plate 3) in the southern Sierra Anchas is at least 295 ft thick where it is intruded near its base by a diabase sill. It thins gradually to the north, and pinches out in the Diamond Butte quadrangle. The formation has a uniform appearance throughout. It is a mottled purple to red siltstone and fine-grained sandstone sequence which is thinly bedded. Although the shale is hard, it forms more gentle slopes than the quartzites above it.

Thin-section studies of a sequence of samples taken through the Pioneer shale at Bull Canyon indicate that the siltstones consist predominantly of pyroclastic material. Quartz grains occur with wedge, crescent, and rod shapes, and some have highly sutured borders. These shapes are believed to be devitrified shards. Some detrital quartz

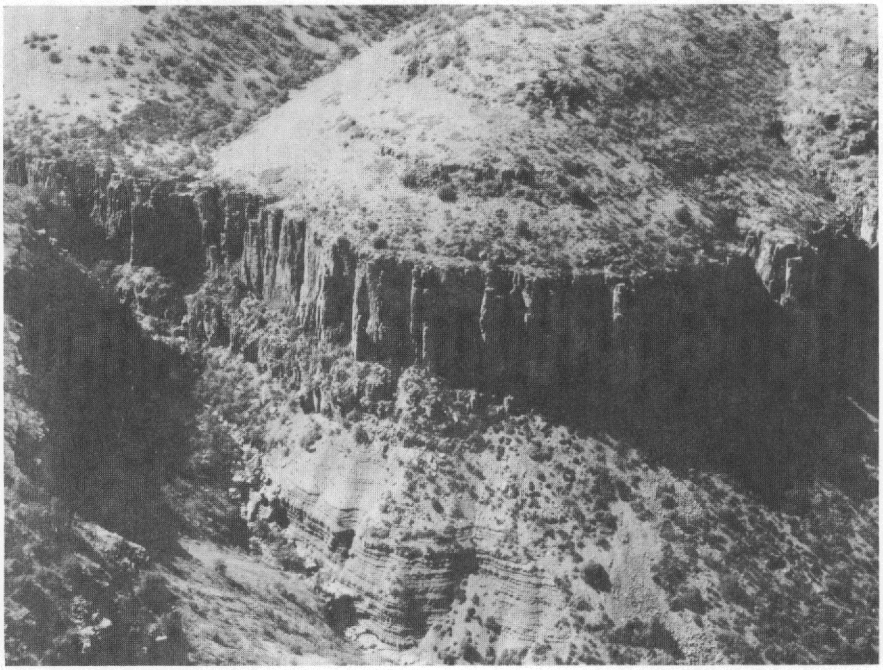


Plate 3. Photograph at Bull Canyon showing Apache group sediments. Looking NW. The steep columnar cliffs are lower Dripping Spring quartzite. Above the cliffs is the thin-bedded upper Dripping Spring quartzite. Pioneer formation is in the canyon below the cliffs.

sand occurs as lenses within the tuff, and the contrast in the shard-shaped and detrital quartz is marked. Feldspars are difficult to identify because of turbidity and small size. Muscovite is present in small amount. A tufted or "shredded" texture emphasized by thin, dark beds of chlorite further suggests the pyroclastic nature of the material. The purple to red color is due to disseminated iron oxide. Pale green spheres or spots on surfaces less than 1/2 inch in diameter are common in some horizons where the iron has been reduced. The tuffaceous character of this formation was first recognized by Gastil (1953; 1954).

3. Barnes Conglomerate This formation is generally conformable with the underlying Pioneer, but at some places it fills shallow channels. It varies in thickness from 15 to 30 ft. Well-rounded, pink to maroon sedimentary quartzite cobbles are held together firmly by a silicified matrix of arkosic pebbles and sand. It forms a distinctive and resistant marker bed throughout the region.

4. Lower Dripping Spring Quartzite The Dripping Spring quartzite is divided for discussion purposes into lower and upper units. The two units can be readily distinguished in the field because of obvious differences in lithologic characteristics.

The lower DS is from 290 to 315 ft thick and is conformable and gradational with the Barnes. It consists of buff to orange-pink, arkosic, quartz sandstone. The quartz grains are fairly well sorted and appear to be of detrital origin. Edges of the grains are sutured, but the grains are approximately equidimensional. Plagioclase, microcline, and orthoclase are common. Some of the feldspars have altered to kaolin to give a spotted appearance. Sorting of grains is fair to good. Although the lower DS is essentially an accumulation of detrital sand, samples taken from near the base of the formation in Cherry Creek consist in part of tuffaceous material similar to that of the Pioneer shale. The formation is thick-bedded, massive, cross-bedded, and is ripple-marked. Recrystallization and cementation have resulted in a hard, brittle, and extremely resistant quartzite which is a cliff-former (Plate 4). Weathering along nearly vertical joints gives a columnar appearance to the cliffs and causes the streams to follow fracture directions.

5. Upper Dripping Spring Quartzite This upper unit is generally conformable with the lower unit, but marked local unconformities were observed in Walnut Creek in the northern Sierra Anchas. The upper DS is 350 ft thick at Bull Canyon (Plate 3), which is about the maximum thickness for the region. It extends over a considerable portion of the Sierra Anchas and eastward, but it is far more restricted than the lower unit due to its less resistant character. The upper DS is distinctive because of its thinner bedding, dark gray intervals, fine grain-size, and tuffaceous composition. It is divided for discussion into three portions.

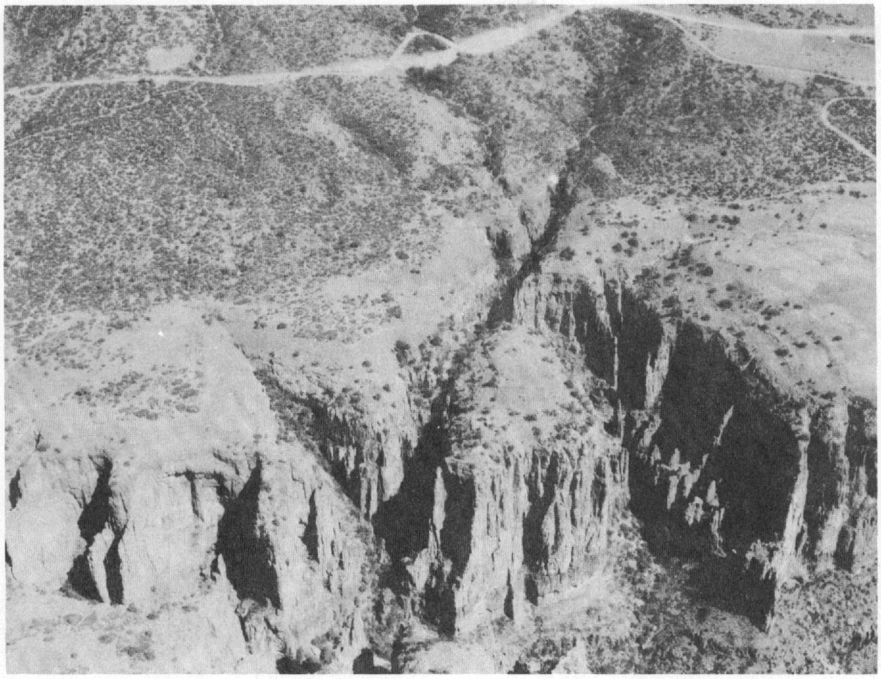


Plate 4. Photograph of Parker Creek, looking East. The canyons are cut into lower Dripping Spring quartzite. The brush covered slope in the background is diabase sill. Most drainage in the quartzite is localized by jointing and fracturing.

The lower 50 to 70 ft is fairly massive, buff to pink sandstone and tuff. Coarse sandstone is more prominent near the base and becomes less and less common higher up. The coarse detrital quartz grains tend to be equidimensional, subangular, and have sutured borders. Near the base these grains grade to pebble size. Orthoclase-rich tuff forms the matrix for the coarser detrital quartz grains. The tuff is made up essentially of feldspar, quartz, and chlorite. The feldspar is fine-grained, turbid orthoclase, which has irregular or sutured grain boundaries. The pyroclastic quartz occurs as long thin wedges, crescents, triangles, and slivers - shapes that suggest devitrified shards. The chlorite forms darker bands which have a shredded appearance and which drape over the coarser quartz grains due to compaction. Small dark spots in the tuff have the appearance of minute pillows. Iron oxides give a pink color to the rock. Small lenses of coarser detrital sand are quite characteristic of this lower portion.

The middle portion is more thinly bedded and has a flaggy fracture. Much of the interval is dark gray on fresh exposure due to abundant, very finely dispersed pyrite and graphite. The rock is very dense, with individual grains being about silt size. This interval, which averages 150 ft thick, is where the primary uranium deposits occur. Mineralogical composition is orthoclase, quartz, pyroxene, pyrite, chalcopyrite, graphite, sphene, and chlorite.

The feldspar makes up about 80% of the rock. The feldspar grains are usually interlocking, but occasionally colloform masses and radiating clusters are observed. Quartz occurs in shard-like shapes, such as wedges, crescents, and rods. Mafic constituents form shreds or thin bands, and small pillow-like structures. Pyroxene is recognizable only as very small, equidimensional grains. Pyrite is abundant as very fine disseminated grains and as small rod shapes which may be replacements of organic material.

The rock is delicately bedded, with cyclic, graded bedding similar to varves being observed universally. Many stylolites are beautifully developed, with pyrite and sometimes sphene being concentrated at the solution zone. Mud cracks, filled with coarser, light-colored, detrital sand, are commonplace. The crack fillings are usually deformed into ptygmatic folds, presumably due to deformation during early compaction of the sediment.

This intermediate, dark, thin-bedded interval forms much gentler slopes than the rocks below it. Weathering produces yellow, orange, and red iron oxide staining over the dark gray rock.

The uppermost stratigraphic interval of the upper DS, averaging 100 ft thick, is light colored in contrast to the gray beds below. It varies from gray to light olive-green to buff, and the top 10 ft immediately below the Mescal limestone are almost white. Bedding is not so well developed in this upper portion.

6. Mescal Limestone This formation lies conformably over the DS. It varies in thickness due to partial erosion prior to deposition of overlying formations, but it is generally about 225-300 ft thick. The limestone is siliceous and cherty, ferruginous, and dolomitic. It is thinly bedded and has variable color banding from green to tan to white. Algal beds are prominent in the upper portion. A superior quality of iron-free, chysotile asbestos is mined from this formation in the Sierra Anchas. Although locally resistant due to silicification, the formation usually forms gentle slopes with relatively few strong outcrops.

7. Basalt Flow A vesicular basalt flow from 0 to 75 ft thick is nearly everywhere present on top of the Mescal. It is purplish, to reddish-brown, to green with vesicles from 1/2 to 1 inch in diameter being typical. Various secretionary products fill or partly fill the vesicles.

C. Paleozoic Sediments

1. Troy Quartzite This formation is considered to be of Middle Cambrian age by Stoyanow (1936). It lies unconformably upon the Mescal limestone in some places, but generally the formations show no angular discordance. The Troy is the uppermost formation of any appreciable extent in the Sierra Anchas, and it forms the tops of the high mountains. Thickness varies from 300 to 400 ft due to erosion at the surface. It is a massive, cross-bedded sandstone containing interbedded pebble conglomerate. Color is tan to light buff on fresh exposure, but when weathered, it tends to be reddish-brown. Because of the massive brittle nature of the formation, and because it is generally flat-lying and vertically jointed, sheer cliffs and flat-topped mountains are its characteristic topographic expression.

D. Diabase Intrusives

Diabase sills of great extent and thickness are almost coextensive with the Apache group. A diabase sill, varying in thickness from 500 to 1000 ft underlies all of the central Sierra Anchas, extending for over 24 miles north-south and 8 miles east-west. The full section of the sill from lower chilled contact to upper chilled contact can be well observed at Pocket and Parker Creeks (Plate 5). It penetrates the thin-bedded upper DS most commonly, but the contacts are slightly transgressive, and from south to north the sill climbs from the upper DS through the Mescal limestone. A lower diabase sill is exposed in the bottom of Parker Creek Canyon where it penetrates the Pioneer shale. Another sill is located in the bottom of Bull Canyon where it has intruded near the base of the Pioneer shale. Feeder dikes varying in width from 20 to 185 ft are present in Oak Creek, Cherry Creek, and Warm Creek. The diabase varies in composition vertically through the sill and laterally across the larger dikes. A typical mineral assemblage is labradorite, augite, olivine, biotite, hornblende, and magnetite. The texture varies from extremely fine at chilled borders, to typically interlocking diabasic texture, to a coarse pegmatitic phase. The diabase weathers more readily than the DS or Troy formations, and has a greenish-gray appearance on exposure. A nodular surface commonly develops as a result of selective weathering of the constituent minerals. The age of the diabase intrusion is indefinite.

E. Structural Geology

The Sierra Ancha region is considered by the writer to be a part of the structural framework of the Colorado Plateau. The southwestern physiographic boundary of the plateau province, the Mogollon Rim, is about 20 miles north of the central Sierra Anchas. The rim is the erosional edge of Paleozoic sediments which extend across the plateau province. Apparently these sediments once covered the Sierra Anchas but have been eroded back. Steep normal faults are common within generally

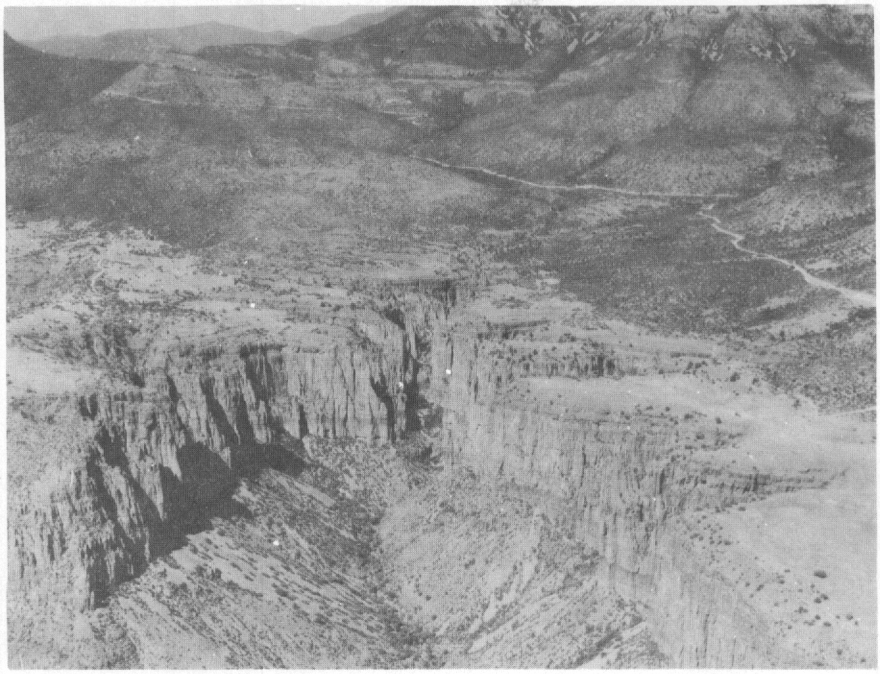


Plate 5. Photograph of Parker Creek, looking north-northeast. The cliffs are lower Dripping Spring quartzite with Pioneer formation forming the gentler slopes below. A diabase sill splits the upper Dripping Spring quartzite and extends from the top of the sharply incised bench of quartzite to near the top of the picture where horizontal bedding can again be observed. The sill is 710 ft thick in the right middle distance at Pocket Creek where the highway makes a V to the right.

flat-lying sediments. Cherry Creek, the eastern border of the region, is structurally a graben. The topographic high of the central Sierra Anchas is a block which is faulted into a higher position than surrounding blocks. Folds are rare in the brittle Apache group sediments but fracturing and slight tilting are common. Although the deformational history has been long, it has been comparatively simple, and jointing and faulting fall into a very few systems. In this region where massive, brittle rocks predominate, and where erosion is largely by physical processes, topography is very much influenced by faults and joints. Steep slopes commonly occur at faults, and streams are localized by fractures.

III. FRACTURE CONTROL OF URANIUM MINERALIZATION

When the field work was undertaken, little was understood of the nature of these uranium deposits. The Red Bluff property, exemplifying strong fracture control, indicated the importance of studying fractures. At the same time, knowledge of the unusually high background of radioactivity of the upper Dripping Spring quartzite, the apparent stratigraphic limits of the known ore deposits, and the uniformity of occurrence within the dark, thin-bedded portion of the upper Dripping Spring indicated the importance of studying sedimentary controls.

The fracture studies consisted of a detailed examination of uranium occurrences, a regional statistical analysis of joints, and a supplemental study of aerial photographs.

A. Detailed Structural Features of Uranium Occurrences

Every known uranium occurrence in Gila County was examined by the writer during the spring and summer seasons of the years 1954 and 1955. This was an opportune time for collecting field data, since this was the period of high initial exploratory and mining activity in the region. Notes or detailed structure maps were made for 38 properties. Particular attention was given to those occurrences where primary ore was well exposed by mining operations.

1. Structural Relations at Uranium Properties

Geologic descriptions and detailed structure maps of the more extensively developed properties are given below.

a. Red Bluff Property (Plates 2 & 6)

Location: Rockinstraw Mtn. quadrangle, 33° 44' N,
110° 57' W. 200 yards east of Globe-
Young highway about 10 miles north of Salt
River bridge.

The upper DS quartzite host rock is structurally and topographically below a 700 to 800 ft thick diabase sill. Ore bodies are in sediments located adjacent to a 185 ft wide diabase feeder dike which joins the overlying sill. The dike strikes N25°E, dips about 75° westward, and is in fault contact with the sediments on the western side. The upper DS to the west has been lifted 175 ft stratigraphically above the block of sediments to the east of the dike. The ore mined to date has been from the block west of the dike, where stoping and trenching have been conducted from the surface downward. The bedding in this block is nearly flat, with a dip of 8° to the northeast. The

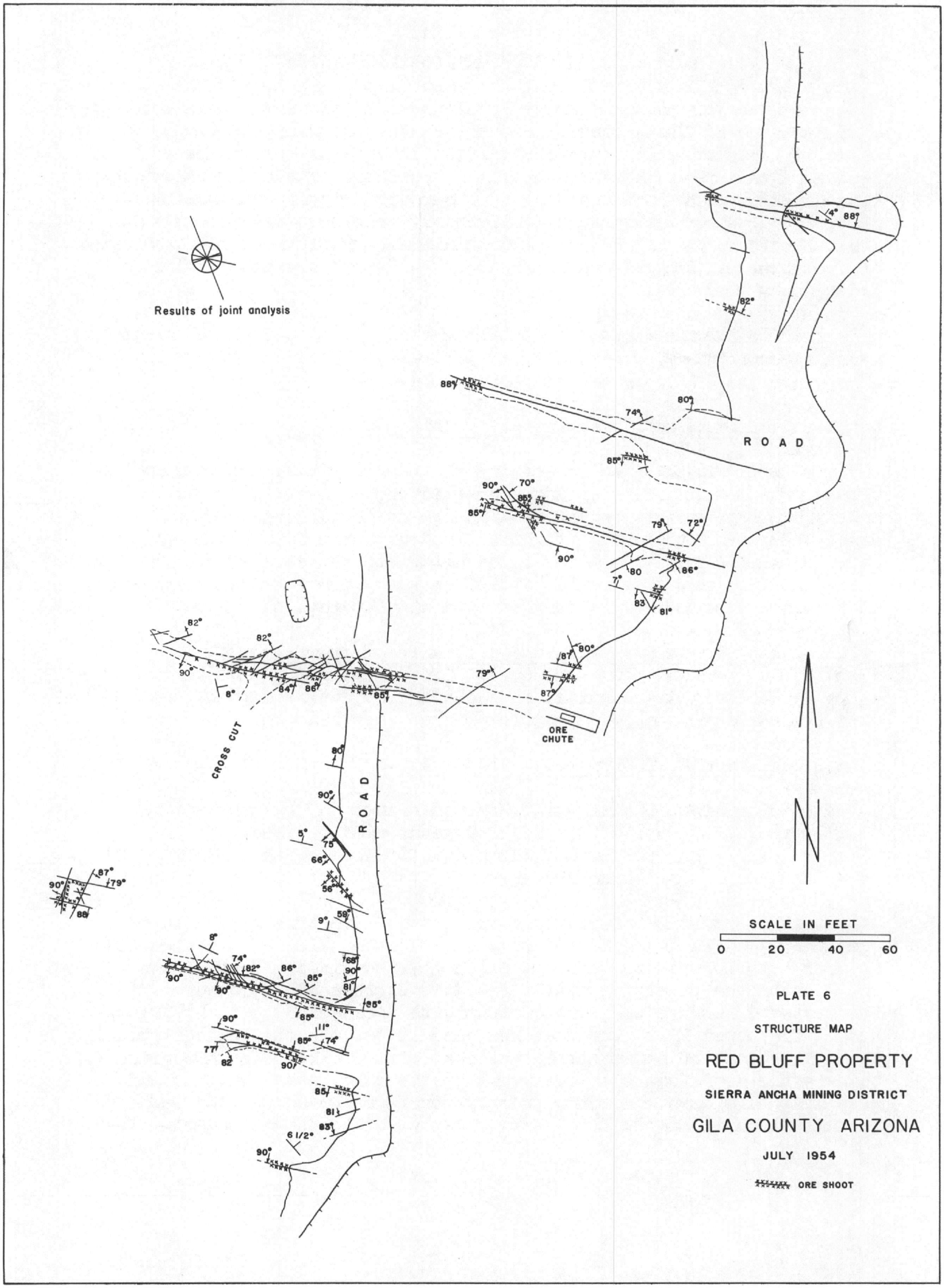


PLATE 6

STRUCTURE MAP

RED BLUFF PROPERTY

SIERRA ANCHA MINING DISTRICT

GILA COUNTY ARIZONA

JULY 1954

ore is bottomed at a particular stratigraphic horizon about 70 ft above the top of the more massive lower DS quartzite. The most conspicuous structural feature of the mine is that all ore is limited to wall rock immediately adjacent to nearly vertical fractures. Selective mining has been carried out almost exclusively along fractures striking from N73°W to N80°W. Another set of nearly vertical fractures with an average strike of N20°E localize the ore, and one fracture striking N40°W, dipping 56°SW has localized some sub-commercial uranium mineralization. Although many fractures branch away from the two principal ore sets, they are mineralized for distances of only 3 or 4 ft from where they branch away from the main ore fracture. The average spacing between the westerly-striking mineralized fractures is 30 ft. There is practically no displacement on any of the fractures in the ore block.

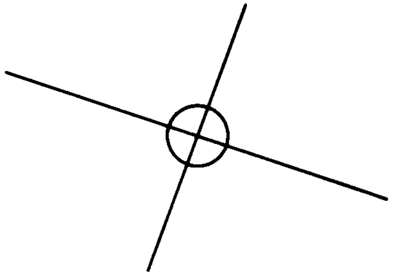
The high grade uranium ore (about 0.8% U_3O_8) at the fractures drops off sharply to non-commercial material (less than 0.10% U_3O_8) within 18 to 30 inches to either side. In two places particular beds are more highly mineralized for distance of 4 to 6 ft away from the fracture. The selective mining indicates this sharp decline in values outward from the fractures. The uranium has been mined from the westerly striking fractures for a horizontal strike distance of 60 to 100 ft. The ore extends from the surface downward about 50 ft to the stratigraphic cutoff. Presumably erosion has removed the top portion of the ore body. Ore localized by the N20°E striking fractures is limited to less than 15 ft horizontally.

Northward from the mine (along the trend of the diabase dike) in the sill above the quartzite there is a lighter colored segregate of the diabase magma, consisting predominantly of labradorite. It is approximately 40 ft wide (E-W), by 100 ft vertically, by 1000 ft horizontally in a N25°E direction. Since this segregate within the sill is elongated directly over and parallel to the strike of the dike it suggests a genetic relation between the dike and the segregate.

A thick diabase sill probably penetrates the Pioneer formation stratigraphically below the Red Bluff property since such a structural relationship exists in the bottom of Parker Canyon 3 miles to the northwest.

b. Sue Mine (Plate 7)

Location: McFadden Peak quadrangle, 33°45½'N, 110°51½'W.
South wall of Bull Canyon, elevation 4730 ft,
near intersection of Bull Canyon and Deep Creek.



RESULTS OF JOINT ANALYSIS

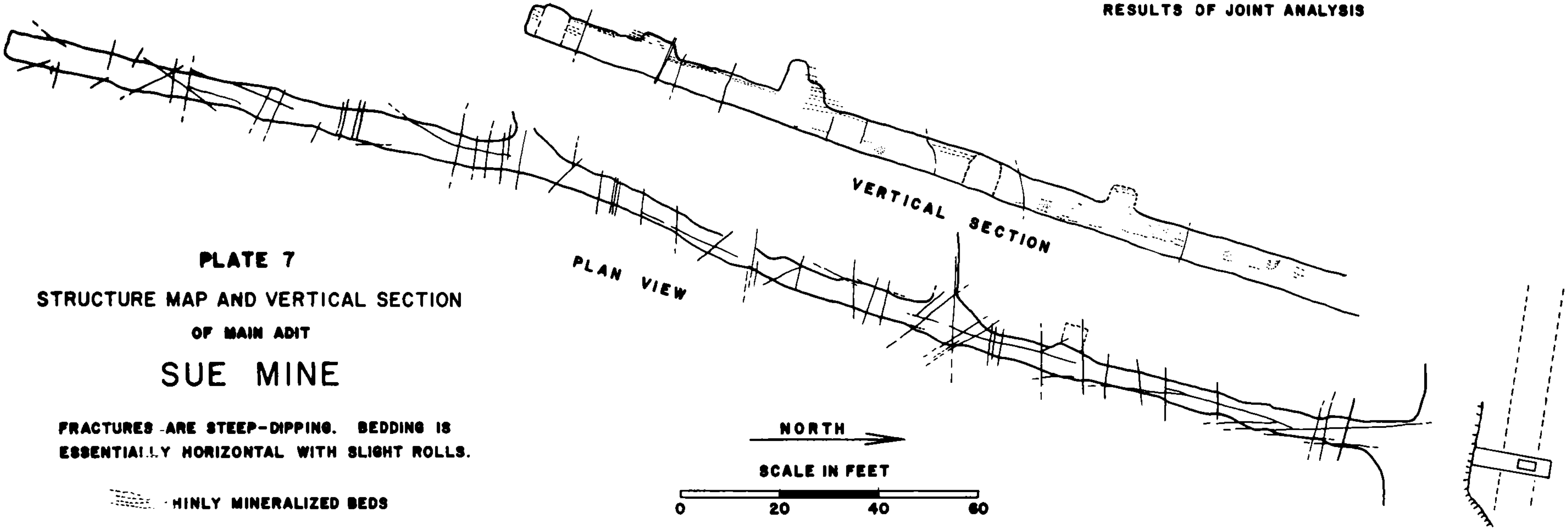


PLATE 7

STRUCTURE MAP AND VERTICAL SECTION

OF MAIN ADIT

SUE MINE

FRACTURES ARE STEEP-DIPPING. BEDDING IS ESSENTIALLY HORIZONTAL WITH SLIGHT ROLLS.

▨ **THINLY MINERALIZED BEDS**

MAPPED, 8-23-55

Apache group sediments have been deeply incised in this area in a north-south direction by Deep Creek and in an east-west direction by Bull Canyon. Mescal limestone crops out on the rounded tops of the mountains and the full section of Dripping Spring quartzite, the Barnes conglomerate, and most of the underlying Pioneer formation are exposed in the canyons. A diabase sill penetrates the Pioneer near its base. Hydrothermal activity has caused local silicic alteration of the Pioneer shale and the emplacement of copper carbonates, calcite, feldspar, and other minerals.

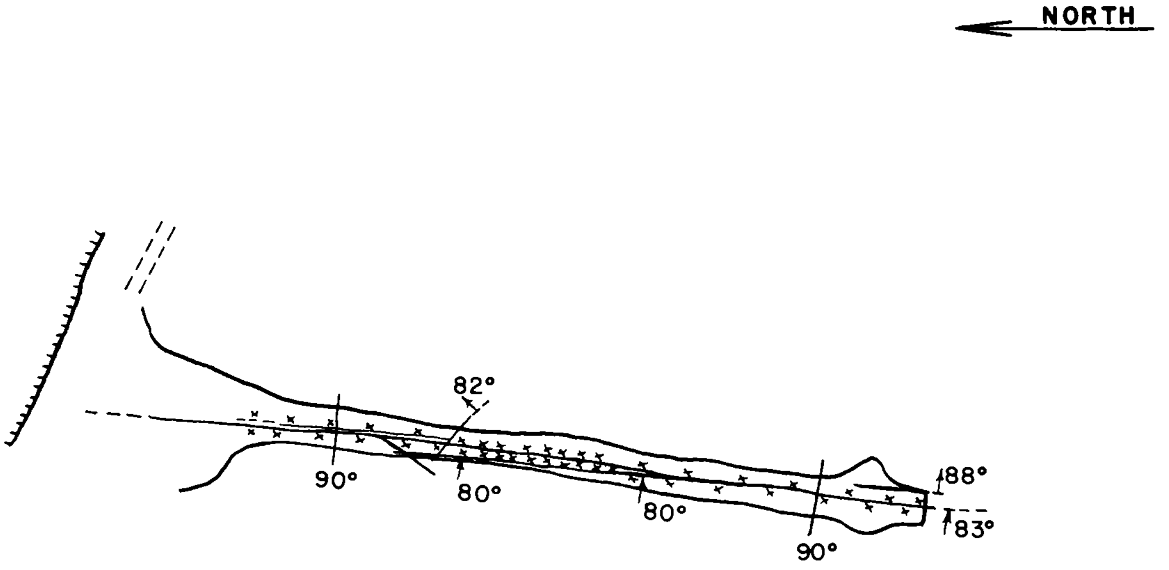
As well as occurring in commercial quantities at the Sue Mine on the south side of Bull Canyon, uranium mineralization and abnormally high radioactivity have been discovered in six other localities north of Bull Canyon on both the east and west slopes of Deep Creek. This mineralization is distributed for a distance of over two miles north of the Sue property. All of the known uranium in this region occurs within the same stratigraphic interval, the dark, thin-bedded, middle portion of the upper DS quartzite. The only other locality where mining has exposed these occurrences is at the Donna Lee property which is described separately.

The Sue mine is located in a relatively undisturbed block of nearly horizontal sediments. Mining carried out on two closely spaced levels and from two adits has shown that the ore is limited to a thin stratigraphic interval in the upper DS quartzite about 20 ft thick. An interval of 70 ft separates the base of the ore from the top of the lower DS. The hydrothermal emplacement of copper and gangue minerals in the Pioneer is 425 ft below the ore, and the top of the diabase sill is 670 ft below the ore. There is no known diabase closer to the mine than this.

A detailed study of the ore body indicates the ore to be localized within the favorable stratigraphic interval by nearly vertical fractures striking from north to NNE. Presently known dimensions of the ore associated with these fractures are 20 ft vertical, 20 to 40 ft east-west, and 120 ft north-south. Other strong sets of nearly vertical fractures strike N72°W, and north-west, but they apparently are not ore controls. The use of an ultraviolet light showed the high grade uranium concentrated in thin, gray to black-streaked beds from 2 to 3 inches thick cut by the fractures. The ore in these thin beds is in some places only on one side of minor fractures and joints.

c. Donna Lee Claim (Plate 8)

Location: McFadden Peak quadrangle, 33°46-1/4'N, 110°51½'W.
On Western slope of Deep Creek about 1 mile
north of Bull Canyon, elevation 4700 ft.



NOTE: Bedding is essentially horizontial, with thin cyclic bedding evident in the face.

PLATE 8

STRUCTURE MAP

DONNA LEE CLAIM

SCALE IN FEET

0 20 40

Ore shoot

Mapped, 8-18-55

This property has essentially the same structural setting as the Sue mine located about 5000 ft to the south. An adit driven 90 ft into horizontal, blue-gray, thin-bedded, upper Dripping Spring quartzite discloses high grade uranium ore. The uranium is localized in the quartzite extending about 2 ft to either side of a nearly vertical fracture striking N5°E to N8°E. The few other fractures mapped in the adit do not affect the uranium distribution. The vertical extent of the ore has not been developed by mining.

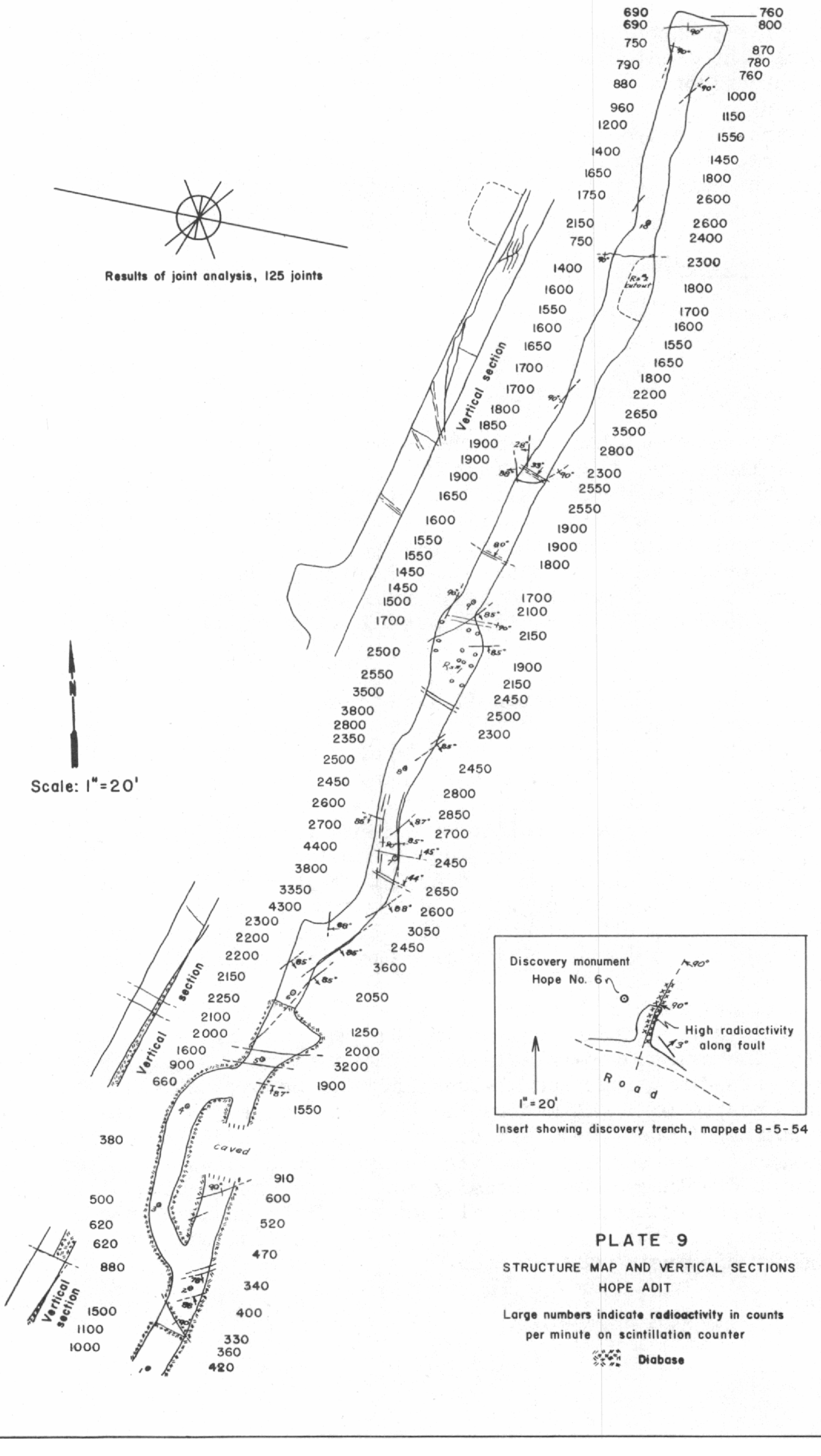
d. Hope Mine (Plate 9)

Location: McFadden Peak quadrangle, 33°51'N, 110°57'W.
1.3 miles up Workman Creek from Globe-Young highway. On NE slope of Workman Creek Canyon, elevation 5920 ft.

Workman Creek has cut downward through the Troy quartzite, the Mescal limestone, the uppermost Dripping Spring quartzite, and into the thick diabase sill which has penetrated the Dripping Spring. The Hope, the Jon, Workman, Little Joe, and Big Joe claims are located in adjacent positions along the north-east side of the creek (Plate 10). At each property mining has disclosed the high grade uranium ore to be located immediately above the diabase sill in the dark, thin-bedded portion of the upper DS quartzite about 200 ft below the Mescal limestone.

At the surface location of high grade ore at the Hope property, the uranium was localized about 18 inches to either side of a vertical fracture striking from N17°E to N26°E in flat-lying quartzite. Starting on this fracture, an adit was driven into the hillside along the ore for a distance of 344 feet. All material removed from the first 290 ft was of ore grade. Further exploration by raises, winzing, and long-hole drilling delimited the ore. This work indicated that the ore body has a maximum horizontal dimension of over 290 ft in a N24°E direction, a maximum vertical extent of 60 ft above the top of the sill, and an average horizontal width of about 6 ft. No uranium other than the usual trace amounts were observed within or below the chilled diabase contact.

All observable fractures were mapped in the main adit, but no strong persistent fractures were noted which strike in the direction of the adit. The ore body parallels a strong fracture and joint set, and because of its dimensions and obvious fracture control at the outcrop, it is presumed to be localized by the NNE fracture system. The individual fractures of the system are commonly limited in strike direction to less than a hundred feet, and vertically from 2 to 25 ft. They have little or no displacement and usually end sharply at bedding planes or at bedding plane faults. Recrystallization of the sediment tends to destroy strong fracture control of the ore by healing the fractures and by slightly dispersing the uranium.



Insert showing discovery trench, mapped 8-5-54

PLATE 9

STRUCTURE MAP AND VERTICAL SECTIONS
HOPE ADIT

Large numbers indicate **radioactivity** in counts per minute on scintillation counter

▨ Diabase

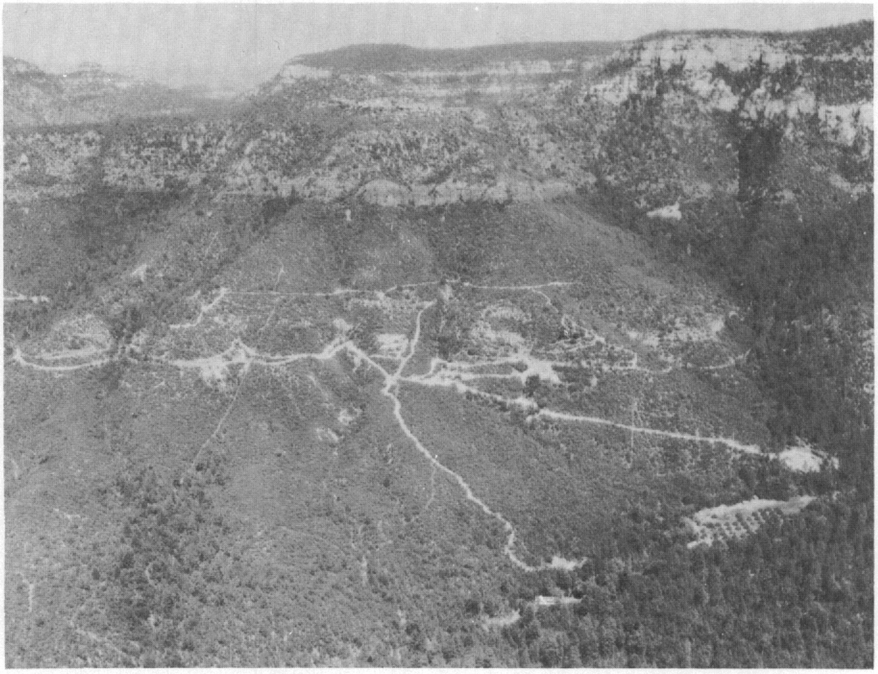


Plate 10. Photograph of Workman Creek, looking north. The lower horizontal scalloped road joins the many uranium prospects located in upper Dripping Spring quartzite at the top of a thick diabase sill. The narrow upper road follows along just below the Mescal limestone. Troy quartzite makes up the cliff exposures at the top of the picture.

In a road cut below the Hope claims, a light pink vein 18 inches wide and dipping steeply westward extends from the sill-sediment contact downward into the sill. Other similar but narrower veins were also observed in the same structural relationship. Petrographic, spectrographic, and chemical studies indicate that these are rheomorphic veins which formed as partly mobilized sediment entered fractures in the sill.

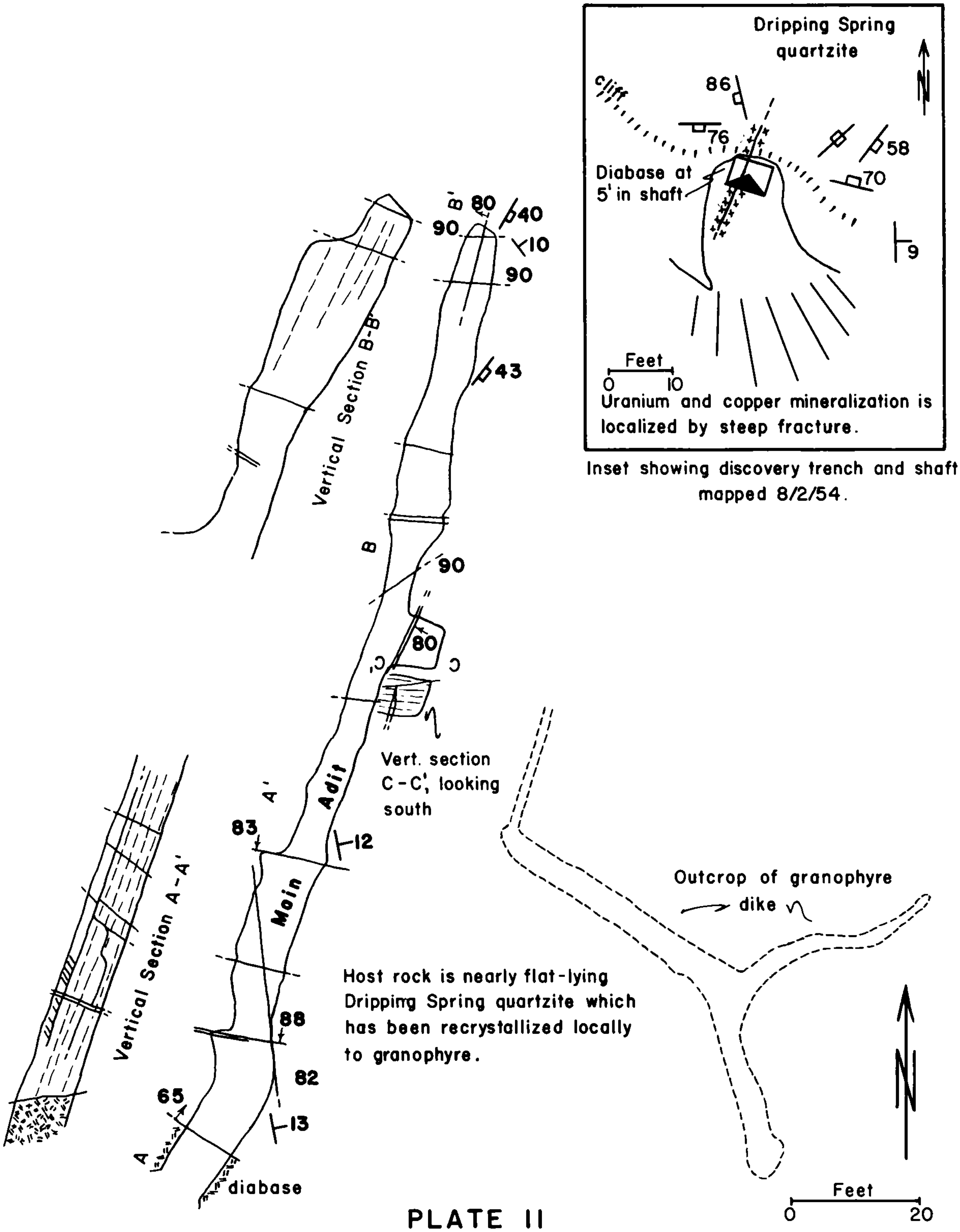
Pink, coarse, diabasic-textured rock occurs in the upper part of the sill. This grades upward into recrystallized and metasomatized sediment with palimpsest bedding. The lower limit of this pink, pegmatitic rock is commonly ragged and gradational into ordinary diabase, but in certain road cuts below the Hope workings this pink, pegmatite portion is separated by a sharp horizontal contact with the normal diabase below. These structural relationships suggest the pink pegmatite to be partly digested sedimentary quartzite that has dropped into the diabase magma.

The Dripping Spring quartzite has been recrystallized and metasomatized for limited distances above the sill contact. This recrystallization is associated with slight mobilization within 10 ft of the contact, but generally sedimentary structures are perfectly preserved indicating a solid state change. The recrystallization is usually selective of particular beds and extends farther along these than along adjacent beds. At one place in the adit, 110 ft from the portal, this recrystallization follows sedimentary cross bedding. However, in places of strong metasomatism near the sill, the sediment loses its bedding structure and becomes massive crystalline, looking very much like an igneous rock. Chemical, petrographic, and spectrographic analyses indicate that the recrystallized sediment received solutions from the diabase. These effects are considered further under chapter V.

Where the ore occurs in partly recrystallized sediment, the uraninite is more abundant in the pyrite-rich, darker unrecrystallized quartzite rather than in the recrystallized or mobilized sediment. However, some of the quartzite which is completely recrystallized is of ore grade where adjacent to the controlling fractures.

e. Workman #3 Property (Plate 11)

Location: McFadden Peak quadrangle, 33°51'N, 110°57'W. 0.5 miles up Workman Creek from Globe-Young highway on north-east slope of Workman Creek, elevation 6008 ft.



Uranium and copper mineralization is localized by steep fracture.

Inset showing discovery trench and shaft mapped 8/2/54.

Host rock is nearly flat-lying Dripping Spring quartzite which has been recrystallized locally to granophyre.

PLATE II

STRUCTURE MAP AND VERTICAL SECTIONS, WORKMAN NO. 3 CLAIM

SCALE: 1" = 20'   MAPPED: 6/26/55

The general structural setting of this uranium deposit is similar to that of the Hope property to the east and the Little Joe property to the west. The upper DS, the Mescal, and Troy formations are generally flat-lying above a thick sill which has split the thin-bedded DS. The uranium occurs in the same horizon about 200 ft below the Dripping Spring-Mescal contact and in this case immediately above the sill contact.

The uranium discovered at outcrop was concentrated within 18 inches to either side of a vertical fracture striking N16°E. The ore was followed underground by drifting, crosscutting, winzing, and long-hole drilling. The ore is located in partly recrystallized and metasomatized sediments from the top of the sill upward for about 20 ft and along a N20°E trend for 100 ft. The width of the ore is apparently limited to 10 ft or less. Minor fractures striking N18°E and N77°W limit locally the recrystallization of the sediments. Bedding plane fractures with small displacement are prominent. Fracture control is less definite where recrystallization has occurred.

Although recrystallization of the sediment above the sill is commonly developed parallel to the bedding, a dike consisting of recrystallized and metasomatized sediment is located about 60 ft to the east of the portal. In plan view, the dike is in the shape of a Y with limbs from 1 to 4 ft wide. Contacts are sharp, and the texture is coarser and readily distinguishable from the fine-grained, unrecrystallized quartzite. The southern end of the dike was traced intermittently through soil cover to the top of the sill. The dike is composed essentially of orthoclase near the sill, but contains a higher percentage of quartz and has a sandy appearance in the upper portions, which are at a higher stratigraphic position. Petrographic and chemical studies indicate the dike is essentially recrystallized sediment with addition of some elements from the diabase. This dike is more radioactive than the adjacent quartzite and detailed radiometric studies were carried out on a suite of samples across the dike and adjacent quartzite. The results of these studies are discussed in chapter VI.

Pink pegmatite, believed to be partly digested sedimentary rock, occurs within the sill below this ore deposit.

f. Lucky Stop Claims (Plate 12)

Location: McFadden Peak quadrangle, 33°50'N, 110°57'W.
0.7 miles up Workman Creek from Globe-Young
highway on south slope of Workman Creek Canyon.

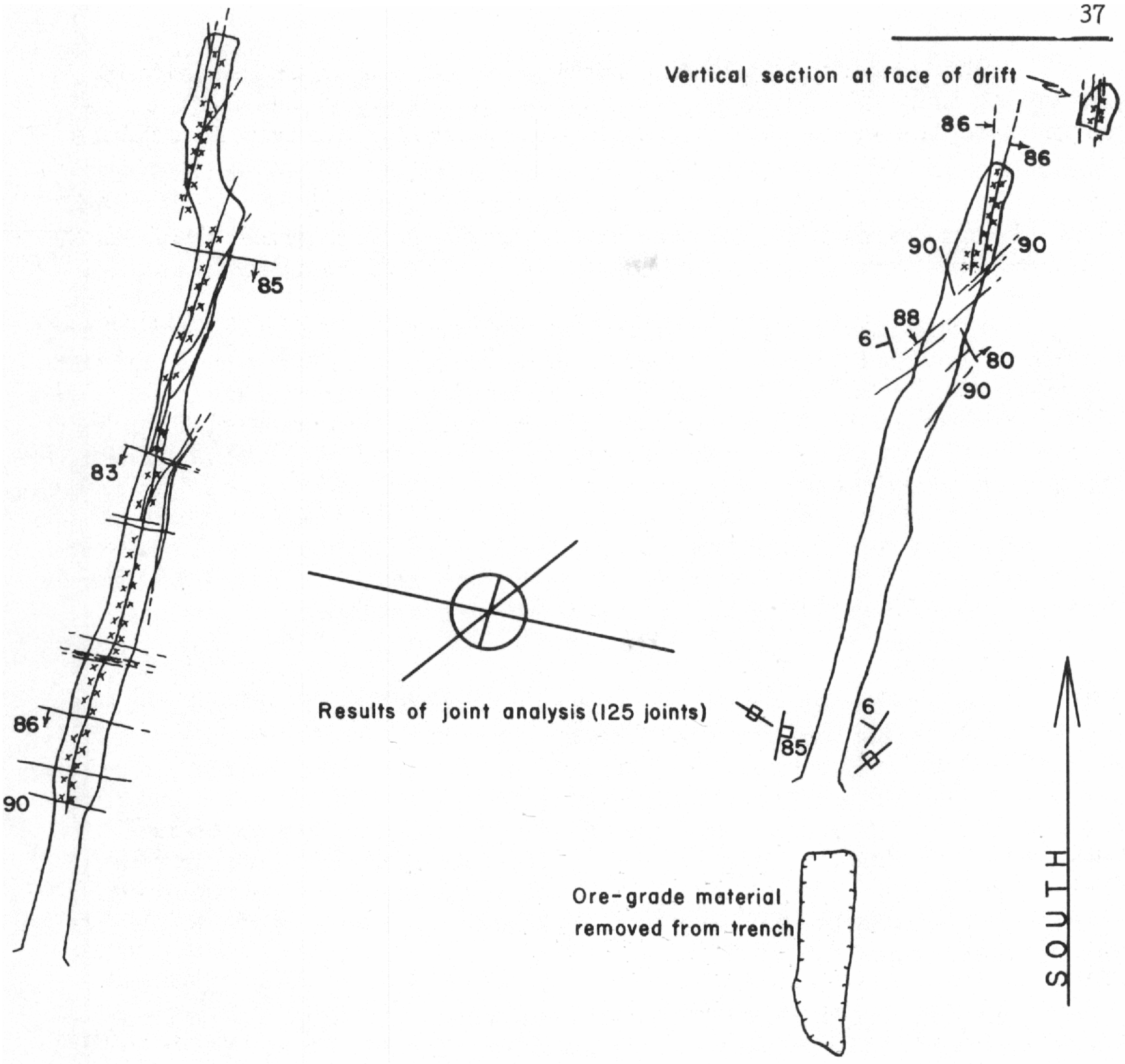
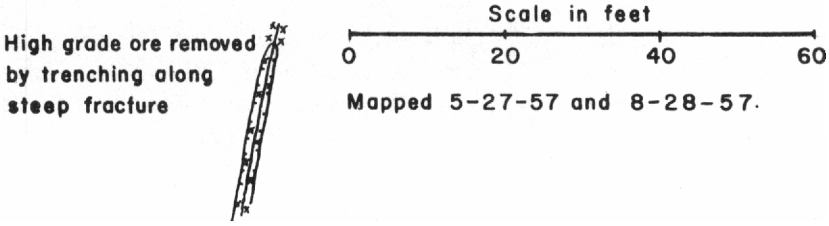


PLATE 12

STRUCTURE MAP

LUCKY STOP CLAIMS



Mapped 5-27-57 and 8-28-57.

This property and the Lost Dog claims joining on the southeast have a similar structural setting to the Hope and Workman properties across the creek. The uraninite ore is mined from the same favorable stratigraphic interval within the upper DS quartzite. The deposits are above and very near to the upper contact of the diabase sill. Selective mining, carried out to produce high grade ore, has disclosed the distribution and nature of the uranium mineralization.

Metatorbernite, discovered at the surface, had poorly defined structural control, but the removal of oxidized rock displayed primary ore precisely localized by nearly vertical fractures striking N10°E to N16°E. The value of the ore drops off sharply a distance of from 1 to 3 ft to either side of the fractures. The vertical limits of the ore had not been reached at the time of the examination, but the individual fractures carry ore along strike for 8 to 100 ft. Branches of the ore-bearing fractures are not mineralized. The presence of high grade mineralization located about 500 ft along the southern projected strike of this ore suggests that the deposit may be continuous throughout this distance.

The ore is accompanied by some recrystallization and metasomatism of the sediments, and where this has occurred, fracture control is vague. However, because the strike of the ore zone in the recrystallized portion remains the same as where the fractures are evident, it is believed that the metasomatism has tended to destroy or to heal fractures which originally were present. The ore zone is wider and contains more volume of ore grade material in the recrystallized places, but the highest grade material is near well-defined fractures where there has been little recrystallization.

Bedding plane faults are common and they limit in various places the vertical fractures, the grade of the ore, and the recrystallization. However, they are also observed to offset vertical fractures and to contain gouge and breccia of recrystallized quartzite.

A very interesting feature observed at this property is the presence of dark green mafic accumulations within the metasomatized quartzite. Samples of this material are unusually rich in pyroxene, chlorite, serpentine, and calcite (samples 469-475, Appendix III).

g. Black Brush Property (Plates 13 and 14)

Location: McFadden Peak quadrangle, 33°53'N, 110°55'W.
On western slope of Cherry Creek Canyon
(eastern side of McFadden Horse Mtn.) at the
end of prominent topographic nose,
elevation 5900 ft.

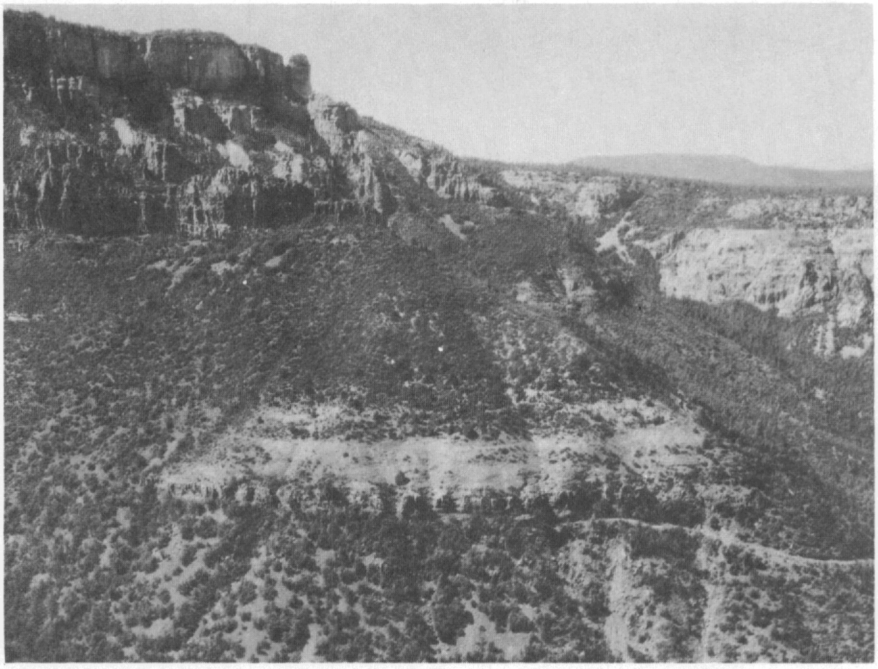


Plate 13. Photograph of the Black Bush property, Cherry Creek, looking North. The road is cut through diabase, which is the upper part of a 1000 ft thick sill. The cliffs immediately above the road are lowermost upper Dripping Spring quartzite. The bald outcrop is middle upper Dripping Spring quartzite. It is very thinly bedded and supports little vegetation. Mescal limestone forms the brush-covered slope above the bald outcrop, and Troy quartzite forms the cliffs to the skyline. Prospect trenches and portals are located above the lower cliffs at the end of the road.

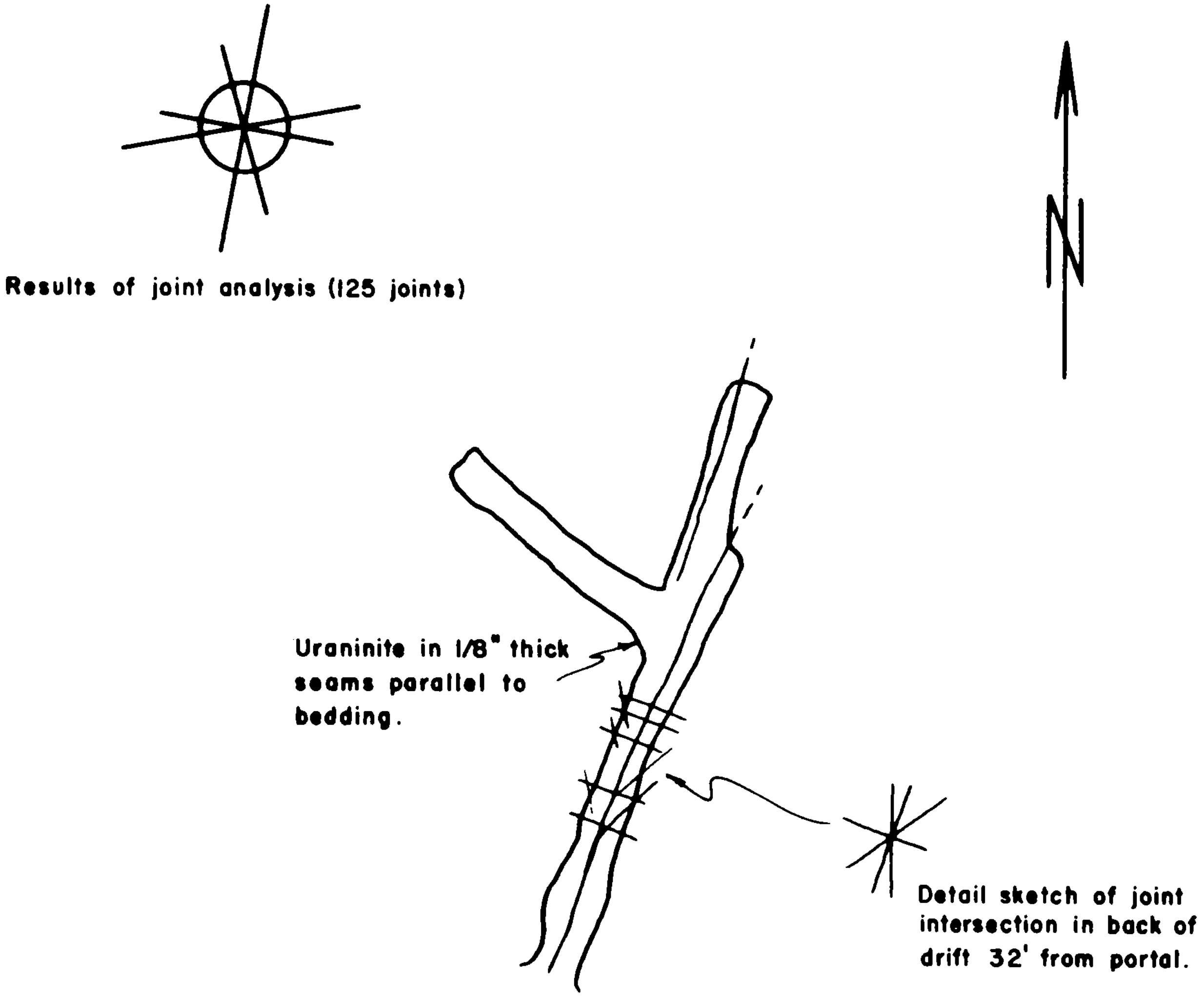


PLATE 14

STRUCTURE MAP

BLACK BRUSH PROPERTY

Scale in feet

0 20 40 60

Mapped 7-15-55

The structural setting for this primary uranium occurrence is well displayed by excellent exposures. Mining, test pitting, and surface examinations indicate that the uranium is limited to the stratigraphic interval of dark, thin-bedded upper Dripping Spring quartzite. The essentially horizontal sediments are intruded by a 1000 ft thick diabase sill, the upper contact of which is approximately 100 ft below the uranium mineralization. Thus the stratigraphic position of the ore is 230 ft below the overlying Mescal limestone and 100 ft above the sill.

The best exposure of the uranium is in the main adit where a good grade of ore was mined along vertical fractures striking N20°E. Examination of the drift and a short crosscut at right angles to it indicates that the mineralization is less and less away from the N20°E striking fractures. The ore is less than 5 ft in width and extends along the strike of the fractures for 40 ft. Vertical extent of the ore is not developed by mining, but surface examinations suggest that it is not more than 30 to 40 feet.

Detailed patterns of vertical fractures are delicately developed within the adit. Almost at right angles to the N20°E ore controlling fracture is a N70°W set. Between these are two sets striking north-south and N50°E respectively. None of the fractures have appreciable displacement, and at one place four fractures representing the different sets intersect.

Recrystallization and slight mobilization of the sediment has occurred 3 to 5 ft above the sill contact. The recrystallization, by favoring certain beds, tends to preserve the original sedimentary characteristics of the quartzite except where it is completely recrystallized. Although exposures are good, no anomalous radioactivity was detected in the 100 ft of sedimentary section between the sill and the exploratory workings above.

Coarse, pink diabase pegmatite occurs within the top portion of the sill below the uranium deposit and is exposed laterally for more than 200 ft.

h. Wilson Creek Property (Plate 15)

Location: McFadden Peak quadrangle, 34°00'N, 110°52'W.
1½ (airline)miles up Wilson Creek from its confluence with Cherry Creek.

Uranium mineralization, explored by four adits into the canyon walls, is located in the dark-gray, thin-bedded upper DS quartzite. The mineralized zone is approximately 200 ft stratigraphically below the Mescal limestone and an undetermined distance above a diabase sill

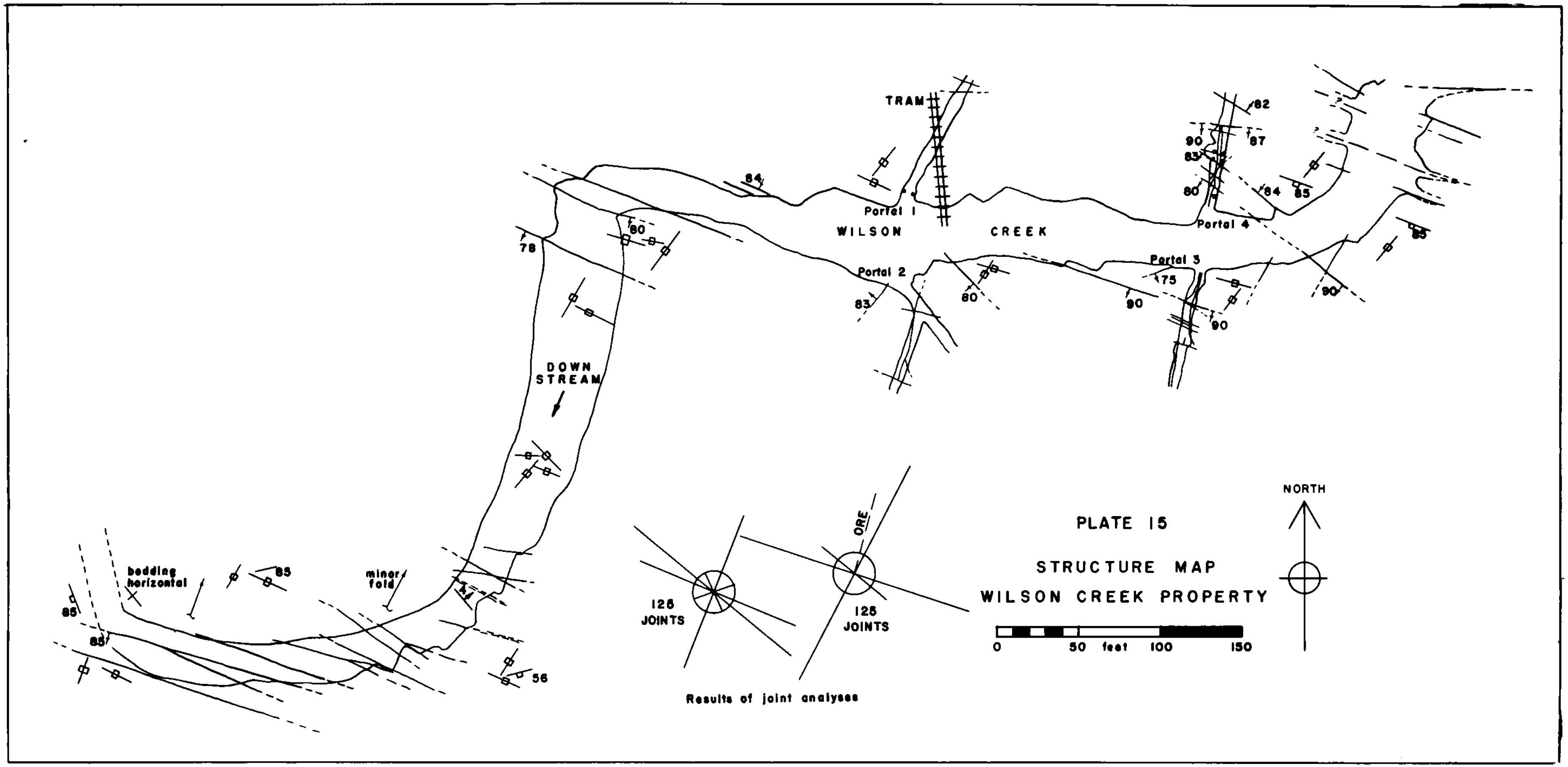


PLATE 15

STRUCTURE MAP
WILSON CREEK PROPERTY

which crops out farther downstream. The uranium is localized near steep-dipping fractures striking N10°E to N15°E, with certain adjacent beds being more radioactive than others. A maximum displacement observed on one of the fractures is 3 inches. The brittle quartzite is highly fractured in many directions and joints are spaced from 2 to 4 inches apart.

2. Interpretation of Data

Although many sets of fractures were observed at each uranium property, the high grade uraninite ore was invariably found associated with one or two sets of nearly vertical fractures. The two sets are approximately at right angles and strike NNE and WNW. This uniform fracture control of ore is especially remarkable, because the ore is controlled by these two fracture directions over the whole Sierra Ancha region. Of the hundreds of fractures examined and mapped, just two that localize uranium departed from this orientation. One was a branch fracture off a WNW striking mineralized fracture and the other displayed only weak uranium mineralization.

The fractures are nearly vertical, generally dipping greater than 80 degrees, and are approximately at right angles to bedding, which is generally within 10 degrees of the horizontal. The uraninite ore is disseminated in the wall rock adjacent to the fractures. The fractures seldom show any displacement, and the openings between fracture walls are seldom more than 1/8 inch wide. The percentage of uranium drops off laterally away from the fractures, with a cutoff of 0.10% U_3O_8 being about 18 to 24 inches to either side of the fractures at many properties. The ore was occasionally found to extend farther from the fracture on a particular bed than on other adjacent beds. The maximum lateral extent of ore on a favorable bed is 6 to 8 ft from the fracture. The fractures tend to be planar features with typically straight strike lines. Where they branch or die out, mineralization becomes less. Ore has been mined along individual fractures for horizontal distances of 100 ft and vertically for 50 to 60 ft. Recrystallization and metasomatism of the quartzite in the vicinity of diabase sills tends to heal and destroy the fractures. Sets of parallel fractures may be mineralized to give ore bodies several hundred feet long in the strike direction.

Diabase dikes and metasomatism of the quartzite by solutions from the diabase are also localized by these fractures. The zones of recrystallized quartzite extend through a considerably greater section of quartzite along the fractures than where there are no fractures.

All localities where fracture control is well expressed have been tabulated together with the strike (and dip if less than 80 degrees) of the fractures and a description of the feature. (See Table 1)

TABLE 1

FRACTURE CONTROL OF ORE BY PROPERTIES

Property with Coordinates	Ore Fracture Directions (Strike)	Description
Red Bluff 33°44'N, 110°57'W	N11°-25°E	Minor ore direction
	N73°-78°W	Major ore direction
	N60°W	Branch fracture
	N38°W (56°SW) dip.	One fracture
Sue Mine 33°45½'N, 110°51½'W	N9°E	Main ore shoot
	N23°E	Fracture limits ore 10 ft
Hope Adit 33°51'N 110°57'W	N24°E	Main ore shoot
	N17°-26°E	Fracture at portal
Lucky Stop 33°50'N, 110°57'W	N10°-16°E	Main ore direction
Black Brush 33°53'N, 110°55'W	N20°E	Ore direction
Workman #3 Claim 33°51'N 110°57'W	N20°E	Ore shoot
	N16°E	Fracture at portal
First Chance #2 Claim 33°48'N, 110°58'W	N25°E	Main ore direction
Donna Lee Claim 33°46-1/4'N, 110°51½'W	N5°-8°E	Main ore direction
Wilson Creek Property 34°00'N, 110°52'W	N10°-15°E (Indefinite)	Ore direction

TABLE 1 (Continued)

Property with Coordinates	Ore Fracture Directions (Strike)	Description
Honey Creek Divide 33°51'N, 110°57'W	N76°W	Ore direction
Lost Dog Claim 33°50'N, 110°57'W	N10°-20°E	Main ore direction
Iris Claims 33°43'N, 110°54' W	N6°E	Ore direction
Little Joe Claim 33°51'N, 110°57½'W	N6°-20°E (Indefinite)	Ore direction

The geographical distribution of these data is presented on Plate 16. The interpretation placed on these data is that fractures have played a role of localizing the primary uranium ore for the deposits throughout the Sierra Ancha region. These fractures acted as channelways for solutions responsible for the localization of the deposits. The two sets of ore fractures, striking NNE and WNW were the only sets available to the solutions and are considered with minor exceptions to be the only pre-ore sets.

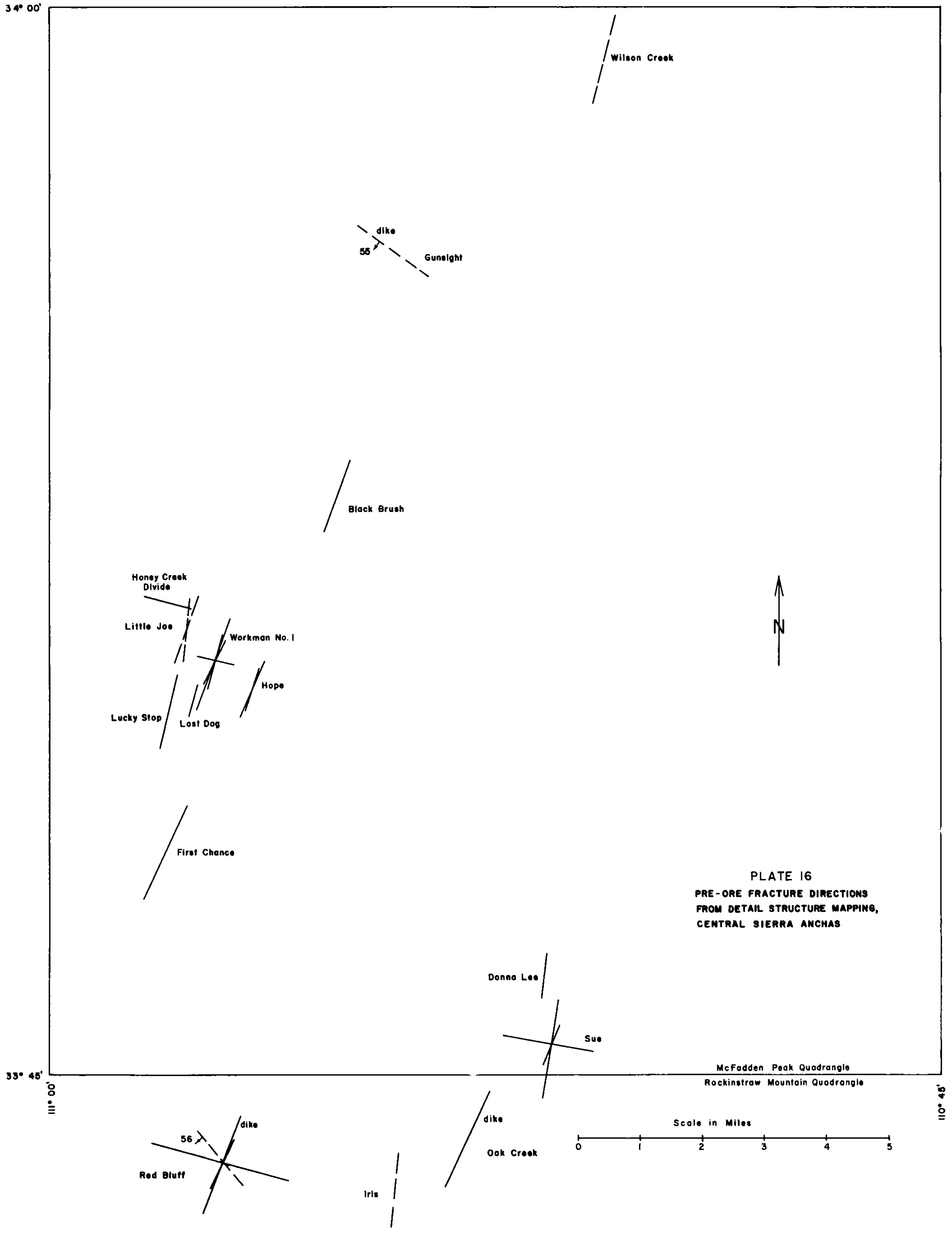


PLATE 16

PRE-ORE FRACTURE DIRECTIONS
FROM DETAIL STRUCTURE MAPPING,
CENTRAL SIERRA ANCHAS

B. Regional Fracture Patterns from Field Analysis

The recognition of strong fracture control of ore limited to two sets over the whole Sierra Ancha region suggested the importance of an analysis of the regional fracture pattern. A program of joint analysis was undertaken to determine the joint systems of the region, their geographical extent, and their expression in various formations. The Dripping Spring quartzite was most intensely studied because it contains the uranium deposits, has good geographical extent of outcrop, and has well-developed jointing. Some studies were made in the large diabase sill, in a young rhyolite flow, and in the old and young granites of the Globe-Miami district to the south.

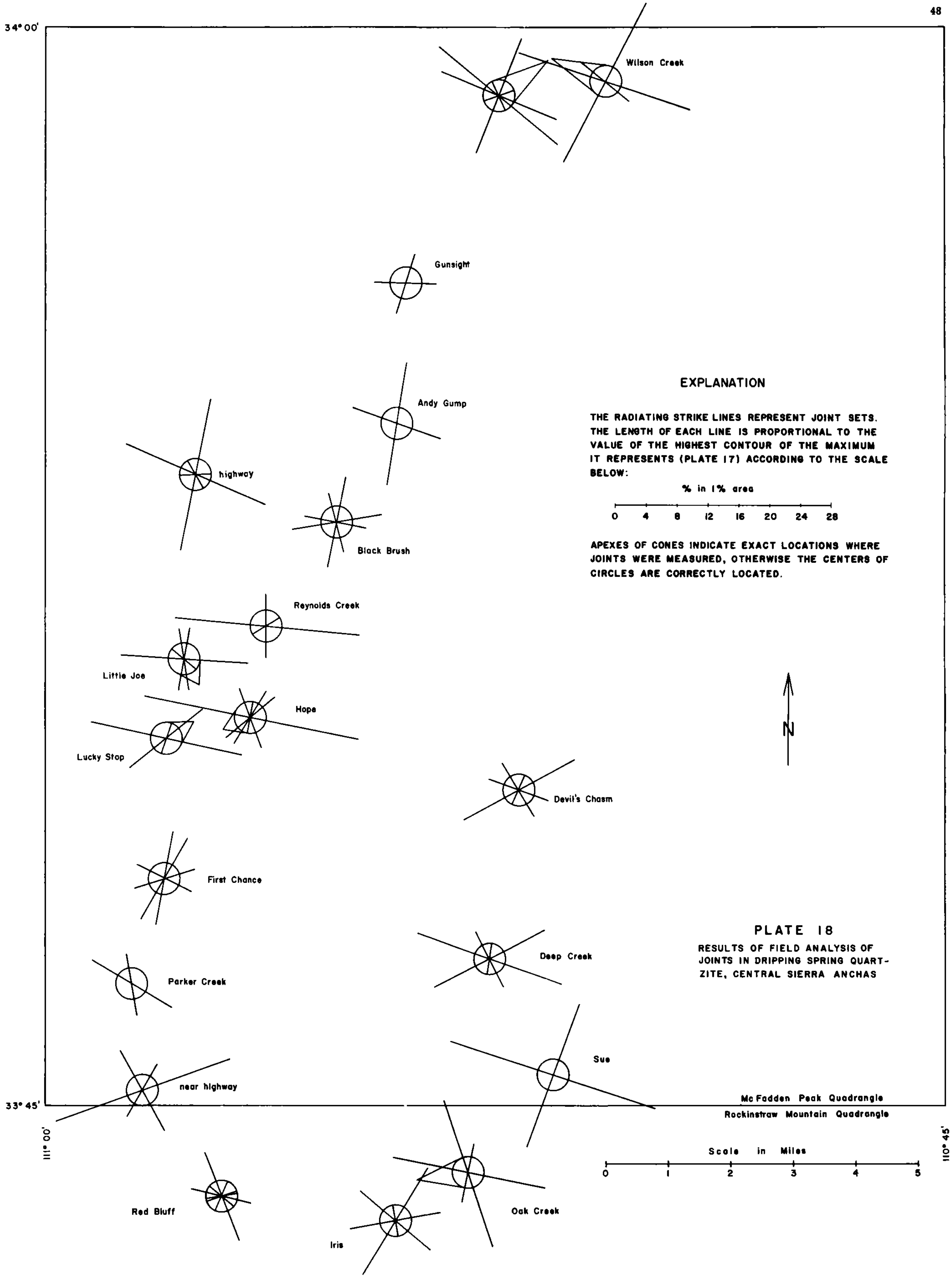
1. Procedures

The field procedure was uniform and simple. Outcrops of DS quartzite were selected to give good geographical coverage of the Sierra Ancha region. Most of the stations selected in the DS formation were in essentially flat beds. However, one station was taken in a tilted block adjacent to a major fault and another was taken in completely recrystallized DS quartzite. Stations in the diabase were selected at outcrops where contraction joints are in the minority.

The strike and dip of 125 or more joints were measured with a Brunton compass at each station. Every exposed joint was measured in the area of outcrop selected. The only exception to this was the station taken in diabase at the Black Brush property where only 63 joints were measured. Notes were taken regarding exceptionally well-developed joints, evidence of movement, joint fillings, and rock alteration. Detailed joint patterns were sketched.

All the joints from each field station were plotted on a Schmidt equal-area stereographic projection with the aid of mechanical equipment developed and described by Duschatko (1955). Each joint plane is represented by a point on the diagram, which is the intersection of a line normal to the joint plane with the upper hemisphere. The resulting point diagram was then contoured by lines representing the per cent of points on the diagram within one per cent area. The contour interval is 4%. The areas with highest contour values were considered to represent the average orientation of the joint sets. These maxima were found to be localized around the circumference of the projection, indicating nearly vertical dips for the joint sets. The reduced contour diagrams developed from joints measured in DS are reproduced on Plate 17. The maxima on the diagrams are normal to the joint sets which they represent.

The data from the contour diagrams were converted to line diagrams with the direction of the lines representing the strikes of the nearly vertical joint sets. The lengths of the lines are proportional to the highest contour of the concentration on the stereographic projection represented (Plate 18).



EXPLANATION

THE RADIATING STRIKE LINES REPRESENT JOINT SETS. THE LENGTH OF EACH LINE IS PROPORTIONAL TO THE VALUE OF THE HIGHEST CONTOUR OF THE MAXIMUM IT REPRESENTS (PLATE 17) ACCORDING TO THE SCALE BELOW:

APEXES OF CONES INDICATE EXACT LOCATIONS WHERE JOINTS WERE MEASURED, OTHERWISE THE CENTERS OF CIRCLES ARE CORRECTLY LOCATED.

PLATE 18

RESULTS OF FIELD ANALYSIS OF JOINTS IN DRIPPING SPRING QUARTZITE, CENTRAL SIERRA ANCHAS

Utilizing data on age relationships developed from the detailed mapping of the uranium occurrences, two sets from within the DS were selected as being pre-ore in age, namely, those falling in the strike direction brackets, N5°-27°E and N68°-85°W. The other sets were considered to be post-ore in age. Trend lines of the two pre-ore sets were plotted on Plate 19 and two of the strongest post-ore sets were plotted on Plate 20.

2. Interpretation of Regional Fracture Patterns

The trend patterns display graphically the remarkable continuity of fracture sets over the region. The nearly right angle pattern formed by the two pre-ore sets (Plate 19) suggests that they are tension breaks formed as the sediments were stretched over deep-seated doming due to differential vertical movement (Bucher, 1953; Gilkey, 1953; Duschatko, 1953).

The continuity of the strong post-ore joints and the right angle pattern they form when plotted together, suggest that they also developed as tension breaks due to updoming (Plate 20).

Four sets of joints predominate in the diabase. They are approximately equivalent to the four stronger sets in the DS formation, with the variation in trend being from 0 to 20 degrees. The sets do not have the sharpness of direction that the sets in the DS formation have, however. This rough correlation may indicate that the NNE and WNW sets in the DS formation are post-diabase, or that post-diabase stresses have broken the diabase along the earlier trends of weakness of the enclosing DS formation. The latter is believed to be the case for reasons discussed later under Chapter V.

C. Application of Aerial Photographs to the Study of Fracture Patterns

Aerial photographs of the Sierra Ancha region were studied with two purposes in mind. The first was to compare the results of photo interpretation of fracture sets with the data obtained by field measurements. The second purpose of the study was to develop information about areas not visited or not examined in the field.

1. Procedures

All available photography of the region was compared, and U. S. Forest Service photos on a scale of 1:20,000 were selected as the most desirable for interpreting geology. Because of considerable time spent in airplane reconnaissance flights over the region, the writer was able to distinguish faults and fractures on the photos from other linear features. Features on the photos from 1/4 to 2 inches in length, which were interpreted as representing strike directions of fractures, were plotted on overlay sheets. The number of measurements that can be

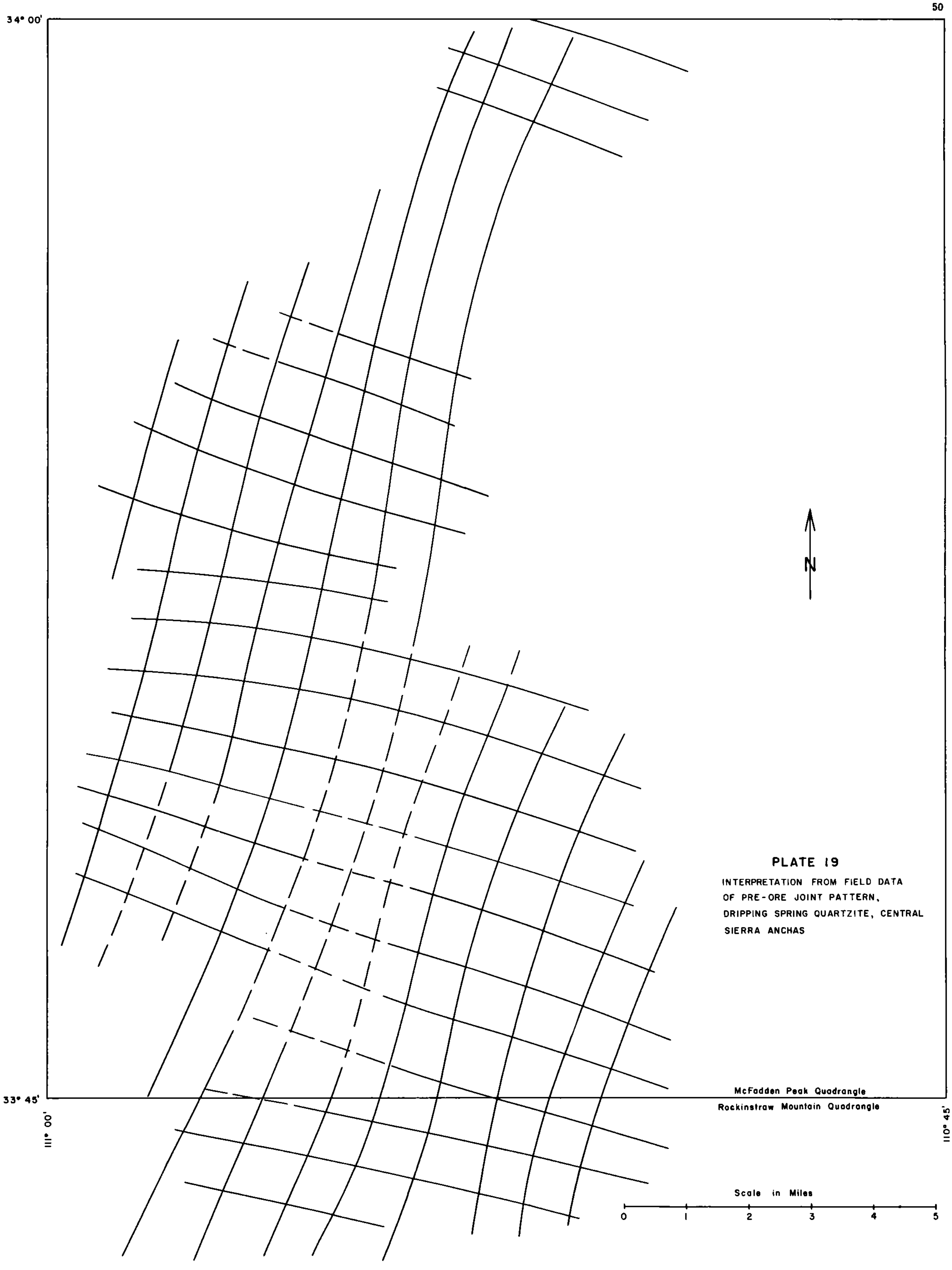


PLATE 19

INTERPRETATION FROM FIELD DATA OF PRE-ORE JOINT PATTERN, DRIPPING SPRING QUARTZITE, CENTRAL SIERRA ANCHAS

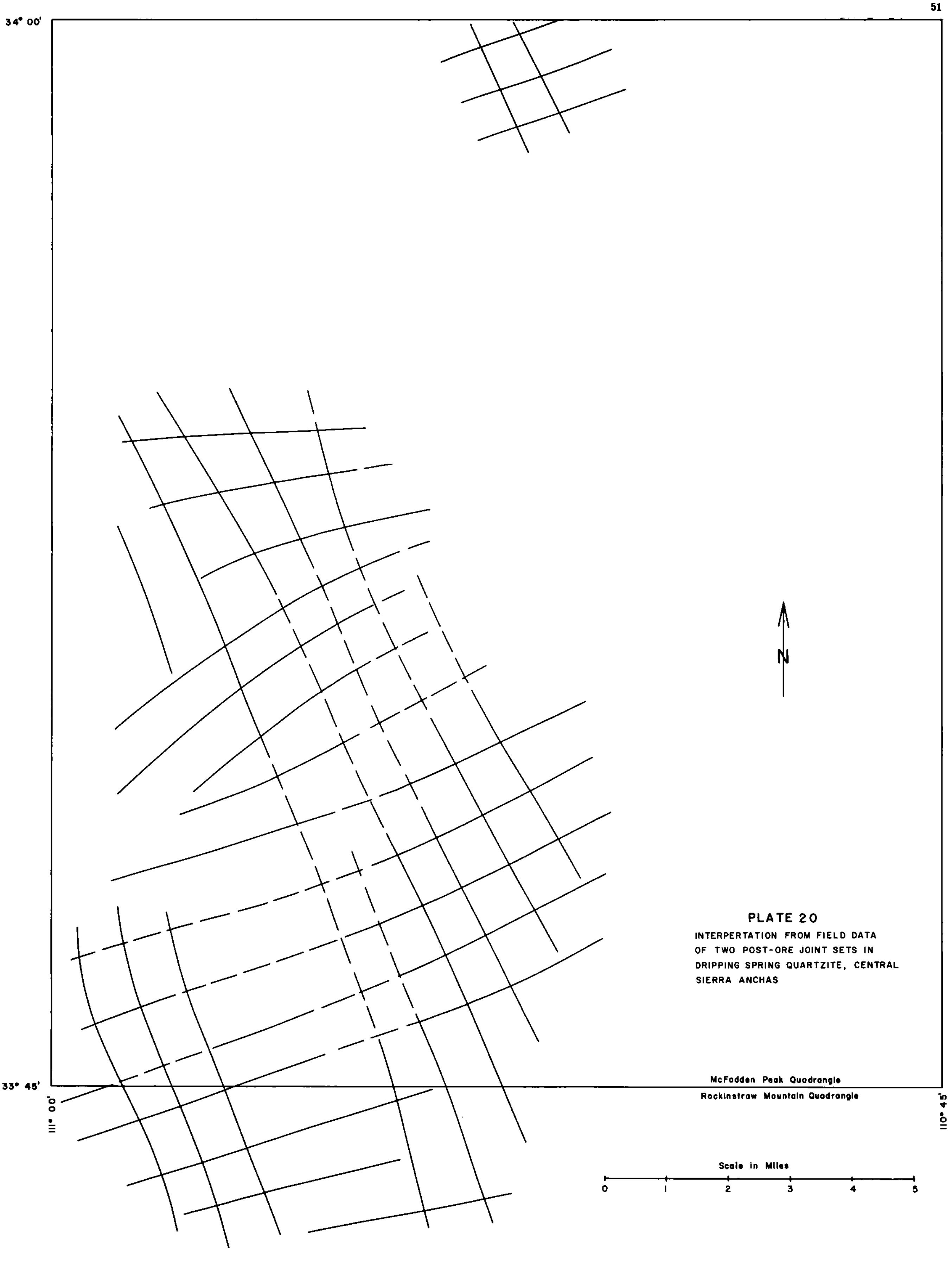


PLATE 20

INTERPERTATION FROM FIELD DATA OF TWO POST-ORE JOINT SETS IN DRIPPING SPRING QUARTZITE, CENTRAL SIERRA ANCHAS made from a photo is variable, from 26 to 132, with the average being 63 measurements per photo for the 27 photos studied. The strike directions taken from the photographs were used to construct pedal diagrams, which were located on a base map at the centers of the photos (Plate 21).

2. Interpretation of Data

The lines taken from the photos are quite easily recognized as representing fractures (as can be seen from the oblique photograph, Plate 4). However, they represent only the larger fracture features and not the smaller joints. Furthermore, they represent fractures from any of all formations cropping out within the limits of the photo. The best definition of fracture sets was obtained from photos covering essentially one formation and displaying many fractures. The pedal diagrams representing fractures from different formations tend to be composite, and those representing too few measurements tend to be arbitrary. Considering all 27 photos interpreted, those with 40 or more measurements gave good definition of joint sets, and those covering essentially one flat-lying formation give good definition with as few as 25 measurements.

Trend diagrams (Plates 22 and 23) show the strong persistence and continuity of the fracture sets across the region. The comparison of trend lines of large fractures developed from the photos with the trend line of joints measured in the field is instructive. The four major sets developed from field joint data have approximate counterparts in the sets developed by photo study. The pre-ore joint sets (NNE and WNW) match the photo sets more closely than the post-ore joint sets. The strongest sets from the photos, with NW and NE strikes, form a right angle pattern. Photos covering only Troy quartzite (mid-Cambrian) display especially well these strong NW and NE striking fractures, and this is the reason they are confidently grouped together.

Since the strong NNE and WNW sets are poorly defined in the Troy they may have formed by deformation occurring before the Troy was laid down. This evidence corroborates the time separation of joint sets of the DS formation into pre-ore and post-ore sets. It seems quite likely that the post-ore sets in the DS were developed by the same deformation that developed the "Troy" sets (NW and NE). Any fractures developed in the Troy parallel to pre-ore sets in the DS formation may have followed underlying planes of weakness developed earlier in the older strata.

The field data and the photo data both give <u>double</u> right angle fracture patterns. The earlier (pre-ore) right angle sets trend NNE and WNW. The later "Troy" sets trend NE and NW. The fact that the Troy sets are better developed in the uppermost formations (Troy and Mescal) suggests two possibilities: (1) The stretching of higher

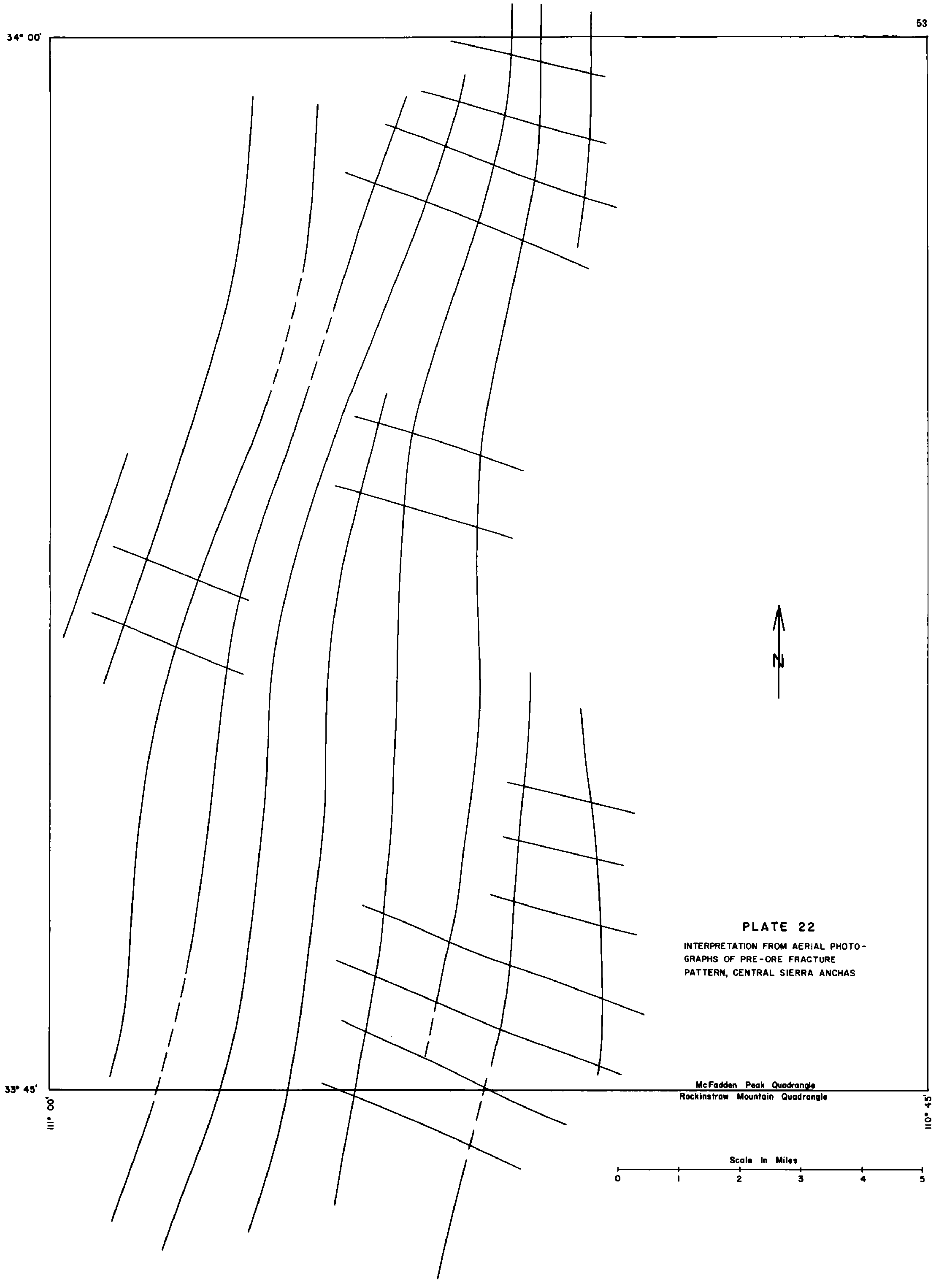


PLATE 22

INTERPRETATION FROM AERIAL PHOTOGRAPHS OF PRE-ORE FRACTURE PATTERN, CENTRAL SIERRA ANCHAS

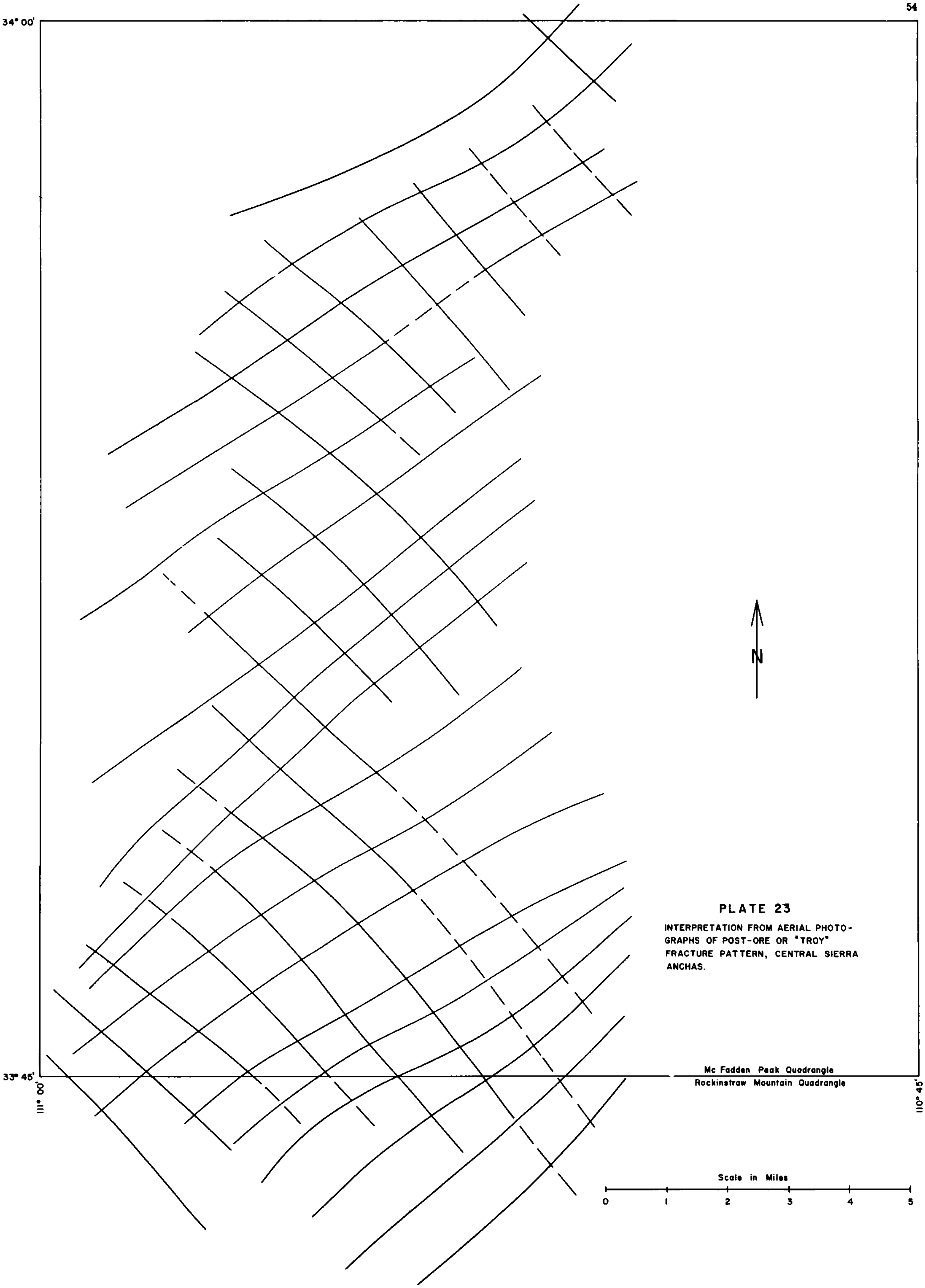


PLATE 23

INTERPRETATION FROM AERIAL PHOTOGRAPHS OF POST-ORE OR "TROY" FRACTURE PATTERN, CENTRAL SIERRA ANCHAS.

formations due to gentle updoming was greater than that of lower formations. All the fractures starting in the Troy would not necessarily extend down to the DS formation. (2) Deformation tending to form Troy patterns in the DS formation would be relieved to some extent by movement along fractures formed by earlier deformations. This latter possibility does not seem so likely however, because the Troy pattern is so strong.

When the two trend maps developed from field joint data are compared, it is evident that the post-ore sets bisect the angles between the pre-ore sets. Similarly, the Troy sets taken from the photos bisect angles formed by the NNE and WNW sets taken from photos. This feature suggests that the greatest tendency for breaking due to later deformation is at the greatest possible angle from old fractures.

D. Conclusions

Detailed study of the uranium occurrence indicates primary ore is localized over the whole district by fractures belonging to two sets striking NNE and WNW. The regional trends of the four most prominent joint sets of the DS formation are presistent. They form double right angle patterns which bisect each other. The NNE and WNW striking sets are pre-ore and the NW and NE sets are post-ore in age. These patterns are formed by tension breaks resulting from gentle updoming. Fracture sets in the diabase sill are similar to those in the DS formation.

IV. SEDIMENTARY CONTROL OF URANIUM MINERALIZATION

At the time this project was undertaken, the nature of the ore controls of many uranium deposits on the Colorado Plateau was also being investigated. The geological evidence generally was divided. For example, the many uranium deposits in the Salt Wash member of the Morrison formation, or the large-tonnage deposits within the lower Chinle formation are apparently localized by sedimentary features. On the other hand, other large uranium deposits, such as those at Temple Mtn., Utah, or Grants, New Mexico, have obvious hydrothermal aspects. The results of the many investigations on the Plateau indicate that the deposits could not have had a common mode of occurrence, but rather that their development was varied and in many cases complex. The fascinating challenge of this present investigation is that both sedimentary and hydrothermal processes seem to have played a significant role in the development of the deposits.

Early geologic studies at the Red Bluff property (Kaiser, 1951) and at the Wilson Creek area (Wells and Rambosek, 1953) indicated the uranium ore to be limited by certain stratigraphic intervals, and that these occurrences are within the upper DS. The abnormally high background radioactivity of this formation was recognized by Mead and Wells (1953), Gastil (1953), and by the writer early in the investigation as a result of airborne and ground reconnaissance.

A. Stratigraphic Position of the Ore

The primary uranium deposits all occur in the middle portion of the upper DS throughout the Sierra Ancha region. This interval is uniform in appearance and can be recognized in outcrop because of its thin beds and bluish-gray to dark-gray intervals. The stratigraphic position of the ore horizons was measured with respect to the DS-Mescal limestone contact wherever possible. The results are as follows:

Locality	Mescal Contact to Base of Ore, Feet
Little Joe Claim, Workman Creek	201
Black Brush Property, Cherry Creek	230
Sue Mine, Bull Canyon	280
Red Bluff Property, Warm Creek	260
Unnamed prospect, Pocket Creek	265

B. Lithologic Characteristics of the Favorable Stratigraphic Interval

Prospecting and mining activities at every property visited allowed examination and selection of fresh, unweathered material for study. Furthermore, four vertical core holes, drilled partly or completely through the upper DS were sampled and studied in detail.

One of the holes was drilled in a selected position on the NE side of Workman Creek where it penetrated the upper DS above the sill, the mineralized and metasomatized sediments near the contact, and for some distance into the sill. Two cores were taken through DS in places where there is no known uranium mineralization and one was taken where there is slight uranium mineralization.

The upper DS of this region is essentially tuff with a few sandstone lenses of detrital origin. The tuff is of silt particle size and the sandstone is made up of medium to very coarse grains. This grain-size difference between the tuff and sandstone allows rapid differentiation in the field. Because less than 10% of the formation is sandstone, much of the following description refers to the tuff.

1. Mineral Composition

Orthoclase, the predominant mineral, makes up from 65 to 75% of the rock. It occurs as very fine grains with sutured boundaries.

Quartz is present in the tuff as devitrified shards, which make up from 5 to 8% of the tuff. These fragments are distinctly larger in size than the orthoclase. They have sharp, angular edges with shapes like wedges, rods, and crescents.

Plagioclase is present in minor amount (less than 2%) as small, finely-twinned, equidimensional grains.

Dark Minerals are generally very fine grained, but a few coarser grains of pyroxene are recognizable. Pyrite is abundant in the gray, thin-bedded, interval of the DS, and is believed to be largely responsible for the dark color of the formation. It is commonly of silt size, but it also occurs in botryoidal forms and as rod shapes which suggest the replacement of organic material. Graphite, occurs as small flakes and streaks parallel to bedding. Many of the mafic constituents are altered to chlorite and serpentine.

Muscovite and microcline were recognized as isolated grains in only a few samples.

2. Rock Textures

The typical tuff is of silt particle size, with larger shards interspersed. The smaller grains, consisting principally of orthoclase, chlorite, and pyrite, are equidimensional and have sutured boundaries due to diagenetic processes. The mafic constituents commonly form thin bands parallel to the bedding, which tend to bend around the larger shards. This feature, which is believed to be due to compaction, gives a distinctive shredded texture to the rock under the microscope.

The sandstone lenses are composed of grains which are sub-rounded to sub-angular. Sorting within a particular lens, bed, or pod is generally good, with coarse sand sizes being common. The grains appear detrital, but the shapes of grains in some of the sand accumulations suggest the grains may be reworked shards from the tuff. Grain boundaries are smooth to slightly sutured.

3. Rock Structures

Very thin bedding is everywhere evident in the fine-grained tuff. Delicate cyclic graded bedding similar to varves is commonly observed. Stylolites are well developed in much of this tuff. They are thin black concentrations of pyrite, or more rarely sphene, which apparently have developed due to compaction and solution of grains. Resistant larger quartz grains cause many peaks to develop in the stylolite surface. Mud cracks are common, and when they occur they are usually filled with lighter colored detrital quartz sand. Ptygmatic folds on a small scale are present where the mud-crack fillings have been deformed by compaction of the sediment.

C. Chemical Composition of the Favorable Stratigraphic Interval

The four chemical analyses given below in Table 3 are believed to represent upper DS which has been unaffected or only very slightly affected by the diabase.

TABLE 2

	Sample Number			
	23	223	770	849
SiO_2	56.48	64.65	66.64	61.70
TiO_2	1.21	0.63	0.74	0.95
Al_2O_3	15.12	13.93	14.31	15.64
Fe_2O_3	1.12	1.09	0.00	0.97
FeO	5.48	3.41	2.27	3.42
MnO	0.08	0.01	0.00	0.03
MgO	0.83	0.49	0.52	1.14
CaO	1.97	0.53	0.81	2.49
Na_2O	0.73	0.20	0.87	0.41
K_2O	13.40	12.31	12.49	11.98
P_2O_5	0.09	0.04	0.13	0.07
H_2O^+	1.71	0.68	0.78	0.22
H_2O^-	0.10	0.13	0.03	0.16
CO_2	0.00	0.00	0.00	nil
S	2.69	1.89		1.45
	101.01	99.99	99.59	100.63
Less O for S	0.67	0.47		0.36
	100.34	99.52		100.27

\# 23 - Black, unrecrystallized portion of tuff from ore horizon, upper DS, Hope #7 Claim, Workman Creek.

\#223 - Gray Tuff with black streaks. Very fine-grained. Much pyrite. Upper DS from Black Brush property, Cherry Creek.

\#770 - Gray, very fine-grained tuff of the upper DS. Workman Claims, Workman Creek.

\#849 - Gray, very fine-grained tuff with thin dark streaks parallel to bedding. Upper DS from Drill Hole #1, Little Joe Property.

An examination of the above analyses reveals a consistent and unusually high percentage of K_2O. This substantiates the high percentage of mineral identified as orthoclase by thin-section study. The FeO and S percentages probably result from the high pyrite content of the sediment.

D. Radioactivity of the Favorable Stratigraphic Interval

One of the earliest field observations made in the search for uranium was that the upper DS is abnormally radioactive. Hundreds of miles of flying with the airborne scintillometer and further ground reconnaissance revealed that this stratigraphic interval gives off 50% to 100% more radioactivity than adjacent strata. Because the uranium ore deposits occur in this same interval, the radioactivity was generally believed to be coming from disseminated uranium in the rock. Gastil (1953) recognized the abnormal radioactivity but could not account for it by his measurements of the uranium, thorium, and potassium in the formation.

The chemical analyses of the tuff, together with separate alpha and beta counting of radioactive particles from the rock, are believed to reveal much regarding the radioactivity of the sediment. Alpha counting techniques, described by Kulp, et al (1952), were used to determine the equivalent uranium and thorium, and beta counting techniques (Gaudin, 1948) were employed to verify the high percentage of potassium.

1. Alpha Counting for Equivalent Uranium

The equipment utilized for these measurements is maintained for low-level alpha counting of rocks and minerals at Lamont Geological Observatory. The end of a photomultiplier tube is thinly covered with activated zinc sulfide. The sample rock is ground, placed in a plastic pan, and brought to a fixed position near the end of the tube. Gamma radiation passes through the thin coating without being absorbed. Beta rays are not completely absorbed, and because the energy released by them is low, it can be discriminated out of the counting circuit. Alpha particles are absorbed, and the resulting light is converted to electrical pulses and counted. Since potassium is not an alpha emitter, this method can be used to measure the amount of equivalent uranium and thorium present.

Background readings were run with an empty pan. A standard sample of Columbia River basalt (Standard sample #788, National Bureau of Standards) which contains 1.39 parts per million uranium (Evans and Goodman, 1941) was compared with the unknown samples to determine equivalent uranium values for them. The amount of thorium in the standard sample is not included in the computation, and the resulting equivalent uranium values obtained for the unknown samples are closer to the actual uranium content. The values contain some error due to the variation in the uranium/thorium ratios of the samples. It is known that the different mineralogy of the standard sample and the tuff affects slightly the accuracy of the values obtained, because of differences in density and atomic number. The error inherent in comparing rocks of completely different mineralogy is believed to be no greater than 25%, and the error resulting from comparing similar mineralogies is negligible.

When a large number of counts are measured over periods which are short compared with the half-life, the expected standard deviation (Sigma) is equal to the square root of the number of counts. If 1000 counts are recorded in 10 hours, the standard deviation of this number is $\sqrt{1000}$ or 32; the counting rate is $1000 \pm 32/10$ or 100 ± 3.2 counts per hour (Friedlander and Kennedy 1949, p. 206). The standard error in the counting rate in per cent would be $\frac{\sqrt{N}}{N} \times 100$ where N is the total number of counts. This error may be used as the percentage statistical error of equivalent uranium content of the sample if the error of the value of the standard sample is not considered.

The results of alpha counting of upper DS are given in Table 3.

TABLE 3

RESULTS OF ALPHA COUNTING, UPPER DS

Sample Number	Total Time (Hours)	Total Alpha Count	Counts/Hr Above Background	Parts/Million Equivalent Uranium	Statistical Error.%
357	40.2	761	13.34	4.09	3.6
409	6.5	135	15.17	4.64	8.6
419	6.23	154	19.10	5.85	8.0
690	16.42	251	9.70	2.97	6.3
869	6.83	109	10.36	3.17	9.6
882	22.97	357	9.90	2.57	5.3
887	23.23	355	7.85	2.52	5.3

#357 - Blue-gray, fine-grained tuff, from 18 ft in core hole, Blevins Canyon.

#409 - Typical tuff, from 51 ft in core hole, May Claim (Western Sierra Anchas).

#419 - Tuff, from 78 ft in core hole, May Claim (Western Sierra Anchas).

#690 - Outcrop, elevation 5355 ft, north side of Pocket Creek.

#869 - Tuff, from 127 ft in core hole, Little Joe Claim, Workman Creek.

#882 - Tuff, from 118 ft in core hole, Little Joe Claim, Workman Creek.

#887 - Tuff, outcrop, Workman #1 Claim, Workman Creek.

Samples 357, 409 and 419 are believed to represent the average sediment containing no hypogene mineralization. Samples 690, 869, 882 and 887 were taken in the vicinity of uranium deposits.

2. Beta Counting for Potassium Analysis

Potassium emits beta particles and gamma-rays, but does not emit alpha particles. By measuring the amount of beta radiation in a sample known to contain little uranium and thorium, comparison with measurements on a known potassium salt will give the per cent K_2O in the sample. The measurement of equivalent uranium and thorium by the alpha technique makes it possible to correct the value of per cent K_2O obtained by the beta counting.

The equipment utilized for these measurements is maintained and constantly used for this purpose at Lamont Geological Observatory. The instrument counts high energy beta particles and a small amount of gamma radiation. Weaker radiation is absorbed by an aluminum disc 0.005 inches thick placed over the sample cup. This disc stops the weaker beta radiation from rubidium, but measures the hard beta rays from K^{40}. Potassium dichromate was used as a standard salt.

Results of the analyses of three samples are given in Table 4. The locations of these samples are given under Table 3.

TABLE 4

RESULTS OF BETA COUNTING FOR POTASSIUM

Sample Number	Total Time (Minutes)	Total Beta Counts	Counts/Minute Above Background	% K_2O (Corrected for U and Th)	Statistical Error, %
409	254	2625	8.67	10.9	2.0
690	162	1954	10.41	13.6	2.3
887	150	1631	9.23	11.9	2.7

3. Results of Radiometric Measurements

The alpha and beta radiometric analyses, together with the known K_2O content of the sediment, indicate that the unusually high radioactivity of the formation is due largely to K^{40}, and that the equivalent uranium and thorium content is not unusually high for a tuff of this composition. The tuffaceous White River formation of Oligocene age in North and South Dakota contains from 0.001 to 0.002% uranium throughout (McKelvey, Everhart, and Garrels, 1955, p. 480). Rhyolite tuffs of the San Juan Mts., Colorado, contain from 2.5 to 6.6 ppm equivalent uranium. The previously recognized correlation between high K_2O content and uranium content of late differentiates is substantiated by these chemical and radiometric data (Larsen, et al., 1956, p. 240-245).

E. Conclusions

The unique characteristics of the favorable stratigraphic interval are:

1. It contains abundant disseminated pyrite.
2. It is a potassium-rich tuff containing nearly 5ppm uranium.
3. It is thinly bedded.

V. THE ROLE OF DIABASE IN THE FORMATION OF THE URANIUM DEPOSITS

A. Spatial Relationships Between Uranium Deposits and Diabase Bodies

Some of the best deposits in the district are exposed at Workman Creek, where all of the ore is located in the sediments immediately above the upper sill contact. This relationship is well developed by mining and exploration at the Hope, Jon, Little Joe, Big Joe, Lucky Stop, and Lost Dog groups of claims. On the west side of Cherry Creek at the Black Brush and adjoining properties the ore is located about 100 ft above the upper contact of the sill.

The Red Bluff property, one of the largest producers of uranium in the district, is located adjacent to a diabase dike 185 ft wide. The dike is below the main sill, which penetrates the sediments stratigraphically and topographically above the Red Bluff ore block.

The Sue Mine, located in Bull Canyon, is 670 ft above a sill exposed in the canyon below. The First Chance Mine at Parker Creek is 240 ft above the main sill, and the Wilson Creek deposits are in a creek bottom an undetermined distance above a sill. No other intrusive bodies are known to be closer to the deposits than these, but it is possible that other unexposed diabase bodies are nearer.

B. Description of Diabase Intrusions

1. Shapes of Intrusive Bodies

The bedding of the invaded sediments and their pre-diabase fracture pattern have determined the shapes and attitudes of the diabase intrusives. Because bedding is far better developed in certain stratigraphic horizons than others, the magma has penetrated the thin-bedded intervals and not the more massive intervals. Steeply dipping jointing and fracturing controlled vertical movement of the magma through the section. The result is that very extensive sills and less extensive steep-dipping dikes are characteristic.

The sills have penetrated the Pioneer formation, the upper Dripping Spring quartzite, and the Mescal limestone. The most extensive sill, although generally conformable, transgresses most of the upper DS quartzite and all of the Mescal limestone in a distance of six miles from Pocket to Reynolds Creek. This sill has a measured thickness of 710 ft at Pocket Creek, and is over 1000 ft thick where exposed in Cherry Creek. The dikes vary in width from 10 to 185 ft.

2. Lithology of the Diabase

The semi-arid climate and rugged relief of the Sierra Anchas allowed a careful study of the diabase. The largest exposed dike was sampled at 15 ft intervals at Warm Creek. The largest sill was sampled in two complete vertical sequences at Pocket Creek and Reynolds Creek. Considerable description of detailed features was developed by surface examinations. Two core holes, which penetrated the upper portion of the sill at Workman Creek and Reynolds Creek were studied in detail.

The magma is olivine diabase consisting essentially of labradorite, augite, and olivine. Orthopyroxene, magnetite, biotite, hornblende, apatite, and sphene are also present. Epidote, chlorite, serpentine, and sericite have developed as alteration products. The mineralogical composition by weight per cent of the sill has been determined by 10 modal analyses for the sequence of samples taken at Pocket Creek (Table 5 and Graph 1). Perhaps the most distinguishing characteristic of the magma is the high percentage of olivine present. A vertical interval of 250 ft within the Pocket Creek section was found to contain over 20% olivine by modal analysis. This interval extends from 190 to 440 ft above the lower contact. A sample taken 300 ft above the lower contact contains a maximum of 25.7% olivine. The amount of pyroxene is relatively high (12-25%) within 150 ft of the lower and upper contacts, and is lower (3-8%) in the central olivine-rich interval. The curve for per cent plagioclase is in general similar to that for olivine, except for sample 719 which is pegmatite schlieren. In it there is no olivine, but a marked increase in per cent of labradorite. Magnetite makes up 12% of a fine-grained diabase taken from 5 ft above the lower contact (sample 745). The rock contains at least 6% magnetite except in the central olivine-rich interval where it varies from 2-4%. Biotite, hornblende, and chlorite vary in a similar manner; they are less abundant through the central olivine-rich interval and are more abundant nearer the upper and lower contacts.

Quartz was not observed at any place within the sills and only as a few ½ inch wide stringers in the diabase dike in the bottom of Warm Creek.

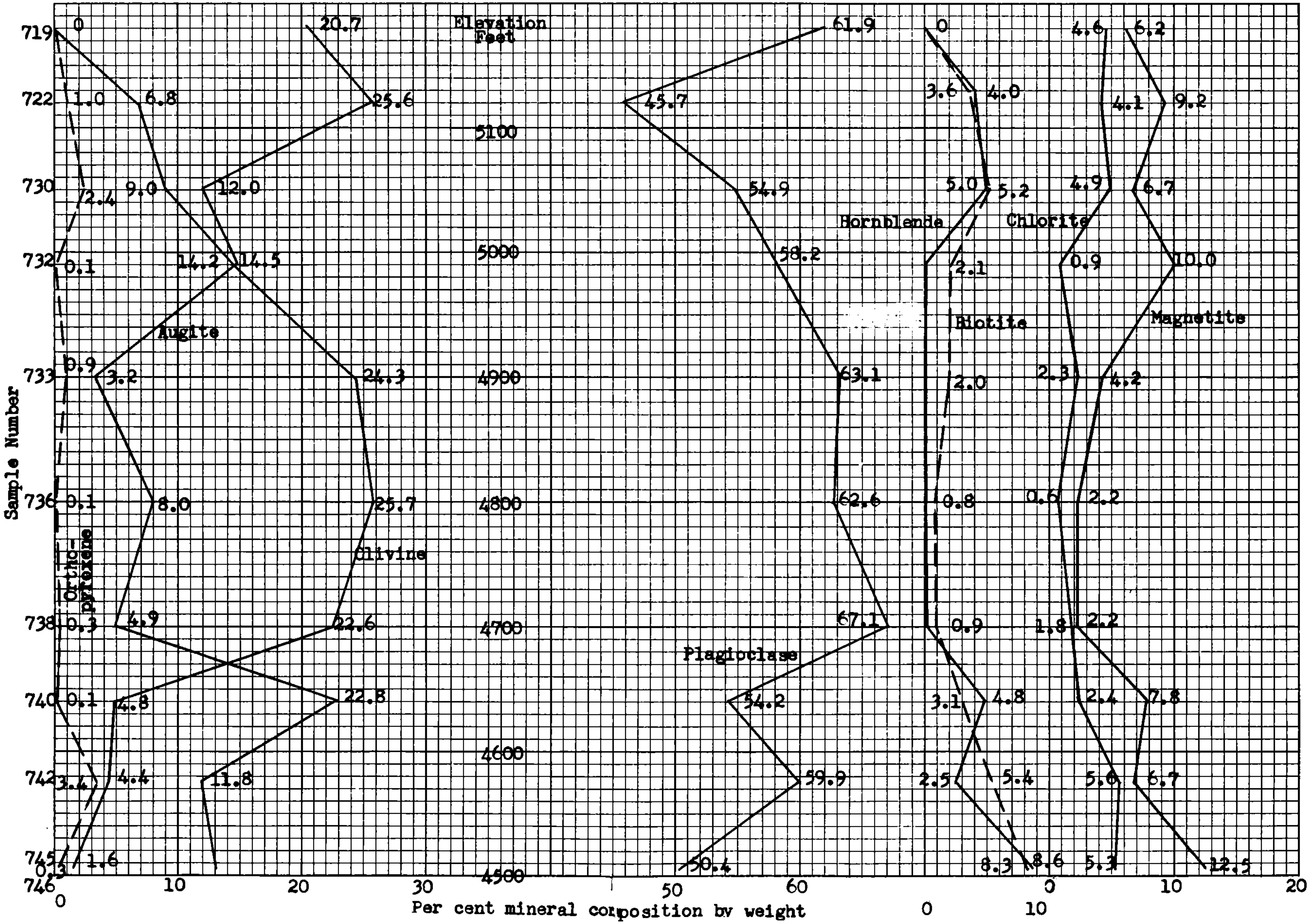
The texture of the diabase varies with distance from contacts both within dikes and sills. Chilled contacts grading into fine-grained porphyritic diabase and then into medium-grained diabase is the usual relationship. Phenochrysts of feldspar are visible in thin sections of the chilled diabase located within 1 inch of the sediment. Pegmatite is developed in sheets of varying thickness (5-15 ft) approximately 30 ft below the top of the sill and roughly parallel to the contact. Within this "schlieren" interval crystals of plagioclase, pyroxene, and magnetite are very coarse, with dimensions of 1 inch or larger being commonplace.

TABLE 5

MODAL COMPOSITION OF DIABASE SILL
POCKET CREEK SECTION

					% By Weight								
Sample Number	Topo. Elev.	Points Counted	Labra-dorite	Augite	Ortho-pyroxene	Olivine	Biotite	Hornblende	Chlorite (& Serp.)	Epidote	Magnetite	Apatite	Sphene
	5210'	Upper Chilled Contact											
719	5180'	1524	61.9	20.7	-	-	-	-	4.6	2.5	6.2	2.0	2.1
722	5120'	1200	45.7	25.6	1.0	6.8	3.6	4.0	4.1	-	9.2	-	-
730	5050'	1001	54.9	12.0	2.4	9.0	5.2	5.0	4.9	-	6.7	-	-
732	4990'	1006	58.2	14.5	0.1	14.2	2.1	-	0.9	-	10.0	-	-
733	4900'	1000	63.1	3.2	0.9	24.3	2.0	-	2.3	-	4.2	-	-
736	4800'	1006	62.6	8.0	0.1	25.7	0.8	-	0.6	-	2.2	-	-
738	4700'	1018	67.1	4.9	0.3	22.6	0.9	0.2	1.8	-	2.2	-	-
740	4640'	1000	54.2	22.8	0.1	4.8	3.1	4.8	2.4	-	7.8	-	-
742	4575'	1005	59.9	11.8	3.4	4.4	5.4	2.5	5.6	-	6.7	0.3	-
745	4505'	1000	50.4	13.0	0.3	1.6	8.3	8.6	5.3	-	12.5	-	-

Graph 1. Per cent mineral composition by weight through diabase sill, Pocket Creek.



Olivine is euhedral except where rounded by alteration. Plagioclase is euhedral in the fine-grained and chilled rocks and is subhedral in the medium and coarse-grained rocks. Pyroxene is subhedral to anhedral, but is commonly patchy due to alteration to biotite, hornblende, or chlorite. An ophitic texture is typical for practically all zones within the sills and dikes.

Deuteric hydrothermal alteration, indicated by sericitized plagioclase, hornblende, and biotite has occurred near the sill contacts and near the dike contacts in Warm Creek.

A large mass with unusual mineral composition was found within the lower portion of the main sill immediately north of the Red Bluff property. It is about 40 ft wide (E-W) by 1000 ft long (N-S) in outcrop. It is parallel to and situated immediately above the wide feeder dike in Warm Creek. The mass (sample 517, Appendix I) is composed of oligoclase, with less abundant pyroxene, hornblende, magnetite, apatite, and sphene. Sharp contacts on either side limit this mass from the normal olivine diabase of the adjacent portions of the sill.

3. Chemical Analyses of the Diabase

A sequence of five samples taken vertically through the sill at Pocket Creek was analyzed chemically (Appendix I). This includes the lower chilled contact taken one inch from the sediment contact (sample 746), olivine diabase 75 ft above lower contact (sample 742), olivine diabase 200 ft above lower contact (sample 738), olivine diabase taken 620 ft above the lower contact (sample 722), and diabase pegmatite taken 680 ft above lower contact (sample 719). Other samples of the diabase analyzed chemically include the upper chilled contact taken one inch from the sediments at the Hope property on Workman Creek (sample 780b), and a sample of the large plagioclase-rich mass at Warm Creek mentioned above (sample 517). Sample 746 of the lower chilled contact is believed to be most representative of the early magma. The analysis of sample 746 and the average analysis are compared in Table 6 with selected analyses of other similar magmas.

The silica content of the Sierra Ancha diabase relates it to the olivine basaltic magmas rather than to the Karroo, Dillsburg, or other tholeiitic magmas. The total iron of the average Sierra Ancha sill is considerably less than that for the lower chilled contact, 12.0 and 17.9% respectively. These amounts are greater than any of the values given for iron in Table 7. The calcium content of the Sierra Ancha sill is somewhat lower than the other values given. This high iron and low calcium of the analysis is consistent with the unusually abundant olivine. Phosphate is high, reflecting the very abundant apatite which makes up as much as 2.0% of the rock in the pegmatite.

TABLE 6

COMPARISON OF CHEMICAL ANALYSES OF SIERRA ANCHA DIABASE WITH OTHER SIMILAR MAGMAS (WATER-FREE BASIS)

	Sierra Ancha Sill Lower Chilled Contact -1-	Sierra Ancha Sill Average -2-	Skaergaard Olivine Gabbro Average -3-	Karroo Dolerite Average -4-	Hawaiin Olivine Basalt Average -5-	Dillsburg, Pa. Diabase Lower Chilled Facies -6-
SiO_2	48.4	48.8	47.92	52.5	48.35	52.0
TiO_2	2.9	2.3	1.40	1.0	2.77	.8
Al_2O_3	11.3	15.9	18.87	15.4	13.18	15.5
Fe_2O_3	6.5	3.0	1.18	1.2	2.35	1.7
FeO	11.4	9.0	8.65	9.3	9.08	9.1
MnO	.3	.2	-	.2	.14	.2
MgO	6.7	7.1	7.82	7.1	9.72	7.4
CaO	7.8	9.1	10.46	10.3	10.34	10.3
Na_2O	3.0	3.4	2.44	2.1	2.42	2.1
K_2O	1.2	.8	.19	.8	.58	.7
P_2O_5	.4	.4	-	.1	.34	.1

1. Sierra Ancha diabase, lower chilled contact, sample 746.
2. Sierra Ancha diabase, average of 5 samples.
3. Skaergaard olivine gabbro, E. Greenland, average of 3 samples, taken to represent composition of original magma (Wager and Mitchell,1951).
4. Karroo dolerite, average of 43 samples (Walker and Poldervaart, 1949).
5. Hawaiian olivine basalt, average of 53 analyses (Macdonald, 1949).
6. Dillsburg, Pa., diabase, lower chilled facies, recalculated on water-free basis (Hotz, 1953).

4. Trace Element Content of the Diabase

Samples of the diabase were analyzed with a Jarrel-Ash 3.4 meter plane grating spectrograph and a Jarrel-Ash console microphotometer. The elements chromium, nickel, cobalt, and copper were determined on all diabase samples analyzed, and strontium was determined for a few of the samples across the top contact of the sill. The data are listed in Table 7 and plotted on Graph 2.

Chromium and nickel vary together through the sill. These elements are generally more abundant through the central olivine-rich portion, but they are unusually high in samples 722 and 738.

Sample 722, taken 620 ft above the bottom contact, gave on duplicate analyses values of over 700 ppm for both chromium and nickel. This sample contained a maximum amount of pyroxene. Sample 738, taken 200 ft above the bottom contact, gave duplicate results of over 300 ppm chromium and 700 ppm nickel.

The tendency for chromium to prefer pyroxene and for nickel to prefer olivine as stated by Wager and Mitchell (1951) is verified by these data. The elements are present in the diabase pegmatite in very low amounts (10 ppm), although pyroxene makes up 20% of the rock.

Cobalt generally varies with the chromium and nickel, but is less abundant except at and near the sill contacts. It remains at its average abundance in the pegmatite. This suggests that the cobalt is more uniformly distributed in the various rock-forming minerals and somewhat less affected by differentiation.

Copper is present in uniform amount throughout the sill, averaging from 50 to 75 ppm. It is practically absent in the pegmatite sample. This distribution may indicate little or no concentration with differentiation or an immiscible sulfide separation from the late melt.

Strontium distribution is discussed later under Chapter VI.

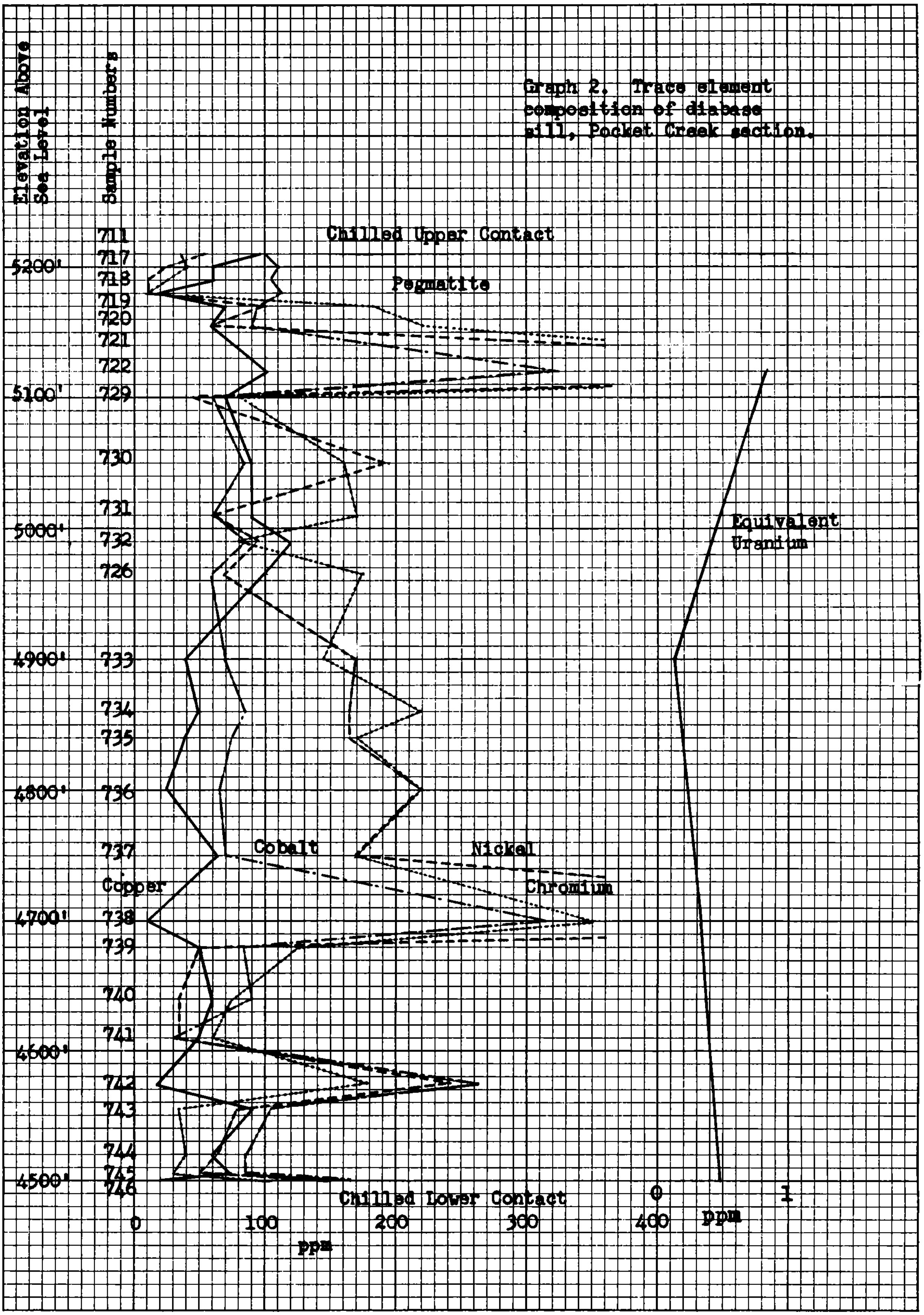
Equivalent uranium was determined for four samples through the sill with the scintillation type alpha particle counter previously described. Sample 747 is chilled diabase from the lower chilled contact of the sill. It contains 0.46 (error ± 7.5%) parts per million equivalent uranium as compared with the standard Columbia River basalt sample. This value best represents the uranium and thorium content of the diabase magma as measured by radiometric means. One gram per ton is an average figure for the uranium content of basalts according to Neuerburg (1956, p.231).

TABLE 7
TRACE ELEMENT COMPOSITION
POCKET CREEK SECTION
DIABASE SILL

			ppm						Other Analyses	
Topo. Elevation	Sample Number	Lithology	Chrome	Copper	Nickel	Cobalt	Equiv. Uranium	Strontium	Modal	Chem.
5210	711	Upper chilled contact	35	95	55	100				
5200	717	Coarse grained somewhat hydroth. alter.	40	60	25	110				
5190	718	Similar to 717. No orthoclase	25	60	10	105				
5180	719 (919)	Light pink diabase pegmatite. No qtz. no ortho.	10 10	<1 35	10 <5	140 85			X	X
5170	720	Med. grained uppermost olivine	185	70	100	95				
5155	721	Med. grained nodular diabase	220	60	60	90				
5120	722	Med. grained 6.8% olivine no qtz.no ortho.	710 760	95 110	840 720	250 400	0.832 (rerun)	330	X	X
5100	729	Olivine diabase	80	70	45	60				
5050	730	Olivine diabase	160	90	195	85			X	
5010	731	Olivine diabase	170	90	60	60				
4990	732	Olivine diabase	80	120	95	85			X	

TABLE 7 (Continued)

			ppm						Other Analyses	
Topo. Elevation	Sample Number	Lithology	Chrome	Copper	Nickel	Cobalt	Equiv. Uranium	Strontium	Modal	Chem.
4965	726	Olivine diabase	175	100	70	60				
4900	733	Olivine diabase	145	40	170	70	0.125		X	
4860	734	Olivine diabase	220	50	165	85				
4840	735	Olivine diabase	170	40	165	75				
4800	736	Olivine diabase	220	25	220	65			X	
4750	737	Olivine diabase	170	65	170	70				
4700	738	Olivine diabase	360	10	720	400	0.325		X	X
			305	10	800	180		460		
			380	15	730	375		455		
4680	739	Olivine diabase	125	50	45	85				
4640	740	Olivine diabase	75	60	35	90			X	
4610	741	Olivine diabase	60	50	35	30				
4575	742	Olivine diabase	120	5	225	190		450	X	X
			235	30	260	335				
4555	743	Olivine diabase	35	90	80	105				
4520	744	Olivine diabase	40	60	60	85				
4505	745	Fine grained diabase	30	75	50	85			X	
4500	746 (747)	Lower chilled contact	105	20	150	165	0.465			X



Graph 2. Trace element composition of diabase sill, Pocket Creek section.

McKelvy, et al., (1955, p. 467) indicate that low silica igneous rocks have an average uranium composition of less than 1 ppm. The values of equivalent uranium through the Sierra Ancha sill never reach 1 ppm, and an intermediate sample of olivine-rich diabase (sample 733) contains only 0.125 ppm (∓7.3%) equivalent uranium.

C. Mutual Effects Between Diabase Magma and the Intruded Sediments

1. Chilled Contacts

The common contact for sills and dikes is chilled diabase welded to slightly baked sediment. The diabase adjacent to the sediment displays in thin section only a few phenocrysts of plagioclase and small pyroxene, biotite, hornblende, and magnetite crystals in a very fine grained groundmass. The sediment is occasionally of a slightly different color for an inch or two away from the contact. Some specimens broke at the contact and others remained welded at the contact and broke elsewhere. Samples 780a and 780b were welded together and represent upper Dripping Spring quartzite and the upper chilled diabase respectively. Both samples were analyzed chemically and spectrographically. A comparison of the analysis of sample 780b with that of a lower chilled border (sample 746) and with the other diabase samples indicates very little contamination of the magma at the contact. A comparison of the chemical analysis of sample 780a with analyses of uncontaminated sediments indicates calcium is the only major element that may have moved from the diabase to the sediment. A comparison of the amount of nickel, cobalt, strontium, and chromium in the welded sediment with amounts typical of unaltered sediments indicates that these trace elements have in part been introduced into the sediment.

Abundant, coarse hornblende and biotite, as well as sericite, chlorite, and antigorite were observed in the chilled diabase on the west side of the diabase dike in Warm Creek. This is considered to be a hydrothermal or deuteric alteration of the chilled border by late solutions from the magma.

2. Mobilization of the Sediments

The study of upper sill contacts disclosed considerable local mobilization of the sediments. Breaking, folding, and contortion of beds, healed into a solid mass by recrystallization between the sediment fragments, is a common feature. This was observed at the upper sill contact at Pocket Creek, at several properties in Workman Creek, below the Black Brush property on Cherry Creek, and at several properties south-east of the Sierra Ancha region. Such brecciation, where it occurs, extends only 4 to 5 ft above the contact and for a maximum of about 20 ft from the contact where localized by a fracture.

Rheomorphic veins in the diabase, formed by the movement of mobilized sediment into partly cooled and fractured diabase, were studied in a road cut in Workman Creek. One vein is 2 inches wide and another is 18 inches wide (sample 88). The dikes are light salmon colored, medium grained, holocrystalline. The larger one, examined in detail, contains predominantly orthoclase, with quartz, plagioclase, pyroxene, sphene, apatite, and chlorite. Chemical analyses indicate the original sedimentary nature of the vein material. It contains 64.49% SiO_2, 1.52% combined iron oxide, and 11.03% K_2O, all of which are characteristic of the sediments and not of the diabase or its differentiates. Neither dike contains significantly more radioactive mineralization than the enclosing diabase.

3. Recrystallization of the Sediments without Mobilization

The sediments are locally altered to coarse-grained, igneous-looking rocks in many places where adjacent to the upper sill contact. The change from sediment to this granophyre was observed in every stage of development. It starts with recrystallization in isolated spots and along delicately selected bedding planes where new orthoclase crystals nucleate on sulfide grains. Further development of the crystallization results in a banded rock displaying beds with original sedimentary texture alternating with bands of holocrystalline rock. The most extreme stage is a massive crystalline rock with vague ghost sedimentary structures. Samples 309 to 319 are a sequence of specimens displaying the varying degrees of transformation (Appendix III).

4. Assimilation of Sediments by Diabase Magma

Blocks of sediment dropped into the sill magma during intrusion and were partly assimilated by the magma. These blocks, displaying original sedimentary texture in their upper part, grade into coarse, pink pegmatite with diabasic texture, which in turn grades into normal olive-gray diabase. No chilled contact is present where this has occurred.

A sharp horizontal contact between underlying normal diabase and overlying pink diabasic pegmatite is exposed in a road cut in Workman Creek. This is believed to be the lower portion of an assimilated block of sediment. At the Tippy #1 claim in Reynolds Creek, surface exposures and drill cores displayed all degrees of assimilation of the sediment by the magma. The drill core through the contact at the Workman #1 claim on Workman Creek also displays the same relationship. The pink diabase pegmatite, which is a mixed rock, contains abundant orthoclase, plagioclase, quartz, pyroxene, hornblende, sphene, apatite, and magnetite. Samples 857 and 862 represent this mixed rock and should be compared with no. 719, a normal diabase pegmatite (See Appendixes I and III). They are very low in MgO, somewhat low in CaO, and considerably higher in K_2O than the normal diabase and diabase pegmatite.

The pink pegmatites were observed in the upper portion of the sill immediately below all of the uranium deposits in the Workman Creek area and below the Black Brush and other properties on Cherry Creek. In every case they can be distinguished megascopically by their distinctive color from the normal, gray-green diabase pegmatite.

5. Metasomatism of the Sediments

Four chemical analyses of unrecrystallized sediments may be compared with 10 chemical analyses of partly or completely recrystallized sediments (Appendix I). The analyses indicate that very little transfer of major constituents has taken place. The high percentage of K_2O, so characteristic of the unaltered sediment, is also present in the recrystallized rocks. Samples 780a, 855 and 873 contain 4.30%, 5.00% and 3.06% CaO respectively, which probably represents an addition from the diabase. These samples were taken from very near the contact.

Dark green, coarsely crystalline masses were observed within the recrystallized sediments in newly opened mine workings of the Lucky Stop property, Workman Creek. These masses contain very abundant pyroxene, chlorite, serpentine, and calcite. Orthoclase, feldspar and some uraninite are also present (samples 469-475). Although it is possible that these mafic masses represent original material located here in the sediment, they probably are concentrations resulting from the movement of ions during metasomatism of the sediment.

A diamond drill core hole was drilled vertically through the upper DS quartzite and the upper portion of the thick diabase sill at the Little Joe property, Workman Creek. The core was examined in thin sections and analyses were made for copper, chromium, nickel, cobalt, and strontium with the spectrograph. Equivalent uranium was determined by alpha counting. The results of this work are listed on Table 8 and plotted on Graph 3, which gives footage in the drill hole as the ordinate. On Graph 3 strontium, chromium and equivalent uranium are plotted in ppm. Per cent recrystallization and orthoclase vs. plagioclase are also plotted. A detailed lithic description of each sample is given in Appendix III.

The spectrographic, radiometric, and petrographic data developed from a study of this core disclose much regarding the relationship between the diabase and the enclosing sediment. Six zones, which can be easily differentiated, were penetrated by the drill at this place. They are: (a) unaltered sediment, (b) recrystallized and metasomatized sediment, (c) hybrid rock, or sediment partly digested in diabase, (d) normal diabase, medium to fine-grained, (e) hybrid rock, and (f) normal diabase.

(a) Unaltered Sediment From the collar of the hole downward to about 140 ft sediment was encountered which is essentially unaltered by the diabase. The rock is unrecrystallized tuff with all typical sedimentary structures such as bedding and stylolites. It contains an average of 15 ppm strontium and 64 ppm chromium. The uranium content was not determined in detail, but it is about 3 ppm. No plagioclase is present.

(b) Recrystallized and Metasomatized Sediment From 140 ft down to 171 ft the sediment is partly or completely recrystallized. Below this zone the rock has a diabasic texture. The transition from partly recrystallized sediment to completely recrystallized sediment is gradual, increasing downward. The amount of strontium increases downward from 20 to 130 ppm through this interval, apparently due to movement from the diabase into the sediment. The amount of chromium is variable through this interval but averages 116 ppm. This zone averages about 3 times the amount of equivalent uranium as the unaltered sediment above. It is apparent that the increase in strontium and chromium values coincides with the upper limits of recrystallization.

(c) Hybrid rock, or sediment partly digested in diabase

This zone extends from 171 ft downward to 184 ft. The rock is pinkish, slightly pegmatitic, and has a diabasic texture. The plagioclase content increases and the orthoclase content decreases downward. Uranium content drops off from about 3 to 1 ppm. At 171 ft there is a low value of 20 ppm for chromium and at 171.4 ft there is a low value of 60 ppm for strontium. These increase rapidly two or three fold to the next zone below.

(d) Normal diabase, medium to fine-grained

From 184 ft downward to 190 ft bluish-gray diabase was encountered. It contains no orthoclase and less than 0.81 ppm equivalent uranium. There are 335 and 180 ppm of strontium and chromium respectively.

(e) Hybrid Rock This zone is similar to the one described above under (c). It extends from 190 ft to 209 ft. The rock is pink, pegmatitic, and has a diabasic texture. Some orthoclase is present, but plagioclase is predominant. Strontium and Chromium content drop off to 10 and 85 ppm respectively. No measurement of equivalent uranium was taken.

(f) Normal diabase From 209 ft to the bottom of the hole at 220 ft normal, medium-grained olivine diabase was cored. It contains no orthoclase. One analysis gave 0.68 ppm equivalent uranium. Strontium content is 170 to 180 ppm and chromium content is 305 to 380 ppm.

TABLE 8

PETROGRAPHIC AND TRACE ELEMENT DATA ACROSS UPPER SILL CONTACT, DRILL HOLE #1, LITTLE JOE CLAIM, WORKMAN CREEK

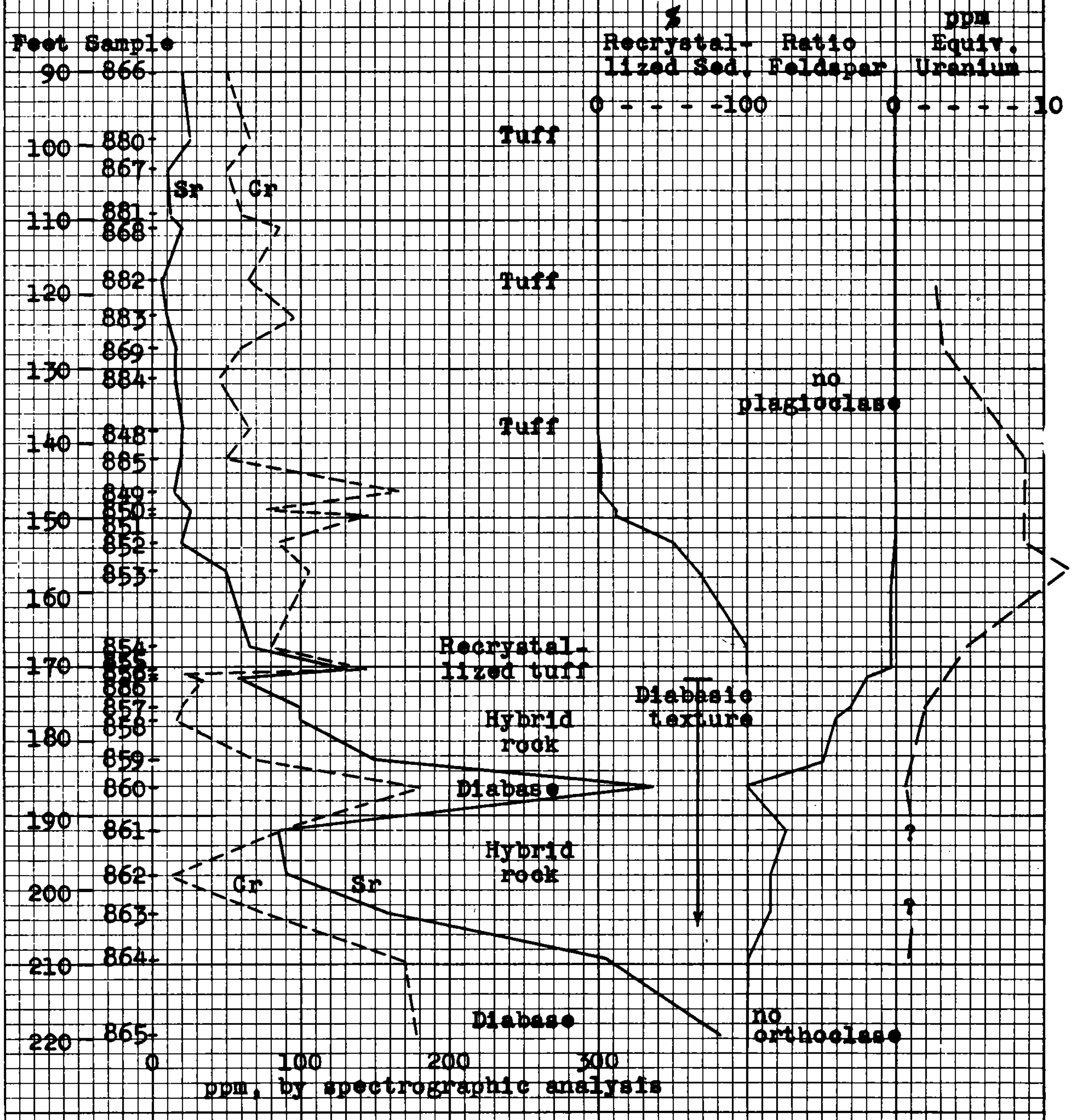
			Orthoclase X100		ppm					
Footage Down Hole	Sample Number	Rock Type	Plag. + Ortho.	% Recrystallized	EU	Sr	Cr	Cu	Ni	Co
90.1	866	Very fine-grained tuff	100	0		20	50	60	<10	-
99.2	880	Tuff	100	0		25	65	110	25	10
103.6	867	Tuff	100	0		10	50	135	10	15
108.8	881	Tuff	100	0		12	60	160	15	15
111.2	868	Very fine-grained tuff	100	0		20	85	260	10	20
118.0	882	Tuff	100	0	2.57	7	65	60	15	<10
122.5	883	Tuff	100	0		10	95	210	20	10
127.2	869	Tuff with stylolites	100	0	3.17	15	60	180	10	15
131.4	884	Tuff	100	0		15	45	130	20	25
138.2	848	Fine-grained, unrecrystallized tuff	100	0		20	65	195	25	30
142.2	885	(Slightly) recrystallized tuff.	100	<1	8.83	20	50	115	15	25

TABLE 8 (Continued)

			Orthoclase X100		ppm					
Footage Down Hole	Sample Number	Rock Type	Plag. + Ortho.	% Recrystallized	eU	Sr	Cr	Cu	Ni	Co
146.6	849	(Slightly) Recrystallized tuff	100	1		15	125 (205)	600 (130)	405 (70)	315 (190)
148.8	850	Partly recrystallized tuff	100	10		25	75	160	15	20
149.8	851	Tuff with sphene stylolites	100	10		25	145	270	65	65
153.4	852	Partly recrystallized tuff	100	50	8.51	20	85	100	30	35
157.2	853	Largely recrystallized tuff with sphene stylolites	98	66	12.06	50	105	85	60	60
167.5	854	Completely recrystallized tuff	97	100	4.67	65	80	140	70	65
170.6	855	Completely recrystallized tuff	97	100		140 (115)	70 (220)	200 (275)	35 (130)	120 (280)
171.0	856	Tuff partly digested in magma	80	100		95	20	10	-	-

TABLE 8 (Continued)

Footage Down Hole	Sample Number	Rock Type	Orthoclase X100 Plag. + Ortho.	% Recrystallized	ppm eU	Sr	Cr	Cu	Ni	Co
171.4	886	Partly digested tuff in diabase	80	-		60	35	30	5	-
175.6	857	Coarse pinkish-green diabase	70	-	2.00	100	20	90	5	20
177.3	858	Diabase pegmatite (perthitic)	60	-		100	15	30	-	-
182.6	859	Diabase pegmatite (perthitic)	50	-		150	70	45	15	15
186.2	860	Medium to fine-grained diabase	0	-	0.81	335	180	90	135	40
192.0	861	Pink pegmatitic diabase	25	-		85	85	25	-	-
198.0	862	Diabase pegmatite	15	-		90	10	185	-	-
203.0	863	Diabase pegmatite	15	-		155	75	150	25	25
209.6	864	Normal grain-size diabase	0	-	0.68	305	170	70	60	40
219.8	865	Medium-grained olivine diabase	0	-		380	175	85	55	40



GRAPH 3

Petrographic and trace element data across upper sill content.
Drill hole #1, Little Joe Claim, Workman Creek.

D. The Diabase as a Concentrating Agent

1. Evidence of solutions from diabase

The spatial relationships between the uranium deposits and the diabase bodies has been discussed. The Red Bluff deposit occurs adjacent to a large feeder dike, and the other prominent deposits occur at or near the tops of diabase sills. There has been mobilization, recrystallization, and metasomatism of the sediments by the diabase, and the diabase has been contaminated locally where blocks of sediment have been partly digested by the magma. These features are characteristic of all the deposits on both sides of Workman Creek, and they are also present at the Black Brush property. Such features are prominent at some places where no uranium deposit occurs, with an outstanding example being the Tippy property, on Reynolds Creek.

At the Red Bluff property, the nearest diabase to the uranium veins displays considerable alteration to hornblende. There is abundant evidence of hydrothermal activity associated with the diabase sill below the Sue Mine. Cross-fiber veins of chlorite are present in the diabase near the top of the sill and also well up into the overlying Pioneer shale where the veins form a stockwork enclosing a small concentration of copper carbonate, calcite and feldspar.

Bateman (1923) concluded that the chrysotile asbestos deposits of the Sierra Anchas were formed as a result of reaction between the Mescal limestone and solutions from the diabase. Such deposits occur in the limestone directly above the Red Bluff property, the Workman Creek properties, the Black Brush property, and the Wilson Creek property. Small but mineable magnetite deposits occur above the sill in Workman Creek and in Rose Creek to the west. The presence of these ores is considered good evidence for hydrothermal activity associated with the diabase sills.

2. Hydrothermal Nature of the Uranium Deposits

The fact that the uranium occurs as high grade uraninite adjacent to fracture channelways is good evidence for hydrothermal emplacement. Associated minerals further indicate such conditions. Comb quartz has grown inward from the walls of the slightly opened fractures along which the uranium has been concentrated at the Red Bluff property. Chalcopyrite, galena, pyrite, and calcite are rare to common in the ore zone of the Hope adit and Workman properties.

3. Time and space relationships between recrystallization of the sediments and uranium ore emplacement

The structural relationships of the Workman Creek deposits are somewhat unique. The top of the thick diabase sill cuts the sedimentary sequence immediately below and within the favorable zone, where the ore has consistently developed. Thus the near-contact metasomatic effects are superimposed upon the ore deposits. Where ore has formed farther removed from the contacts, it is not associated with obvious metasomatism.

The petrographic and chemical data developed from the core hole #1, Little Joe Claim (Graph 3) indicate that metasomatism and recrystallization exist together spatially in this area, but recrystallization rather than metasomatism will be referred to below where only detailed field observations are relied upon.

The fractures which localize the ore at the properties on Workman Creek also have localized the most extensive recrystallization of the sediments. For example at the Hope adit, Workman #1 adit, Lucky Stop trenches and adits, and at the Little Joe and Big Joe properties, the ore bodies are tabular, extending about 2 feet to either side of nearly vertical fractures striking N6°-20°E. These same fractures are the locus of from 10' to 20' of vertical development of recrystallization of the sediments. Recrystallization can be observed at many places within 4' to 5' of the intrusives, but it has not been observed farther removed from the diabase other than where adjacent to the pre-ore sets of fractures. At many places, there is no recrystallization except adjacent to the ore fractures. At a few places in the Workman #1 adit small joints (the lateral limits of which can be observed) separate recrystallized sediment. Such joints are oriented in the pre-ore directions.

These observations suggest that the metasomatism as well as the ore forming process occurred during the same time interval between the formation of the pre-ore and post-ore joint sets and that the solutions causing recrystallization of the sediment followed in many instances the same channel fractures as the ore forming fluids. The ore is limited to the favorable stratigraphic interval of the UDS and the recrystallization is limited to the vicinity of upper sill contacts. However, at the properties on Workman Creek these conditions are spatially superimposed.

4. Conclusions regarding diabase as a concentrating agent

The diabase magma gave off solutions which penetrated the invaded rocks to metasomatize them and to create asbestos and magnetite deposits. The uranium deposits are the result of a hydrothermal-type process and are spatially very near the diabase. No other source of hydrothermal activity is known in the vicinity of the deposits. Furthermore, the solutions from the diabase came into the sediments at about the same time and place as the uranium ore. The conclusion, based upon these data and observations, is that the uranium deposits were formed by hydrothermal activity accompanying the diabase.

The fracture and sedimentary ore controls have been discussed in previous chapters. The presence, size, and position of diabase intrusives with respect to the favorable stratigraphic interval is a third major structural control of the deposits. The deposits are located in pre-ore fractures in the favorable middle upper DS in places where hydrothermal activity accompanying the diabase intrusion has penetrated the host rock.

VI. THE SOURCE OF THE URANIUM IONS

The principal objectives of this research have been the development of structural controls of the uranium deposits. However, part of the data developed have a bearing on the problem of the source of the uranium.

A. Uranium from Diabase Magma

Radiometric measurements of samples of diabase from the sill at Pocket Creek (Table 7) gave 0.465 ppm equivalent uranium for the lower chilled contact, a minimum value of 0.125 ppm and a maximum value of 0.832 ppm from olivine diabase. Other normal diabase samples from the core hole on the Little Joe Claim, Workman Creek (Graph 3) contain 0.81 and 0.68 ppm. Samples of diabase pegmatite were analyzed also, but these were later recognized to be hybrid pegmatites resulting from blocks of sediments being partly incorporated within the magma. Three such samples gave 2.00, 1.85, and 5.65 ppm equivalent uranium (Appendix II). The normal pegmatite which occurs as a 10'-20' thick layer below an unbroken, upper chilled contact is light greenish-gray and contains no quartz or orthoclase. If such a pegmatite represents the final product of differentiation of the diabase, crystallization was probably complete shortly after an iron-rich stage was developed. Because of the low initial content of uranium in the magma and the lack of extreme stages of differentiation, it seems doubtful that the diabase magma contributed the uranium.

B. Uranium from Dripping Spring Quartzite

Radiometric measurements made on three samples of upper DS believed to be most nearly representative of the formation before intrusion of the diabase gave 4.09, 4.64 and 5.85 ppm equivalent uranium respectively, with an average value of 4.86 ppm. This is over 10 times the amount of equivalent uranium in the diabase magma.

Detailed mapping of the mine workings on the Red Bluff property and a knowledge of the grade of the ore removed made possible a calculation of the amount of sediment that would be required to contribute the uranium to form the west ore block at this property. The following data are used:

(a) The original sediment contained 4.8 ppm equivalent uranium or 5.6 ppm equivalent U_3O_8.

(b) The average grade of the ore removed was 0.20% U_3O_8 or 2000 ppm U_3O_8.

(c) The ore block is 50' deep in vertical dimension and contains 2905 square feet in plan (each vein calculated separately and all added together).

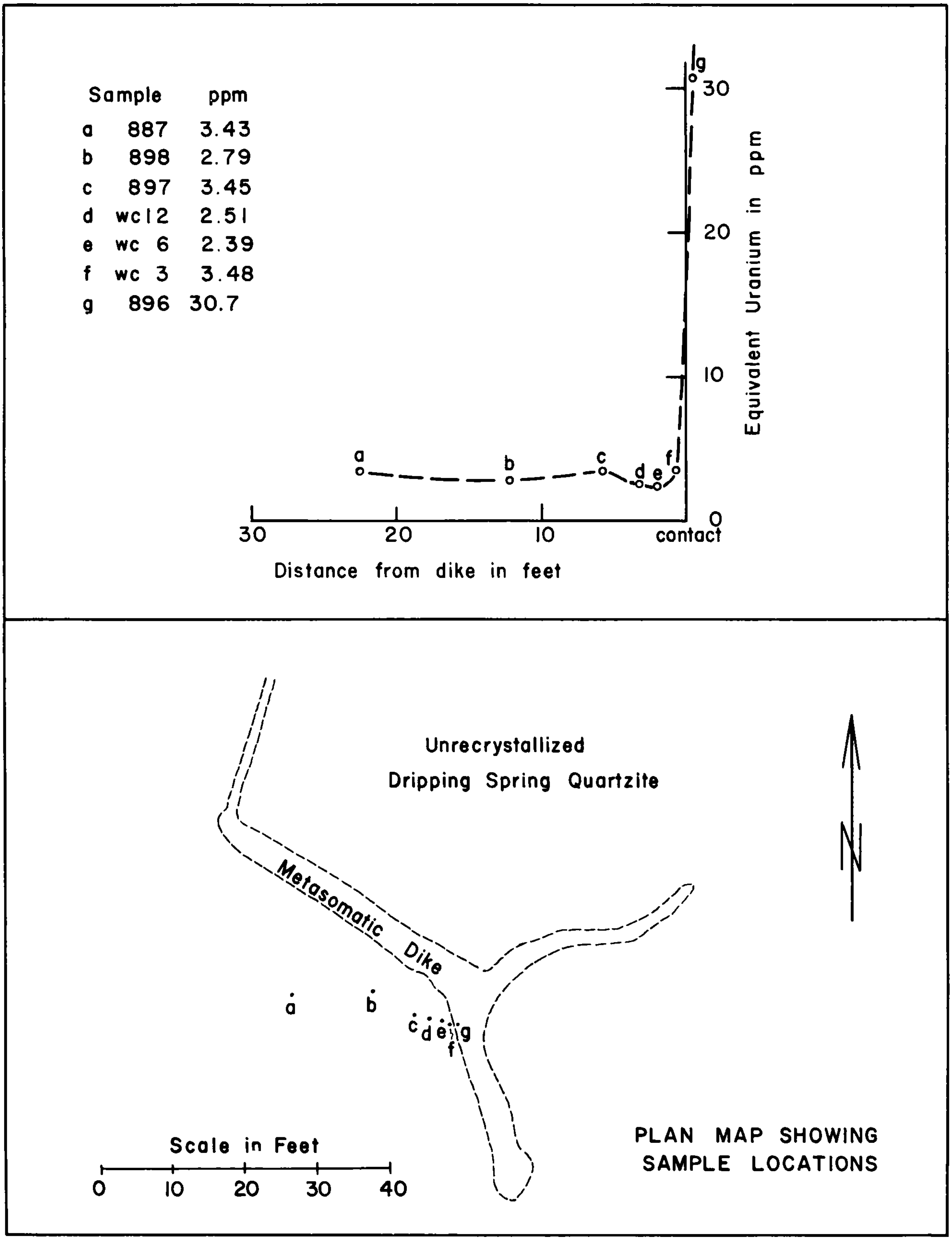
If it is assumed that the deposit is formed by the removal of 50% of the uranium from sediment engulfed or penetrated by diabase magma or its hydrothermal solutions, the block of sediment might have the dimensions, 100' thick by 100' wide by 500' long.

A special radiometric study was made across the west contact of the Y shaped metasomatic dike (sample 761, Appendix III) located about 60' east of the main adit on the Workman #3 claim (Plates 11 and 24). Closely spaced samples taken across the contact were analyzed by the alpha counting technique previously described. the equivalent uranium values in ppm are plotted against distance in feet from the contact on the inserted graph on Plate 24.

The graph is interpreted as follows:

(a) There is an intimate spatial relationship between the metasomatic granophyre and the uranium concentration within the dike.

(b) The unrecrystallized quartzite, represented by samples 887, 897 and 898, contains an average of 3.22 ppm equivalent uranium which is less than the average of 4.86 ppm for samples of UDS unaffected by diabase. This indicates general impoverishment throughout the vicinity of the sampling.



Sample		ppm
a	887	3.43
b	898	2.79
c	897	3.45
d	wc12	2.51
e	wc 6	2.39
f	wc 3	3.48
g	896	30.7

PLATE 24 RESULTS OF RADIOMETRIC ANALYSIS OF SAMPLES ACROSS A METASOMATIC DIKE, WORKMAN NO. 1 CLAIM

(c) The dip in the curve through samples WC-6 and WC-12 represents impoverishment of 6' of unrecrystallized rock adjacent to the dike.

(d) Although some uranium moved toward the dike from the adjacent 6', most of the uranium in the dike was brought in from a more distant source along a channel now marked by the dike.

DuToit (1920) concluded from his study of the Karroo dolerite that diabase spreads laterally through parted sediments with the aid of expanding gases including water and other volitiles distilled from the heated sediments. These gases would tend to split the strata, aiding penetration of the magma. They would also make the syngenetic uranium unstable and transport it from the sediments.

The partly assimilated blocks of sediments and the rheomorphic veins have less radioactivity than the unaltered sediment. It is believed that such assimilation by the magma would efficiently remove the uranium from the enclosed sediment and add it to the hyperfusible constituents of the magma.

Escaping gases and hyperfusibles would escape vertically through the NNE and WNW sets of fractures to precipitate the ore where it is now found.

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APPENDIX I

CHEMICAL ANALYSES GROUPED BY ROCK TYPES

1. Unrecrystallized Upper Dripping Spring Quartzite

Sample Number	23	223	770	849
SiO_2	56.48	64.65	66.64	61.70
TiO_2	1.21	0.63	0.74	0.95
Al_2O_3	15.12	13.93	14.31	15.64
Fe_2O_3	1.12	1.09	0.00	0.97
FeO	5.48	3.41	2.27	3.42
MnO	0.08	0.01	0.00	0.03
MgO	0.83	0.49	0.52	1.14
CaO	1.97	0.53	0.81	2.49
Na_2O	0.73	0.20	0.87	0.41
K_2O	13.40	12.31	12.49	11.98
P_2O_5	0.09	0.04	0.13	0.07
H_2O+	1.71	0.68	0.78	0.22
H_2O-	0.10	0.13	0.03	0.16
CO_2	0.00	0.00	0.00	nil
S	2.69	1.89		1.45
	101.01	99.99	99.59	100.63
Less O for S	0.67	0.47		0.36
	100.34	99.52		100.27

2. Recrystallized Upper Dripping Spring Quartzite

Sample Number	761	780a	311	317	346	24	699	811	855	873
SiO_2	78.28	61.46	59.50	60.17	59.96	60.12	67.36	61.02	59.18	70.02
TiO_2	0.53	0.83	1.14	1.11	0.90	1.00	0.61	1.03	0.96	0.78
Al_2O_3	7.90	14.96	17.03	17.74	15.88	14.67	13.76	17.29	15.24	10.93
Fe_2O_3	1.00	0.59	2.31	0.38	1.28	0.00	0.72	1.34	2.50	1.21
FeO	0.56	2.85	0.85	2.27	1.35	5.19	2.42	0.71	1.64	1.92
MnO	0.02	0.08	0.01	0.03	0.03	0.02	0.03	0.02	0.08	0.07
MgO	1.50	2.15	0.40	1.14	1.10	0.40	1.06	0.61	2.18	1.62
CaO	2.00	4.30	0.88	0.97	2.58	0.64	1.46	1.81	5.00	3.06
Na_2O	0.51	0.71	0.79	1.10	0.90	0.48	0.82	0.76	3.87	1.29
K_2O	7.43	10.91	13.57	13.53	12.72	13.46	9.45	12.45	6.46	8.22
P_2O_5	0.08	nil	0.07	0.00	0.01	0.09	0.07	0.05	0.06	0.06
H_2O+	0.79	0.61	1.87	0.81	1.43	1.84	1.51	0.99	0.70	0.65
H_2O-	0.19	0.16	0.05	0.06	0.34	0.10	0.18	0.60	0.18	0.34
CO_2	0.00	0.32	0.00	0.00	0.00	0.00	0.00	nil	nil	0.21
S		0.27	2.38	0.84	1.79	2.15		1.05	1.55	0.06
	100.79	100.20	100.85	100.15	100.27	100.16	99.45	99.73	99.60	100.44
Less O for S		0.07	0.60	0.21	0.45	0.54		0.26	0.38	0.01
		100.13	100.25	99.94	99.82	99.62		99.47	99.22	100.43

3. Rheomorphic Vein of Upper Dripping Spring Quartzite in Diabase

4. Vertical Sequence Through Diabase Sill

Sample Number	88	746	742	738	722	719	780b
SiO_2	64.49	47.54	45.94	47.11	47.24	52.34	47.76
TiO_2	0.75	2.85	2.30	0.69	2.14	3.15	3.00
Al_2O_3	16.65	11.11	17.50	20.28	15.95	13.34	18.62
Fe_2O_3	0.53	6.38	3.41	1.14	2.48	1.14	0.71
FeO	0.99	11.17	9.46	7.33	9.25	6.83	10.21
MnO	0.04	0.26	0.23	0.09	0.23	0.23	0.30
MgO	0.95	6.59	6.62	9.17	8.03	4.68	4.81
CaO	2.05	7.70	8.60	9.67	9.92	8.92	6.37
Na_2O	1.66	2.96	2.79	3.09	2.81	5.04	3.52
K_2O	11.03	1.21	0.87	0.29	0.81	0.92	2.08
P_2O_5	0.05	0.37	0.44	0.12	0.26	0.65	0.39
H_2O+	0.50	2.50	2.07	1.46	1.15	2.38	2.00
H_2O-	0.20	0.06	0.02	0.03	0.06	0.27	0.14
CO_2	0.00	0.00	0.00	0.00	0.00	0.00	nil
S	0.02						nil
	99.91	100.70	100.25	100.47	100.33	99.89	99.91

	5. Segregate of Diabase Magma	6. Hybrid Rocks - Upper Dripping Spring Quartzite Partly Digested in Diabase Magma	
Sample Number	517	857	862
SiO_2	49.48	53.15	52.89
TiO_2	1.00	2.95	3.16
Al_2O_3	24.52	15.64	15.87
Fe_2O_3	0.38	1.28	2.46
FeO	3.13	8.56	9.06
MnO	0.03	0.25	0.25
MgO	1.06	0.92	0.65
CaO	11.44	7.84	5.95
Na_2O	3.63	3.62	4.78
K_2O	1.50	3.16	2.20
P_2O_5	0.18	0.11	0.20
H_2O+	2.91	1.79	1.60
H_2O-	0.06	0.22	0.17
CO_2	0.00	nil	nil
S	0.05	0.09	0.10
	99.37	99.58	99.34
Less O for S	0.01	0.02	0.02
	99.36	99.56	99.32

APPENDIX II

SUMMARY OF RADIOMETRIC DATA BY ROCK TYPES

Category #1 - Upper Dripping Spring Quartzite.
Unrecrystallized, unmatasomatized, and not near any known intrusive body.

#357 - 4.09 ppm eU, error 3.6%
409 - 4.64 ppm eU, error 8.6%
-10.9% K_2O error 2.0%
419 - 5.85 ppm eU, error 8.0%

Category #2 - Upper Dripping Spring Quartzite.
Unrecrystallized, but in the vicinity of a diabase sill.

#690 - 2.97 ppm eU, error 6.3%
- 1.36 % K_2O error 2.3%
(145' above sill)
882 - 2.57 ppm eU, error 5.3%
(53' above sill)
869 - 3.17 ppm eU, error 9.6%
(44' above sill)
887 - 3.43 ppm eU, error 9.0%
11.9% K_2O error 2.7%
897 - 3.45 ppm eU, error 4.8%
898 - 2.79 ppm eU, error 6.1%
WC3 - 3.48 ppm eU, error 9.7%
WC6 - 2.39 ppm eU, error 5.7%
WC12- 2.51 ppm eU, error 6.9%

Category #3 - Upper Dripping Spring Quartzite.
Metasomatized, recrystallized and near diabase sill.

#896 -30.7 ppm eU, error 6.2%
854 - 4.67 ppm eU, error 8.2%
853 -12.1 ppm eU, error 7.4%
852 - 8.51 ppm eU, error 8.6%
885 - 8.83 ppm eU, error 3.5%

Category #4 - Diabase sill

#860 - 0.81 ppm eU, error 6.8%
864 - 0.68 ppm eU, error 5.4%
722 - 0.832 ppm eU, error 8.0%
733 - 0.125 ppm eU, error 7.3%
738 - 0.325 ppm eU, error 6.9%
747 - 0.465 ppm eU, error 7.5%

SUMMARY OF RADIOMETRIC DATA BY ROCK TYPES (Continued)

Category #5 - Hybrid rocks - Upper Dripping Spring Quartzite partly digested in diabase magma.

#857 - 2.00 ppm eU, error 6.8%
879 - 1.85 ppm eU, error 7.2%
875 - 5.65 ppm eU, error 7.6%

APPENDIX III

DESCRIPTIONS OF SELECTED SAMPLES

SAMPLE NUMBER

1 WORKMAN #3 CLAIM, WORKMAN CRK. UDS FM
Partly recrystallized with sulfides parallel to bedding. Contains orthoclase, quartz(-), pyrite(+), biotite, sphene(+). Unrecrystallized tuff in corner of slide.

2 WORKMAN #3 CLAIM Vertical vein of recrystallized upper Dripping Spring Fm containing predominantly orthoclase with plag(-), quartz(-), pyrox(-), biotite(-), pyrite, magnetite, and sphene. Pyrox altering to chlorite. Pyrite is coarse. Unrecrystallized tuff in corner of slide. Pyrite fine in tuff.

9 WORKMAN #3 CLAIM, WORKMAN CRK. Coarse recrystallization of tuff of UDS Fm. Contains clouded orthoclase, clear plagioclase(-), quartz (interstitial), pyrox(-) altering to chlorite, orthopyrox(-), sphene, pyrite. Unrecrystallized tuff in corner of slide is darker than other.

21 HOPE #6 CLAIM Recrystallized tuff of UDS Fm. contains 1/4" dia. button of galena with a halo of chlorite and serpentine around it. Rock contains orthoclase, plagioclase, clinopyrox, orthopyrox(-), biotite, magnetite, galena, sphene, apatite. Sample taken at upper contact of diabase sill in transition zone between diabase and sediment.

23 HOPE #7 CLAIM DISCOVERY PIT, WORKMAN CRK. Black, fine-grained, partly recrystallized DS Fm. Shows thin bands of dark feldspar (recrystallized) parallel to bedding. The unrecrystallized portions look like tuff, with pyrite, biotite, and feldspar(?) intimately jumbled together. The recrystallized portion contains orthoclase, quartz, pyroxene altering to chlorite, pyrite(+), biotite, and sphene(+). Spect. anal. ppm -

Cr	Cu	Ni	Co
110	25	25	25

See chemical analysis of the unrecrystallized portion, Appendix I.

SAMPLE NUMBER

24 HOPE #7 DISCOVERY PIT, WORKMAN CRK. Gray recrystallized UDS Fm. Bedding still evident. Taken from very near #23 - to be compared. Contains orthoclase, biotite, pyrox (-) altering to chlorite(-), pyrite, and sphene.
Spect. anal. ppm -

Cr	Cu	Ni	Co
130	25	60	-

See chemical analysis of the unrecrystallized portions, Appendix I.

73 RED BLUFF PROPERTY. Partly oxidized high grade uranium ore in UDS Fm. Not recrystallized. Fine-grained (silt). Contains plagioclase, pyrite, leucoxene, quartz(-), hornblende(-), and abundant serpentine. Appears hydrothermally altered. Polished sections and film emulsion discloses uraninite parallel to bedding in 1/32" bands. Alpha tracks indicate position of uraninite.

85 HOPE #6 and #7 CLAIMS, WORKMAN CRK. 2" wide dike cutting coarse-grained diabase just below upper contact of diabase sill. Contains quartz and orthoclase in graphic intergrowth. Plagioclase, pyrox, sphene(?), chlorite. Similar structurally and compositionally to #88, which is rheomorphic.

86 HOPE #7 CLAIM, WORKMAN CRK. Greenish-gray to blue diabase in sill. Adjacent to rheomorphic vein (#88). Highly altered. Contains plag, pyrox, hornblende, biotite, magnetite, sphene, sericite, chlorite.

87a HOPE #7 CLAIM, WORKMAN CRK. Fine-grained upper sill (above #86). Appears pink on outcrop. Contains plagioclase, orthoclase, orthopyrox, clinopyrox, hornblende(+), magnetite, apatite(+), sphene(-), sericite, chlorite, in sharp horizontal contact with gray diabase below. Probably represents engulfed sediment.

88 HOPE #7 CLAIM, WORKMAN CRK. Light salmon colored 18" dike in diabase near top of sill. Composed of uniform grains of orthoclase (predominant), quartz, plagioclase, pyroxene, sphene, apatite, and chlorite. Quartz much more abundant than in diabase. Probably rheomorphic.
Spect. analysis ppm -

Cr	Cu	Ni	Co	
10	5	85	-	
-	30	-	-	(rerun, #988)

See chemical analysis, Appendix I.

SAMPLE NUMBER

90 WORKMAN #3 CLAIM, 150' SOUTH OF PORTAL. Pink diabase pegmatite. Contains orthoclase, plag, quartz(-), clino-pyrox, ortho-pyrox, mico-cline(-), coarse spene, apatite(+), magnetite, chlorite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
60	10	40	-	100

205 NELS HILL NEAR DILLSBURG, PENNSYLVANIA. Fine-grained pink diabase (granophyre ?). Contains orthoclase, quartz, very little plagioclase, hornblende(+), magnetite, stilpnomelane, apatite. No pyroxene. Hydrothermally altered. Orthoclase altering to sericite.

215 TOMATO JUICE CLAIM, REGAL CREEK, UDS Fm. Fine-grained tuff with late $CaCO_3$. Stylolites of pyrite and other dark minerals. Shredded texture. Sutured and odd shaped quartz grains suggesting shards.

218 TOMATO JUICE CLAIM, REGAL CREEK, UDS Fm. Black fine-grained tuff composed of feldspar(?) and secondary calcite with bands of coarser quartz and microcline and sand grains. Shrinkage cracks in tuff filled by samd. The coarser grains of sand in the shrinkage cracks are somewhat rounded, however, they appear to be partly derived from pyroclastic material.

223 BLACK BRUSH PROPERTY, CHERRY CREEK, UDS Fm. Very fine horizontal bands or streaks in fine-grained ss. The very fine bands are unrecrystallized tuff with quartz and feldspar fragments of odd shapes. Mafic minerals altering to secondary minerals. Graphite (?), pyrite. No recrystallization.
Spect. analysis ppm -

Cr	Cu	Ni	Co
45	35	75	-

See chemical analysis, Appendix I.

226 BLACK BRUSH PROPERTY, CHERRY CREEK. Piece of uranium ore. Dark rock with thin bands of ss and sulfides. Quartz grains of the ss bands are sutured. Some water sorting but not enough to round grains. Dark bands are tuff with larger quarts grains.

SAMPLE NUMBER

229 BLACK BRUSH PROPERTY, CHERRY CREEK, UDS Fm. Graded bedding in tuff and shrinkage crack filling, giving wormy structures on cross section due to plastic deformation. Cracks filled with coarser, less compactable pyroclastic material and the fine-bedded material is draped over the crack fillings. The tuff displays delicate graded bedding which is high in dark mineral content.

233 BLACK BRUSH PROPERTY, CHERRY CREEK, UDS Fm. White, fine-grained, with sulfides. ±60% coarse sutured sand grains of pyroclastic quartz, ±30% med-fine grained orthoclase, ±10% very fine partly altered dark minerals (pyrox, hornblende, chlorite, etc.). Coarse pyrite. Little or no rounding of grains.

249 SUE MINE, BULL CANYON. High grade uranium ore with thin bands in gray tuff. Very fine-grained. Stylolites. Contains quartz with wedge and rod shapes, sharp angles, sutures etc. Possibly much orthoclase but hard to identify. Plagioclase, microcline, muscovite, pyrite(-).

271 TOMATO JUICE CLAIM, REGAL CREEK. UDS Fm. Pink, fine-grained pyroclastic ss with angular quartz, orthoclase, plag(-), microcline(-), botryoidal pyrite. The sharp contrast in grain size in successive beds suggests great variation in source material.

309 BIG JOE CLAIM, WORKMAN CREEK. Part of a sequence of specimens showing progressive metamorphism of tuffaceous UDS Fm., #309-319. This sample is ±10% recrystallized with secondary orthoclase occurring in spots within the tuff. Commonly a few grains of pyrite are bunched in the center of the recrystallized spot. Also magnetite and graphite are in the centers of the spots. Rock as whole contains orthoclase ±90%, pyrox. altering to chlorite, quartz .5%, sphene, pyrite, magnetite, graphite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
325	670	820	485	50

311 BIG JOE CLAIM, WORKMAN CREEK. Recrystallization (metamorphism) sequence. Splotches and some continuous bands of secondary recrystallization parallel to bedding. The coarse recrystallized portion contains: orthoclase, pyrox (-), quartz, biotite, pyrite, sphene(+), plage.(-) (clear), chlorite. The fine-grained tuff was apparently high in pyrite before recrystallization.

SAMPLE NUMBER

311 Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
220	345	410	465	
370	520	270	490	20 (duplicate #888)

See chemical analysis, Appendix I.

314 BIG JOE CLAIM, WORKMAN CREEK. Recrystallization sequence. Fairly continuous beds of unrecrystallized dark tuff remain in UDS Fm. Contains orthoclase, quartz(-), biotite, sphene(+), apatite, pyrite, chlorite. See 309-319.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
300	500	180	275	120

315 BIG JOE CLAIM, WORKMAN CREEK. Recrystallization sequence. Coarsely recrystallized almost throughout rock. The recrystallized orthoclase (90%) occurs around pyrite and pyrox, as small clusters of crystals. Quartz 5%. See 309-319.

316 BIG JOE CLAIM, WORKMAN CREEK. Recrystallization sequence. Very few dark bands of unrecrystallized tuff remain. Recrystallization is crudely parallel to bedding, but originates in isolated spots.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
410	600	320	395	50

317 BIG JOE CLAIM, WORKMAN CREEK. Recrystallization sequence in UDS Fm. Black tuff a few feet above diabase sill. See 309-319. ±80% recrystallized with abundant sulfides. Contains orthoclase, pyrite(+), biotite(+), sphene(+). No quartz or plag. observed. Chlorite and serpentine. Recrystallization gives homogeneity by separating the coarser minerals.
Spect. analysis ppm -

Cr	Cu	Ni	Co
120	340	10	-

See chemical analysis, Appendix I

SAMPLE NUMBER

319 BIG JOE RECRYSTALLIZATION SEQUENCE - Almost 100% recrystallized.

Cr	Cu	Ni	Co	Sr (ppm)
20	40	-	-	55

323 RED BLUFF PROPERTY. Fresh diabase from exposure in Warm Creek contains: plagioclase(+), orthoclase(?), orthopyrox, clinopyrox (+), biotite, hornblende, magnetite, sericite, and chlorite. Highly altered. (Looks fresh in hand specimen, but actually hydrothermally altered).

330 HOPE ADIT, WORKMAN CRK., STA. 18 x 35'. High grade ore. Uraninite in veins. Siltstone - not recrystallized. Much fine-grained quartz with odd and sutured shapes, feldspar, small pyroxene crystals, biotite, small hornblende. Pyrite and graphite (?) make dark spots which are high in U_3O_8.

346 LUCKY STOP CLAIM, SW SIDE WORKMAN CRK. Recrystallized UDS Fm. Bedding still evident. Contains clouded orthoclase (boundaries of grains interfere), clear plagioclase, small minor pyrox, interstitial quartz, sphene (+), pyrite(-) concentrated along bedding planes. The formation of secondary (coarse) feldspar grains excludes dark opaque mineral (graphite?).
Spct. Analysis ppm -

	Cr	Cu	Ni	Co	Sr
	75	160	205	230	
(Duplicate Sample #894)	225	130	295	375	50

See chemical analysis, Appendix I

352 FIRST CHANCE CLAIM, PARKER CRK, IN ROAD CUT 300± YARDS WEST. Two inch veinlet in diabase. Fresh plagioclase (minor sericite), pyrox, hornblende(+), orthopyrox(-), biotite, magnetite, pyrite(-), chlorite. Little or no orthoclase in this segregate.

357 BLEVINS CANYON HOLE #1 AT 18 ft, blue-gray, fine-grained UDS Fm. Tuffaceous. Mostly siltstone-size grains. Quartz grains not rounded by water transport. Contains dark spots which are concentrations of mafic minerals (pyrox.) surrounded by a circle of quartz grains. The darker masses are in a matrix of quartz and feldspar.

SAMPLE NUMBER

357 Equivalent Uranium by Alpha Counting:
Time 40.2 hrs. Total count 761.
13.34 counts/hr above background.
Results: 4.09 ppm eU, error 3.6%

409 MAY CLAIMS, LAUFFER MTN, WESTERN SIERRA ANCHAS, DRILL HOLE #1 AT 51 FT. UDS Fm. Tuff that is typical of the formation.

Percentage K_2O by beta counting technique. Time 254 minutes. Total count 2625. Counts per minute above background, 8.67. Correction for U-th content 1.1%. Results 12.0 - 1.1 = 10.9% K_2O, error 2%.

419 MAY CLAIMS, LAUFFER MTN. WESTERN SIERRA ANCHAS HOLE #1 AT 78 FT (27 FT BELOW #409). Typical tuff of UDS Fm. Equivalent uranium by alpha counting. Time 6.23 hrs. Total count 154, 19.1 counts/hr above background. Results 5.85 ppm eU, error 8.0%.

469 LUCKY STOP CLAIM, WORKMAN CRK, EAST ADIT. Dark green, heavy, UDS Fm. This portion of the formation is unusually rich in pyroxene, chlorite, serpentine, and calcite. Also contains orthoclase. Contains enough U_3O_8 to be ore ($>$0.15% U_3O_8).

471 LUCKY STOP CLAIM, WORKMAN CRK. Dark segregate in UDS Fm. Secondary chlorite, serpentine and calcite have replaced most of the feldspar and quartz. Sphene present. These dark heavy samples are from recrystallized UDS Fm which is being mined for uranium. The upper contact of the diabase sill is only a short distance below the mine workings. (Exact interval not determined because covered.)

472 LUCKY STOP CLAIM, WORKMAN CRK. Basic segregate in UDS Fm. Similar to #471, but this sample is predominantly of orthoclase (?). Chlorite, calcite, pyrox(-). Recrystallization has resulted in an unusual hexagonal pattern.

473 LUCKY STOP CLAIM, WORKMAN CRK. Mafic DS Fm. Orthoclase (sutured). Plag (minor). Mafics (chlorite) predominate, pyrox(-), calcite(-).

474 LUCKY STOP CLAIM, WORKMAN CRK. Green and brown banding in recrystallized UDS Fm. Fine-grained tuff. Orthoclase predominant, albite minor, chlorite, calcite. The plagioclase replaces the other secondary minerals. It is patchy and coarse - later than the fine-grained minerals.

SAMPLE NUMBER

475 LUCKY STOP CLAIM. Recrystallized tuff of UDS Fm. Rich in mafics. Recrystallization more prominent along certain beds. Most of the feldspar is probably orthoclase, but coarse, patchy plagioclase is present.

496 BULL CANYON BELOW SUE MINE AT STRONG COPPER MINERALIZATION. Stockwork of closely spaced 1/8 to 3/4 inch wide vertical veins in altered Pioneer Fm. Veins filled with various minerals. This sample contains calcite, chlorite, magnetite (+). The walls of the veins contain plagioclase(?) altering to sericite. This mineralization is accompanied by local heavy copper carbonates, See #498 for other type of vein filling.

498 BULL CANYON BELOW SUE MINE AT STRONG COPPER MINERALIZATION. Some of the veins in the stockwork are filled with cross-fiber consisting of chlorite with an outer band of calcite at the edge. The wall rock is very fine diabasic texture with plagioclase and iron ore. Farther removed from the vein to either side is silicified Pioneer shale.

517 RED BLUFF PROPERTY. Diabase segregate in sill exposed just north of mine. Contains plagioclase, pyrozene, hornblende, magnetite, apatite, sphene. Distinctly lighter in color and different texture than normal diabase.
Spect. analysis ppm -

Cr	Cu	Ni	Co
75	5	25	25

See chemical analysis, Appendix I

529 NORTH OF RED BLUFF PROPERTY. Small 2" wide, white dike in normal diabase along west side of segregated mass. Contains plagioclase altering to sericite, pyroxene, orthoclase(-), biotite, apatite. No essential difference between dike and wall rock. The dike has less pyrox and biotite and more feldspar.

532 HILL NORTH OF RED BLUFF PROPERTY. "Pink" diabase pegmatite. This "pink", orthoclase-rich pegmatite is probably the result of blocks of sediment which have been partly consumed by the diabase sill magma. Modal Anal. Orthoclase 78.7%, quartz 7.6%, hornblende 9.3%, sphene 1%, pyrite 1.7%, magnetite 1.1%, biotite 0.6%, chalcopyrite trace. Total 100.0% (1004 points).

SAMPLE
NUMBER

690 POCKET CRK, UDS FM, ELEVATION 5355' (145' Above Top of Sill)
Nearly black, unrecrystallized UDS Fm.
Spect. analysis ppm -

Cu	Cr	Ni	Co	Sr
25	190	90	105	-

Equivalent uranium by alpha counts. Time 16.42 hrs. Total count 251. 9.70 counts/hr above background. Results 2.97 ppm eU, error 6.3%. K_2O content by beta counting. Time 162 min. Total count, 1954. 10.41 counts/min. above background. Results: 14.5%-0.9= 13.6% K_2O, error 2.3%. (0.9 subtracted to make correction for uranium and thorium present.)

699 POCKET CRK, UDS Fm, ELEVATION 5213' (3' Above Diabase Contact.)
Coarsely recrystallized. Sulfides. Contains orthoclase, quartz, pyrox., hornblende, sphene.
Spect. analysis ppm -

Cr	Cu	Ni	Co
20	45	5	20

See chemical analysis, Appendix I

711 POCKET CRK, UDS Fm Welded to upper chilled contact of diabase sill.
Spect. Analysis ppm -

Cr	Cu	Ni	Co
35	95	55	100

717 POCKET CRK, DIABASE SECTION, ELEVATION 5200'. Coarse-grained diabase with large apple-green spots. Contains twinned plagioclase lathes, clinopyrox, hornblende(-), calcite(-), magnetite (+), apatite(+). Chlorite and serpentine are abundant. They form the green megascopic spots. Appears somewhat hydrothermally altered
Spect. analysis ppm -

Cr	Cu	Ni	Co
40	60	25	110

718 POCKET CRK, DIABASE SECTION, ELEVATION 5190. Coarse-grained. Same as #717 under microscope. No orthoclase present.
Spect. analysis ppm -

Cr	Cu	Ni	Co
25	60	10	105

SAMPLE
NUMBER

719 POCKET CRK, DIABASE SECTION, ELEVATION 5180'. Diabase petmatite with light pink feldspar. Contains by modal analysis: labradorite 61.9%, augite, 20.7%, chlorite and serpentine 4.6%, epidote 2.5%, magnetite 6.2%, apatite 2.0%, sphene 2.1%. (No quartz or K feldspar).
Spect. analysis ppm -

Cr	Cu	Ni	Co	
10	< 1	10	140	
10	35	< 5	85	Second run as #919.

See chemical analysis, Appendix I.

720 POCKET CRK, DIABASE SECTION, ELEVATION 5170'. Contains: Labradorite partly altered to sericite, augite altering to chlorite, biotite(+), olivine (+), magnetite, hornblende(-).
Spect. analysis ppm -

Cr	Cu	Ni	Co
185	70	100	95

721 POCKET CRK, DIABASE SECTION, ELEVATION 5155'. Medium-grained, nodular diabase. Contains: labradorite, augite altering to chlorite and serpentine, orthopyrox, biotite, magnetite, sphene.
Spect. analysis ppm -

Cr	Cu	Ni	Co
220	60	60	90

722 POCKET CRK, DIABASE SECTION, ELEVATION 5120'. Medium-grained diabase. Contains by modal analysis: labradorite 45.7%, augite 25.6%, orthopyrox 1.0%, olivine 6.8%, biotite 3.6%, hornblende 4.0%, chlorite and serpentine 4.1%, magnetite 9.2%. (No quartz and no K feldspar).
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
710	95	840	250	330	
761	110	720	400	-	Rerun

Equivalent uranium by alpha counts. Time 17.62 hrs. Total count 156. 3.20 counts/hr above background. Results: 0.832 ppm eU, error 8.0%.

See chemical analysis, Appendix I

SAMPLE NUMBER

726 POCKET CRK, DIABASE SECTION, ELEVATION 4956'. Medium-grained nodular diabase. Contains fresh labradorite, augite altering to chlorite, orthopyrox, biotite, olivine, magnetite. Typical diabase.

Spect. analysis ppm -

Cr	Cu	Ni	Co
175	100	70	60

730 POCKET CRK, DIABASE SECTION, ELEVATION 5050'.

Modal Analysis: Labradorite 54.9%, augite 12.0%, orthopyrox 2.4%, olivine 9.0%, biotite 5.2%, hornblende 5.0%, chlorite and serpentine 4.9%, magnetite 6.7%.

Spect. analysis ppm -

Cr	Cu	Ni	Co
160	90	195	85

733 POCKET CRK, DIABASE SECTION, ELEVATION 4900'.

Modal Analysis: Labradorite 63.1%, augite 3.2%, orthopyrox 0.9%, olivine 24.3%, biotite 2.0%, chlorite and serpentine 2.3%, magnetite 4.2%, muscovite, trace.

Spect. analysis ppm -

Cr	Cu	Ni	Co
145	40	170	70

Equivalent uranium by alpha counting. Time 30.67 hrs. Total count 188. 0.48 counts/hr above background. Results: 0.125 ppm eU, error 7.3%.

738 POCKET CRK, DIABASE SECTION, ELEVATION 4700'.

Modal Analysis: Labradorite 67.1%, augite 4.9%, orthopyrox 0.3%, olivine 22.6%, biotite 0.9%, hornblende 0.2%, chlorite and serpentine 1.8%, magnetite 2.2%. No quartz, no K feldspar.

Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
305	10	800	180	460	
360	10	720	400		Rerun
380	15	730	375	455	Duplicate sample #891.

Equivalent uranium by alpha count. Time 31.22 hrs. Total count 208. 1.06 counts/hr above background. Results 0.325 ppm eU, error 6.9%.

See chemical analysis, Appendix I

SAMPLE
NUMBER

742 POCKET CRK, DIABASE SECTION, ELEVATION 4575'.
Modal Analysis: Labradorite 59.9%, augite 11.8%, orthopyrox 3.4%, olivine 4.4%, biotite 5.4%, hornblende 2.5%, chlorite and serpentine 5.6%, magnetite 6.7%, apatite 0.3%; no quartz and no orthoclase.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
120	5	225	190		
235	30	260	335	450	Duplicate sample #892.

See chemical analysis, Appendix I

746 POCKET CRK, DIABASE SECTION, ELEVATION 4500'. Lower Chilled Contact. Too fine-grained for modal analysis. Contains plagioclase phenocrysts, pyroxene, magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co
105	20	150	165

See chemical analysis, Appendix I

747 POCKET CRK, DIABASE SECTION, ELEVATION 4500'. Lower Chilled Contact. Companion piece to #746. Equivalent uranium by alpha counting. Time 23.92 hrs. Total count 178. 1.79 counts/hr above background. Results: 0.465 ppm eU, error 7.5%.

761 EAST OF WORKMAN #1 ADIT, WORKMAN CRK. Abnormally radioactive recrystallized dike in UDS Fm. Contains graphic intergrowth of quartz and orthoclase, small crystals of pyroxene altering to chlorite. Sphene. No plagioclase. Compare with #770.
Spect. analysis ppm -

Cr	Cu	Ni	Co
20	10	5	-

See chemical analysis, Appendix I

SAMPLE
NUMBER

770 EAST OF WORKMAN #1 ADIT, WORKMAN CRK. Unrecrystallized UDS Fm. 4 to 5 feet from recrystallized abnormally radioactive dike. Very fine-grained, unrecrystallized. Looks like tuff. Contains: feldspar, pyrox, quartz, biotite, sphene, pyrite. Compare with #761.
Spect. analysis ppm -

Cr	Cu	Ni	Co
90	30	5	-

See chemical analysis, Appendix I

772 HOPE #2 CLAIM, WORKMAN CRK. Uraninite ore. Contains uraninite and sulfides in UDS Fm. Slide shows boundary between recrystallized and unrecrystallized UDS Fm. Contains 75% orthoclase, 10% quartz (sutured where recrystallized), zircon(?), pyrite, which is distinguishable only in the coarser recrystallized portion. Suggests fine opaques in unrecrystallized portion are also pyrite.

780a HOPE #1 ADIT, WORKMAN CRK. Pink UDS Fm sediment welded to diabase at upper chilled contact. Contains orthoclase, interstitial quartz(-), fresh pyrox, sphene. This is recrystallized tuff with some addition of elements from diabase. No plagioclase.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
60	40	380	95		
185	25	135	225	235	Duplicate sample #893.

See chemical analysis, Appendix I.

780b HOPE #1 ADIT, WORKMAN CRK. Chilled upper contact of diabase sill. Very fine-grained. Phenocrysts of long plagioclase lathes parallel to contact. Small but abundant pyrox, biotite, hornblende, magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co
60	105	85	70

See chemical analysis, Appendix I

SAMPLE
NUMBER

811 LITTLE JOE CLAIM, WORKMAN CRK. Radioactive recrystallized DS Fm with sulfides. Coarse orthoclase poikilitically encloses all other minerals. Plag < 1%, quartz, pyrox, pyrite, sphene.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
90	640	290	220		
195	765	300		90	Duplicate sample #895.

See chemical analysis, Appendix I

816 REYNOLDS CRK NEAR FORK IN ROAD. "Pink" diabase pegmatite. Contains quartz, orthoclase, augite altering to chlorite, magnetite(-), biotite(-), sphene, apatite, little or no plag. A mixed rock of sediment in diabase.

825 REYNOLDS CRK, TIPPY CLAIMS. "Pink" diabase grading into pink recrystallized rock with UDS Fm inclusions grading into UDS Fm in place. This is best field evidence for "pink" diabase being a mixed rock resulting from blocks of sediment (UDS tuff) being absorbed into diabase magma. Contains highly altered orthoclase (?), plagioclase, augite(+), calcite, sphene, magnetite, apatite.

848 LITTLE JOE CLAIM WORKMAN CRK, DD HOLE #1, 138.0'-138.5' IN HOLE. (DIST. BELOW COLLAR.) Very fine-grained with stylolites rich in sphene. 90% orthoclase, quartz(-), pyrox concentrated in clusters, pyrite, sphene. Essentially unrecrystallized.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
65	195	25	30	20

849 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1 AT 146.4'-146.9' DEPTH. Unrecrystallized UDS Fm contains orthoclase, sutured quartz, small clustered pyrox, sphene, pyrite (pyritahedrons), biotite. Some homogenization or collection of pyrox. Possibly this is start of recrystallization.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
125	600	405	315	15	
205	130	70	190	-	Duplicate sample #889.

See chemical analysis, Appendix I

SAMPLE
NUMBER

850 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 148.5-149.0' DEPTH. UDS Fm tuff about 10% recrystallized. Two coarse bands parallel to bedding. This sample displays the difference between primary recrystallization which occurs with time and normal rock temperature and pressure, and secondary recrystallization which occurred as heat and solutions from the invading diabase metasomatized the rock. Contains orthoclase, quartz, pyrite, biotite, sphene. Secondary recrystallization tends to separate or group the mineral constitutents. In this sample the pyrox is concentrated into bands of small grains on either side of a coarse feldspar band. Euhedral feldspar indicates secondary recrystallization.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
75	160	15	20	25

851 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 149.7-149.9' DEPTH. Secondary recrystallization of UDS Fm tuff localized by sphene stylolites. Recrystallization commonly follows sedimentary and diagenetic features. Contains orthoclase, quartz, pyrox, pyrite. Some orthoclase is euhedral.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
145	270	65	65	25

852 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 153.2-153.5' DEPTH. About 50% recrystallized tuff of UDS Fm. Contains orthoclase, quartz, pyrox (small crystals), pyrite, chalcopyrite, sphene. Stylolites consisting of small sphene crystals form boundaries between recrystallized and unrecrystallized tuff.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
85	100	30	35	20

Equivalent uranium by alpha counting. Time 3.52 hrs. Total count 135. 32.75 counts/hr above background. Results: 8.51 ppm eU, error 8.6%.

SAMPLE
NUMBER

853 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 157.0-157.4' DEPTH. 2/3 recrystallized UDS Fm. Contains orthoclase, plagioclase(-), clino and ortho pyrox, pyrite. Very abundant sphene in stylolites.
Spect analysis ppm -

Cr	Cu	Ni	Co	Sr
105	85	60	60	50

Equivalent uranium by alpha counting. Time 3.53 hrs.
Total count 184. 46.45 counts/hr above background.
Results: 12.06 ppm eU, error 7.4%.

854 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 167.3-167.7' DEPTH. Completely recrystallized UDS Fm. Contains coarse feldspar, pyrox, pyrite (euhedral), sphene. The mafic minerals collect at the boundaries of coarse feldspar crystals. The coarse feldspar crystals are not euhedral, and their inner parts look like the silt-size particles of the unrecrystallized rock.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
80	140	70	65	65

Equivalent uranium by alpha counting. Time 7.15 hrs.
Total count 149; 15.24 counts/hr above background.
Results: 4.67 ppm eU, error 8.2%.

855 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 170.5-170.8' DEPTH. Coarse-grained, completely recrystallized UDS Fm tuff. (Similar to sample 811). Modal analysis: orthoclase 62.6%, albite 1.4%, quartz 0.3%, diopside 25.6%, sphene 3.7%, pyrite 5.5%, chlorite 0.9%.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr	
70	200	35	120	140	
220	275	130	280	115	Duplicate sample #890.

See chemical analysis, Appendix I

SAMPLE
NUMBER

856 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 170.8-171.1' DEPTH. Recrystallized tuff of UDS Fm metasomatized by diabase. Contains subhedral, zoned orthoclase (+), plagioclase, hornblende, quartz(-), pyrox, apatite(+), magnetite, chlorite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
20	10	-	-	95

857 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 175.4-175.9' DEPTH. Fairly coarse-grained, pinkish-green diabase. Contains orthoclase, plagioclase (+), hornblende (+), pyrox, calcite, magnetite, chlorite, sphene, apatite, zircon. A mixed rock resulting from absorption of sediment into diabase magma.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
20	90	5	20	100

Equivalent uranium by alpha counting. Time 17.53 hrs. Total count 213. 6.54 counts/hr above background. Results: 2.00 ppm eU, error 6.8%.

See chemical analysis, Appendix I

858 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 177.0-177.6' DEPTH. Fairly coarse-grained diabase pegmatite. Contains plagioclase, orthoclase (+), clinopyrox, orthopyrox (-), chlorite, serpentine, hornblende, pyrite, massive sphene, apatite(+), magnetite. Feldspars are perthitic in places.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
15	30	-	-	100

859 LITTLE JOE CLAIM, DD HOLE #1, WORKMAN CRK, 182.2-182.9' DEPTH. Fairly coarse-grained diabase pegmatite. Orthoclase and plagioclase about equal in amount. Also pyrox, sericite, chlorite, massive sphene, apatite, magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
70	45	15	15	150

SAMPLE
NUMBER

860 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 186.0-186.5' DEPTH. Medium to fine-grained diabase (not pegmatite). Plagioclase (unusually clear with slight development of sericite), quartz(-)(?), pyrox, hornblende, biotite, sphene, magnetite. No orthoclase or apatite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
180	90	135	40	335

Equivalent uranium by alpha counting. Time 24.38 hrs. Total count, 214. 3.13 counts/hr above background. Results: 0.81 ppm eU, error 6.8%.

861 LITTLE JOE CLAIM, DD HOLE #1, WORKMAN CRK, 191.6-192.3' DEPTH. Pink pegmatitic diabase. Contains plagioclase(+), orthoclase, sericite, augite, chlorite, hornblende, sphene, magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
85	25	-	-	85

862 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 197.7-198.2' DEPTH. Diabase pegmatite. Contains plagioclase (albite), orthoclase(-), pyrox, chlorite, hornblende, green biotite, sphene, magnetite, apatite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
10	185	-	-	90

See chemical analysis, Appendix I

863 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 203.7-203.2' DEPTH. Diabase pegmatite (not coarse). Contains plagioclase, orthoclase, pyrox, chlorite, apatite, magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
75	150	25	25	155

SAMPLE
NUMBER

864 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 209.3-210.0' DEPTH. Diabase of average grain size. Contains plagioclase(+), sericite, clinopyrox, orthopyrox, chlorite, biotite, apatite, magnetite, pyrite. (Ordinary diabase)
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
170	70	60	40	305

Equivalent uranium by alpha counting. Time 40.72 hrs. Total count 337. 2.63 counts/hr above background. Results 0.68 ppm eU, error 5.4%.

865 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 219.5-220.0' DEPTH. Medium-grained diabase. Contains plagioclase (some clear, some altered to sericite), clinopyrox, orthopyrox, hornblende, olivine, biotite, magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
175	85	55	40	380

866 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 90.0-90.2' DEPTH. Very fine-grained tuff of UDS Fm. About 2% coarser-grained ss. Poorly sorted. Sutured, rod, and angular shaped quartz, orthclase, pyrox(-), biotite(-), pyrite, chlorite, leucoxene(+); shrinkage cracks in fine-grained tuff are filled with coarser grains.
Spect. Analysis ppm -

Cr	Cu	Ni	Co	Sr
50	60	<10	-	20

867 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 103.5-103.8' DEPTH. Tuff of UDS Fm. No secondary recrystallization. Contains orthoclase, sutured, rod, and odd shaped quartz, pyrox(-), pyrite, tremolite(-). Folded shrinkage cracks contain coarser grains and abundant pyrite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
50	135	10	15	10

868 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 110.6-111.8' DEPTH. Very fine-grained tuff, UDS Fm. Contains quartz, orthoclase, pyrox(-), pyrite, zircon.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
85	260	10	20	20

SAMPLE
NUMBER

869 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, 126.7-127.6' DEPTH. Tuff with stylolites. UDS Fm. Contains quartz, orthoclase, pyrox(-), calcite, hornblende, pyrite(+), magnetite, sphene common in stylolites. First appearance downward of calcite and magnetite.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
60	180	10	15	15

Equivalent uranium by alpha counting. Time 6.83 hrs. Total count 109. 10.36 counts/hr above background. Results: 3.17 ppm eU, error 9.6%.

873 TIPPY #1 CLAIM, REYNOLDS CRK, DD HOLE #1, 62.0-62.2' DEPTH. Above Diabasic texture. Recrystallized UDS Fm tuff. Contains orthoclase and quartz in graphic intergrowth, calcite, pyrox, sphene, orthopyrox(-), serpentine, patchy plag(-).
Spect analysis ppm -

Cr	Cu	Ni	Co
25	1	5	-

See chemical analysis, Appendix I

874 TIPPY #1 CLAIM, REYNOLDS CRK, DD CORE #1, 69.0-69.7' DEPTH, A mixed rock resulting from UDS Fm tuff being engulfed by diabase magma. Pink. Grades into unconsumed sediments above. Contains clouded orthoclase, quartz, augite, plag(-), pyrite, sphene, magnetite needles. Some graphic intergrowth of quartz and orthoclase.

875 TIPPY #1 CLAIM, REYNOLDS CRK, DD HOLE #1, 77.4-78.0' DEPTH. Coarse, pink diabase (pegmatite). Equivalent uranium by alpha counting. Time 6.25 hrs. Total count, 171: 21.75 counts/hr above background. Results: 5.65 ppm eU, error 7.6%.

879 TIPPY #1 CLAIM, REYNOLDS CRK, DD HOLE #1, 132.7-133.4' DEPTH. Equivalent uranium by alpha counting. Time 16.40 hrs. Total count 191; 6.04 counts/hr above background. Results: 1.85 ppm eU, error 7.2%

SAMPLE
NUMBER

880 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, AT 99.2' DEPTH.
Unrecrystallized UDS Fm.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
65	110	25	10	25

881 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1 AT 108.8'.
Unrecrystallized UDS Fm.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
60	160	15	15	12

882 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, AT 118.0'.
Unrecrystallized UDS Fm.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
65	60	15	<10	7

Equivalent uranium by alpha counting. Time 22.97 hrs. Total count 357; 9.90 counts/hr above background. Results: 2.57 ppm eU, error 5.3%.

883 LITTLE JOE DD HOLE #1, WORKMAN CRK, DEPTH, 122.5'.
Unrecrystallized UDS Fm.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
95	210	20	10	10

884 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, DEPTH, 131.4'.
Unrecrystallized UDS Fm.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
45	130	20	25	15

885 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, DEPTH 142.2'.
Partly recrystallized UDS Fm.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
50	115	15	25	20

Equivalent uranium by alpha counting. Time 23.23 hours. Total count 799; 28.8 counts/hr above background. Results: 8.83 ppm eU, error 3.5%.

SAMPLE NUMBER

886 LITTLE JOE CLAIM, WORKMAN CRK, DD HOLE #1, DEPTH 171.4'. Partly digested UDS Fm in diabase magma.
Spect. analysis ppm -

Cr	Cu	Ni	Co	Sr
35	30	< 5	-	60

Similar to #856.

887 LITTLE JOE CLAIM, WORKMAN CRK. 40' east of adit and 22.5' west of abnormally radioactive dike in UDS Fm (samples 760-769). Unrecrystallized UDS Fm.

K_2O analysis by beta counting. Time 150 minutes. Total count= 1631; 9.23 counts/minute above background. Results: 12.5-0.6 = 11.9% K_2O, error 2.7%. (0.6 subtracted for correction for U & Th content).

Equivalent uranium by alpha counting. Time 7.32 hrs. Total count 123; 11.20 counts/hr above background. Results: 3.43 ppm eU, error 9.0%.

898 WORKMAN CLAIM #1, WORKMAN CRK. Recrystallized Y shaped dike in UDS Fm. just east of main adit.

896 WORKMAN CLAIM #1, Equivalent uranium by alpha counts. Time 2.12 hrs. Total count 262; 118.0 counts/hr above background. Results: 30.7 ppm eU, error 6.2%.

897 WORKMAN CLAIM #1, Equivalent uranium by alpha counts. Time 22.83 hrs. Total count 432; 13.26 counts/hr above background. Results: 3.45 ppm eU, error 4.8% (5.5' from contact).

898 WORKMAN CLAIM #1. Equivalent uranium by alpha counts. Time 18.43 hrs. Total count 271; 9.10 counts/hr above background. Results: 2.79 ppm eU, error 6.1% (12.0' from contact).

WC-3 WORKMAN CLAIM #1. Equivalent uranium by alpha counts. Time 6.2 hrs. Total count 105; 11.35 counts/hr above background. Results: 3.48 ppm eU, error 9.7%.

WC-6 WORKMAN CLAIM #1. Equivalent uranium by alpha counts. Time 20.62 hrs. Total count 306; 9.18 counts/hr above background. Results: 2.39 ppm eU, error 5.7%.

WC-12 WORKMAN CLAIM #1. Equivalent uranium by alpha counts. Time 15.18 hrs. Total count 209; 8.20 counts/hr above background. Results: 2.51 ppm eU, error 6.9%.

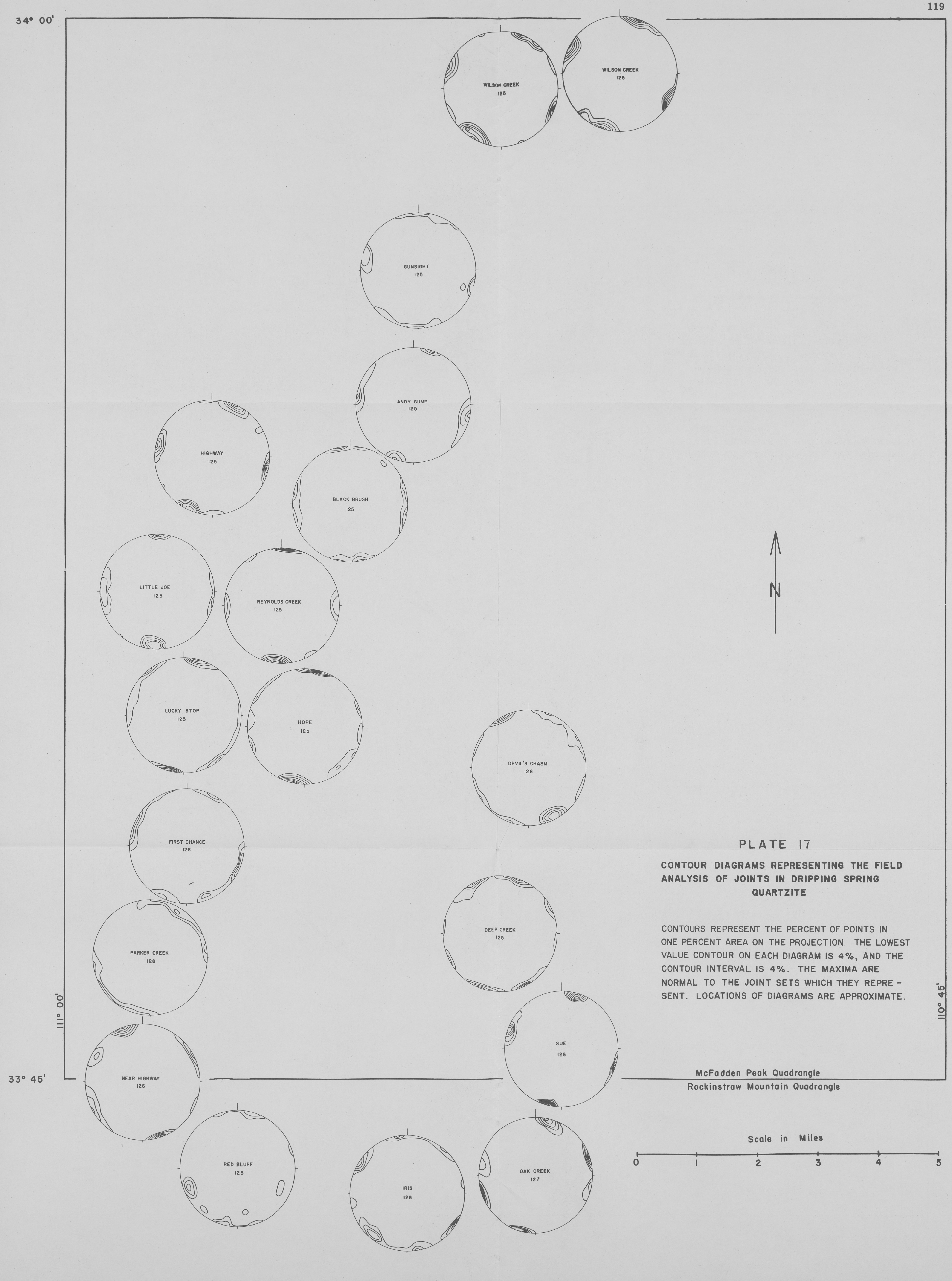


PLATE 17

CONTOUR DIAGRAMS REPRESENTING THE FIELD ANALYSIS OF JOINTS IN DRIPPING SPRING QUARTZITE

CONTOURS REPRESENT THE PERCENT OF POINTS IN ONE PERCENT AREA ON THE PROJECTION. THE LOWEST VALUE CONTOUR ON EACH DIAGRAM IS 4%, AND THE CONTOUR INTERVAL IS 4%. THE MAXIMA ARE NORMAL TO THE JOINT SETS WHICH THEY REPRESENT. LOCATIONS OF DIAGRAMS ARE APPROXIMATE.

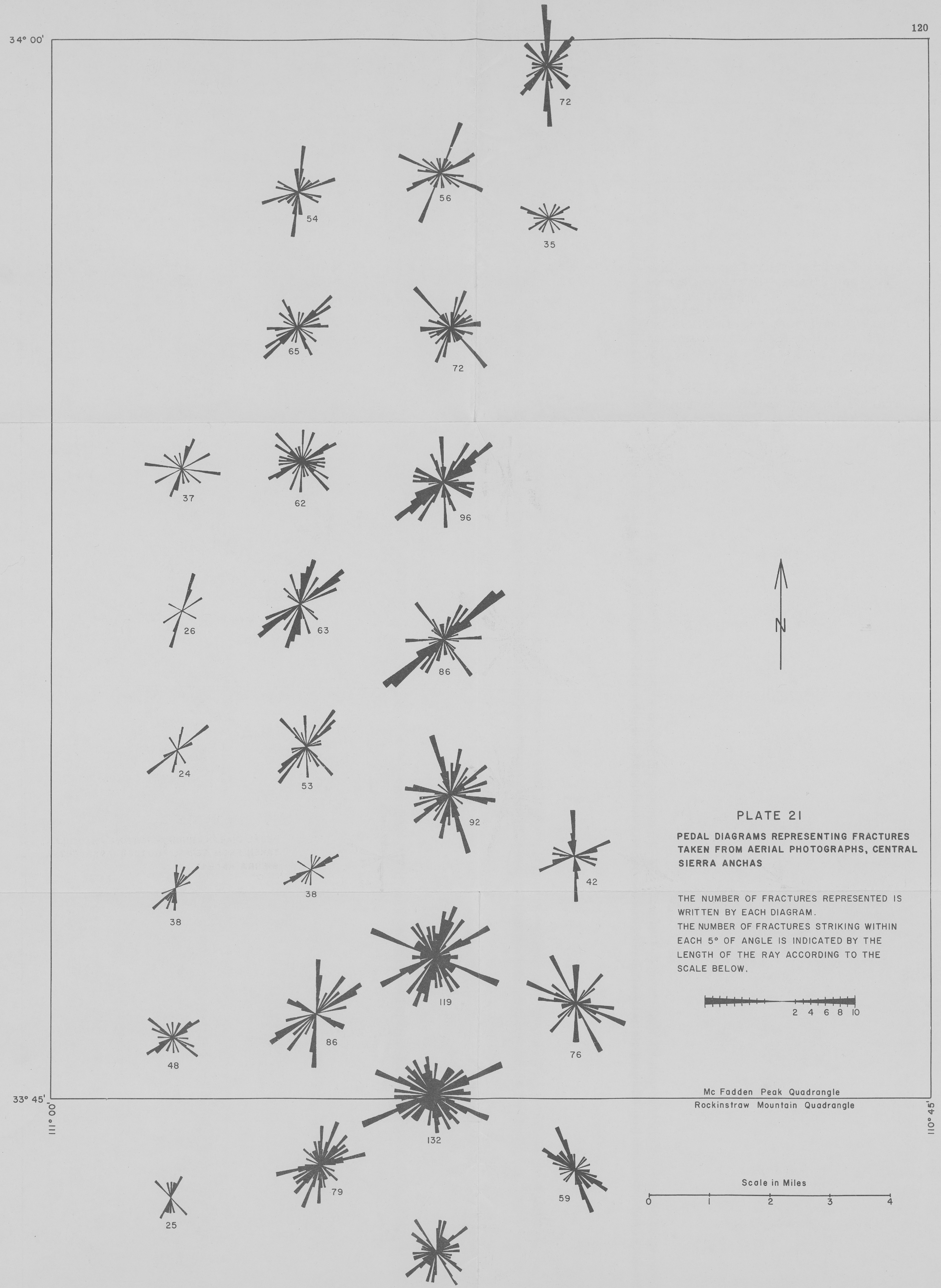


PLATE 21

PEDAL DIAGRAMS REPRESENTING FRACTURES TAKEN FROM AERIAL PHOTOGRAPHS, CENTRAL SIERRA ANCHAS

THE NUMBER OF FRACTURES REPRESENTED IS WRITTEN BY EACH DIAGRAM.
THE NUMBER OF FRACTURES STRIKING WITHIN EACH 5° OF ANGLE IS INDICATED BY THE LENGTH OF THE RAY ACCORDING TO THE SCALE BELOW.

PLATE 25

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

UNITED STATES
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

MCFADDEN PEAK QUADRANGLE
ARIZONA-GILA CO.
15 MINUTE SERIES (TOPOGRAPHIC)

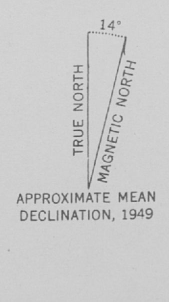
Mapped, edited, and published by the Geological Survey

Control by USGS, USC&GS, and USFS

Topography from aerial photographs by multiplex methods
Aerial photographs taken 1947. Field check 1949

Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, east zone

Unchecked elevations are shown in brown



APPROXIMATE MEAN DECLINATION, 1949

SCALE 1:62500

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS

FOR SALE BY U. S. GEOLOGICAL SURVEY, FEDERAL CENTER, DENVER, COLORADO OR WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS		DRY WEATHER ROADS
Heavy-duty	4 LANE | 6 LANE	Improved dirt
Medium-duty	4 LANE | 6 LANE	Unimproved dirt

Loose-surface, graded, or narrow hard-surface

U. S. Route ○ State Route

MCFADDEN PEAK, ARIZ.
N3345—W11045/15

EDITION OF 1950