# GEOLOGIC EVALUATION OF THE KELVIN COPPER-MOLYBDENUM PROSPECT PINAL COUNTY, ARIZONA

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New Mexico Institute of Mining and Technology

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Master of Science

by
William P. Zelinski
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# ABSTRACT

The Kelvin prospect is located in the northern Tortilla Mountains about ten miles southwest of the Ray porphyry-copper mine in Pinal County, Arizona. The property is situated along the northeast margin of the newly identified Grayback batholith of Laramide age. Reconnaissance mapping and comparative lithologic studies indicate a very close genetic relationship with the Granite Mountain Porphyry, which is the mineralizing porphyry at Ray; identical K-Ar dates of 63 million years have been obtained for both plutons. With the possible exception of the Kelvin prospect, no extensive alteration or mineralization was found associated with the batholith, but the Ray mine is located on the northeast tip of the Granite Mountain Porphyry stock, which may be a faulted portion of the batholith. The relative absence of mineralization around the batholith may be due to a deeper level of erosion in the Tortilla Mountains which are part of the Florence Uplift.

The Kelvin prospect was mapped in detail. Although mineralization is widespread, it is generally restricted to fracture zones in the Precambrian Oracle Granite; the intervening rock is generally fresh and barren. An induced potential survey using a 1000-foot dipole spacing indicated a large low grade anomaly which was tested with two rotary drill holes 1500 and 1625 feet deep. Sufficient low grade, pyritic mineralization was encountered in the drill holes to account for the anomaly. Three induced potential lines using a 500-foot dipole spacing revealed a stronger, 200-foot wide, depth-limited anomaly over the largest east-trending fracture zone. The depth-limited nature of the anomaly suggests supergene enrichment and two inclined diamond drill holes, 400 to 600 feet deep, are recommended to test this anomaly.

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# ILLUSTRATIONS

(all plates in pocket)

# INTRODUCTION

## Purpose and Scope of the Investigation

It is the purpose of this investigation to evaluate the Kelvin copper-molybdenum prospect located in Pinal County, Arizona, and owned by Tipperary Resources Corporation. The prospect was mapped in detail with all notable geological features including rock contacts, faults, joints, mineralization, and alteration recorded. These data, in conjunction with petrographic analysis of rock samples, an induced polarization survey, and drilling records aided in predicting the possible existence and extent of ore-grade mineralization. As part of the data collecting process, it was necessary to map a much larger area on a reconnaissance basis to determine the regional geologic setting. It was beyond the scope of this investigation to differentiate the various mid-Tertiary volcanic rocks, the basic hypabyssal intrusive rocks or the rhyodacite porphyry dikes.

## Methods of Study

The field data in sections 8 and 9 of the prospect were plotted directly on an enlarged portion of the U. S. Geological Survey Grayback Mountain topographic quadrangle using a plane table and alidade. The geological information for sections 10, 16, and 17 was plotted without the aid of surveying equipment since it was found that topographic control was excellent. The detailed mapping was done on a scale of one inch equals two hundred feet. The Zelleweger mine near the center of the prospect also was mapped and chip samples were taken across the tunnel at regular intervals.

Two holes, 1500 and 1625 feet deep, were drilled concurrently with the detailed mapping using a reverse circulation rotary rig (Con-cor). The drill holes were logged and assays were made on five-foot samples.

Heinrich's Geoexploration Company ran an induced polarization survey across sections 8, 9, 16, and 17. Eleven north-south lines were laid out at 1000-foot intervals with a 1000-foot dipole spacing. A 500-foot spacing was also used on the three central lines.

Thin sections of rock specimens from the prospect were analyzed petrographically to determine their composition and texture and to identify alteration minerals. The first sixteen thin sections were prepared and analyzed by the Colorado School of Mines Research Foundation; x-ray diffractograms were used to identify clays and other minerals. Their descriptions were carefully checked and twenty-five other thin sections were analyzed by the author.

The detailed mapping and the drilling were carried out during the spring of 1970 and much of the reconnaissance mapping was accomplished during the following summer. A total of approximately four and a half months was spent in the field on this problem while employed by Tipperary Land Exploration and Development Corporation.

## Location

The Kelvin prospect is located in the Riverside mining district, also known as the Mineral Creek or the Kelvin mining district (Fig. 1). The prospect consists of 40 unpatented lode mining claims, one patented mining claim known as the Zelleweger claim, and one and a half sections of state land (Fig. 2). All the property is in a contiguous block located in sections 8, 9, 10, 16, 17, T. 4 S., and R. 13 E., of the Gila and Salt River Base Line and Meridian, Pinal County, Arizona. The prospect is located five miles southwest of Kennecott Copper Corporation's open pit mine at Ray. Access to the prospect is via State Highway 177 south from Superior, Arizona, to Kelvin (15 miles) where an improved gravel road extends from Kelvin to Florence, Arizona. This road is followed six miles west to the A-Diamond Ranch road and Southern Pacific Railroad's access road. The railroad access road is followed two miles west and then south to the prospect. Access to the surrounding area is via other unimproved dirt roads and jeep trails leading north from the Florence-Kelvin Road.

## Climate and Vegetation

Temperatures range from a minimum of approximately 20° F. during the winter months to a maximum of 120° F. during the summer. Rainfall is scant and averages between 10 and 15 inches per year. Periods of excessive rainfall create hazardous conditions in gullies and washes where flash flooding is a danger.

Vegetation consists predominantly of saguaro, cholla, prickly pear, pincushion, and barrel cacti. Ocotillo, creosote bush, and paloverde are common, as is mesquite, in the lower areas. Cottonwoods are present near the Gila River and along a few of the larger washes where there are trap basins in the bedrock that collect water.

## Previous Work

No detailed work had been published on the area south of the Gila River prior to the start of this investigation. In 1954 Roland Schwartz carried out a "detailed reconnaissance" of the northern Tortilla Mountains in which the prospect is located. However, his thesis fails to mention major geological features in the area including a granodiorite porphyry batholith of Laramide age. Ransome's work in 1919 in the Ray-Miami area included Ray and Kelvin but did not extend farther to the southwest. Eberhard Schmidt is currently working on a PhD dissertation (University of Arizona) which overlaps the area covered in this study.

Prior to the acquisition of the Kelvin prospect by Tipperary Resources Corporation, Minbanco Corporation initiated an exploratory drilling program on the property. Drilling was accomplished using an air-hammer technique and rock-bit methods when excessive water was encountered. Due to improper sampling techniques, extensive mixing of cuttings, and incomplete and inaccurate drilling records, the results are not considered reliable.

# LOCATION OF THE KELVIN PROSPECT

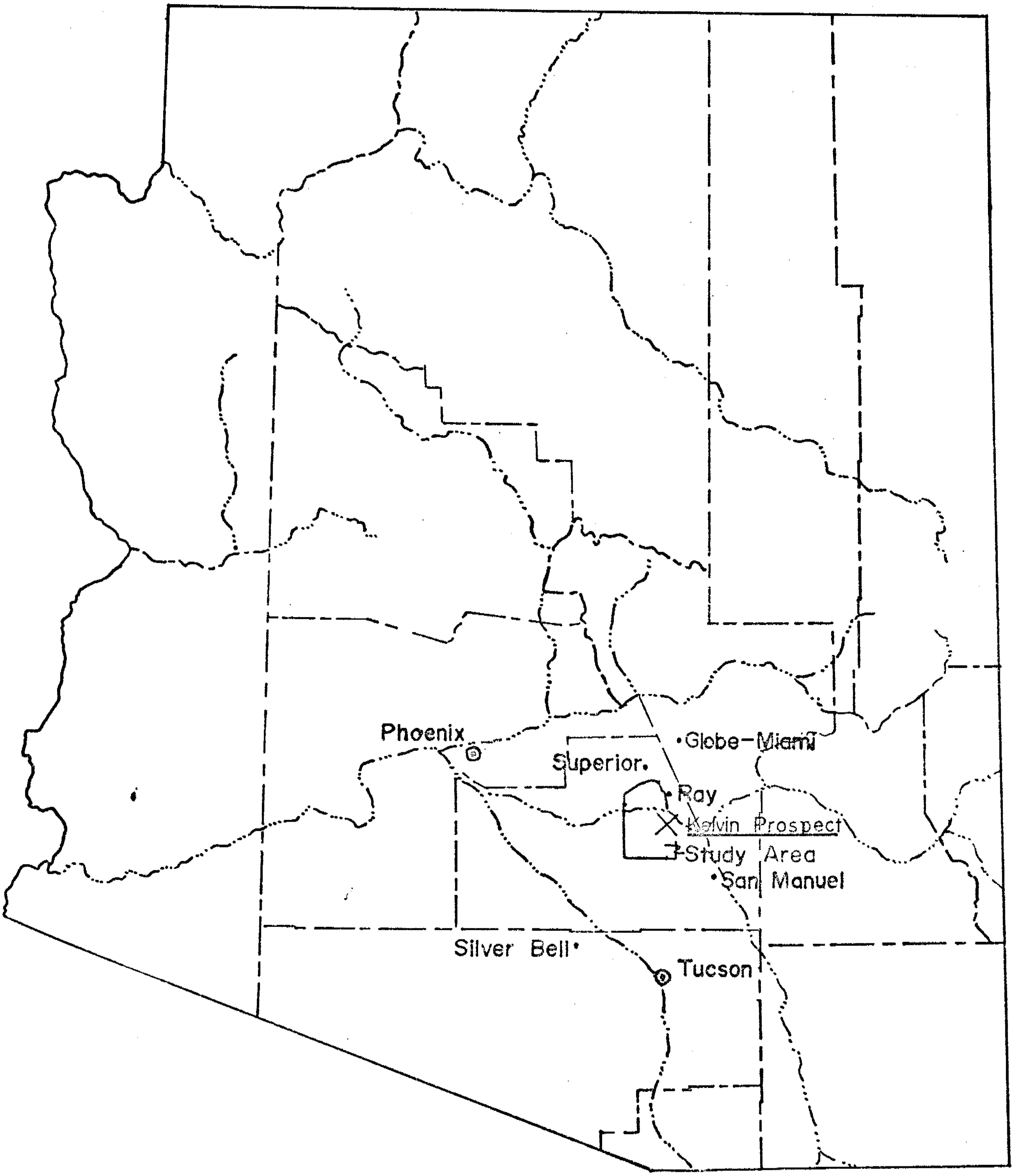


FIGURE 1

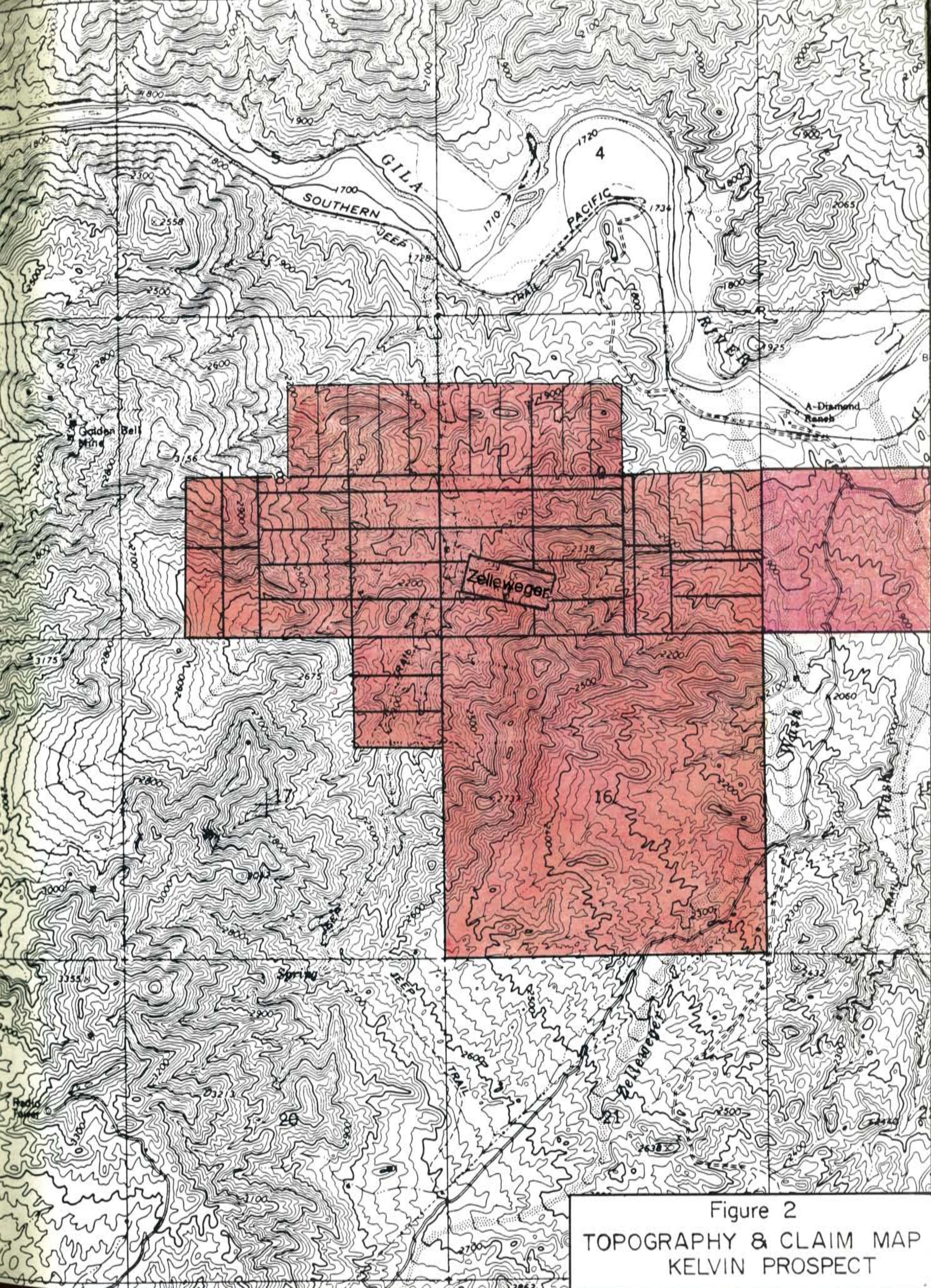


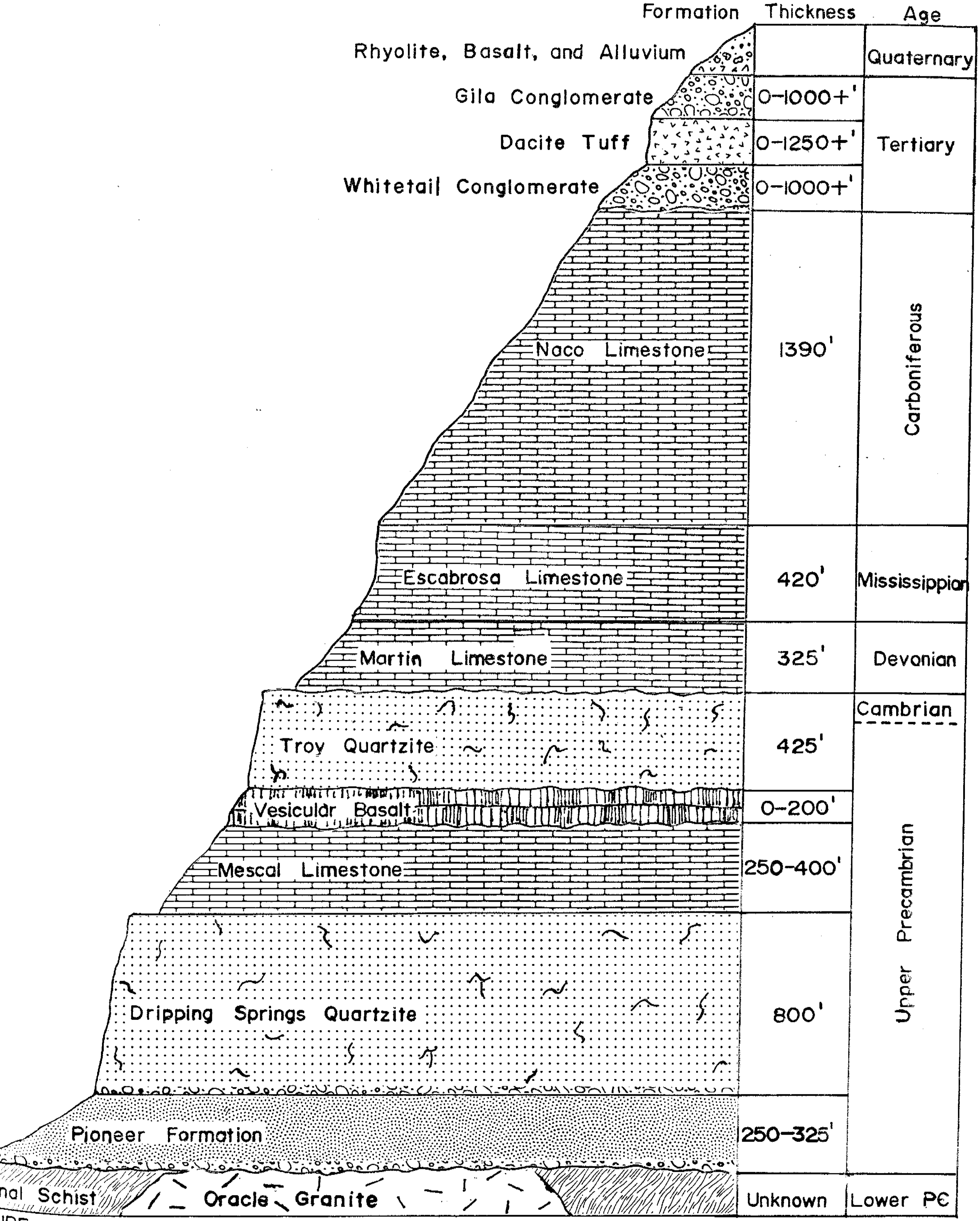
Figure 2
TOPOGRAPHY & CLAIM MAP
KELVIN PROSPECT

# ROCK UNITS

## Geological Section

The stratigraphic setting of the Kelvin prospect is relatively simple. At the base of the geologic section (Fig. 3) is the older Precambrian Pinal Schist which has been intruded by the Madera Diorite and the Oracle (Ruin) Granite, both of which are also older Precambrian in age. The younger Precambrian is represented by the Apache Group, which includes the Pioneer Shale, the Dripping Springs Quartzite, the Mescal Limestone, and the Troy Quartzite. These units have been intruded by diabase which is also Precambrian in age. Diabase of similar age has been reported in the Grand Canyon, in the Salt River Canyon associated with asbestos deposits, and at numerous other locations in Arizona. Above the Precambrian lies a series of Paleozoic sedimentary units including, in ascending order, the Martin Limestone (Devonian), the Escabrosa Limestone (Mississippian), and the Naco Limestone (Pennsylvanian). These formations have been intruded by a series of Laramide intrusive bodies, followed at a later time by hornblende andesite. The Whitetail Conglomerate, of mid-Tertiary age, unconformably overlies the pre-Cenozoic units and is overlain by a series of Miocene volcanics including the thick dacite ash flows which once covered most of the region. A broad expanse of these ash flows has survived erosion in the area east of Highway 177 between Ray and Superior. One of the youngest igneous rocks in the region is an olivine basalt that occupies post-dacite faults and occurs as minor flows resting on an eroded dacite surface as described by Short and others (1943). Capping the stratigraphic sequence are the Gila Formation and more recent pediment and stream gravels.

# GEOLOGIC SECTION



URE 3

## Pinal Schist

The Pinal Schist does not crop out on the Kelvin prospect, but it was encountered during reconnaissance mapping north of the Gila River where it comprises much of the basement. It probably has been derived principally from regionally metamorphosed clastic sediments, but it is not uniform in appearance. Most of the important variations are due to differences in the original material; it would probably be possible to divide the Pinal into a number of formations if a detailed regional study were made of the schistose rocks in southeastern Arizona.

Subordinate bands of amphibolite schist up to 200 feet thick and a mile long were observed within the Pinal Schist in the area north of the Gila River and west of Ray. These bands, which may have been derived from basic igneous rocks, have been described by Ransome (1919). Another unusual facies of the schist occurs near Ray in an east-trending band north of Granite Mountain. It was described in detail by Ransome (1919, pp. 33-34) as a light colored metamorphic rock showing "conspicuous lenticular eyes of quartz, the largest a centimeter in length, around which the finer material of the schist curves in flowing lines of foliation." Ransome believes this facies may originally have been a rhyolitic lava flow. Livingston (1969) obtained K-Ar dates on this variety of the Pinal Schist which he interpreted as indicating a maximum primary age of the rhyolite of 1900 million years with a probable primary age of 1650 ± 100 million years and a metamorphic age of 1500 ± 100 million years.

Ransome (1903) described the type locality for the Pinal Schist in the Pinal Mountains south of Globe, Gila County, Arizona. Typically, it is a light-gray to greenish-gray, fine-grained, friable quartz-sericite schist belonging to the greenschist facies. The variations in color are due principally to differences in the biotite and chlorite content. Northwest of Superior, irregular bands of milky white quartz paralleling the schistosity constitute up to forty percent of the rock. Some local varieties carry andalusite which gives the schist a knotty appearance.

Muscovite from the Pinal Schist has been dated by Livingston (1969) at 1385 million years using the K-Ar method. This should correspond to the most recent period of regional metamorphism. Additional dates obtained by Livingston indicate that the primary ages of the different facies may differ substantially. Two age groups have been obtained on the Madera Diorite, which intrudes the Pinal Schist in some areas. Some of the Precambrian diorites, which commonly are foliated, have been dated at 1730 ± 30 million years, which is older than the probable primary age of the metarhyolite near Ray. The second period of intrusion by the Madera Diorite occurred at 1540 ± 50 million years, approximately concurrent with the metamorphism of the Precambrian rhyolitic lava flow. The geological history of the Pinal Schist obviously is complex, but no detailed study has been undertaken which might resolve the stratigraphy of the Pinal and some of the older Precambrian history of the region. Such a study would be useful in working out structural problems in southeastern Arizona.

Although the facies mentioned in this section were all observed in the field, they were not plotted on the reconnaissance map of the region. A number of other local variations in the Pinal Schist were also observed. A spotted variety noted by Ransome (1919) in the vicinity of the Laramide Granite Mountain Porphyry east of Ray is probably the result of local contact metamorphism. This variety is a speckled schist with abundant aggregates of chlorite in a light matrix of sericite and quartz. The schist at the south end of the Grayback Granodiorite in the Ninety-six Hills grades into gneiss in the vicinity of the contact with the intrusion. It is beyond the scope of this study to define and determine the relationships of the facies within the Pinal Schist. The Pinal Schist adjacent to the mineralizing Laramide porphyries is an important host rock at the Ray and the Miami-Inspiration mines.

## Oracle Granite

The Oracle Granite, described in great detail by Banerjee (1958), composes most of the Tortilla Mountains. It is the principal host rock on the Kelvin prospect and is virtually indistinguishable from the Ruin Granite north of Miami, Arizona (Ransome, 1903; Peterson, 1962). Similar Precambrian intrusions, of approximately the same age, crop out over large areas of southern and central Arizona.

K-Ar dates of 1420 million years have been obtained on biotite differentiates from the Oracle Granite and on muscovite from associated pegmatites. The same study yielded an age of 1500 million years on biotite from the Ruin Granite near Roosevelt Lake (Damon, Livingston, and Erickson, 1963). The agreement between these dates is well within experimental error. The closeness of the dates and the physical similarity of numerous other Precambrian intrusions, which are widely distributed in Arizona, indicate a well defined orogenic disturbance in this portion of the Southwest; this has been named the Mazatzal Revolution (Wilson, 1936).

The Oracle Granite is a coarse-grained, porphyritic rock containing large, conspicuous microcline phenocrysts up to five centimeters long. It weathers into rounded, dull-brown to ashen-gray boulders with the microcline phenocrysts protruding somewhat from the decomposing rock. On fresh surfaces, the groundmass is light gray due to a mixture of biotite, chlorite, quartz, and plagioclase feldspar, and the microcline crystals are flesh colored to pink. Its essential minerals are quartz, plagioclase, and microcline with subordinate biotite. The accessory minerals are magnetite, ilmenite, epidote, sphene, tourmaline, and zircon. Petrographically, the Oracle Granite is a quartz monzonite porphyry composed principally of microcline phenocrysts in a fine- to medium-grained groundmass of quartz and plagioclase. Varying subordinate amounts of biotite are present in the groundmass. The biotite is largely altered to iddingsite and chlorite with grains of leucoxene enclosed within the altered mass. Relatively fresh hydrothermal biotite occurs near the contacts of some Laramide plutons, particularly the Grayback Granodiorite on the Kelvin prospect, suggesting that some of it may be secondary in these areas.

The microcline phenocrysts constitute as much as 35 percent of the rock. They measure up to five centimeters in length, and crystals over three centimeters long are abundant. Microscopically, the phenocrysts are subhedral, poikilitic crystals containing tiny grains of biotite, chlorite, quartz, and sometimes plagioclase. The microcline usually exhibits a slight perthitic texture. Chemical analyses of the Oracle Granite by Banerjee (1958) yielded an unexpectedly high sodium content that cannot be explained by the observed degree of perthitic intergrowth and the plagioclase content. Schmidt (1971) thinks that this may be due to sodium incorporated into the microcline crystal lattice.

The plagioclase, which composes approximately 30 percent of the rock, is of the andesine variety. It occurs as anhedral to subhedral grains in the groundmass that exhibit albite twinning and minor zoning. The plagioclase often shows incipient sericitization along microfractures, but otherwise it is generally fresh. The quartz also occurs in subhedral grains about equal in volume to the plagioclase feldspar.

The Oracle Granite contains schist xenoliths scattered throughout its mass. A number of large, irregular xenoliths were observed near the western margins of this Precambrian batholith north of Black Mountain in the southern portion of the Tortilla Mountains. Generally, however, the xenoliths are small, flat fragments a few inches across and about an inch thick. No preferred orientation is discernible in the northern portion of the batholith. Schwartz (1953) reported schist xenoliths in the southern portion of the Oracle batholith near San Manuel. Drilling there encountered schist over an interval of 10 to 15 feet in scattered holes, but these large xenoliths were unusual occurrences. The source of the xenoliths is undoubtedly the Pinal Schist which constitutes most of the Precambrian rocks older than the Oracle in southeastern Arizona.

One of the most notable features of the Oracle and the Ruin Granites, and of other Precambrian intrusive rocks of the same age, is the uniformity of composition and texture. They are generally unaltered but commonly are decomposed and weathered, and obtaining samples suitable for thin sections is often difficult. The general appearance of the Oracle Granite changes slightly in the vicinity of its contact with the Grayback Granodiorite and its satellite plutons. Fresh outcrops of the Precambrian intrusive rocks are rare; generally, they have been deeply affected by weathering through long exposure. However, a number of fresh outcrops were noted near the eastern contact of the granodiorite and in the vicinity of the Mineral Mountain Monzonite along the Gila River west of North Butte. The freshness of these outcrops is largely a result of rapid erosion, but the rock may also be somewhat denser, resisting the deep weathering prevalent elsewhere in the Tortilla Mountains. Under these conditions, erosion is more likely to keep pace with chemical decomposition of the granite.

The effects of Laramide intrusions upon the Precambrian "granite" are subtle even in fresh outcrops. There is a visible increase in the biotite content of the Oracle Granite near the Laramide granodiorite contact. In one place along the southern edge of section 8, T. 4 S., R. 13 E. of the Kelvin prospect, wispy stringers of biotite-rich granodiorite were noted along fractures in the Oracle Granite. The biotite is strongly foliated parallel to the fractures and the stringers grade laterally into the wall rock without a distinct contact between the granodiorite and the granite. The biotite content of the granite is increased adjacent to the stringers. Another variation in the Oracle Granite near the Laramide granodiorite is an apparent pinkening of the microcline phenocrysts. These metasomatic effects of the Laramide intrusive rocks are minimal, but they do affect the weathering characteristics of the rock. Similar alteration has been reported by Banerjee (1958) along some shear zones where the feldspars are iron stained and the microcline phenocrysts reduced to augen.

Aplites and pegmatites associated with the Oracle Granite are relatively abundant, but they are often difficult to distinguish from Laramide aplites in the vicinity of the Grayback Granodiorite. Both are composed of potash feldspar, plagioclase, and quartz with subordinate muscovite. However, the Precambrian aplites and pegmatites commonly contain black tourmaline crystals. In the absence of tourmaline or diagnostic crosscutting relationships, positive identification is not possible in the field and no distinctive petrographic features of either aplite have been noted. Aplites, which are presumed to be Precambrian on the basis of association and size, occur as large irregular masses in the Oracle Granite; others, which may carry tourmaline, occur as dikes that seem to have a preferred east-west trend.

## Apache Group

The younger Precambrian sedimentary units were not found on the Kelvin prospect since the sedimentary strata, which once covered the Tortilla Mountains, have been eroded away except for steeply-dipping beds along the eastern flank. However, boulders from the more resistant beds are abundant in a few of the larger washes, and smaller pebbles were found near the tops of ridges in section 9, T. 4 S., R. 13 E. of the prospect. For this reason, a brief description of these units is included in this report; Ransome (1903) described the type locality for the Apache Group in the vicinity of Barnes Peak in Gila County, Arizona.

The Pioneer Formation is the basal unit of the Apache Group; it is approximately 325 feet thick and includes the Scanlan Conglomerate at its base. The Scanlan was interpreted by Ransome (1919, pp. 39-40) as having formed from the materials that "waves of an advancing sea found lying on a well-worn surface of low relief." The Pioneer Formation consists principally of dark, reddish-brown, arenaceous shales composed mostly of fine arkosic detritus. The unit characteristically crops out at the base of slopes buried by talus from overlying strata.

Above the Pioneer Shale are nearly 600 feet of Dripping Springs Quartzite. Its basal member is the Barnes Conglomerate which ranges from 10 to 40 feet in thickness and contains large, distinctive, rounded pebbles, commonly 3 to 4 inches in diameter, in an arkosic matrix. The lower third of the Dripping Springs Quartzite is one massively-bedded member with pronounced striping due to red and gray bands alternating with black bands averaging about a foot thick. There is no differential resistance to weathering between these bands. The middle third of the formation is composed of thickly-bedded quartzite, and the upper third grades upward from quartzite into thin, rusty, flaggy beds with some interbedded shale.

The overlying Mescal Limestone is a thin-bedded dolomitic limestone with thin siliceous segregates parallel to the bedding planes. It is between 250 and 300 feet thick and is overlain in the Ray area by a very thin layer of vesicular basalt.

The Troy Quartzite rests unconformably on this basalt. Weathered exposures are generally buff to rusty brown. The Troy is a cliff-forming unit composed of interbedded quartz pebble conglomerate and quartzite grading into a yellowish, thin bedded shaly quartzite at the top of the formation. The quartzite is thick to massively bedded, and the conglomerate beds contain quartz pebbles averaging less than 1 centimeter in a quartzite matrix. Although the Troy is frequently included in the Apache Group, it is separated from the other units by an erosional disconformity, and its age may also lap over into the Cambrian Period.

## Diabase

Only a few outcrops of diabase occur on the Kelvin prospect but they are more numerous a few miles to the south. One outcrop is a crescent-shaped mass above the Zelleweger mine. The others appear to be part of a relatively broad, north-trending dike which has been offset by east-west faulting. Other basic to intermediate dikes on the prospect lack the typical diabasic texture and appear to be relatively young; in one place, these rocks have been intruded along the margins of a Laramide dike.

Diabase in the Ray area is generally accepted as being late Precambrian since large volumes intrude the Apache Group but not the overlying Paleozoic strata. Undoubtedly, much of this material broke through to the surface and was completely removed by erosion during the Precambrian. The diabase is susceptible to rapid decomposition upon weathering and often forms hollows and depressions in the surface. It tended to intrude along the less competent sedimentary beds, especially the Mescal Limestone, thereby dilating the section several hundred feet. Diabase is the most important host rock at Ray where virtually all of the recently developed "silicate" ore occurs in it, as well as much of the richest sulfide ore.

The diabase is a dark gray, holocrystalline, medium-grained rock which is very tough when fresh, but weathering rapidly reduces it to a soft, crumbly material. This makes it difficult to obtain samples suitable for thin sections; therefore, no thin sections of the diabase were examined in this study. The diabase is composed of plagioclase, augite, and magnetite.

There have been considerable confusion and disagreement over the age of the diabase. This probably stems from the difficulty in differentiating Mesozoic and Cenozoic basic, hypabyssal intrusive rocks from the Precambrian diabase. The Precambrian diabase is present in the Grand Canyon and in the Salt River Canyon; Silver (1960) dated samples from the Sierra Ancha at 1140 million years by the K-Ar method. Damon (oral communication, March 1971) obtained an age of approximately 1100 million years on samples from the Globe area, but Peterson (1962) suggested a post-Paleozoic age for the Globe diabase.

Petrographic examinations performed in this study indicate that there are two groups of mafic hypabyssal intrusions in the mapped area in addition to the diabase. One is andesitic in composition and may be mid-Tertiary in age. The other is basaltic and is difficult to distinguish in hand specimen from the first group. It probably corresponds to the Quaternary basalt described by Short and others (1943) about twenty miles north of the Kelvin prospect near Superior, Arizona. That basalt intruded the Concentrator fault and dacitic ash-flow tuffs; Nelson (1966) reported a date of 20 million years on the dacite tuff. Although there are numerous younger basic to intermediate intrusive rocks, the diabase is probably late Precambrian in age. Both regional and detailed investigations support this conclusion.

## Paleozoic Strata

The Paleozoic strata, like the Precambrian Apache Group, have been stripped from the Tortilla Mountains by erosion, except for a few steeply-dipping beds along the eastern flank. However, rounded pebbles, cobbles, and boulders from the more resistant limestone beds were found in the vicinity of the Kelvin prospect; a few of them came from the top of an east-west ridge along the boundary between sections 9 and 16, T. 4 S., and R. 13 E. Since this area is elevated above outcrops of the Paleozoic units east of the prospect, the limestone pebbles are probably derived from Paleozoic beds which once were present within the Tortilla Mountains.

The basal unit is the Martin Limestone of Devonian age which is approximately 325 feet thick in this area. Ransome (1904) described the type locality at Mount Martin about five miles north of Naco, Arizona on the Mexican border. In the Ray area it grades from a yellowish-gray sandy limestone at its base into a dingy, yellow calcareous shale at the top. The limestone is generally dolomitic and contains minor amounts of carbonaceous material. The Martin is a very favorable host rock for mineralization. The rich sulfide replacement ore body at the Magma mine in Superior and much of the complex metasomatic mineralization at Christmas occur in the lower portion of the Martin Limestone.

The overlying Escabrosa Limestone of Mississippian age and the Naco Formation of Pennsylvanian age have a composite thickness in excess of 1000 feet in the Ray area, but the contact between the two units is indistinct. However, the Escabrosa is characteristically a clean white, cliff-forming limestone. It is thick-to massively-bedded and is a relatively poor host for mineralization throughout southern Arizona. At both Superior and Christmas, the Escabrosa is a nearly barren unit separating the richly mineralized Devonian and Pennsylvanian limestones.

The Pennsylvanian Naco Limestone is composed of light gray thin- to medium-bedded limestone. It is generally a slope-forming unit, but a few thick, light gray beds in the lower portion of the unit locally form minor cliff faces. The Naco Formation in the Ray area correlates with the Horquilla Limestone, the basal formation of the Naco Group in Cochise County, Arizona as described by Gilluly (1956). The Naco Limestone and other Pennsylvanian and Permian limestones in southeastern Arizona are important host rocks in a number of major ore deposits. The newly developed stacked ore bodies in the Magma mine at Superior and the upper mineralized zones at Christmas are notable examples of important mineralization in the Naco within a 25-mile radius of the Kelvin prospect.

## Laramide Intrusive Rocks

The Laramide orogeny is represented by a variety of intrusive rocks within the area covered by this study. Among these are numerous dikes, sills, and irregular plutons of rhyodacite, rhyodacite porphyry, granodiorite, the Grayback Granodiorite, the Granite Mountain Quartz Monzonite Porphyry, and the Teapot Mountain Quartz Monzonite Porphyry. Evidence accumulated in this report suggests that many of these intrusive rocks, as well as the Lost Gulch Monzonite and the Schultz Granite (with its granite porphyry facies in the Globe-Miami mining district north of Ray), could have been derived from one cooling, differentiating magma source.

Rhyodacite and rhyodacite porphyry. K-Ar dating by Damon (1970) indicates that the rhyodacite intrusive rocks, which are approximately 67 to 70 million years, are the oldest Laramide plutons in the region. In contrast, numerous rhyodacite porphyry dikes appear to be among the youngest local Laramide intrusive rocks that cut across the rhyodacite and most of the other larger Laramide plutons. However, there are such a variety and number of the dikes that there may be many exceptions to this generalization of the relative age of the rhyodacite porphyry. The rhyodacite and the rhyodacite porphyry were originally identified by Ransome (1919) as quartz diorite and quartz diorite porphyry and are referred to by these names in the older literature.

The rhyodacite occurs as irregular intrusive masses, the largest of which is the Sonora Diorite north of the Gila River, just west of Kelvin, Arizona. It is typically a medium to dark gray medium-grained rock composed of subhedral plagioclase grains, abundant subhedral to euhedral hornblende and biotite crystals, interstitial quartz and minor potash feldspar. Traces of pyrite and chalcopyrite are commonly disseminated through the rock.

The rhyodacite porphyry occurs throughout much of the region as east- to east-northeast-trending dikes and less frequently as sills in the Paleozoic strata and as irregular masses. Typically, it is a light to medium gray porphyritic rock composed of plagioclase, quartz, and biotite phenocrysts seldom exceeding one centimeter across in a fine-grained groundmass of quartz, plagioclase, and minor potash feldspar. One unusual variety in the southwestern corner of section 9, T. 4 S. and R. 13 E. contains phenocrysts constituting less than 25 percent of the rock; biotite-chlorite gives the fine-grained groundmass a very dark color (Figs. 4 and 5). This small mass of rhyodacite porphyry is cut by numerous veinlets of Grayback Granodiorite and granite. Xenoliths of the same rock were noted in the Grayback Granodiorite at several points in the northern portion of the batholith. Other rhyodacite and quartz latite dikes cut across Grayback Granodiorite elsewhere.

Microscopically, the plagioclase phenocrysts are usually subhedral to euhedral crystals somewhat larger and more abundant than the other phenocrysts (Fig. 5). The quartz crystals are characteristically sharp to rounded, embayed dipyramids measuring up to one centimeter across. The rounding of the dipyramids in

Figure 4. Photograph of a sawed slab of porphyritic rhyodacite (SP2). 3/4 inch granodiorite dike cuts across both the host rock and two smaller granite dikelets.

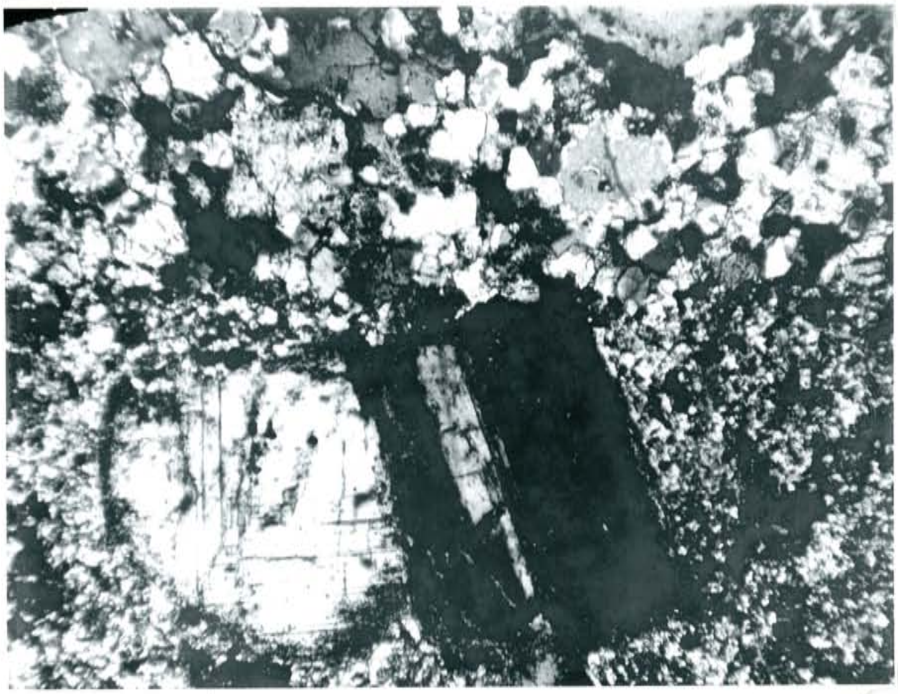


Figure 5. Photomicrograph of a thin section of porphyritic rhyodacite and granodiorite (SP2). The contact between dark gray porphyritic rhyodacite (lower) and the light gray granodiorite dike (upper) is shown. The rhyodacite contains plagioclase, quartz, and biotite phenocrysts in an aphanitic groundmass containing abundant biotite-chlorite. The granodiorite dike is composed principally of plagioclase with potash feldspar rims and a lesser amount of quartz.

some of the rhyodacite porphyry intrusions suggests that the quartz has reacted and has been partially resorbed by the groundmass. The relative proportions of the constituent minerals are variable but plagioclase and quartz always predominate. Among the local variations are several dikes in the northern half of section 9, T. 4 S., and R. 13 E. of the Kelvin prospect. The plagioclase phenocrysts in these dikes commonly have epidotized centers which seem to be a product of deuteric alteration. Dikes in the southern half of section 16 in the same township are generally poor in potash feldspar and grade into quartz diorite porphyry.

In summary, these intrusions cropping out in the northern Tortilla Mountains range compositionally and texturally from granodiorite to quartz diorite porphyry, but are largely classifiable as rhyodacite and rhyodacite porphyry. The plagioclase is predominantly andesine and is usually zoned with calcic rims or alternating calcic and sodic zones. Quartz is an abundant constituent, occurring in interstitial spaces and as dipyramidal crystals. Subordinate amounts of microcline or orthoclase and biotite are usually present.

Grayback Granodiorite. The Kelvin prospect is located on the eastern margin near the north end of the Laramide Grayback Granodiorite Porphyry batholith. The porphyry was named recently by Schmidt (1971) but no detailed study of the batholith and its relation to other Laramide plutons in the area was made. The Grayback is the largest Laramide intrusion in the region but it has not been recognized previously except by Schmidt, whose work is concurrent to this study. The granodiorite crops out over an area in excess of 70 square miles, but it may be considerably more extensive since much of its western contact is covered by valley fill. In addition, the Granite Mountain Quartz Monzonite Porphyry at Ray is probably part of the same intrusive mass.

In some areas, the Grayback Granodiorite approaches the composition of quartz monzonite. Its principal constituents are plagioclase feldspar and quartz with a variable subordinate content of potash feldspar, biotite, and muscovite. The plagioclase is oligoclase-andesine occurring as anhedral to subhedral phenocrysts as much as eight millimeters in diameter and as interstitial filling. The larger crystals are usually zoned with alternating calcic and sodic zones. The quartz grains are similar to those in the rhyodacite porphyry intrusions except that they are generally more rounded and embayed. The orthoclase occurs as large anhedral, untwinned crystals and the microcline, which is less abundant, is usually present as ragged, anhedral phenocrysts containing poikilitic inclusions of quartz and biotite. The combined potash feldspar content is variable. Several samples from the northern portion of the batholith were examined in thin section and a couple could have been classed as quartz monzonite on the basis of a point-count study. In all of the samples, the potash feldspar constituted over 10 percent of the feldspar content of the rock. The biotite and potash feldspar contents of the granodiorite appear to increase toward the northern and eastern margins of the batholith. In the central and the southern portions, muscovite is generally more abundant at the expense of biotite. In the Ninety-six Hills, at the south end of the batholith, the biotite-muscovite zoning is especially evident over a relatively short east-west distance. However, zoning is not uniform in the intrusive mass. Local concentrations of biotite occur throughout the Grayback Granodiorite and a detailed study of the batholith and all of its facies would be required to fully document the observed zoning of biotite and muscovite. There are many local variations in the texture of the granodiorite and in the proportion of its constituent minerals. One facies has a salt-and-pepper appearance due to its uniform, fine-grained texture and the abundance of biotite. Another variety, a quartz monzonite porphyry, contains abundant potash feldspar phenocrysts as much as three centimeters in length. However, a typical composition for the Grayback Granodiorite in the northern portion of the batholith is 52 percent plagioclase, 27 percent quartz, 16 percent potash feldspar, and 5 percent biotite.

The Grayback Granodiorite is a long, narrow batholith with its long axis striking north-northeast. However, the east-northeast structural grain of the region has exerted considerable influence over the emplacement of the granodiorite. This system of fractures and faults appears to be separate from the east-trending system which was active during the Precambrian and was reactivated during the Laramide. The east-trending fractures were open during the Laramide orogeny as evidenced by a multitude of dikes with this trend, including granodiorite dikes on the Kelvin prospect. The east-northeast faults are major shears which bound some of the larger Laramide intrusions; these fractures are less frequently occupied by dikes than the east-west system. The Grayback Granodiorite, which apparently was emplaced as a rather viscous magma, does not occur as long narrow dikes; however, it did intrude a few fracture zones forming short, irregular dike-like projections of the batholith (Fig. 6). The east-trending monzonitic dike along the southern boundary of section 8 is a good example, and the east-northeast-trending "porphyry break" in the Pearl Handle pit at the Ray mine contains a network of Granite Mountain Porphyry masses. The Granite Mountain intrusion seems to be an extension of the Grayback Granodiorite, which appears to have been emplaced by a penetrative stoping process.

Foliated granodiorite, rich in biotite, occurs within the main mass of the batholith near the contact in the immediate vicinity of the Kelvin prospect and as stringers filling fractures in the adjacent Oracle Granite. Figure 8 is a photograph of foliated granodiorite showing apparent flow structures within the batholith.

The shape of the Grayback Granodiorite mass makes it appear that the batholith has been offset by several east-northeast-trending wrench faults with right-lateral displacements as great as five miles. This pattern of apparent wrench faulting is evident in a sketch map of the region in Figure 9. However, careful examination of the eastern contact of the batholith and of the adjacent faulted areas reveals that the faults largely predate the granodiorite, although there has been substantial post-Laramide vertical displacement along a few of them. The granodiorite intruded the ground between the east-northeast faults for sharply varying distances by means of a penetration and stoping process. The initial penetration into the

Figure 6. Photographs of quartz-monzonite dikes. Two of numerous small dikes extending outward from the Grayback batholith parallel to the large east-trending dike along the southern boundary of section 8.

Figure 7. Photograph of a quartz monzonite porphyry dike. This is one of the most sharply defined Laramide dikes paralleling the northeastern margin of the Grayback batholith. Other parallel dikes of rhyodacite and granodiorite are exposed in a nearby railroad cut in section 6, T. 4 S., R. 13 E., but the margins of these dikes grade imperceptibly into the Oracle Granite wall rock.

Figure 8. Photograph showing flow structure within the Grayback batholith. North is to the left.

country rock was along fractures extending from the advancing magma front. The large easterly striking dike along the southern border of sections 8 and 9 of the Kelvin prospect is one of the clearest examples of these extensions of the Grayback Granodiorite. Much smaller granodiorite dikes, shown in Figure 6, are east-striking sub-extensions of this larger dike. The granite Mountain Porphyry intrusions in the "porphyry break" at Ray and the east-trending monzonitic dike at the south edge of the Kelvin prospect were emplaced in this manner. Closer to the main mass of magma, fractures parallel to the contact also were intruded. Small dikes and stringers of granodiorite were noted in the Oracle Granite paralleling the east contact of the batholith in sections 6, 7, and 8, T. 4 S., R. 13 E. There, as blocks of the country rock were broken off or assimilated, the main mass of granodiorite magma advanced. In Stringham's (1966) classification of plutons, the Grayback Granodiorite is a passive intrusion which has not disturbed the surrounding rock from its original position.

The rate and distance of advance by the magma appear to be dependent, in part, on the degree of fracturing in the country rock. The differences in the distance of advance by the granodiorite on opposite sides of the major east-northeast faults are probably due to differences in the intensity of fracturing in the separate fault blocks. Since the major east-northeast faults are important pre-Laramide breaks, it is likely that the fault blocks which they displaced were structurally independent to some degree. This can account for the apparent differences in competence and magma advance in adjacent fault blocks. Although the east-northeast system is indistinct in the Oracle Granite, its presence and the structural independence of the fault blocks are substantiated by the discontinuity of structure across the faults as they are projected away from the margins of the batholith. These projections cannot be made over long distances, however, because of complicating north-northwest to north-trending faults which are also poorly defined in the Oracle Granite.

The character of the contacts of the batholith suggest deep-seated, passive emplacement of the granodiorite. No chilled margins were noted, and the Oracle Granite is penetrated by numerous small stringers and veins of granodiorite which sometimes grade into the wall rock without a distinct contact.

Laramide aplite and pegmatite veins, which are associated with the Grayback Granodiorite, occupy east- to east-northeast-trending fractures within the batholith and also fill fractures in the Precambrian wall rock. The Laramide aplites in the Oracle Granite are difficult to distinguish from the Precambrian aplites. Both are composed of potash feldspar, quartz, and plagioclase with minor muscovite. Many of the aplites associated with the Oracle Granite contain tourmaline and the Laramide aplites are generally light gray due to a greater plagioclase content. However, these characteristics are not reliable criteria for identification since not all of the Precambrian aplite masses contain tourmaline and the color of the Grayback aplite grades into pink in many places. The pink color is especially common where the aplite veins open into pegmatitic zones in which the potash feldspar content increases at the expense of plagioclase. Both aplites have a general easterly trend and positive identification is not possible in the absence of diagnostic cross-cutting relationships and tourmaline. The Laramide aplites are numerous along the eastern margin of the batholith, particularly at the north end. The veins are thin and relatively less abundant in the central and southern portions of the Grayback batholith.

Granite Mountain Quartz Monzonite Porphyry. Several samples of the Granite Mountain Porphyry were examined in thin section because of the similarity and proximity of this pluton to the Grayback Granodiorite. The samples were collected from the area between Granite Mountain and Copper Butte, a few miles west of Ray. The samples came from outside the zone of intensive alteration and mineralization at Ray where the Granite Mountain Porphyry was first identified and described by Ransome (1919).

Petrographically, the Granite Mountain Porphyry is virtually identical to the Grayback Granodiorite; the texture is the same, and the samples of Granite Mountain Porphyry which were examined microscopically are more correctly identified as granodiorite porphyry. A typical composition for these samples is 44 percent plagioclase, 38 percent quartz, 11 percent potash feldspar, and 7 percent biotite.

The emplacement of the Granite Mountain Quartz Monzonite Porphyry was controlled by the east-northeast system of faulting which also influenced emplacement of the Grayback Granodiorite. The east end of the Granite Mountain stock is a complex network of small plutons within the "porphyry break" in the Pearl Handle pit at Ray. The "break" is a 2000-foot-wide, east-northeast-trending shatter zone which was important in controlling both the intrusion of the Granite Mountain Porphyry and the later copper mineralization (Metz, 1966). The porphyry is presumed to have been the source of mineralization in the Ray porphyry copper mine, but it was a poor host rock and seldom constitutes ore. The plutons in the "porphyry break" are more potassic than the Granite Mountain Porphyry west of Granite Mountain and it was correctly identified as quartz monzonite porphyry in the mine area (Ransome, 1919).

The Granite Mountain Porphyry does not crop out east of the Ray mine, but fragments of this rock were reported in pebble dikes a quarter of a mile east of any surface outcrops (Metz, 1966). This suggests that the network of plutons continues at depth to the east-northeast beyond the mine workings.

The western end of the Granite Mountain mass is a low-angle fault contact with the Whitetail Conglomerate at Copper Butte. The conglomerate contains spotty copper-oxide mineralization which has been selectively mined for flux material and sold to the smelter at Superior. The Ray Mines Division of Kennecott Copper Corporation has recently completed a drilling program at Copper Butte. The results of the drilling are not public, but Granite Mountain Porphyry was rumored to be beneath the Whitetail in some of the drill holes. Only Pinal Schist was encountered in other holes suggesting that there may be a network of Laramide plutons at depth similar to the porphyry break at Ray (C. Phillips, oral communication).

Granodiorite dikes. Granodiorite dikes occur on the Kelvin prospect as steeply-dipping, east-trending intrusive masses concentrated between the large rhyolite or quartz latite dike on the north and the quartz monzonite porphyry dike at the south end of the Rare Metals group of claims. East of the northeast-trending faults which bisect the prospect, the granodiorite dikes are prominent in topographically high areas crossing the northwest-trending ridges and forming the backbone of easterly ridges. These dikes may be extensions of the Grayback Granodiorite, but no connection was mapped. The granodiorite dikes do not crop out between the northeast-trending faults and the eastern margin of the batholith except for isolated exposures in a few gullies.

In hand specimen, the granodiorite is a light to medium gray, inequigranular phaneritic rock containing abundant plagioclase, a lesser amount of quartz, minor biotite, and some potash feldspar. The general appearance of the granodiorite dikes resembles both the Sonora Diorite and the Grayback Granodiorite which are composed of the same suite of rock-forming minerals. The dikes are lighter in color and coarser grained than the Sonora Diorite but they are darker gray and more equigranular than the Grayback.

Thin-section examination revealed that the granodiorite dikes are porphyritic with phenocrysts making up more than 75 percent of the volume. The groundmass is composed principally of sericitized plagioclase and quartz. The plagioclase phenocrysts are in the oligoclase-andesine range, and some zoning was noted. A few of the larger crystals exhibit incipient sericitization. The quartz generally occurs as anhedral grains that are clear and embayed, usually with rounded edges.

Minor plagioclase is present as large anhedral phenocrysts with poikilitic inclusions of quartz and biotite. Pleochroic, green phenocrysts of biotite partially altered to chlorite and containing inclusions of sphene partially altered to leucoxene are scattered through the rock. The biotite-chlorite phenocrysts are usually platy with wavy extinction and ragged edges but they also occur as spherulitic aggregates. Minor to trace amounts of magnetite and apatite are also present. Scattered traces of pyrite and chalcopyrite were noted disseminated through the rock. Similarities in composition and texture and the proximity of the dikes to the Grayback Granodiorite indicate a genetic association.

Teapot Mountain Quartz Monzonite Porphyry. The Teapot Mountain Porphyry occurs at Ray as plugs and dike swarms in a zone north of the Ray mine area, roughly paralleling the porphyry break. A nearly identical intrusive mass is present along the margin of the quartz monzonite dike on the southern border of section 8, T. 4 S., R. 13 E. of the Kelvin prospect. The outcrops on the Kelvin prospect cut the Grayback Granodiorite as east-trending dikes.

The Teapot Mountain Porphyry at Ray was described by Ransome (1919) as a quartz monzonite porphyry containing euhedral orthoclase phenocrysts as much as three centimeters long. Outcrops in the mine area are usually yellowish to yellowish-brown due to decomposition from weathering. The Teapot Mountain Porphyry there is generally more susceptible to weathering than the older Granite Mountain Porphyry. Outcrops on the Kelvin prospect of a very similar rock are generally fresh, and comparison with fresh samples of the Teapot Mountain Porphyry from the Ray pit reveals the similarity of the intrusions. The orthoclase crystals do not attain the large dimensions of some of those at Ray, but otherwise they appear the same.

The principal minerals of the Teapot Mountain Porphyry are plagioclase, quartz, and orthoclase. The orthoclase is abundant in the plutons at Ray giving the rock a quartz monzonite composition. However, in the smaller intrusions in the mine area and on the Kelvin prospect, the potash feldspar phenocrysts are sparsely distributed through the rock. This variety is more accurately classified as a rhyodacite porphyry in which orthoclase occurs as pink, euhedral phenocrysts seldom measuring over two centimeters in length. These crystals usually contain poikilitic quartz and biotite inclusions.

More abundant quartz dipyramids, averaging about seven millimeters across, and scattered, subhedral to euhedral plagioclase occur in a medium gray fine-grained groundmass. The rock has been intensely sericitized on the Kelvin prospect making positive identification of the feldspar grains difficult except for the euhedral orthoclase phenocrysts which are not affected. In some cases only relics of the original feldspar crystals remain in a sericitic groundmass.

The Teapot Mountain Porphyry at Ray cuts both the Granite Mountain Porphyry and pebble dikes located east of the pit. The pebble dikes are reported by Metz and Rose (1966) to contain fragments of the Granite Mountain Porphyry, suggesting that the Teapot Mountain Porphyry is considerably younger than the Granite Mountain pluton. This is substantiated by the nature of the contacts. The Grayback Granodiorite and its extensions including the Granite Mountain stock do not possess chilled margins and have not disturbed the surrounding rock. These intrusions have been passively emplaced at a relatively deep level in the crust. The Teapot Mountain Porphyry, however, exhibits well developed chilled margins in which only scattered quartz crystals are visible in an aphanitic groundmass. A few very thin dikes, only a few feet wide, are completely devoid of identifiable crystals in hand specimens. This suggests comparatively shallow emplacement, and a significant amount of time must have elapsed between the emplacement of the Grayback Granodiorite and the Teapot Mountain Porphyry.

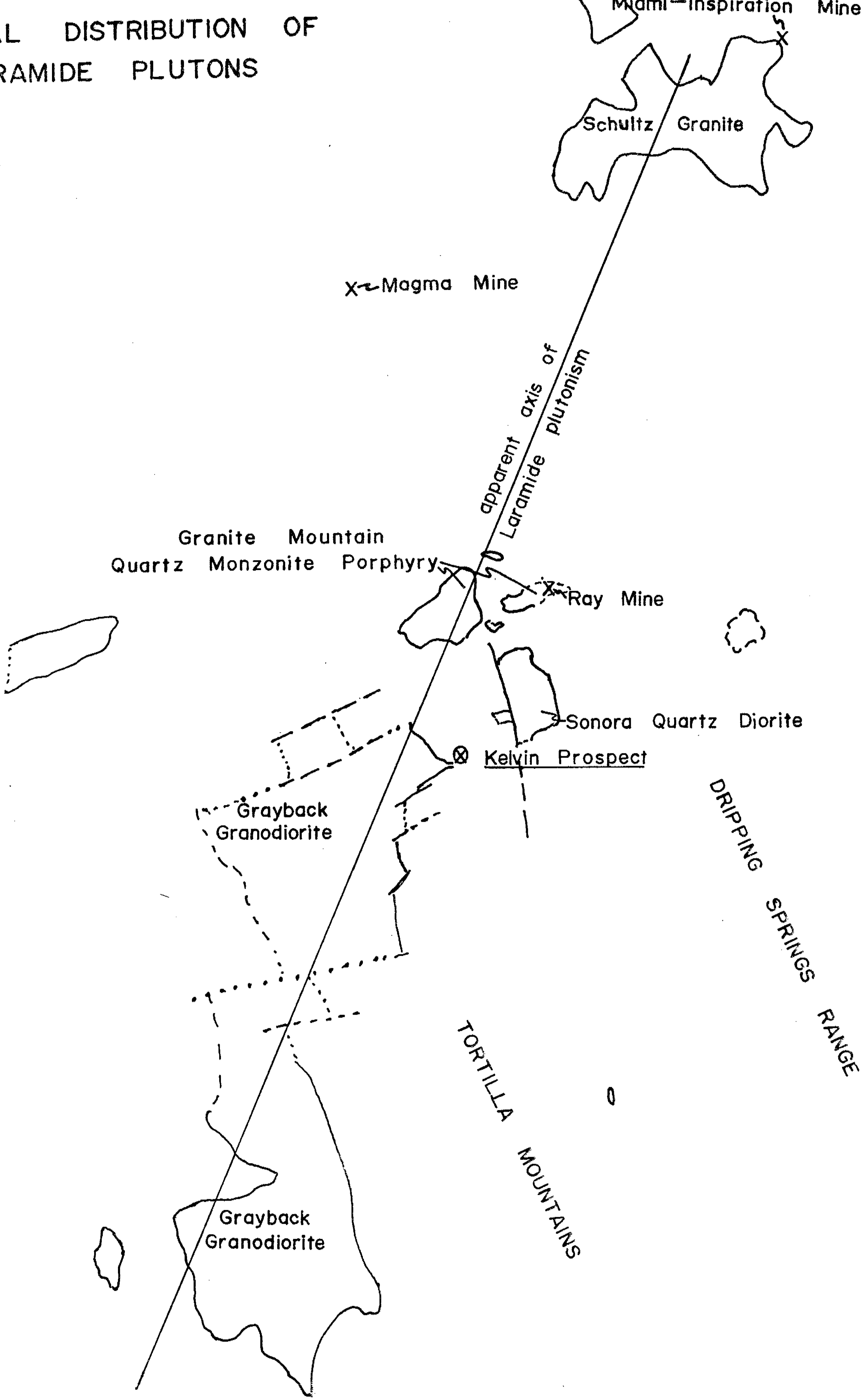
The Teapot Mountain Quartz Monzonite Porphyry is also apparently younger than the mineralization at Ray, although veinlets of pyrite and chalcopyrite occur in the Teapot pluton in the Red Hill area northwest of the mine. Metz and Rose (1966), who described this mineralization, believed that it was representative of a later, weaker period of metallization. Pyrite crystals and casts were noted in the Teapot Mountain Porphyry in the southwest corner of section 8, T. 4. S. and R. 13 E. of the Kelvin prospect but no chalcopyrite was found.

Comparison and relationships of the Laramide intrusive rocks. This study, and other available information, suggests that many of the Laramide intrusions in this region could have a common, differentiating magma source. Figure 9 is a sketch of the major Laramide plutons in the general region of this study. The oldest Laramide intrusions are the rhyodacite and quartz diorite plutons which are generally low in potash feldspar. The largest of these is the Sonora Quartz Diorite just south of the Ray mine. Samples from this pluton and another pluton about 13 miles to the south in the Copper Hills area east of Crozier Peak were dated by Damon (1970, 1964) at 69 and 68 million years, respectively, using the K-Ar method on biotite.

The rhyodacite porphyry occurs principally as steeply dipping, east- to northeast-trending dikes which commonly extend for miles. A few of these dikes cut the Sonora Quartz Diorite, indicating an age younger than 69 million years. However, they were not seen to penetrate Laramide plutons dated at 63 million years. It is likely that the dikes have varying ages and may represent a continuum of igneous activity. They vary texturally from an aphanitic porphyry to a very coarse-grained, phaneritic porphyry in which the phenocryst content composes as much as 70 percent of the rock. Estimates of the potash feldspar content, by both visual estimates in the field and by point-counts on thin sections of selected specimens, increase with the phenocryst content of the dikes. A few dikes, which are tentatively described as quartz latite porphyry, penetrate the Grayback Granodiorite batholith and although they are described under a separate heading, they may represent a relatively young stage of Laramide activity in this area.

The Grayback Granodiorite and the Granite Mountain Quartz Monzonite Porphyry have both been dated at 63 million years by Damon (1970) and by Creasey and Kistler (1962) respectively; Teapot Mountain Quartz Monzonite Porphyry is found fringing both intrusions. These facts, when considered with the physical similarity and the proximity of the granodiorite batholith and the Granite Mountain stock, indicate that they are both outcrops of the same batholithic mass. The Ray porphyry copper mine is located at the extreme northeastern point of the composite Grayback-Granite Mountain mass.

REGIONAL DISTRIBUTION OF LARAMIDE PLUTONS



GURE 9

It is also interesting to note that the Lost Gulch Quartz Monzonite at the Castle Dome and Copper Cities mines north of Miami, and the Schultz Granite southeast of Miami, are on line with the long axis of the Grayback Granodiorite batholith as indicated in Figure 9. Like the plutons in the northern Tortilla Mountains, the Laramide intrusions in the Globe-Miami mining district are controlled by east-northeast-trending structures and, similarly to Ray's position on the Grayback batholith, the Miami-Inspiration porphyry copper mines are located at the northeastern tip of the Schultz granite stock. All of the known disseminated mineral deposits in the Globe-Miami district occur north of the Schultz Granite, and none is known along the southern margin of the stock.

This can be explained by extending the Laramide tectonic pattern delineated in the Tortilla Mountains northward into the Globe-Miami district. The hypothesis involves a primary north-northeast control, which may be a major break in the crust, and a general south-to-north progression of intrusion by a differentiating magma source. However, the north-northeast trend is masked by secondary east-northeast controls which strongly influenced the emplacement of the Laramide plutons. Only the Grayback batholith reflects the proposed primary north-northeast control because it is too large to be entirely limited by the east-northeast system. The batholith is over 20 miles long and less than 10 miles wide at its widest point. The east-northeast controls are reflected, though, in abrupt changes of strike in the contact from a northerly to an easterly direction.

The north-northeast primary control is also reflected in a general regional zoning of the Laramide plutons. The younger intrusions, which were apparently more viscous at the time of emplacement, are concentrated along the north-northeast-trending long axis of the Grayback batholith. There is a general increase in the potash feldspar content of the major Laramide plutons moving northward along this line which supports the hypothesized south-to-north trend of intrusive events. The northern end of the granodiorite batholith approaches quartz monzonite in composition and in the Globe-Miami district farther north the intrusions are monzonitic to granitic. The Schultz Granite is a porphyry containing potash feldspar phenocrysts as much as five centimeters in length and its granite porphyry facies contains a much larger percentage of these phenocrysts.

K-Ar dating by Damon (1964, 1965, 1970) of the Laramide rocks in this region supports the theory of a common source for many of the plutons. The oldest dated Laramide rocks in this area are the Sonora Quartz Diorite between Ray and the Kelvin prospect, the Troy Granodiorite east of Ray, and the quartz diorite in the Copper Hills, all of which are fine- to medium-grained and deficient in potash feldspar. The Grayback Granodiorite, the Granite Mountain Quartz Monzonite Porphyry, and the Lost Gulch Monzonite all have been dated at 63 million years by Damon (1970) and by Creasey and Kistler (1962). These plutons are coarser grained, usually porphyritic, and richer in potash feldspar than the older Laramide intrusions. The Schultz Granite at Miami has been dated at 58 million years (Creasey and Kistler, 1962). This stock is porphyritic with a high potash feldspar content and its younger porphyry facies has an even greater content of potassium feldspar phenocrysts. This evidence suggests that the Laramide plutons in this region may have had a common, differentiating magma source and that the more fluid magma phases penetrated the country rock for the greatest distances to the east along open east-trending fractures, thus forming numerous diorite, quartz diorite, and rhyodacite dikes. However, a trace element study of minor constituents, additional age dating, and more extensive petrological studies of the Laramide plutons are required to evaluate this hypothesis.

## Rhyolite and Quartz Latite Porphyry

The age of the porphyry is uncertain. It occurs in east-northeast- to east-trending dikes which are younger than the Grayback Granodiorite. The dikes vary considerably in texture and composition and they may represent several intrusive pulses. The dikes are younger than 63 million years but they are probably Laramide in age. However, a mid-Tertiary age cannot be excluded.

In 1964, Watson reported mid-Tertiary quartz latite dikes in the Silver Bell Mountains, located about fifty miles southwest of the Kelvin prospect. The age of these dikes is based upon cross-cutting relationships with dated volcanic units. The quartz latite dikes have an easterly trend but their strike changes abruptly in places where the intruding magma encountered open cross-cutting fractures. A segment of one east-west dike in the Silver Bell Mountains occupies a north-trending fracture for a short distance before resuming its easterly trend. Other changes in strike are generally more oblique. Some of these dikes branch into smaller subparallel dikes.

The rhyolite and quartz latite dikes in the Kelvin area resemble those in the Silver Bell Mountains in their mode of occurrence. The strikes vary from east to northeast, but the general trend is about N. 65 E. to N. 80 E. The large dike in sections 8 and 9 of the Kelvin prospect is one of the largest Laramide dikes in the northern Tortilla Mountains. The western end, which penetrates the Grayback Granodiorite, strikes east-northeast. The strike turns abruptly to the east near the eastern contact of the batholith in section 8. In section 9, the dike branches into at least two thinner, parallel dikes, and in section 10 a dike of similar composition strikes east-northeast again just north of the Gila River. Other east-trending quartz latite dikes occasionally occupy the contact zone between the Grayback batholith and the Oracle Granite but they seldom penetrate the granodiorite.

In hand specimen, the rock appears to be a quartz latite or quartz diorite porphyry. The smaller dikes frequently have the appearance of white aplite veins. The dikes often contain minor mineralization in the form of copper and limonite staining with occasional traces of pyrite and chalcopyrite. This mineralization occurs in association with chlorite and epidote along the borders of the dikes.

A petrographic examination of a sample from the large dike in sections 8 and 9 and a second sample from a dike two miles south of the prospect revealed intensive alteration, making classification of the rock difficult. The first specimen exhibited rounded quartz dipyramids and relic sericitized feldspar phenocrysts in a quartz-sericite groundmass. The quartz crystals averaged two to four millimeters in diameter and the feldspar phenocrysts were as much as one centimeter long. In the other specimen, the feldspar phenocrysts showed incipient sericitization but a number of the larger crystals were clearly identified as orthoclase. The groundmass was intensely sericitized.

The quartz latite in the Kelvin area is probably a late stage phase of the Grayback Granodiorite. However, the dikes are similar in many respects to those in the Silver Bell Mountains which cut mid-Tertiary volcanic rocks.

## Basic Hypabyssal Intrusive Rocks

This study indicates that there are two fairly distinct groups of basic hypabyssal intrusive rocks in addition to the Precambrian diabase. A more detailed study might prove that they represent two different periods of igneous activity and additional subdivisions may be possible. These younger intrusions have frequently been confused with the Precambrian diabase.

Petrographic examinations of samples from the Kelvin prospect and general observations of the basic intrusions in this region suggest that there are at least two general varieties of post-Paleozoic basic hypabyssal rocks. One group is andesitic, although both the texture and composition are variable, and hornblende is a common constituent, as is andesine. In some varieties which cut the Grayback Granodiorite as flat-lying dikes and sills, hornblende occurs abundantly as needle-like phenocrysts in a fine-grained, greenish groundmass. In other varieties, white subhedral plagioclase phenocrysts measuring less than one centimeter in length are abundant.

The greenish color of these rocks is due to chlorite disseminated through the groundmass and, in a few outcrops, phenocrysts are entirely lacking. These rocks may correspond to the Miocene volcanic episode although some varieties could be Late Cretaceous in age.

The second group is basaltic but it also is variable in texture and composition. Many varieties are indistinguishable in hand specimen from the aphanitic and very fine-grained andesite intrusions. However, the basalts are easily identified microscopically by their labradorite and pyroxene content. These two minerals are the principal constituents with minor quartz, magnetite, and potash feldspar occurring in some varieties. A few of the basalt intrusions contain scattered phenocrysts of plagioclase or pyroxene. The basalts may correspond to either Miocene or Pleistocene volcanism. Basaltic rocks composed largely of labradorite and augite were reported by Short in 1943 along the Magma and Concentrator faults and as flows resting on an eroded dacite porphyry surface near Superior, Arizona.

## Whitetail Conglomerate

The Whitetail Conglomerate consists of coarse fanglomerate containing subrounded fragments up to a foot in diameter. It is very similar to the Gila Conglomerate and would be indistinguishable from that unit were it not for the intervening dacitic ash-flow tuffs. The Whitetail was described by Ransome (1903) near the Continental mine northwest of Globe, Arizona. Recent drilling through the volcanic rocks between Superior and Miami, Arizona has shown conglomerate beds to be interbedded with dacitic ash-flow tuffs.

The texture and composition of the Whitetail are generally variable. It ranges in color from light gray to rusty red and is normally composed of debris of local origin which was deposited in topographically low areas. In some places, such as beneath South Butte west of the Kelvin prospect, the conglomerate is composed of rather angular, stony detritus with a tuffaceous matrix. In contrast, the Whitetail Conglomerate at Copper Butte, which is located between Ray and the Kelvin prospect, is made up of imperfectly rounded fragments of limestone, chert, and other rocks in a limonitic matrix. The limestone and chert pebbles here occasionally carry enough oxidized copper to constitute ore. The Copper Butte area is currently being explored by Kennecott Copper Corporation.

The angularity of much of the detritus and the presence of limestone pebbles indicate rapid deposition in an arid climate with relatively little chemical weathering. Based upon the physical history of the region and its relation to the overlying ash-flow tuffs, the Whitetail Conglomerate is presumed to have been deposited during the early Miocene or the Oligocene, although a somewhat greater age cannot be disproven. The Whitetail and Gila Conglomerates probably represent a continuing depositional process throughout most of the middle and late Tertiary whose geological record was interrupted by widespread Miocene volcanism.

## Tertiary Volcanic Rocks

Much of the Tertiary volcanism in this area occurred during the Miocene. At one time, most of the Globe-Ray-Superior area must have been covered by thick dacite ash-flow tuffs which have been dated at 19.5 million years by the K-Ar method, as reported by Nelson in 1966. Although much of the dacite has been eroded away, a large area between Miami and Superior remains covered. Scattered outcrops may be found over an area of approximately 1500 square miles which extends roughly from Apache Junction east to Globe and from the Gila River north to Roosevelt Lake. The thickness of the ash-flow sheet near Superior now exceeds 1000 feet in places.

The dacite consists of an undetermined number of individual ash flows which generally constitute one simple cooling unit. The top and bottom portions are unwelded while the middle section has been partially or completely welded. The lower flows contain abundant rock fragments picked up from the surface upon which they were extruded. Higher in the section, lithic fragments constitute only a small percentage of the rock. The phenocryst content is relatively uniform comprising between 30 and 50 percent of the dacite. Plagioclase is the most abundant phenocryst, with lesser amounts of quartz and biotite.

The area north of the Gila River and south of Superior contains a number of compound vents which were not examined in detail. They are generally composed of rhyolite flows and plugs with accompanying tuffs and tuffaceous sediments that predate the dacite ash-flow tuffs. Since the primary objective of this investigation is to study the Laramide mineralization on the Kelvin prospect, no attempt was made to differentiate the Tertiary volcanic units in the reconnaissance mapping.

## Gila Conglomerate

The Gila Conglomerate is a fluviolacustrine deposit which was first described by Gilbert in 1875. Typically, it consists of well-rounded to subangular pebbles, cobbles, and boulders in a moderately- to well-consolidated sandy matrix. The Gila near Ray is an unusually hard and well indurated conglomerate that eroded into steep bluffs and rounded towers of which Big Dome is a notable example (Fig. 10).

Toward the center of the valleys, the Gila grades into sandy or silty gypsiferous deposits of the playa facies. This facies is poorly consolidated and is usually covered by reworked stream gravels and sediments. In some reports, these younger sediments are included in the Gila. The lower portions of the Gila Conglomerate contain abundant volcanic debris and occasional flows of rhyolite tuff. The thickness of the Gila ranges up to thousands of feet in the deeper basins. Exposures are generally poor but bedding in the well-indurated rock at Ray is essentially horizontal. The Gila is late Tertiary in age and its similarity to the Whitetail Conglomerate suggests that the two units may have been deposited as a continuous sequence but interrupted by volcanic ash flows during the Miocene.

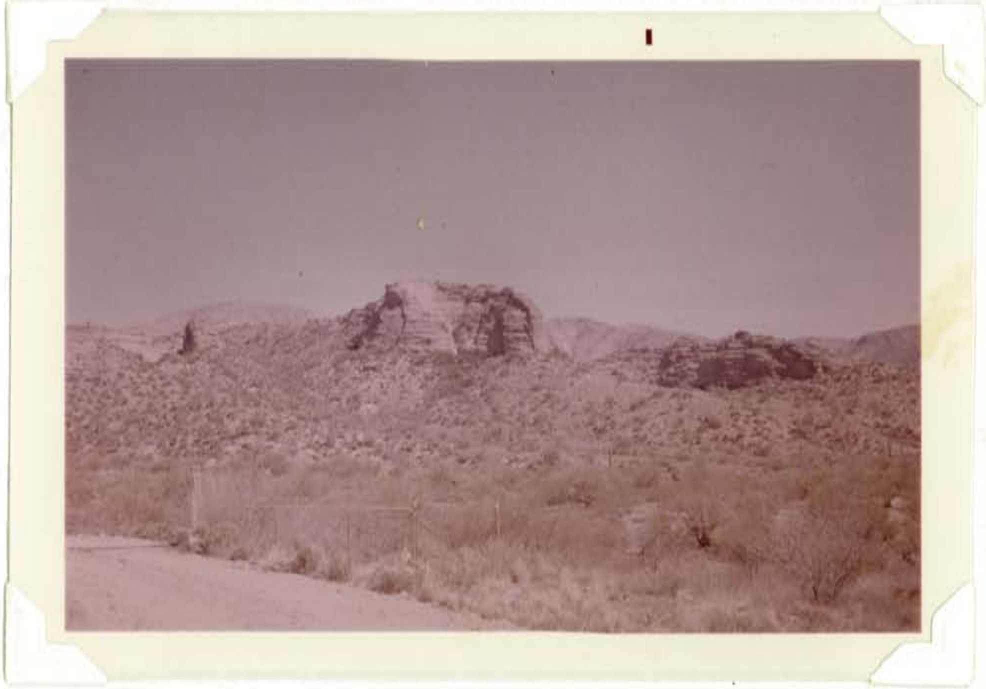


Figure 10. Photograph of Gila Conglomerate bluffs. Steep, resistant bluffs of unusually hard, well indurated Gila Conglomerate are common in the Ray-Kelvin area.

## Quaternary Surficial Deposits

Alternating lenticular beds of coarse, unconsolidated conglomerate and finer grained clastic sediments cover much of the surface in the central valleys. These clastic deposits are often included in the Gila Conglomerate but they differ from that unit in two respects: 1) they are not consolidated, and 2) they have been formed largely by intermittent reworking of the older Gila Conglomerate. There is a general lack of stratification within the beds and these recent deposits were observed occupying stream channels cut into the harder Gila Conglomerate near Ray.

Pediment gravels cover much of the surface in the prospect area. These are especially pervasive west of the prospect where they cover much of the Grayback batholith. Near Kearny, and elsewhere, the Gila River has truncated extensive pediment surfaces at the base of the Tortilla Range.

# STRUCTURE

## Regional Structures

The Kelvin prospect is located on the northeastern edge of the Florence uplift. The uplift appears to be bounded on the east by a major structural hinge that passes south from Superior down the Gila and San Pedro river valleys along the eastern flank of the Tortilla Mountains. It is marked by large fault blocks as much as one or two miles long which have been uplifted and tilted to the west. Several blocks have been rotated 90° so that Apache beds of Precambrian age now have a vertical dip. This hinge zone is well documented by Short and others (1943). It appears to be part of a major lineament structure which extends past Bisbee into Mexico. Jerome also lies along the same line to the north but this may just be a coincidence.

The Tortilla Mountains may be bounded on the north by a major fault system, striking between N. 50° E. and N. 70° E. This system could have originated as a right lateral wrench fault but subsequently there has been substantial vertical displacement. The break is not evident east of the structural hinge. However, in this area it may be concealed beneath several thrust plates such as the Emperor and Empress thrust faults which are exposed in the Ray mine.

Geological evidence indicates that both the east-northeast and north-northwest fault systems have been recurrently active since sometime during the Mesozoic Era. Both the Apache group and the Paleozoic carbonate strata have been eroded from the uplifted western block of the structural hinge, and Miocene ash-flow tuffs rest directly on the Precambrian basement south of Superior. This suggests a Mesozoic age for the greatest movement on the hinge. However, Schmidt (1971) reported tilted beds of Whitetail Conglomerate that indicate activity during the middle and late Tertiary. The detailed structure of the hinge is further complicated by the

Concentrator fault and its branches which also trend north-northwest. This fault existed prior to the Laramide mineralization of the Magma vein but there has also been substantial displacement along the fault during the Tertiary. The fault is currently active and has caused some mining problems in the Magma mine at Superior.

The proposed east-northeast-trending break at the north end of the Tortilla Mountains is probably also Mesozoic in age but its history and importance are uncertain. The existence of this break is further indicated on the magnetic contour map of Arizona which shows a major magnetic discontinuity across the north end of both the Tortilla and the Dripping Springs Mountains. Most of the suspected right-lateral displacement is probably pre-Laramide. Many other faults with this trend in the Tortilla Mountains are intruded by Laramide dikes and occasionally by Cretaceous andesite dikes. In addition, the Emperor and Empress thrust faults at Ray, which could be related to deeper wrench faults, are largely pre-mineralization structures. There has also been vertical displacement along the wrench fault accompanying the Florence uplift during the Tertiary. Miocene volcanic rocks generally occur in the northern block of this fault.

The presence of thrust faults in the Pearl Handle pit at Ray supports the existence of nearby wrench faulting since, theoretically, thrusts would be expected to cap wrench faults where the vertical component is so reduced that it becomes the minimum stress axis. It has been generally accepted that southern Arizona has been subjected to compressive stress oriented in an east-west direction. If the stress were great, vertical wrench faults with strikes at about $30^{0}$ to the maximum east-west stress axis should have developed at a depth where loading is sufficiently great so that the north-south direction will correspond to the minimum stress axis. At shallow depths, where the vertical component is the minimum stress axis, gently dipping faults (thrusts) striking north-south should have developed.

It is significant that the Emperor and Empress thrust faults are recognized only in the Pearl Handle pit which is located in the lowest part of the valley separating the Tortilla and the Dripping Springs Mountain Ranges. The thrusts appear to dip beneath the Dripping Springs Range to the east and they are probably truncated by the north-northwest-trending structural hinge which passes down the west side of the valley. The thrusts seem to be much larger and more extensive than past studies have shown. It is possible that the entire Dripping Springs Range may be part of the upper plate of a major thrust fault. Thrust faults could also underlie the Tortilla Mountains but it is more likely that erosion has proceeded to such a deep level in the elevated block that the upper plates of the thrust faults have been largely removed. There are, however, numerous flat-lying andesite, hornblende andesite, and basalt dikes exposed in the Box O and Donnelly washes located about five to ten miles west and southwest of the Kelvin prospect.

## Structural Controls of Laramide Plutonism

The east- and east-northeast-trending systems of faults are the most obvious structural controls of Laramide intrusions. Numerous Laramide dikes with this trend occur throughout the Dripping Springs Range and the northern Tortilla Mountains. The strikes of individual dikes vary somewhat between east-west and N. 50° E. but very few of these dikes have strikes outside of this range. The east-northeast pattern is also reflected in the Granite Mountain Porphyry and the Schultz Granite. The Schultz Granite, described by Ransome (1919) and by Peterson (1962), occurs south of Miami, Arizona, as a chonolithic stock. The long axis of the stock strikes about N. 70° E. and Laramide dikes in the Globe-Miami district, located on the north side of the pluton, have a parallel trend. The Granite Mountain Porphyry at Ray already has been shown to have a similar trend. Rehrig and Heidrick (1971) have also noted the recurrent association of the east-northeast system of faults and dikes with several other Laramide stocks in southern Arizona.

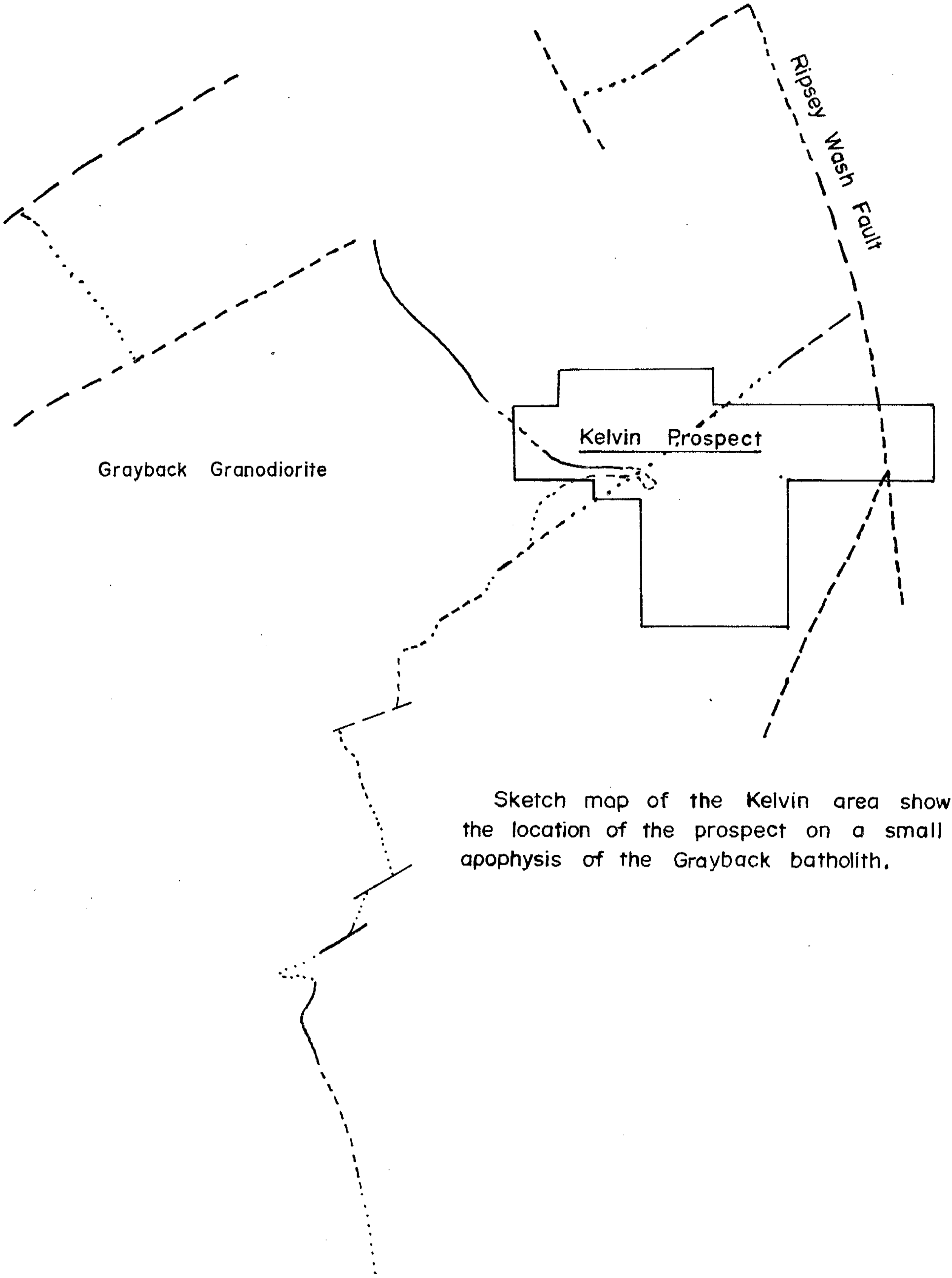
Although the Laramide fabric of the region is east- to east-northeast-trending, Figure 9 shows the concentration, along a hypothetical line trending north-northeast, of most of the major Laramide plutons, including the Grayback Granodiorite, the Granite Mountain Porphyry, the Schultz Granite, and the Lost Gulch Quartz Monzonite. The line also coincides with the long axis of the Grayback Granodiorite batholith. Although there is little proof, Laramide magmas may have risen along a major deep-seated break trending north-northeast. The more fluid magma penetrated the surrounding territory near the surface through the open system of east-northeasterly-trending fractures and faults. However, the more viscous, porphyritic magmas and the larger magma masses were restricted to the vicinity of the north-northeasterly break which was their source. This hypothesis is further supported by the shape of the Grayback batholith. The batholith is about eighteen miles long and only about five or six miles wide, on the average, and its long axis trends about N. 25° E. There are several apparent right lateral displacements of the batholith along east-northeast-trending faults as is indicated in Figure 11. However, careful examination of these areas showed that the faults are principally pre-Laramide and that the granodiorite intruded the two fault blocks of each fault to different distances, giving the appearance of lateral offset. This is accentuated by subsequent vertical displacement on the east-northeasterly faults. Therefore, the influence of this fault system over the emplacement of the granodiorite was extensive, and the hypothetical north-northeasterly control is still apparent only because of the large volume of the magma mass.

There is a growing body of evidence which indicates that the formation of many, if not all, of the porphyry copper deposits in the Southwest occurred at very shallow depths. For example, the mineralizing porphyry in the Silver Bell mine described by Kenyon and Courtright (1966) northwest of Tucson, Arizona is virtually surrounded by contemporaneous Cretaceous volcanic rocks. The Pima-Mission mine described by Kinnison (1966) south of Tucson is located in carbonate strata which have probably never been buried to any great depth. There also appears to be a moderate correlation between Laramide porphyry copper deposits and nearby Cretaceous volcanism. The mineralizing porphyry intrusions may represent the roots of Cretaceous volcanic centers where the overlying volcanic piles have been largely removed by erosion. Generally, many of the characteristics of porphyry copper deposits, both physical and chemical, are most easily explained in a shallow environment.

If this model is valid, it would have a significant impact on the exploration criteria for porphyry copper deposits. Past exploration has heavily emphasized the importance of porphyritic intrusions, varying in composition from granite to quartz diorite and more recently of alteration zoning. Now, most of the exposed plutons of this nature have been extensively explored. However, deep exploration in the future around volcanic centers, which are contemporaneous with the major ore deposits in that region, may prove fruitful. There is nothing new about the importance of volcanic activity in mineral deposition, but it is only in recent years that volcanism has been given much emphasis in porphyry copper exploration.

If porphyry copper deposits are basically shallow phenomena, this would help to explain the distinction between mineralized and barren porphyry intrusions of the same age and lithology. The model would also be important in evaluating porphyry copper prospects such as the Kelvin property. The barren nature of many Laramide porphyries in southern Arizona may be due, at least partially, to a deep level of erosion or to a deep level of emplacement of the porphyry. This appears to be the case on the Kelvin prospect. The region appears to be quartered by two major fault zones. The Ray mine and the ore deposits in the Globe-Miami mining district are located in the downthrown block of both fault zones and the level of erosion is consequently relatively shallow. The Kelvin prospect is located in the upthrown block of both faults, and erosion has proceeded to a very deep level, cutting deeply into the

# SKETCH OF LARAMIDE INTRUSIVE MASSES IN THE KELVIN AREA



Sketch map of the Kelvin area showing the location of the prospect on a small apophysis of the Grayback batholith.

FIGURE 11

Grayback batholith which is closely related to the Granite Mountain Porphyry at Ray. As a result, there is only scattered minor mineralization known in the northern Tortilla Mountains. Any important mineralization which might have been associated with the Grayback batholith probably has been eroded away.

This model for the shallow formation of porphyry copper deposits may also help to explain why many deposits occur within the porphyry intrusion and a few, such as Ray, are located adjacent to the mineralizing porphyry. Both the chemical characteristics and the physical preparation of the wall rock adjacent to the mineralizing porphyry intrusive masses may account for extensive wall rock mineralization at some mines. Nevertheless, this does not explain the difference between mineralized and unmineralized porphyry intrusions associated with porphyry copper deposits. For instance, at San Manuel Creasey (1965) and Thomas (1966) show that the great bulk of the ore rock is Laramide quartz monzonite porphyry. On the other hand, Metz and Rose (1966) state that the Granite Mountain Quartz Monzonite Porphyry, which is the mineralizing porphyry at Ray, seldom constitutes ore even in the most richly mineralized portions of the deposits. Those porphyry copper deposits in which the porphyry intrusion is extensively mineralized may have formed at very shallow depths. In a rapidly cooling magma mass near the surface, an intensive system of crackling could have developed due to uneven cooling. This crackling would have allowed mineralizing fluids to collect and to permeate the intrusive mass. Those deposits, such as Ray, in which the porphyry is very weakly mineralized may represent a somewhat deeper environment of formation where the magma cooled more slowly and uniformly without the development of intensive crackling. Where the wall rock is an exceptionally favorable host rock, such as the diabase at Ray, mineralization may still occur adjacent to the mineralizing porphyry, but intensive physical preparation of the country rock is necessary. At Ray, the intersection of at least two major fault systems appears to have been largely responsible for ground preparation in that deposit.

In summary, the barren character of many of the Laramide porphyries in southern Arizona may be the result of either a deep level of erosion or a relatively deep level of emplacement of the pluton. Porphyry copper deposits located on the margins of barren or weakly mineralized porphyries may represent the deepest levels at which porphyry copper mineralization can be formed due to physical and chemical limitations. In these deposits, the main intrusive mass may have been relatively impermeable to mineralization fluids, but ideal wall rock conditions allowed the formation of an ore deposit adjacent to the mineralizing pluton. Most porphyry copper deposits probably formed at very shallow depths where rapid cooling produced a system of "crackle fractures" in the intrusive mass. In these deposits, the wall rock may or may not be mineralized, depending upon its chemical and physical nature.

## Structural Controls of Miocene Volcanism

The Miocene volcanic rocks are generally restricted to the northern block of the inferred east-northeast-trending wrench fault which bounds the Tortilla Mountains on the north. This probably reflects prior uplift on the southern block which limited the southerly movement of the rhyolite and dacite ash flows. There are also a number of compound fissures and vents distributed in a broad belt as much as eight miles wide and extending from the Gila River to several miles north of Superior, Arizona. The general trend of these mid-Tertiary fissures and vents is north-south and cuts across the Mesozoic fabric of the region.

Breccia pipes and dikes composed of Precambrian schist fragments in a hematitic matrix are associated with the mid-Tertiary volcanism in several areas. The pipes were first noted in an area about seven miles northwest of Superior, Arizona, which is outside the study area. There are at least two dozen breccia pipes at this location scattered around a hypabyssal rhyolite pluton two miles long and a mile wide; all the pipes occur within the Pinal Schist of Precambrian age (making a positive age determination of the pipes in the field impossible). However, identical injection breccias into Miocene volcanic rocks occur on the north side of the Gila River across from Cochran Crossing about six miles west of the Kelvin prospect. The breccia, which has been injected into Miocene rhyolite ash flows, is composed of Precambrian schist fragments in a red hematitic matrix. No volcanic fragments are present in the breccia.

## Detailed Structure of the Kelvin Prospect

Prominent east-, northeast-, west-northwest-, and north-trending faults and fissure zones are frequently occupied by dikes in the vicinity of the Kelvin prospect. Offsets and breaks in most of the dikes reflect repeated movement along the different fault systems.

The east-trending system is apparently the oldest set of fractures on the prospect. It is marked by numerous small Precambrian aplite-pegmatite veins composed of potash feldspar and quartz with subordinate black tourmaline and muscovite mica. These fractures were apparently reopened and intruded by granodiorite and quartz diorite dikes during the Laramide orogeny.

A system of vertical faults and fractures with strikes ranging from N. $45^o$ E. to N. $75^o$ E. also has been intruded by numerous Laramide dikes; this system is usually difficult to distinguish from the older east-trending fractures. Still, there seem to be at least two differences between the two systems. First, the Precambrian aplite-pegmatite veins have easterly strikes and very few strike east-northeast to northeast. Secondly, the east-trending fractures appear to have relatively small displacements, whereas the northeast- and east-northeast-trending shears frequently have large displacements. The stresses responsible for the development of the east-northeasterly system of shears appear to have also caused the reopening of many east-trending Precambrian fractures.

The Kelvin prospect is bisected by a system of closely spaced northeast-trending faults and there is very little correlation in the geology between the opposing fault blocks. The faults are poorly defined on the prospect but they are more conspicuous several miles to the southwest where they have caused an apparent right lateral displacement in the eastern contact of the Grayback Granodiorite batholith. However, the reconnaissance mapping showed that these faults are probably pre-Laramide structures with post-Laramide vertical displacement. One of these shear zones was apparently responsible for the extensive caving which occurred in drill hole number two between 300 and 500 feet.

The granodiorite apparently intruded the northern block of the northeast-trending fault for a much greater distance to the east by means of a stoping process. Several large blocks of Precambrian Oracle Granite, measuring up to 100 yards in diameter, occur within the granodiorite, and numerous narrow dikes of granodiorite penetrate the adjacent Precambrian granite. Many of these dikes are parallel to the granodiorite batholith contact and other vertical dikes extend away from the contact at about 90 degrees to the contact. Apparently, as blocks of Precambrian granite were broken off by the advancing magma, they sank to lower levels in the molten mass where they may, or may not, have been assimilated. Partial assimilation of this material could account for the change in composition in the granodiorite in the vicinity of its northern contacts.

Most of the east- to northeast-trending faults and fracture zones are obscure and ill defined within the Grayback batholith. Locally the fracture zones are marked by Laramide quartz or aplite veins as much as several inches wide but usually there are only a few chlorite-stained fractures. One exception is a large east-trending quartz latite dike which passes through sections 8 and 9 of the Kelvin prospect. This dike is first exposed several miles to the west near the center of the Grayback batholith. Its strike and dip are about N. 70° E. and vertical. Near the granodiorite/granite contact in section 8, the strike changes abruptly to due east and in section 9, the dike branches into several smaller parallel dikes which disappear in the vicinity of Ripsy Wash. However, a dike of similar composition strikes N. 70° E. just north of the Gila River in section 10. This dike reflects the influence of both the Mesozoic east-northeast trend and the reopened east-trending Precambrian fractures.

A set of fissures trending west-northwest has also been identified on the Kelvin prospect. The fissures appear to be the most important control of mineralization on the property but they are only locally significant. They appear to be tensional fissures formed as the result of lateral displacement along the northeast-trending shears which bisect the property. The fissures can be traced eastward to Ripsy Wash in section 10. They strike about N. 65$^0$ W. at their western end near the northeast-trending fault zone, but they swing to an easterly trend near Ripsy Wash. The change in strike probably reflects the influence of the reopened east-trending Precambrian fractures. Mineralization is concentrated near the western end of the fissures and diminishes steadily to the east.

There are numerous segments of a north-trending dike system composed of diabase and/or basalt in section 8 of the Kelvin prospect and in the area to the south. This fracture system appears to be younger Precambrian in age since the dikes have been cut into short segments by most of the other fault systems. This precludes a Tertiary age and makes a Cretaceous age unlikely. These are the only periods, other than the later Precambrian, in which basic volcanic rocks and hypabyssal intrusions are known to have been emplaced. About ten to twenty miles south of the Kelvin prospect, several of these north-trending dikes may be traced continuously for several miles.

In summary, the principal Precambrian structural trends are north-south and east-west, whereas the principal Laramide or Mesozoic trends are east-northeast and north-northwest. This may reflect a 20$^0$ counterclockwise rotation in the stress field. However, more detailed investigations of Precambrian structures in southern Arizona are needed to verify this observation.

# MINERALIZATION

## Surface Mineralization

Traces of copper mineralization are abundant throughout much of the northern Tortilla Mountains but they are generally stronger and more numerous in the Oracle Granite along the eastern margin of the Grayback Granodiorite batholith. Copper carbonates and limonite staining with minor chrysocolla occur along east-northeast- to northeast-trending shears and in east-trending fracture zones. Although the two systems are difficult to distinguish, the east-trending fractures zones are probable Precambrian structures that were reopened by activity along the northeast-trending shears during the Laramide orogeny. Generally, fractures with more easterly trends are more intensely mineralized and conversely, the northeast shears are relatively barren.

The mineralization that occurs along these fractures consists principally of limonite staining, specular hematite and chrysocolla stringers, green copper carbonate staining, and minor sulfides. The chrysocolla and specular hematite occur along open spaces in east-trending fracture zones in the Oracle Granite. Green copper carbonate staining with minor pyrite and chalcopyrite is common along the margins of quartz latite dikes and quartz veins of east to northeast trends. Both the fractures and the quartz latite dikes penetrate the Grayback Granodiorite in many places (plates 2 and 3). However, the degree of fracturing, the intensity of mineralization, and the size and number of the dikes are all greatly reduced within the granodiorite. Toward the center of the batholith, the fracture zones are commonly barren or they are marked only by minor chlorite, epidote, and limonite. Scattered traces of copper staining or sulfides occur along the margins of a few of the quartz latite dikes in the granodiorite.

On the Kelvin prospect, the most intense mineralization is located within west-northwest-trending tensional fissures which are indicated in the photograph in Figure 13. The Zelleweger mine is located along one of these fissure zones and the induced polarization survey, using the 500-foot dipole spacing on three center lines, indicated a shallow anomaly which is centered on a larger fissure zone 700 feet north of the Zelleweger workings. A deeper induced polarization anomaly, indicated by a 1000-foot dipole spacing, has a similar west-northwesterly trend but it is much broader. The fissures pinch and swing to an easterly trend (plate 3) on the east side of the prospect where they may have been influenced by much older Precambrian fractures. Mineralization and alteration are most intense at the western end of the fissure zones in the vicinity of several northeast-trending shears that bisect the prospect. The fissures may be tensional structures resulting from right-lateral displacements along the northeasterly shears. Weaker mineralization occurs along these shears and no tensional fissures were found in the northwest fault block. Also, iron staining and mineralization along the fissures diminish to the east and the fissures cannot be traced past Ripsy Wash.

Mineralization on the Kelvin prospect is varied. Malachite and azurite coatings up to 3/4 of an inch thick were found along fractures in the Precambrian granite, and black melanconite, which is usually mixed with limonite, gave some unexpectedly high assay results. Melanconite is a black, earthy variety of tenorite (CuO). The melanconite could not be identified visually in the field but it was detected by mixing a little powdered limonite with a few drops of dilute sulfuric acid. When the tip of a geological pick or a pocket knife was rubbed in the wet limonite, copper plated out on the iron if melanconite was present. Other forms of secondary copper mineralization that are present include chrysocolla stringers and wide-spread, unidentified copper staining in fractured areas.

Molybdenum mineralization is exposed in several shallow workings in the central portion of the Kelvin prospect. It is most conspicuous in the Johnson mine workings (Fig. 12) on the Rare Metals group of four claims, near drill hole 1, at the southern boundary of the property. Ferrimolybdite and molybdenite are the principal molybdenum minerals. Molybdenite occurs along the southern margin of the east-trending quartz monzonite porphyry dike on the southern edge of the prospect, in quartz veinlets in the same area, and in shear zones and fractures in the Precambrian granite at several locations. Ferrimolybdite was found along fractures exposed in shallow workings near both drill sites.

The richest molybdenum mineralization yet discovered is in the vicinity of the Johnson mine. The mine workings consist of two shafts (now inaccessible) which were described by Kirkemo, Anderson, and Creasey (1965). One shaft is about 60 feet in depth and the other is 84 feet deep with "...an 80-foot crosscut extending N. 15° W., and two drifts, 18 and 15 feet long extending west from the crosscut at 18 and 62 feet respectively, northwest of the shaft" (op. cit., p. 14). The country rock is Precambrian granite, which is cut by east- to northeast-trending quartz monzonite porphyry and aplite dikes as much as several feet wide. Narrow, vertical quartz veins striking N. 75° E. were encountered along the crosscut; a few of these contained pyrite, chalcopyrite, and traces of molybdenite. Molybdenite also occurred as thin seams in the gouge zones of two faults that strike east to northeast.

At least traces of disseminated pyrite and chalcopyrite occur within most of the Laramide plutons in this region as accessory constituents. In the southwest corner of section 8, T. 4 S. and R. 13 E. near the Kelvin prospect, a few small outcrops similar to the Teapot Mountain Quartz Monzonite Porphyry contain euhedral pyrite cubes. Elsewhere (most notably at the Ray mine) the sulfides occur as veinlets and disseminated grains in the Teapot Mountain Porphyry. Traces of sulfides were also noted in the Sonora Diorite south of Ray, in granodiorite dikes in section 9 of the prospect, and in a few other small plutons south of the Kelvin prospect. An area of intense disseminated mineralization measuring about 100 feet by 50 feet occurs at the eastern tip of the quartz monzonite dike in the southwestern corner of section 9 on the prospect. The dike is an extension of the Grayback Granodiorite; its tip is intensely

Figure 12. Photographs of the Johnson molybdenum workings in the southeast corner of section 8. The underground workings, now flooded, were described by Kirkemo and Anderson (1965).

fractured and the sulfide grains are more abundant near and along the fracture surfaces. No disseminated mineralization was found within the main mass of the batholith. Abundant sulfide mineralization occurs in the Oracle Granite along fissures in the Zelleweger mine and pyrite cubes up to half an inch across were found in pegmatite zones in section 8 on the Kelvin property west of the northeast-trending shears which bisect the prospect.

## Alteration

Pervasive alteration is characteristic of porphyry copper deposits in the southwest. Lowell and Guilbert (1970) have proposed a model for alteration and mineralization zoning on the basis of their detailed study of San Manuel. In general, their model appears to be applicable to most other porphyry copper deposits in southern Arizona, but there are many local complications which tend to obscure the zoning relationships.

The absence of pervasive alteration is the most negative feature of the Kelvin prospect. The Laramide dikes have undergone intensive quartz-sericite alteration, and mild sericitic and propylitic alteration also occurs locally with some sulfides along narrow fracture zones. However, the Precambrian Oracle Granite which comprises the country rock is relatively fresh. Likewise the Grayback Granodiorite in the western portion of section 8 appears to be unaltered except that there is an increase in the biotite content. The additional biotite could be of hydrothermal origin, but the restricted area involved and the absence of other alteration effects discredits the potential for a large ore body of disseminated mineralization.

## Zelleweger Mine

The Zelleweger mine is located along a west-northwest-trending fissure vein dipping steeply to the north in the western half of section 9, T. 4 S. and R. 13 E. It was patented in 1924 and gold, copper, and zinc valued at $40,000 were reportedly mined during the 1920's and early 1930's. On the surface, the vein is marked by a zone of intensive fracturing with moderate to heavy iron staining (Fig. 13). Occasional stringers of specular hematite and a little secondary copper (principally chrysocolla) are fairly abundant in the fracture zone. The vein probably terminates at its western end against the northeast-trending set of faults which bisects the prospect and can be traced for about half a mile to the east where the strike turns gradually to an easterly direction. The fracture zone ends at Ripsy Wash.

The workings consist of an adit extending 350 feet into the ridge, which is connected to two other short drifts above and below the main level by a vertical shaft which extends to the surface (plate 7). In addition to the main workings, there are a number of prospect pits and an inclined shaft elsewhere on the claim.

The principal host rock is the Oracle Granite, but the tensional fissure in which the mineralization occurs also penetrates an east-trending basic dike. The basic intrusion is not mineralized except for a few tiny veinlets of chalcopyrite and pyrite near the back of the main level. The vein, ranging from two to four feet in width, is composed of actively oxidizing sulfides with some associated specular hematite. The sulfides occur as fracture fillings and as disseminated grains in the wall rock. The walls of the tunnels are coated with chalcanthite which has been leached from the granite; the chalcanthite has been partially dehydrated in most sections of the mine, giving it a very pale blue color. Two short crosscuts on the main level show that the mineralization is mostly confined to the fissure zone and the vein appears to be pinching out near the back of the mine.

The minerals present, in order of abundance, are pyrite, chalcopyrite, bornite, secondary copper minerals including chalcanthite and chalcocite, and traces of sphalerite and arsenopyrite. Chalcocite is rare but it sometimes occurs as a coating on sulfide grains or as filling in microfractures cutting sulfide grains and

Figure 13. Photograph of the Kelvin prospect looking east showing the Zelleweger fissure vein (left center) and the larger fissure zone over which the shallow induced potential anomaly is centered (extreme left). The location of the two drill holes and the Johnson molybdenum workings are also indicated.

veinlets. The presence of dehydrated chalcanthite and small amounts of chalcocite indicate that the vein has been subjected to varying redox conditions which are related to seasonal variations in the amount of moisture present. Bornite also occurs as veins as much as one inch wide which appear to cut across other sulfide minerals. In one veinlet, both chalcocite and bornite are present in about equal proportions. Traces of gold, possibly carried by the pyrite, were reported in a few assays. Plate 7 is a map of the Zelleweger workings showing the assay results from chip samples across the drifts at regular intervals.

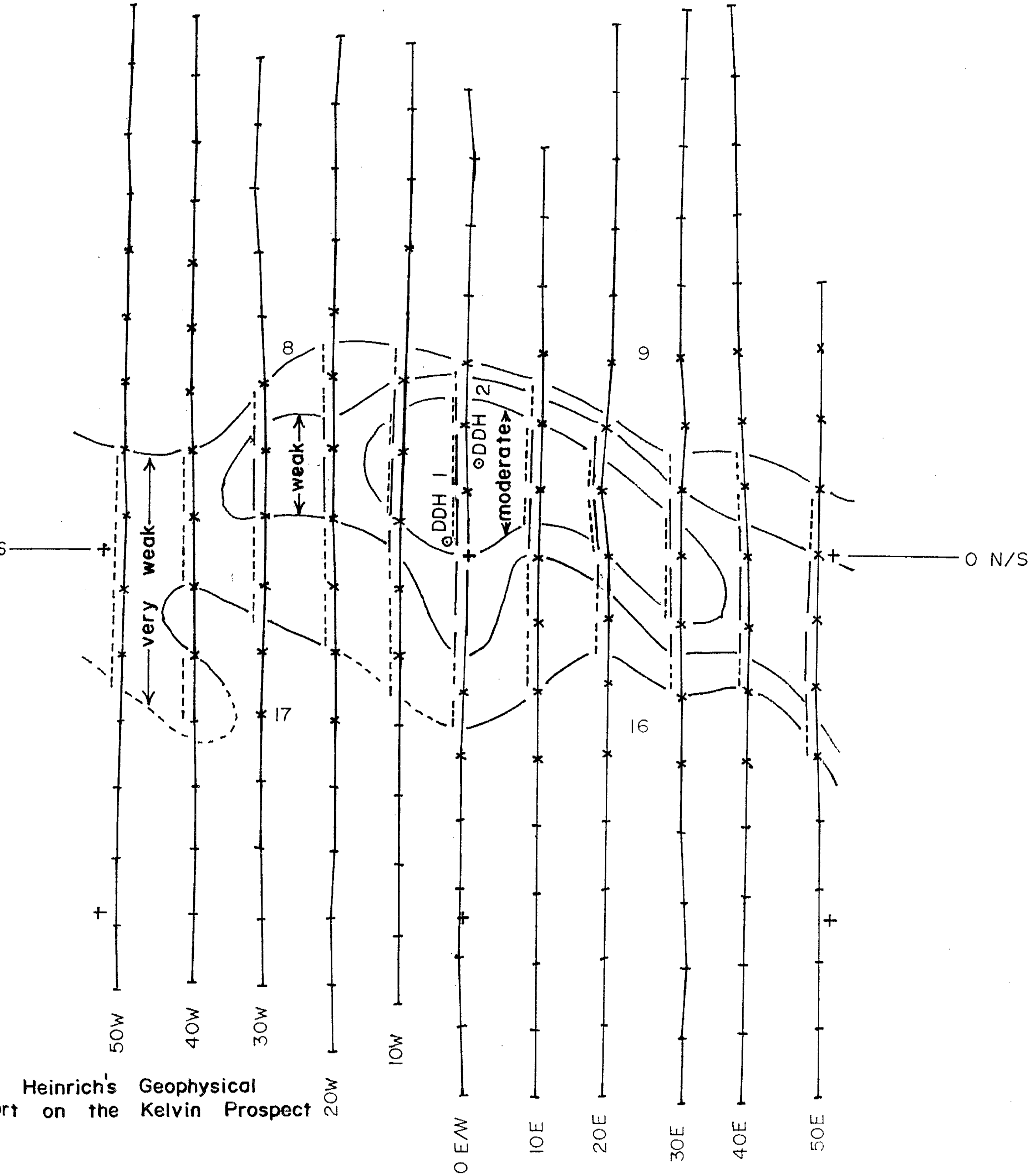
In conclusion, the principal ground preparation for mineralization was fracturing of the Oracle Granite along a tensional fissure which may be due to strike-slip movement along northeast-trending faults. This interpretation is supported by the change in strike of the fissure zone from west-northwest at its western end, in the vicinity of the northeast-trending faults, to east-west farther to the east. Preexisting Precambrian fractures may be responsible for the deflection of the fissure to an easterly trend.

## Induced Potential Geophysical Survey

An induced potential geophysical survey was conducted by Heinrich's Geoexploration Company of Tucson, Arizona. Eleven north-south lines were completed on a coordinate grid whose origin was the southwest corner of section 9, T. 4 S. and R. 13 E. The lines were separated by 1000 feet, and a 1000-foot dipole spacing was utilized on all eleven lines. In addition, a 500-foot dipole spacing was used on lines 0, 10 East, and 10 West. The dual-frequency induced potential technique was used with sending frequencies of 0.3 and 3.0 Hertz. A colinear dipole-dipole electrode configuration was employed which typically should give resolvable penetration from 300 feet to 1200 or 1500 feet in depth with the 1000-foot spacing (Fig. 14).

The detailed coverage on lines 0, 10 East, and 10 West defined a near-surface anomaly centered on the most prominent west-northwest-trending fissure. Plate 13 shows the location of this anomaly on the

# INDUCED POTENTIAL SURVEY LINES



Heinrich's Geophysical
rt on the Kelvin Prospect

URE 14

Kelvin prospect. The zone is marked for over a mile to the east of the 0 line by intensive fracturing and iron staining, some boxwork structure, and chrysocolla and hematite stringers. The chrysocolla is probably derived from oxidizing sulfides as was observed in the Zelleweger mine. The anomaly was interpreted by Heinrich's as being about 500 feet in width with the top of the anomaly being within 150 feet of the surface. The source extends to a depth of 300 or 400 feet where it weakens and merges with the broad anomaly detected with 1000-foot dipole spacing. Heinrich estimated that the source contained 1.0 to 4.0 weight percent sulfide. The depth-limited character of the source of the induced potential response, between 150 feet and 300 to 400 feet, suggests secondary enrichment. The presence of oxidizing sulfides and traces of chalcocite in the Zelleweger mine support this interpretation. Lateral resolution of induced potential anomalies is not generally possible within the dipole spacing. The thickness or inclination of a source which is thinner than the dipole spacing is difficult or impossible to determine. The width of the source of the shallow anomaly may be considerably less than the estimated 500 feet but it would have to be correspondingly richer than 1.0 to 4.0 weight percent sulfides to account for the strength of the response.

The stronger, shallow anomaly terminates in the vicinity of the northeast-trending faults. Mineralization may have preceded some of the activity along these faults. However, if the tensional fissures were formed as a result of strike-slip movement, they would not cross the northeast faults. In general, blocks separated by strike-slip faults are structurally independent and this could account for the termination of the shallow anomaly between lines 0 and 10 West.

A deep anomaly was detected on all eleven lines (Fig. 14 and plate 12). Its general trend is west-northwest and it also appears to be controlled by the tensional fracture system oriented in the same direction. Because resolution of the anomaly is poor on a 1000-foot dipole spacing, structural controls of mineralization are less certain. The stronger portion of the deep anomaly again terminates in the vicinity of the northeast-trending faults. The source also appears to be much deeper on line 20 West and successive lines to the west. The response observed on line 10 West may be a lateral effect from mineralization near line 0. This suggests subsidence of the northwest block, offsetting the source of the induced potential response. In addition, the stronger portion of the anomaly is substantially wider at its west end. This may be due to more extensive fracturing between parallel northeast-trending strike-slip faults.

## Drilling

Prior to this study, Inspiration Copper Company ran two induced potential lines across the property in 1967, and Minbanco Corporation drilled nine holes in 1968 and 1969. Minbanco used a rotary drilling rig with an air hammer, and rock-bit methods when excessive water was encountered; samples were collected from the sample trench leading to the mud pits. The results of this drilling program are inconclusive and unreliable due to extensive mixing of the samples, possible loss of ore minerals, and failure to distinguish rock types in the logs.

Tipperary Resources Corporation drilled two holes, 1500 and 1625 feet deep, as part of their evaluation of the Kelvin prospect. A Con-cor reverse circulation rig, utilizing a double string of drill pipe and a special sample catcher, was used by the drilling contractor, Elenburg Exploration, Inc. Water was pumped down the hole to the drilling bit through the outer pipe and returned to the surface carrying the rock chips up the central pipe. The sample collection system involved cycling all of the sample and drilling fluids through a rotating circular splitter which was set to retain one-quarter of the sample and fluids. The portion retained was cycled through sizing screens and into a centrifuge which recovered all of the fine particles. Due to the tendency of molybdenum to escape by suspension in drilling fluids, a Baroid molybdenum depressant was used to settle out and coagulate molybdenum particles.

The advantages and disadvantages of this type of drilling are now apparent. The Con-cor drilling rig costs much more to operate per hour than does a wire line unit due to the much higher capital investment, the need for a three-man crew, and the higher cost of bits which ranged from $50 to $300 per bit, depending on the type used. It was hoped that a faster drilling rate would compensate for these cost factors, but Con-cor drilling proved to be only slightly faster in hard granitic rocks than coring with a wire-line rig. Also, bits had to be replaced at an excessive rate, sometimes after only one to five feet of drilling.

There are a few distinct advantages to Con-cor drilling, however. With Elenburg's sampling system, 100 percent recovery was attained in highly-fractured ground where there are frequently problems with core recovery. Although mixing and contamination of the sample are major disadvantages of rotary drilling, these problems are eliminated by the reverse circulation technique. Con-cor rigs have been used successfully in the Texas sulphur fields where the rock is soft and drilling can proceed at a rapid rate. This type of drilling may have some limited use in mineral exploration in highly fractured and broken ground where good core recovery is difficult and in soft carbonates, arenites, and argillites where drilling is rapid.

Plates 10 and 11 are the logs for the two holes drilled by Tipperary Resources Corporation. The first hole, 1500 feet deep, is located in the southeast corner of section 8, T. 4 S. and R. 13 E. near the Johnson molybdenum workings. Only two short intervals of significant mineralization were encountered. A ten-foot interval with an average copper content slightly over 0.8 percent was intersected at a depth of 130 feet. A second zone of mineralization was encountered starting at 720 feet and extending to 780 feet. Copper values ranged to as much as 0.8 percent and molybdenum to as much as 0.55 percent. This interval corresponds to one of the thin, rich veins of molybdenum which were explored through two shafts near the drill hole.

Drill hole number 2, which is located approximately 1100 feet north of the first drill hole, intersected several large intervals of low-grade mineralization ranging from 0.1 to 0.3 percent copper. The mineralization correlates with fractured zones in which drilling was relatively rapid and easy. Personal observation of the drilling showed that within the mineralized intervals, zones of hard, unfractured, fresh, barren granite alternated with intensely fractured zones containing pyrite and chalcopyrite. The apparent thickness of these zones varied from 2 or 3 feet to as much as 10 feet. This pattern is partially obscured in the assay results by the use of composite samples over each 5-foot interval. It appears that the drill intersected zones of closely-spaced, steeply dipping, mineralized fractures cutting through relatively barren Precambrian granite.

An intensely fractured, barren interval was encountered between 250 feet and 400 feet. Material from this interval sloughed into the hole each time the rods were pulled so that from 50 to 200 feet of muck had to be redrilled each time in order to reach bottom. By the end of the project, an open space several yards in diameter must have been formed between 250 and 400 feet. This interval corresponds to the projected location of one of the principal northeast-trending shears which bisect the prospect.

Microscopic examination of the cuttings showed that the principal host rock is the Oracle Granite of Precambrian age which is cut by several narrow dikes of diabase, quartz monzonite, and quartz diorite. As much as one percent pyrite and chalcopyrite occurred in the mineralized intervals as open-space filling in fractures and microfractures. The pyrite frequently occurred as euhedral cubes, measuring less than 0.5 millimeters across.

# SUMMARY AND CONCLUSIONS

The purpose of this study was to evaluate the Kelvin property as a porphyry copper prospect. Prior to this work, virtually no geological data were available on the northern Tortilla Mountains in which the prospect is located. Therefore, it was necessary to prepare a reconnaissance geologic map of the region in addition to detailed geologic and geophysical studies on the prospect.

The Kelvin prospect is located on the eastern margin of a Laramide batholith similar in composition and texture to the Granite Mountain Porphyry a few miles to the northeast. Subsequent K-Ar dating and geologic mapping indicate a close genetic relationship between the two Laramide plutons. The granite Mountain intrusion is generally accepted as the mineralizing porphyry at the Ray mine. No significant mineralization or alteration was found in or along the margins of the batholith which is referred to as the Grayback Granodiorite. Field evidence suggests that emplacement of the batholith occurred by means of a stoping process from south to northeast and that Ray is located on the extreme northeastern tip of the composite Grayback Granodiorite-Granite Mountain Porphyry mass.

The northern Tortilla Mountains are on the upthrown block of a major structural hinge which passes south-southeast from Superior down the San Pedro River Valley along the eastern flank of the Tortilla Mountains. Erosion has proceeded to a very deep level west of this hinge line, possibly removing any ore deposits which may have been associated with the Grayback Granodiorite batholith. Likewise, the portion of the Granite Mountain Porphyry cropping out in the west block of the hinge zone is fresh and barren. In contrast, the Ray porphyry-copper mine is located in the east block of the hinge zone where the depth of erosion is much less.

Minor pyrite, chalcopyrite, and molybdenite are disseminated through several Laramide dikes on the Kelvin prospect, but the most important mineralization occurs along several narrow, east-trending fissure zones in section 9. However, the Oracle Granite between these fracture zones is fresh and generally barren. This observation is verified in drill hole number 2, which was located near the center of the induced potential anomaly that was detected using a 1000-foot dipole spacing. The drill hole encountered sub-economic sulfide mineralization confined principally to fracture zones in relatively fresh, barren Oracle Granite. Information from this drill hole satisfactorily accounts for the induced potential response.

A small copper deposit may exist along the largest fissure zone located about 700 feet north of the Zelleweger mine. Based upon the geophysical survey and detailed geologic mapping, the exploration target in this fissure would be in excess of 2,000,000 metric tons of 2.5 percent copper. An upper limit to the tonnage cannot be determined due to uncertainty as to the length and width of the source of the induced potential anomaly. The grade estimate is based on an average obtained from channel samples in the Zelleweger mine.

This fissure is marked on the surface by intensive fracturing, extensive hematite and limonite staining with some silica boxwork, specular hematite and chrysocolla stringers, and minor copper staining. The limonite generally contains melanconite, an impure form of tenorite (CuO). The induced potential survey, using a 500-foot dipole spacing on lines 0 and 10 East detected a depth-limited anomaly centered on this fissure zone. The nature of this anomaly suggests supergene enrichment. This interpretation is supported by observations in the Zelleweger mine, which is located along a much smaller fissure zone. There was no identifiable induced potential response over the Zelleweger fissure, but actively oxidizing sulfides were found along the entire length of the workings. Channel samples collected across the tunnels at regular intervals averaged 2.5 percent copper over a length of 160 feet (plate 7).

In conclusion, it appears improbable that a major porphyry deposit exists in the vicinity of the Kelvin prospect. The east-trending fissure zone located 700 feet north of the Zelleweger mine in section 9 appears to be the only viable exploration target in the area. This deposit probably never would support more than a relatively small mining operation but, because of the potential grade of the ore, it is recommended that one or two inclined holes be drilled to test the fissure between 200 and 300 feet below the surface.

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This thesis is accepted on behalf of the faculty of the Institute by the following committee:

Charles E. Chapin

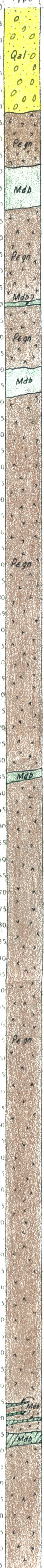
Robert H Weber

Gale K. Billings

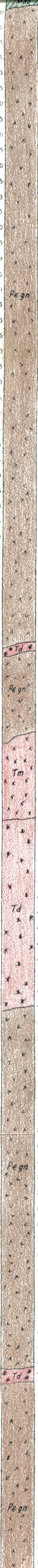
Date 5/3/74

# KELVIN PROSPECT - HOLE No. 2    TD 1625'    Mar. 12, 1970

Location: 1260' FSL & 150' FWL of Section 9
T 4 S, R 13 E, PINAL CO., ARIZONA

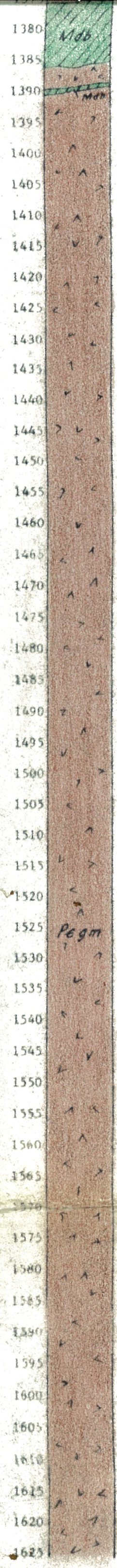


| Description | Cu | Mo | Cueq |
|---|---|---|---|
| Alluvium | | | |
| granite: 60% qtz, 20% chlor, 20% orth, tr mal. stn | .34 | | |
| aa numerous micro fract fill w/chlor | .03 | | |
| gran w/numerous fracts Fe stn, tr py | .03 | | |
| gran aa to 49, diabase, blk vfn grn w/stgrs cpy | .07 | | |
| diabase tr py, cpy, chl alt along fracts | .03 | | |
| diabase aa | .05 | | |
| diabase to 62, alt gran to 65 | .02 | | |
| hily fract gran, chlor 30%, feld 20%, qtz 50% | .02 | | |
| aa | .04 | | |
| gran fract w/fe stns, tr py, sph | .02 | | |
| aa few qtz stgrs | .04 | | |
| gran aa | .02 | | |
| diabase stgr at 90-93 gran to 95, gran 40% chlor | .03 | | |
| hily alt gr, stgr of dbs, gr: 40% chl, 50% qtz, 10% alt feld | .05 | | |
| aa diabase stgr, hvy Fe stns along fracts | .03 | | |
| hily alt gran, 50% chlor | .02 | | |
| diabase, chlor alt. along fracts | .03 | | |
| diabase to 118, gran to 120 | .03 | | |
| gran: 40% qtz, 45% chlor, 15% orth feld fract & sli alt | .03 | | |
| gran highly alt, 50% chlor, Fe stns, tr py | .04 | | |
| aa tr red oxide Fe | .03 | | |
| gran 30% chlor, 20% feld, 50% qts | .01 | | |
| aa hvy Fe stn | .02 | | |
| aa tr py & Fe stn | .03 | | |
| gran 45% chlor, 50% qtz, 5% orth, tr py | .03 | | |
| aa | .03 | | |
| gran 20% feld, 60% qts, 20% chlor, tr py, stgrs qtz w/py | .03 | | |
| hily alt & fract gran hvy fe stns along fracts, tr py | .06 | | |
| aa tr py cpy | .04 | | |
| aa hvy red & orng fe stns | .03 | | |
| sml stgr diabase 182-183, gran hily alt orth along frac w/chlor fill | .03 | | |
| gran 20% orth, 60% qtz, 20% chlor, tr py, cpy | .03 | | |
| gran: aa | .03 | | |
| gran tr py, cpy, chlor, qtz, hvy Fe stn 1% | .02 | | |
| gran: aa | .04 | | |
| hvy shr zn w/Fe stns, tr py, cpy, gran | .05 | | |
| gran 10% orth (alt) 60% qtz, 30% chlor, 7% Fe stns, hily alt | .06 | | |
| gran: aa sli decrease in Fe stns | .05 | | |
| hily alt gran tr shr, tr py, cpy | .04 | | |
| gran: aa | .04 | | |
| gran: aa diabase at 234 1/2 | .03 | | |
| diabase to 237, gran (hily alt) to 240, tr py | .05 | | |
| gran, sli alt; 30% chlor, 20% orth, 50% qtz, tr py | .21 | | |
| gran: aa tr Fe stns | .08 | | |
| gran 10% orth, 10% chlor, 80% qtz, tr biot (v. little alt. | .03 | | |
| gran: aa tr epidote | .02 | | |
| gran 15% orth, 15% chlor, 70% qtz | .02 | | |
| gran: aa inc epidote, tr py | .02 | | |
| gran: aa | .02 | | |
| gran few qtz stgrs, dissem py, cpy | .03 | | |
| gran: aa tr py, cpy, bn, cc after py | .07 | | |
| gran: tr fe stn, 20% alt feld, 60% qtz, 20% chlor, tr cc | .02 | | |
| gran: aa tr cpy, py, bn, cc in alt gran, dissem tr mag | .02 | | |
| gran: aa 1% sulfides, tr mo, .5% spec, tr cc | .02 | | |
| gran: tr spec, 70% qtz, 10% feld, 20% chlor, tr mag | .02 | | |
| gran: inc orth 20%, 20% qtz, 10% chl, 2% spec, tr cpy,py,cc | .02 | | |
| gran: aa | .02 | | |
| gran: aa orth fract indist bndries, tr cpy, py, 1% spec | .03<br>.02 | | |
| gran: aa tr evid. | .036 | | |
| gran hily fract aa, tr mo, py, cpy, .5% spec | .084 | | |
| gran: aa tr bn, cpy, spec, cc | .030 | | |
| gran 1% spec, 20% orth, 60% qtz, 20% chlor-epidote | .029 | | |
| dec spec aa | .03 | | |
| gran: aa, inc chlor 25% | .032 | | |
| gran inc spec >1% tr py, cpy chlor 25%, feld 10%, qtz 65% | .044 | | |
| gran: aa | .074 | | |
| gran inc in spec, tr mag, tr cc, py 20% feld, 20% chlor 60% qtz | .030 | | |
| gran: aa spec >1%, tr cc, cpy, py | .024 | | |
| gran 2% spec, tr mo, cpy, cc, py bn (hily alt gran stgrs qtz & spec | .048 | | |
| gran: aa >1% spec | .363 | | |
| gran 20% feld (alt) 25% chlor & hem, 55% qtz, tr py | .029 | | |
| gran: aa 1% mag, tr cpy | .028 | | |
| gran: aa | .016 | | |
| alt gran tr fe stns, 2% spec, tr cpy, py, 20% feld, 60% qtz | .058 | | |
| alt gran: aa | .025 | | |
| alt gran: aa | .013 | | |
| hily alt gran, dec spec to 1%, inc. chlor 25%,tr py, mag | .033 | | |
| hly alt gran, 3% spec & mag, chlor 25%, tr mo, cpy, py | .016 | | |
| gran 30% orth tr cpy, py, cc sph, mo | .074 | | |
| th. diabase stgrs 27, 29, 30 | .018 | | |
| th. diabase stgr at 32, granite 34.5, diabase to 35, tr spec, mag, py | .010 | | |
| diabase to 39.5 tr calc, crscutting diabase, tr py, gran to 40 | .010 | | |
| sli alt gran,1% spec,tr py, 25% orth, 65% qtz, 10% chlor | .010 | | |
| alt gran, inc Fe stns, moly seam, tr ep, cpy, py | .014 | | |
| gran aa, tr mo, py, cc, cpy | .023 | | |
| alt gran hvy Fe stns (red-yellow) tr py, cpy | .032 | | |
| gran aa, tr py, cpy | .052 | | |
| alt gran aa, tr py | .034 | | |
| gran aa, tr py, mag, spec | .025 | | |



| | | | | |
|---|---|---|---|---|
| | diabase to 39.5 tr calc, cracutting diabase, tr py, gran to 40 | .010 | | |
| 440 | sl alt gran. 1% spec, tr py, 25% orth, 65% qtz, 10% chlor | .010 | | |
| 445 | alt gran, inc Fe stns, moly seam, tr ep, cpy, py | .014 | | |
| 450 | gran aa, tr mo, py, cc, cpy | .023 | | |
| 455 | alt gran hvy Fe stns (red-yellow) tr py, cpy | .032 | | |
| 460 | gran aa, tr py, cpy | .052 | | |
| 465 | alt gran aa, tr py | .034 | | |
| 470 | gran aa, tr py, mag, spec | .025 | | |
| 475 | aa, tr mo, py, mag, cc | .066 | | |
| 480 | aa, tr mo, cpy, py, mag 3% Fe stns & stgrs | .116 | | |
| 485 | gran, hily alt, hvy (2%) Fe stns, tr py, mo, cc | .040 | | |
| 490 | aa, tr py, cpy, mo, bn, sulfides 1% hvy fe stn silic an, qtz | .067 | | |
| 495 | gran: highly alt, chl & Fe stain, spec, tr py, tr orth | .086 | | |
| 500 | gran: highly alt. <1% py, cpy, & mo | .05 | | |
| 505 | gran: highly alt, tr py & cpy | .118 | 23. | |
| 510 | gran: highly alt, tr py | .086 | 14. | |
| 515 | gran: heavy chl, slickenside w/lm, Fe oxide | .027 | 6. | |
| 520 | gran: tr py, less Fe oxide | .093 | 7. | |
| 525 | gran: aa | .159 | 8. | |
| 530 | gran: py stringers, tr Fe stn; 533 gran: 30% pink orth | .02 | | |
| 535 | gran: ≈ 30% orth, dec chl. | .03 | | |
| 540 | gran: ≈ 40% orth | .02 | | |
| 545 | gran: som sec orth | .03 | | |
| 550 | gran: aa | .02 | | |
| 555 | gran: aa | .02 | | |
| 560 | gran: some Fe color | .03 | | |
| 565 | gran: some Fe color | .04 | | |
| 570 | gran: ≈ 15% orth, lim, <1% py, tr cpy & mo | .093 | 6. | |
| 575 | gran: lim, tr py & mo | .032 | 4. | |
| 580 | gran: ≈ 25% orth, tr py & mo | .024 | 1. | |
| 585 | gran: ≈ 25% orth, lim | .019 | 7. | |
| 590 | gran: ≈ 10% orth, Fe stain, tr py | .026 | 14. | |
| 595 | gran: lim, Fe stain | .028 | 16. | |
| 600 | gran: lim | .02 | | |
| 605 | gran: ≈ 10% orth, tr lim | .02 | | |
| 610 | gran: ≈ 15% orth, lim, tr py & spec | .03 | | |
| 615 | gran: ≈ 20% orth, tr lim | .03 | | |
| 620 | gran: ≈ 15% orth, lim <1%, tr py | .03 | | |
| 625 | gran: ≈ 10% orth, tr ep, lim | .02 | | |
| 630 | gran: spec, lim, tr py | .054 | 16. | |
| 635 | gran: spec & lm | .023 | 7. | |
| 640 | gran: spec & lm | .13 | | |
| 645 | Dior., qtz, p'crysts in dk green Matrix of ferro-mag: minerals, ptly chlor, <1% pyr | .03 | | |
| 650 | gran from ~647', ~20% K-spar, tr py | .02 | | |
| 655 | gran w/spec. | .042 | 6. | |
| 660 | gran ~85% qtz & orth, 1% spec, tr py & mo | .018 | 3. | |
| 665 | gran w/spec, tr py; 669: gran <1% m | .029 | 4. | |
| 670 | gran, bi alt chl, spec, py | .029 | 7. | |
| 675 | monz dike, bi ~20%, tr py, ep | .072 | 10. | |
| 680 | monz, qtz ~50%, bi ptly alt chl, ep, tr lim af py | .021 | 2. | |
| 685 | monz, orth <1%, ep, tr py, cp & mo | .018 | | |
| 690 | monz, <1% sph, tr py, cp & mo | .040 | | |
| 695 | monz, tr mo, py; <5° bt, tr cpy | .048 | | |
| 700 | monz w/spec, tr py & ep; 703: dior, <5% orth, <1% sph, <2% bt | .038 | | |
| 705 | dior, <5% bi ptly alt chl, orth <1%, some py, spec, cpy | .044 | | |
| 710 | dior, ≈2% py as stringers, tr ep | .028 | | |
| 715 | dior, tr py stringers, <1% cpy | .015 | | |
| 720 | dior, <1% py & ep | .022 | | |
| 725 | dior, <1% sph, tr py & mo | .016 | | |
| 730 | dior, <1% mo, <1% py | .024 | | |
| 735 | dior, <2% orth, tr py & mo | .038 | | |
| 740 | dior, <4% orth, tr py, ep & mo | .054 | | |
| 745 | dior, tr sph & py; 748: dior, qtz stringers, tr py | .208 | | |
| 750 | dior, tr py & mo | .084 | | |
| 755 | dior, tr py, mo & ep | .018 | | |
| 760 | dior, tr py & ep; gran: 25% orth, 1% py stringers | .041 | | |
| 765 | gran, tr mo | .039 | | |
| 770 | gran, <1% py, spec | .064 | | |
| 775 | gran, <1% mo, tr py, <1% spec | .050 | | |
| 780 | gran, <1% mo, tr py & cpy | .036 | | |
| 785 | gran, <1% mo, tr py | .049 | | |
| 790 | gran, tr mo, py | .030 | | |
| 795 | gran, <1% mo, <1% spec, tr py | .040 | | |
| 800 | gran, <1% mo, spec, py, tr cpy | .046 | | |
| 805 | gran, <1% py, <1% spec, tr mo | .048 | | |
| 810 | gran, ~1% py, spec, tr mo | .075 | | |
| 815 | gran, <1% py, <1% spec, tr sl sides | .106 | | |
| 820 | gran, <1% py, <1% spec, tr mo | .132 | | |
| 825 | gran, ~60% qtz, 30% orth, some spec, 1% py | .094 | | |
| 830 | gran, bi alt chl, <1% spec | .026 | | |
| 835 | chlor gran, spec, tr sph, tr py, tr qtz veins w/lm stn | .110 | | |
| 840 | gran, bi & orth lgly alt chlor, <1% py, <1% spec | .15 | | |
| 845 | gran, bi mostly alt chl, <1% py, tr spec, tr ep | .13 | | |
| 850 | gran, bi & orth alt chl, <1% py, tr ep | .09 | | |
| 855 | gran, ~10% fresh orth, <1% py, tr ep, tr mo, tr cc | .04 | | |
| 860 | gran, <1% py, tr mo; sl sides, py veins, chl, mo | .07 | | |
| 865 | gran, <1% py, tr mo | .06 | | |
| 870 | gran, <1% py, tr spec | .07 | | |
| 875 | gran, bi fresh, <1% py, tr ep, spec | .26 | | |
| 880 | dior, bi, ptly alt chl, <1% py, tr bn, tr mo, tr cpy, tr spec | .162 | .025 | .28 |
| 885 | gran w/ 1% py, tr cc, 1% spec | .141 | .016 | .2 |
| 890 | gran, 1% py, 1% spec, tr mo | .192 | .010 | |
| 895 | gran, 2% sul, spec, py | .141 | .010 | |
| 900 | gran, micro-fract w/mo + spec, 1% py | .050 | .010 | |
| 905 | gran, mo + spec, m veins & micro fract, 1% py | .084 | .010 | |
| 910 | gran, 1% mo & spec, 1% py (no fines) | .092 | .010 | |
| 915 | gran, 2% sul, tr mo, py, cc | .088 | .012 | .14 |
| 920 | gran, 2% sul, tr mo, spec, py | .504 | .017 | .58 |
| 925 | gran, 1% sul, tr mo, py | .160 | | |
| 930 | gran, 2% sul & spec, tr cpy | .102 | | |
| 935 | gran, 1% sul & spec, tr py | .029 | | |
| 940 | gran, 1% sul tr py, cpy | .132 | | |

| | | | | |
|---|---|---|---|---|
| 910 | gran, 1% mo & spec, 1% py (no fines) | .092 | .010 | |
| 915 | gran, 2% sul, tr mo, py, cc | .088 | .012 | .14 |
| 920 | gran, 2% sul, tr mo, spec, py | .504 | .017 | .58 |
| 925 | gran, 1% sul, tr mo, py | .160 | | |
| 930 | gran, 2% sul & spec, tr cpy | .102 | | |
| 935 | gran, 1% sul & spec, tr py | .029 | | |
| 940 | gran, 1% sul tr py, cpy | .132 | | |
| 945 | gran, 2% sul, sl side, fract, overall dk gray color | .151 | | |
| 950 | gran, 1% sul, tr py, tr sph | .144 | | |
| 955 | gran, 1% sul & spec, tr py | .098 | | |
| 960 | gran, 15% orth, 65% qtz, 20% chl, tr spec, tr mo, py, cpy | .057 | | |
| 965 | gran, 20% orth, 20% qtz, 10% chl & biot, tr spec, tr py, cpy | .058 | | |
| 970 | gran aa | .08 | .003 | |
| 975 | gran to 971, diabase alt to biotite & chlor to 975 | .13 | | |
| 980 | aa | .35 | | |
| 985 | diorite porph dike @ 981-985 qtz, amph, biot & epid. plag feld 5% | .24 | | |
| 990 | gran 15% alt orth, 65% qtz, 20% biot-chlor 1% py & cpy, tr mo | .104 | | |
| 995 | gran to 996 tr orth, tr plag hily alt w/75% qtz, 25% bio-chl, w/2% cpy, py | .088 | | |
| 1000 | qtz diorite phpy dike, mo in seams, dissem cpy, py 1% | .258 | | |
| 1005 | aa qtz dior porph, tr mo, cpy, py, spec 1% sulfides | .146 | | |
| 1010 | gran w/25% orth, 65% qtz, 10% bio-chlor, tr mo, cpy, py, fe stn, spec | .182 | | |
| 1015 | aa | .051 | 33. | |
| 1020 | gran aa tr mo, cpy | .044 | 12. | |
| 1025 | gran w/dissem cpy, py, tr mo (tot sul 1%) gran: 25% orth, 65% qtz, 10% chlor & spec | .10 | | |
| 1030 | gran, dec sul, tr py, cpy | .11 | | |
| 1035 | gran aa, tr py, mo, cpy, spec | .18 | | |
| 1040 | gran: 20% orth, 60% qtz, 20% chlor & spec, w/tr py, cpy | .15 | | |
| 1045 | gran aa, tr py, cpy; 1048: gran, fresh 40% orth | .19 | | |
| 1050 | gran, fresh 40% orth, tr py | .078 | .004 | |
| 1055 | gran, 1% py, Fe stain, fract., 5% dior, 20% plag | .218 | | |
| 1060 | gran, 1% py, tr mo | .060 | | |
| 1065 | gran, py stringers, tr bt | .106 | | |
| 1070 | gran, 1% py, tr mo, & bt | .074 | | |
| 1075 | gran, tr py & mo | .049 | | |
| 1080 | gran, tr py, cpy, mo, sph, ep | .059 | | |
| 1085 | gran, py stringer, tr cpy | .776 | .010 | .83 |
| 1090 | gran, 1% py & cpy, mud, tr Fe color | .133 | .019 | .33 |
| 1095 | gran, tr bt, 1% py, cpy | .214 | .015 | .26 |
| 1100 | gran, 1% py & cpy | .08 | | |
| 1105 | gran, tr py, cpy & mo, light chl, heavy mud | .10 | | |
| 1110 | gran, tr ep & py, light scattered Fe stain, tr ep | .15 | | |
| 1115 | gran, cpy stringers, 1% py & cpy | .12 | | |
| 1120 | gran, 1% py, tr mo & misc. | .144 | .011 | .20 |
| 1125 | gran, 1% py, tr ep & mo, tr bt, 20% orth | .138 | .012 | .19 |
| 1130 | gran, 1% py Xl, tr mo | .184 | | |
| 1135 | gran, tr mo, 1% mo | .22 | | |
| 1140 | gran, tr py & chl | .20 | | |
| 1145 | gran, tr py, cpy; 1149: diab, tr ep | .12 | | |
| 1150 | gran, 5% diab, tr py, fresh, 35% orth | .14 | | |
| 1155 | gran, 10% diab; 1157: diab, 5% orth, tr ep | .09 | | |
| 1160 | diab, 10% orth, tr ep; 1161: gran, 30% orth, 10% diab, tr ep | .240 | .016 | .32 |
| 1165 | gran, 20% diab, 1% py | .131 | .008 | |
| 1170 | gran, 40% orth, 1% py, tr ep, heavy mud | .22 | | |
| 1175 | dior, py stringers, 20% orth | .21 | | |
| 1180 | dior, py stringers, 5% diab, 15% orth, mud; 1182: 1% py & cpy, mud | .122 | .019 | .22 |
| 1185 | tr py, 1% cpy, mud | .165 | | |
| 1190 | gran, tr py, tr ep, tr diab | .10 | | |
| 1195 | gran, 1% py, some m veins, tr cpy, tr ep | .09 | | |
| 1200 | gran, tr py, tr mo | .488 | .007 | |
| 1205 | gran, 20% diab, tr py | .230 | | |
| 1210 | diab 60%, 1% py, tr gran | .15 | | |
| 1215 | gran 50%, tr py | .10 | | |
| 1220 | gran, chl 5%, tr py | .11 | | |
| 1225 | gran, orth 5%, a few diab frags, 1% py | .11 | | |
| 1230 | gran, bi & chl 10%, 1% py, some veins | .166 | .010 | .21 |
| 1235 | gran, bi mostly alt chl, 1% py, tr mo | .472 | | |
| 1240 | gran w/ 2% diab, 1% py, bi compl alt to chl | .15 | | |
| 1245 | gran, chl 20%, tr py, tr spec | .05 | | |
| 1250 | diab 70%, tr ep | .17 | | |
| 1255 | gran, chl 10%, tr py | .28 | | |
| 1260 | diab 95% w/tr py | .20 | | |
| 1265 | diab 40%, tr py; 1268, 1269: heavy mud - 1% py | .131 | | |
| 1270 | diab & gran - 2% py, tr mo | .25 | | |
| 1275 | diab, 40% qtz | .08 | | |
| 1280 | gran, 40% orth, tr py, cpy, 10% diab | .262 | | |
| 1285 | gran, tr py cpy | .216 | .004 | |
| 1290 | gran, tr py, 40% orth | .14 | | |
| 1295 | gran, tr lim & py, 1% bt | .07 | | |
| 1300 | gran, tr py & chl, | .05 | | |
| 1305 | gran, tr py & chl | .18 | | |
| 1310 | gran, py stringers | .15 | | |
| 1315 | gran, tr py, chl fract. | .19 | | |
| 1320 | gran, tr chl, barren | .280 | | |
| 1325 | gran 30% orth, 55% qtz, 15% chlor, 1% py, tr cpy, spec | .180 | | |
| 1330 | gran aa 1% py, tr cpy, mo | .254 | .016 | .33 |
| 1335 | gran aa 1% py, cpy, tr mag, spec, num micro fracts | .212 | | |
| 1340 | aa 0.5% py, cpy, micro fracts w/Fe stns | .115 | | |
| 1345 | gran 40% orth, 15% chlor, 45% qtz, tr py, cpy, spec, mag, micro fracts, tr diabase | .070 | | |
| 1350 | gran aa 1% py, tr cpy, bn | .150 | | |
| 1355 | gran 40% orth, sli alt, 15% chlor, 45% qtz, tr py, cpy | .085 | | |
| 1360 | gran crs phase w/50% orth, micro fracts w/cpy, mo, py, spec | .106 | .002 | |
| 1365 | aa dec 0.5% sulf, tr cpy, py, mo | .100 | | |
| 1370 | gran 35% orth, 20% chlor, 45% qtz, tr py, cpy, mag | .100 | | |
| 1375 | diabase @ 1376 w/stgrs qtz & tr py, cpy | .140 | .004 | |
| 1380 | diabase 1% py, cpy in stgrs dissem | .150 | .004 | |
| 1385 | diab to 86 gran to 90 1% py, cpy, gran w/30% chl | .626 | .011 | .68 |
| 1390 | stgr diab @ 90 gran 90.5 to 95, 65% qtz, 20% orth, 15% chl w/tr mo, py, cpy | .200 | | |
| 1395 | gran 20% qtz, 20% orth, 10% chl, tr py | .110 | | |
| 1400 | gran aa tr py, cpy | .070 | | |
| 1405 | aa | .100 | | |
| 1410 | gran w/20% orth, 20% chl, 60% qtz, 0.5% py, tr cpy | .150 | | |
| 1415 | | | | |



| | | | | |
|---|---|---|---|---|
| diabase @ 1376 w/stgrs qtz & tr py, cpy | .140 | .004 | | |
| diabase 1% py, cpy in stgrs dissem | .150 | .004 | | |
| diab to 86 gran to 90 1% py, cpy, gran w/30% chl | .626 | .011 | .68 | |
| stgr diab @ 90 gran 90.5 to 95, 65% qtz, 20% orth, 15% chl w/tr mo, py, cpy | .200 | | | |
| gran 20% qtz, 20% orth, 10% chl, tr py | .110 | | | |
| gran aa tr py, cpy | .070 | | | |
| aa | .100 | | | |
| gran w/20% orth, 20% chl, 60% qtz, 0.5% py, tr cpy | .150 | | | |
| aa | .069 | | | |
| gran aa tr py, cpy, mo | 10 | | | |
| gran 30% chl, 20% orth, 50% qtz, tr py | 19 | | | |
| gran aa | 08 | | | |
| gran less alt than above biot alt to chlor, 10% chl, 25% or, 65% qtz | 08 | | | |
| gran tr py, cpy | 15 | | | |
| aa | 12 | | | |
| barren gran, tr py | 13 | | | |
| gran 35% orth, 15% chl, 50% qtz, 0.5% py, cpy, tr mo | 230 | | | |
| aa tr mo, py, cpy | .110 | | | |
| gran 40% orth, 20% chl, 40% qtz, tr py | .080 | | | |
| aa | .130 | | | |
| aa | .090 | | | |
| gran 25% orth, 20% chl, 55% qtz, tr mo, py, cpy | .110 | .017 | .19 | |
| aa tr py, cpy | .120 | | | |
| gran aa tr py, cpy, mo, inc chlor | .090 | | | |
| aa | .134 | | | |
| gran 20% chlor, 30% orth, 50% qtz 1% sulf-py & cpy, tr mo | .080 | | | |
| aa 1% py, cpy, tr mo | .100 | | | |
| gran 25% chlor, 20% orth, 55% qtz, 0.5% sulf-py | .103 | | | |
| aa | .087 | | | |
| gran 1% sulf all py, tr cpy, mo aa | .168 | .004 | | |
| gran 25% chlor, 20% orth, 55% qtz, tr py, cpy | .150 | | | |
| aa tr py, cpy, 0.5% sulf | .231 | | | |
| gran 15% chlor, 20% orth, 65% qtz, tr mo, cpy, py | .167 | | | |
| aa 0.5% sulf, py, cpy | .132 | | | |
| gran 25% chlor, 25% orth, 50% qtz, tr py, cpy | .062 | | | |
| gran aa tr py | .053 | | | |
| gran w/tr py, cpy & mo 1% tot sulf | .110 | .003 | | |
| aa tr sulf | .050 | .002 | | |
| gran 1% sulf, py, cpy, mo | .160 | | | |
| gran 25% chlor, 25% orth, 50% qtz 1% py, tr cpy, mo | .106 | | | |
| gran aa tr py, cpy | .195 | .005 | | |
| gran aa 1% py, tr cpy | .178 | .007 | | |
| gran 20% chlor, 30% orth, 50% qtz, 1% sulf - py, cpy mo | .160 | | | |
| aa | .245 | | | |
| gran tr py | .060 | | | |
| gran 70% qtz, 10% chlor, 20% orth, tr py, cpy | .180 | | | |
| aa | .203 | | | |
| gran aa tr py | .299 | .005 | | |
| gran aa tr py, cpy | .304 | .004 | | |
| aa | | | | |

TD 1625

PLATE 10

KELVIN PROSPECT – HOLE No. 1 TD 1400' Mar. 5, 1970

Location: 125' FSL & 300' FEL of Section 8
T 4 S, R 13 E, PINAL CO, ARIZONA

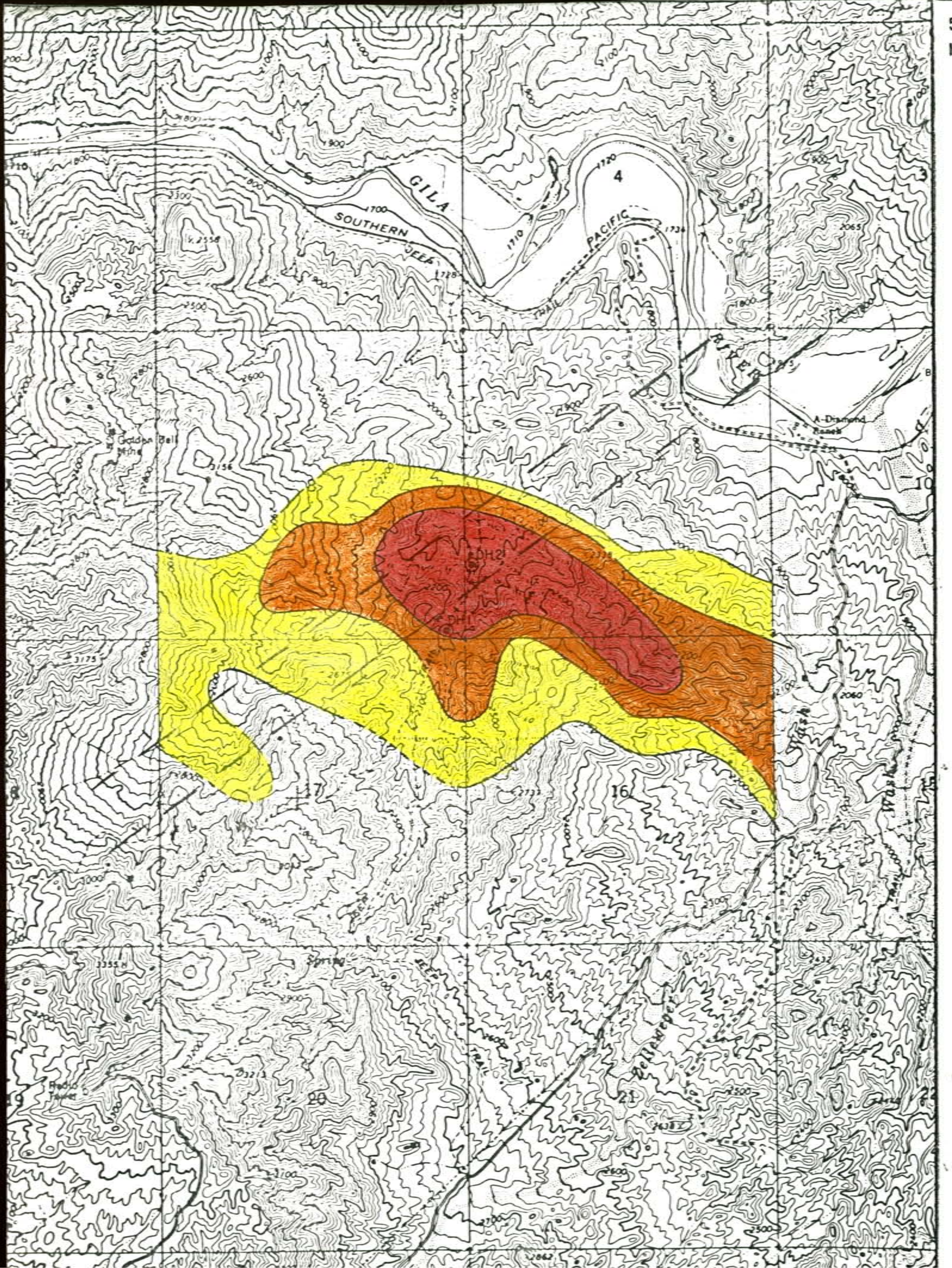
ASSAY DATA

| | Rock Type | Description | Cu | Mo | Cueq |
|---|---|---|---|---|---|
| 0 | Qal | Alluvium: Med-crs frags granite, diabase, diorite, quartz | | | |
| 5 | | | | | |
| 10 | | | | | |
| 15 | | | | | |
| 20 | | | | | |
| 25 | | | | | |
| 30 | | | | | |
| 35 | PЄgn | PЄ granite: wht qtz, orang orth feld, tr biot, 10% | | | |
| 40 | | grn chlorite, tr micro fract w/iron stns. | | | |
| 45 | | gran: qtz, orth hily alt, tr chlor biot, hvly chloritized, micro fracts w/iron stn. | | | |
| 50 | | gran: inc qtz, som sec. qtz, Fe stn, alt orth, chlorite, tr py, tr qtz vng. | | | |
| 55 | | aa tr py, cpy | | | |
| 60 | | gran aa | | | |
| 65 | | gran w/inc chlor (15%) sec qtz tr py (orth, qtz, chlor) | | | |
| 70 | | gran w/tr cpy, py, tr Mo (orth, qtz, chlor) | | | |
| 75 | | chloritic granite w qtz & orth, orth boundaries indistinct som alt | | | |
| 80 | | gran aa w/stgrs alt diabase (amph & chlor) chlr cutting orth. | | | |
| 85 | | aa tr py few chlor pods replcg biot. | | | |
| 90 | | aa stgrs chl cutting orth, feld, qtz dominant | | | |
| 95 | | aa 20% chl, 20% feld, 60% qtz. | | | |
| 100 | | gran, inc in qtz 70%, 20% chlor, 10% feld. | | | |
| 105 | | aa, tr slickensides, micro fract | | | |
| 110 | | gran 20% feld 20% chlor, 60% qtz, tr micro fract | | | |
| 115 | | aa, abt py, tr cpy, inc fracts | | | |
| 120 | | gran w/microfracts, qtz veins; gran, gry-grn w/chlor, | .017 | .010 | |
| 125 | | orth, qtz, hvly chloritized gran, comp of orth, qtz | .027 | .010 | |
| 130 | | aa chlor stgrs crs cutg orth | .418 | .040 | .6 |
| 135 | | gran to 138 gran w/dissem py, cpy, mo to 140, sml cpy rimmed w/Mo. 1% Sul. | .800 | .069 | 1.15 |
| 140 | | Mo, cpy 1% in gran as dissem on feld & in qtz, ct diabase dike @144 | .097 | .010 | |
| 145 | Db | black diabase dike w/stgrs qtz, cpy, Py | .058 | .010 | |
| 150 | | diabase to 153, ct w/gran to 155 hvly chloritized qtz, orth | .064 | .023 | .16 |
| 155 | PЄgn | chloritized gran | | | |
| 160 | | Chlor granite w/abt py | | | |
| 165 | | aa gran w/chlor, bio, tr pyr, cpyr | | | |
| 170 | | gran w/bt, >chl & feld. <1% pyr & cp | | | |
| 175 | | gran w/bt trace cp & py | | | |
| 180 | | gran w < 1% py, tr bt & chl | | | |
| 185 | | gran w/chlor, py, < 1% plag, bio, tr cp | | | |
| 190 | | chlor gran tr py Fe color | | | |
| 195 | | gran 20% chlor 20% orth 60% qtz tr py cp bi plag | | | |
| 200 | | chl gran no orth Fe color | | | |
| 205 | | gran w/chl, Fe color, sil | | | |
| 210 | | chl gram, tr Fe color, sil | | | |
| 215 | | chl sil gran, tr cp & py, little orth | | | |
| 220 | | gran upper sil & alt, lower fresh feld | | | |
| 225 | | monz dike 10% bt, 20% feld, 70% qtz, feld alt tr py | | | |
| 230 | | gran w/chl | | | |
| 235 | Tm | monz w/Cu, 1% bt, plag | | | |
| 240 | | Chl, monz | | | |
| 245 | | chl, monz, bt books, tr py bt partly chl | | | |
| 250 | | chl, monz, py dissem & stringers, some orth | | | |
| 255 | | monz w/orth, pyr stringers | | | |
| 260 | | monz qtz 50% wht plag 30% bi 10% chlor 10% orth <1% | | | |
| 265 | | monz aa | | | |
| 270 | | monz w/tr chl & Fe color | | | |
| 275 | | monz w/tr py | | | |
| 280 | | monz w/Fe stain & chl bt | | | |
| 285 | | monz, bt fresh w/chl | | | |
| 290 | | monz, tr Fe stain & py w/chl | | | |
| 295 | | monz, tr Fe stain, chl | | | |
| 300 | | monz, tr Fe stain | | | |
| 305 | | monz bt partly chl | | | |
| 310 | | monz bt partly chl | | | |
| 315 | | monz py stringer, bt chl | | | |
| 320 | | monz, chl bt tr py | | | |
| 325 | | monz | | | |
| 330 | | monz w/bi chl tr py | | | |
| 335 | | | | | |
| 340 | | monz w/bio chl, <1% orth | | | |
| 345 | | monz w/bio chl, 1% orth | | | |
| 350 | | monz, fe-st, tr py | | | |
| 355 | | monz w/chl as flakes & diss on qtz, tr py | | | |
| 360 | | monz, tr py on qtz | | | |
| 365 | | monz <1% py 10% orth | | | |
| 370 | | monz | | | |
| 375 | | monz 5% orth, chl bt | | | |
| 380 | | monz bt slightly chl | | | |
| 385 | | monz, Fe stains | | | |
| 390 | | monz bt partly chl | | | |
| 395 | | monz | | | |
| 400 | | monz, w/Fe stain | | | |
| 405 | | monz | | | |
| 410 | | monz w/slight Fe staining | | | |
| 415 | | monz, bt sl chl | | | |
| 420 | | monz abundant Fe stains on bt | | | |
| 425 | | monz some Fe stains but bt fresh | | | |
| 430 | | monz, tr Fe | | | |
| 435 | | monz | | | |
| 440 | | monz | | | |
| 445 | | monz | | | |
| 450 | | monz, Fe-st flakes from fracts | | | |
| 455 | | monz, Qtz Fe-st bi ptly alt chl | | | |
| 460 | | monz w/cpy py flakes w/cpy on mal from fract | | | |
| 465 | | monz tr py cpy mal | | | |
| 470 | | monz w/ ≈10% orth | | | |

| | | | | |
|---|---|---|---|---|
| | monz, tr Fe | | | |
| 435 | monz | | | |
| 440 | monz | | | |
| 445 | monz | | | |
| 450 | monz, Fe-st flakes from fracts | | | |
| 455 | monz, Qtz Fe-st bi ptly alt chl | | | |
| 460 | monz w/cpy py flakes w/cpy on mal from fract | | | |
| 465 | monz tr py cpy mal | | | |
| 470 | monz w/ ≈10% orth | | | |
| 475 | tr slickensides w/sul tr py cpy ≈10% orth | | | |
| 480 | tr py cpy on qtz, micro fract | | | |
| 485 | monz w/tr py | | | |
| 490 | monz tr Fe st bi partly alt chl | | | |
| 495 | monz, 70% qtz, 10% fldsp, 10% bi, 10% chl tr py | | | |
| 500 | monz | | | |
| 505 | monz, tr Fe-st on qtz, sul, tr py | | | |
| 510 | monz | | | |
| 515 | monz w/fresh bi tr py | | | |
| 520 | monz | | | |
| 525 | monz, ~60% qtz 20% fldsp 20% bi & chl, tr Fe-st | | | |
| 530 | monz, ~10% chl, <1% orth | | | |
| 535 | monz | | | |
| 540 | monz, striations on fresh plag, tr py w/Fe st rim in qtz | | | |
| 545 | monz tr py Fe-st | | | |
| 550 | monz tr py cpy | | | |
| 555 | monz | | | |
| 560 | Monz, 10% bi, 5% chl | | | |
| 565 | Monz, Tr Fe stain & Py | | | |
| 570 | Monz, py stringers, tr cp | | | |
| 575 | Monz, tr py, chl bt | | | |
| 580 | Monz. | | | |
| 585 | Gran, tr Fe stain | | | |
| 590 | Monz, <5° orth | | | |
| 595 | Monz w/partly chl bt, no orth | | | |
| 600 | Monz, tr Fe stain | | | |
| 605 | Monz, tr Fe & py | | | |
| 610 | Monz, bt partly chl & some w/Fe stain | | | |
| 615 | Monz, Fe stains less bt | | | |
| 620 | Monz w/chl bt, tr py & cp | | | |
| 625 | Monz w/Fe stain, tr py cp, mo | | | |
| 630 | Monz w/Fe stain, <1% Mo, tr py | | | |
| 635 | Monz w/tr py & Fe | | | |
| 640 | Monz w/tr py, cp, Fe stain | | | |
| 645 | Monz w/<2% bt, Fe stain, light chl. | | | |
| 650 | Monz w/<2% bt | | | |
| 655 | Monz w/Fe stain | | | |
| 660 | Monz, Fe stain abundant | | | |
| 665 | Monz, chl bt | | | |
| 670 | Monz w/pipe dope, Fe stain | | | |
| 675 | Monz w/only tr Fe stain | | | |
| 680 | Monz w/Fe stain, chl bt | | | |
| 685 | Monz w/chl bt, tr Fe stain | | | |
| 690 | Monz w/Fe stain, chl bt | | | |
| 695 | Monz / tr Fe stain | | | |
| 700 | Monz w/almost no fresh bt | | | |
| 705 | Monz w/almost no fresh bt | | | |
| 710 | Monz w/almost no fresh bt | | | |
| 715 | Monz w/partly chl bt, tr Fe stain | | | |
| 720 | Monz w/chl bt Fe stain | | .023 | .17 |
| 725 | Monz w/tr Fe stain | | .184 | .720 |
| 730 | Monz w/chl bt | | .168 | .840 |
| 735 | Monz w/chl bt | | .068 | .35 |
| 740 | Monz w/tr mo, sil & alt, feld boundaries indistinct | | .010 | .03 |
| 745 | Monz w/<1% cp & py, tr Mo | | .010 | .08 |
| 750 | Monz w/tr py, Fe stain | | .555 | 2.94 |
| 755 | Monz w/<1% Mo, <1% py and cp (Mo obvious) | | .329 | 1.81 |
| 760 | Monz w/<1% Mo, cp, py | .798 | .087 | 1.2 |
| 765 | Monz w/≈1% Mo, Cp, py; no Fe | .632 | .073 | .98 |
| 770 | Monz w/≈1% py, tr cp & Mo | .265 | .019 | .365 |
| 775 | Monz w/≈1% py & cp, tr Mo | .818 | .032 | .97 |
| 780 | Monz w/≈2% py & cp, tr Mo | .363 | .039 | .56 |
| 785 | Monz < 1% py & cp | .076 | .024 | .178 |
| 790 | Monz w/partly chl bt, < 1% py | .114 | .010 | .114 |
| 795 | Monz w/tr py, fresh & chl bt | .058 | .010 | |
| 800 | Monz w/chl bt tr py | | | |
| 805 | Monz w/tr py & Fe stain | | | |
| 810 | Monz w/tr py | | | |
| 815 | Monz w/tr py | | | |
| 820 | Monz, bt mostly fresh | | | |
| 825 | Monz w/tr cpy | | | |
| 830 | Monz 10% chl < 5% bi, tr py, cpy | | | |
| 835 | Monz w/tr py, cpy | | | |
| 840 | Monz w/tr py, cpy | | | |
| 845 | Monz, bi < 1%, tr py, cpy | | | |
| 850 | Monz w/tr py, cpy | | | |
| 855 | Otz monzonite, pfel & o-fel consid alt biot, alt to cl, tr cpy, py, Mo. | | | |
| 860 | Monz predom qtz minor o & plag biot alt to chlorite | | | |
| 865 | aa | | | |
| 870 | aa | | | |
| 875 | aa | | | |
| 880 | Qtz monz microfracts, biot alt to chlor <1% py cpy mo tr mo, cpy nat cu | | | |
| 885 | aa | | | |
| 890 | Qtz monz w/stgrs gran tr cpy | | | |
| 895 | Qtz monz w/biot alt to chlor | | | |
| 900 | aa tr Mo | | | |
| 905 | Qtz monz incl orth feld 5% predom qtz & chlor | | | |
| 910 | aa tr cpy, py | | | |
| 915 | 918 qtz monz-granite contact monz predom qtz-chl/gran orth, qtz, chlor | | | |
| 920 | granite w/crs grn qtz, orth & chlor | | | |
| 925 | aa tr py | | | |
| 930 | gran w/milky qtz, or-pnk orthfeld grn chlor | | | |
| 935 | aa tr py | | | |

| | |
|---|---|
| | Qtz monz incl orth feld 5% predom qtz & chlor |
| 910 | aa tr cpy, py |
| 915 | 918 qtz monz-granite contact monz predom qtz-chl/gran orth, qtz, chlor |
| 920 | granite w/crs grn qtz, orth & chlor |
| 925 | aa tr py |
| 930 | gran w/milky qtz, or-pnk orthfeld grn chlor |
| 935 | aa tr py |
| 940 | aa tr py cpy |
| 945 | aa |
| 950 | gran milky qtz, sli alt orthfeld, grn chlorite(alt biot) |
| 955 | aa som kaol alt |
| 960 | aa |
| 965 | gran qtz alt feld, grn chlorite |
| 970 | gran aa cut by few thin qtz stgrs carrying py, tr mo. |
| 975 | gran w/milky qtz indistinct orth feld, biot, chlor tr apatite, tr cpy, py |
| 980 | gran qtz orth chlor tr plag. |
| 985 | inc plag, qtz monz |
| 990 | inc plag, qtz monz, qtz, biot, tr orth, plag |
| 995 | aa equal plag, orth |
| 1000 | biotite, qtz monz, tr py, chlor |
| 1005 | aa contact w/gran @ 1009 |
| 1010 | gran: qtz, orth, chlor |
| 1015 | gran qtz, orth, biot, chlor |
| 1020 | aa |
| 1025 | aa tr py |
| 1030 | granite, qtz, orth, biot alt to chlor |
| 1035 | aa |
| 1040 | aa |
| 1045 | gran inc chlor, tr qtz vning feld 10% chlor 6% qtz |
| 1050 | aa |
| 1055 | gran inc orth feld 40% qtz 40% biot & chlor 20% |
| 1060 | aa |
| 1065 | aa 30% feld |
| 1070 | aa 40% feld |
| 1075 | aa inc 25% chl |
| 1080 | aa |
| 1085 | gran 35% feld 20% chlor, 45% qtz. |
| 1090 | aa |
| 1095 | gran 35-40% feld 10-20% chlor 45-55% qtz |
| 1100 | gran 35-40% feld 10-20% chlor 45-55% qtz |
| 1105 | 20% chlor aa |
| 1110 | larger orth phenocrysts, biot alt to chlorite tr py |
| 1115 | gran aa |
| 1120 | gran aa |
| 1125 | gran aa tr py |
| 1130 | gran w/dissem py tr py <1% |
| 1135 | gran: qtz, orth, inc chlorite tr py, sph |
| 1140 | gran: inc orth 50% qtz 40% chlor 10% |
| 1145 | aa |
| 1150 | aa tr py |
| 1155 | gran aa inc 15% chlor |
| 1160 | gran aa |
| 1165 | aa |
| 1170 | gran 40% orth 40% qtz 20% chlor |
| 1175 | qtz, biot, chlor, plag, <15% orth tr py |
| 1180 | crs grn qtz monz dike to 1181, gran to 85 w/tr py |
| 1185 | gran w/1% sul |
| 1190 | gran w/dissem py, cpy, bn, tr mo sulfides 1% |
| 1195 | gran inc in plag dec in orth, gradational chg. |
| 1200 | gran w/20% orth, 10% plag, 60% qtz, 10% chlor |
| 1205 | aa, tr Fe stn, tr cpy, py |
| 1210 | aa |
| 1215 | gran w/60% qtz, 20% orth, 20% chlor, tr py dissem. |
| 1220 | aa |
| 1225 | gran 60% qtz, 25% orth, 15% chlorite |
| 1230 | aa sli inc chlor |
| 1235 | aa tr py, cpy dissem |
| 1240 | aa |
| 1245 | gran, tr qtz stgrs, 60% qtz,30% orth,10% chlor & biot |
| 1250 | aa tr py |
| 1255 | gran aa inc 20% chlor, tr py dissem |
| 1260 | aa: 15% chlor, tr py dissem |
| 1265 | gran: 50% qtz, 35% orth, 15% chlor |
| 1270 | gran: 55% orth, 30% qtz, 15% chlor |
| 1275 | aa |
| 1280 | gran: 40% orth |
| 1285 | aa; tr qtz fracts |
| 1290 | aa:, numerous qtz stgrs |
| 1295 | aa:, tr cpy in qtz stgrs |
| 1300 | gran; 35% orth, 50% qtz, 15% chlor, tr py |
| 1305 | aa |
| 1310 | aa |
| 1315 | gran w/tr py |
| 1320 | gran: 35% orth, 50% qtz, 15% chlor, tr py |
| 1325 | gran: 30% pink orth, 50% qtz, 20% chlor |
| 1330 | aa: tr qtz stgrs, tr cpy, py |
| 1335 | gran aa |
| 1340 | gran aa |
| 1345 | gran: 15% orth, 70% qtz, 15% chlor, tr py, cpy |
| 1350 | aa |
| 1355 | gran: 20% orth, 70% qtz, 10% chlor, tr py |
| 1360 | aa tr py |
| 1365 | aa tr py, cpy |
| 1370 | gran: 30% orth, 50% qtz, 20% chlor, tr py, cpy |
| 1375 | aa |
| 1380 | gran aa |
| 1385 | aa: tr py, cpy |
| 1390 | aa |
| 1395 | gran aa tr py, cpy |
| 1400 | |

TD 1400' granite
6-5/8 casing @ 52' Temp Abd.



516-70
MAY 1970

### TOPOGRAPHIC MAP
of
### THE KELVIN AREA
### PINAL COUNTY, ARIZONA
for
TIPPERARY RESOURCES CORPORATION
by
HEINRICHS GEOEXPLORATION COMPANY

ZONES OF EQUAL RELATIVE ANOMALY STRENGTH
BASED ON a 1000' DATA:

🟥 MODERATE
🟧 WEAK
🟨 VERY WEAK

NOTE: This map is a portion of U.S.G.S. Grayback quadrangle, 7.5 minute series (scale 1:24 000) 1964.

TRC 6-18-70

HEINRICHS
GEOEXPLORATION COMPANY
POST OFFICE BOX 5964. TUCSON, ARIZONA, 85703
Phone: 602/623-0578 Cable: GEOEX, Tucson
geophysical engineers
vancouver
sydney

PLATE 12

516-70
MAY 1970

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