Geology of the Pinal Ranch Quadrangle Arizona

By N. P. PETERSON

CONTRIBUTIONS TO GENERAL GEOLOGY

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CONTENTS

ILLUSTRATIONS

CONTRIBUTIONS TO GENERAL GEOLOGY

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By N. P. Peterson

ABSTRACT

The Pinal Ranch quadrangle in Arizona embraces a rugged area at the northwest end of the Pinal Mountains. Deep erosion that occurred during and after uplift of the mountains has removed all the Paleozoic sedimentary rocks and all but a few small patches of the upper Precambrian Apache group, exposing the rocks of early Precambrian age. The latter are a thick sequence of foliated micaceous rocks, known as the Pinal schist, and some intruded masses of quartz diorite.

Other igneous intrusions are the stock of Schultze granite (Tertiary(?)), the Solitude granite (Upper Cretaceous or lower Tertiary), and small sill-like bodies of granite porphyry and diabase. Welded dacitic tuff and alluvial deposits of Tertiary(?) and younger ages crop out in the southwestern parts of the quadrangle.

The dominant structural trend in the area is northeasterly, roughly parallel with the bedding and foliation of the schist. Only a few relatively young faults strike north to northwest.

The quadrangle contains many small mineral deposits, of which only the Gibson copper deposit has had noteworthy production. They are mostly vein and lode deposits in schist and are mineralized chiefly with pyrite and chalcopyrite. The sulfides are partly oxidized and leached near the surface, but enrichment in copper was slight. In one area the schist contains disseminated sulfides, but the average copper content is too low to be of economic importance. A few small veins in or near the Schultze granite stock contain tungsten and molybdenum minerals associated with greisen.

INTRODUCTION

The Pinal Ranch 7½-minute quadrangle is the southwest quarter of the original Globe 15-minute quadrangle as mapped by the U.S. Geological Survey in 1901. The geology of the Globe 15-minute quadrangle was studied by Ransome (1903, 1904) in 1901 and 1902. The geology of the Pinal Ranch quadrangle was remapped on a scale of 1:12,000 in 1947 and 1957–59 in connection with a comprehensive study of the Globe-Miami mining district.

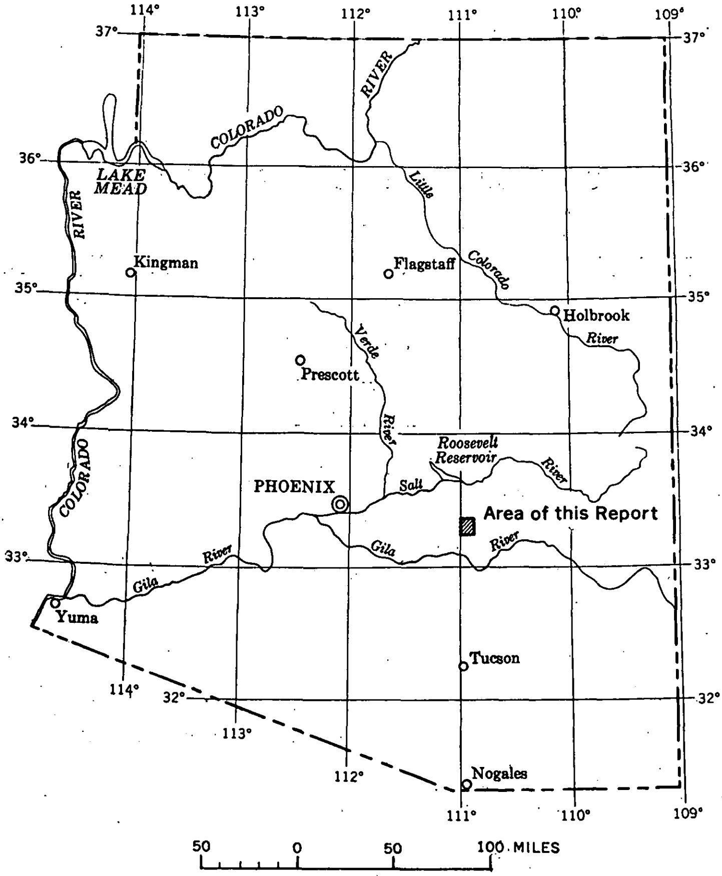

FIGURE 1.—Index map of Arizona.

The area embraced by the quadrangle (fig. 1) is a part of the Crook National Forest except for about 8 square miles in the southwest corner. It includes the Summit mining district, which is partly in Gila County and partly in Pinal County.

U.S. Highway 60–70 between Superior and Miami crosses the northern part of the quadrangle from Pinal Ranch to Schultze Ranch. The only other routes of travel are unimproved dirt roads that link a number of cattle ranches with the main highway and give access to various small mines and prospects. There are no permanent towns or settlements. Cattle raising is the principal industry, and several ranches have headquarters within the quadrangle.

The main supply of stock water is surface drainage, caught and stored in reservoirs formed by earth dams across shallow draws. A few shallow wells in alluviated creek beds also provide some water for domestic and stock-watering purposes.

TOPOGRAPHY AND DRAINAGE

The topography of the Pinal Ranch quadrangle is dominated by the Pinal Mountains, of which one of the highest peaks is Mount Madera, near the middle of the east boundary. Four miles southeast of Mount Madera, the crest of the range rises to an altitude of 7,850 feet on Pinal Peak. Within the quadrangle, altitudes range from 2,650 feet in the bed of Mineral Creek near the southwest corner to about 6,690 feet on Mount Madera.

The quadrangle straddles the watershed between the drainage system of the Salt River to the north and that of the Gila River to the south. This divide is the crest of a spur extending westward from Mount Madera to Five Point Mountain, whence it makes a sharp loop around the northern rim of the small basin in which Pinal Ranch is situated.

All the area south of this divide is drained by Mineral Creek and its tributaries. Mineral Creek heads near the top of Pinal Peak and enters the quadrangle about 1 mile north of the southeast corner. It follows a westerly course near the southern boundary to a point near the southwest corner, whence its course is nearly due south for 10 miles to its junction with the Gila River near Kelvin.

In the area north of the divide, the declining axis of the northwest end of the Pinal Mountains forms the watershed between the drainage of Pinto Creek to the west and Pinal Creek to the east. From Mount Madera, this divide swings northward around the head of Pinto Creek and follows a ridge westward along the north side of the creek to a point near the head of Mead Canyon, whence it follows a northerly ridge and crosses the north boundary of the quadrangle at about the midpoint.

The area northeast of this divide is drained by Bloody Tanks Wash, which heads at the junction of the Castle Dome road with U.S. Highway 60–70. The wash crosses the north boundary only 1½ miles northeast of its head and continues eastward through the town of Miami. Its drainage reaches the Salt River by way of Miami Wash and Pinal Creek.

Pinto Creek heads about 1 mile north of Mount Madera and flows northwestward, leaving the quadrangle about 2½ miles east of the northwest corner, whence its course is nearly due north for about 19 miles to Roosevelt Reservoir on the Salt River.

Within the quadrangle, none of the streams have surface flow except during periods when snow is melting on the higher peaks of the Pinal Mountains, or during shorter intervals following heavy rains. The lower reaches of Mineral Creek, Lyons Fork, and Hale Tank Wash have some subsurface flow in their alluviated channels, which may persist during most of the year and which shows as seepage where bedrock is shallow or crops out in their beds. The upper reaches of the main canyons and most of the minor gulches have steep gradients, and their channels are swept clean or are strewn with boulders too large to be moved except during rare periods of heavy flow.

GENERAL GEOLOGY

The rock formations of the region that includes the Pinal Ranch quadrangle (pl. 1) have been adequately described in many published reports (Ransome, 1903, 1904, 1919; Darton, 1925; Short and others, 1943; Peterson, 1960; Peterson and others, 1951; Peterson, 1954, 1962), and further detailed descriptions are omitted in this report. Columnar sections of the sedimentary and volcanic rocks of the northern part of the adjacent Ray quadrangle to the south and the southern part of the Inspiration quadrangle to the north as compared with the section of the Pinal Ranch quadrangle are shown in figure 2.

During the Precambrian, Paleozoic, and Mesozoic eras, the geologic history of the Pinal Ranch quadrangle probably was little if any different from that of the surrounding region. In early Precambrian time, there was widespread and long-continued deposition of very uniform, mostly fine grained thin-bedded arkosic and argillaceous sediments. These sediments had accumulated to thicknesses of many thousands of feet when deposition ceased and a period of diastrophism ensued, which in central Arizona has been named the Mazatzal revolution (Wilson, 1939).

During this orogeny, compressive forces acting from the northwest and southeast folded the sediments into northeast-trending mountain ranges and transformed them into the foliated micaceous rocks that are known as the Pinal schist. During and following the mountain building, granitic magma invaded the folded rocks and caused further distortion and metamorphism near the intruded bodies. In the Pinal Ranch quadrangle, these intrusions are represented by the Madera diorite and the sill-like bodies of gneissic granite near the northwest corner. Erosion began with the mountain building and continued until at least all of what is now southeastern Arizona had been reduced to a plain of very low relief sparsely strewn with erosional detritus.

In late Precambrian time, a shallow sea spread over parts of this plain, and in it the sedimentary sequence of the Apache group was deposited. Sedimentation ended with the outpouring of a thin but extensive sheet of basalt lava, after which erosion was again active.

During the Paleozoic era, sedimentary formations of Middle Cambrian, Devonian, Mississippian, Pennsylvanian, and possibly Permian

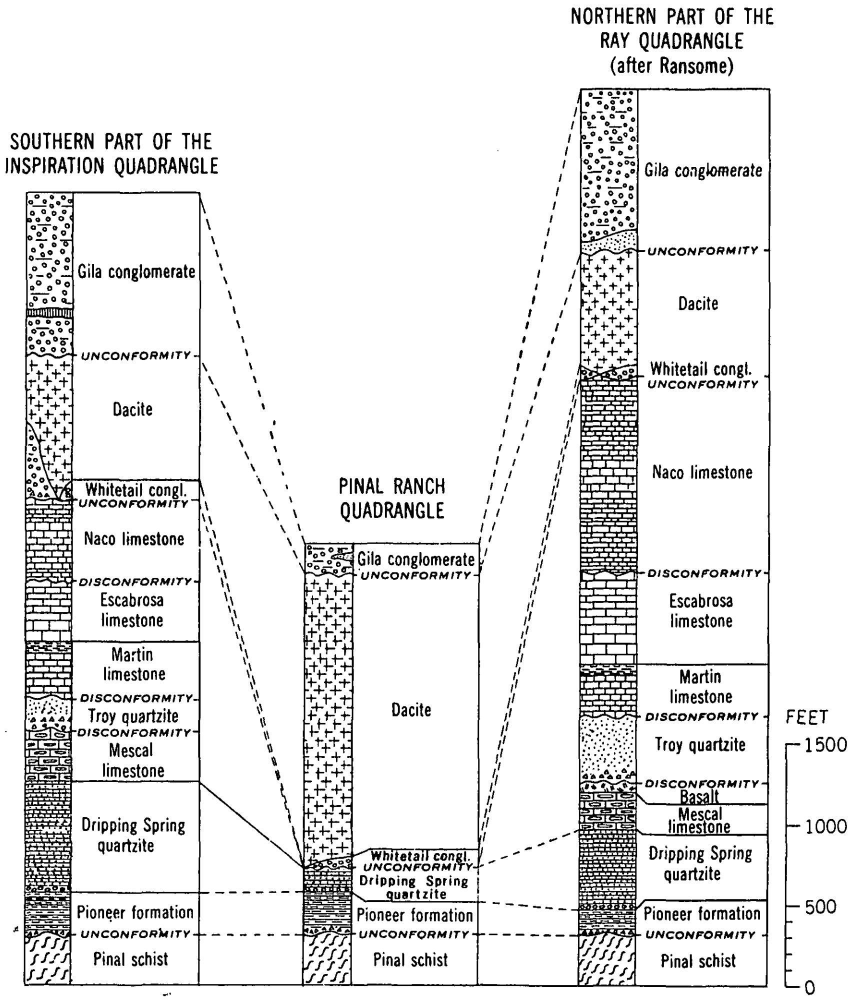

Figure 2.—Columnar sections of the sedimentary and volcanic rocks that crop out in the Pinal Ranch quadrangle and adjacent parts of the Inspiration and Ray quadrangles.

ages were deposited. All are apparently conformable with the strata of the Apache group, in spite of two intervening erosional disconformities, one of which represents a hiatus that includes Late Cambrian, Ordovician, Silurian, and Early Devonian time. It is assumed that the late Precambrian and Paleozoic sequences were deposited over the entire Pinal Mountain area, of which the Pinal Ranch quadrangle is a part.

The uplift of the Pinal Mountains and the intrusions of Solitude granite, diabase, Schultze granite, and associated granite porphyry dikes probably took place during the Rock Mountain orogeny in Late

Cretaceous or early Tertiary time. The extensive mineralization of the Globe-Miami, Pioneer, and Mineral Creek districts to the north, west, and southwest, respectively, and also the mineralization within the quadrangle, took place after the intrusion of the Schultze granite stock and probably was the culminating event of the igneous activity that accompanied this orogeny.

Vigorous erosion was initiated by the uplift of the mountains. In the Pinal Ranch quadrangle, the sedimentary formations of late Precambrian and Paleozoic age were completely stripped off except in the extreme southern part. The erosional debris was carried away and deposited far from the source areas except for small local accumulations in channels and low-lying areas of the old terrain. These local deposits comprise the Whitetail conglomerate.

At this stage, erosion was interrupted by a volcanic eruption, which began with sporadic local outpourings of viscous silicic lavas and magma that solidified to form perlitic glass, and some minor ejections of tuff. These rocks are widely exposed in the adjacent Superior and Haunted Canyon quadrangles but do not crop out in the Pinal Ranch quadrangle, though they probably are present in some places beneath younger formations. Later, the eruption became more violent, and a vast sheet of dacitic tuff was deposited on the earlier volcanic rocks, extending out over the older sedimentary and crystalline rocks to a radius of 30 miles or more. The tuff was compacted and welded to form the rock herein referred to as the dacite. In some places, remnants of the dacite are as much as 2,000 feet in thickness. The sheet overlapped the flanks of the Pinal Mountains, but it is doubtful that more than a thin mantle of the tuff extended as high as the top of the range.

Erosion resumed after the eruption and much of the dacite was removed, again exposing the older rocks. Great alluvial fans formed on the northeastern slopes of the Pinal Mountains. Sinking of the foothills area while the fans were forming caused the fanglomerate to accumulate to thicknesses known to exceed 4,000 feet in some places. The composition of these fans clearly indicates that erosion had progressed for a considerable time before the intruded masses of Madera diorite were uncovered.

On the southwest side of the mountains, the debris from the erosion that occurred immediately after the eruption of dacite was largely carried away. The Gila conglomerate that remains in the southern part of the quadrangle was derived mainly from the south and southwest and is composed chiefly of fragments of Apache group, Paleozoic limestone, diabase, and dacite that have been eroded from blocks uplifted by relatively young faults. However, it contains some admixture of schist throughout, and the uppermost part is predominantly schist fragments that could only have been derived from outcrops in the Pinal Mountains area to the north and northeast.

Probably in early Pleistocene time, there was regional uplift that was accompanied by much faulting in the surrounding areas but very little in the Pinal Mountains area. A new drainage pattern was developed, and erosion began wearing away the Gila conglomerate. It is likely that at one time Gila conglomerate completely mantled the northern, western, and southern parts of the quadrangle and lapped well up on the lower flanks of the mountains much higher than any of the remaining outcrops.

STRUCTURE

The prevailing strike of the bedding and foliation of the Pinal schist is N. 30°–60° E., the prevailing dip is 50°–70° NW. There are, however, many local exceptions to this general attitude, mostly near the borders of intrusive bodies. Wide departures from the general attitude are common also along the west side of the schist outcrop near the contact between the schist and the dacite; however, this relation with the contact probably is fortuitous, the actual cause of the anomalous attitudes being obscured by the dacite cover. Near intrusive bodies, the beds are commonly crumpled and distorted; but elsewhere, except for the tilting, the beds are not noticeably deformed.

The possibility of isoclinal folding cannot be entirely ignored, but drag folds and cleavage patterns that usually result from close folding have not been recognized. Sedimentary features that might indicate the tops and bottoms of beds are vague, inconsistent, and nowhere conclusive. A study of these features gave only a poorly founded impression that the beds are top side up, that is, the top of the section is toward the northwest.

Faults in the schist that are parallel or roughly parallel with the strike of the bedding are difficult to recognize unless they have been mineralized to some extent. Nearly all the faults that have been recognized in the schist do strike northeast, and commonly their general strike is more northerly than that of the bedding. Throughout most of their strike length, they seem to be essentially parallel with the bedding; but at intervals they are offset to other horizons in the schist by short discordant segments. If a fault is followed northeastward, the offset is generally toward the north. Many of the faults intersect igneous contacts; others would intersect if projected on the strike of their recognizable outcrops; but the contacts show only a few minor offsets caused by faults. If the movements along these faults or any unrecognized faults were large, the movements must have occurred before the intrusion of the Madera diorite and Schultze granite. Granite porphyry sills in schist continue into igneous bodies as dikes with no marked change in continuity or general trend, suggesting that they were intruded along old bedding-plane faults.

Undoubtedly some of the small faults that displace rocks of the Apache group in the area south of Mineral Creek west of Hagen Ranch formed as a result of the diabase intrusions, others formed after the dacite eruption, possibly during the general uplift that occurred after the Gila had been laid down.

Meager evidence suggests that movement on the fault forming the boundary between schist and dacite in the west-central part of the quadrangle occurred before the Gila was laid down. However, the relation shown on the map east of Hutton Peak is not conclusive, because the Gila shown overlapping the fault may actually be talus. Owing to the nature of the Gila conglomerate, boundaries of the formation are usually indefinite, and only under ideal conditions can faults be traced across its outcrops.

Although this fault is unusually persistent in strike extent, its displacement is relatively small; the vertical component probably is not more than 200 feet at any point. The basal vitrophyre of the dacite is exposed where the fault crosses the bottom of a canyon southeast of Hutton Peak, and fragments of the vitrophyre are seen in the drag of the fault at several places farther north.

The dacite west of Lyons Fork and the Dry Wash of Mineral Creek is cut by a network of widely spaced, steeply dipping fractures, one set of which strikes northwest and another about east-northeast. The fractures are mostly large joints, but some of the northwest-striking breaks are shear zones along which some movement has occurred. Although the displacement along any one zone probably is small, the aggregate could be large. Most of the faults traversing the dacite for which the relative movements of the two walls can be ascertained show displacement down on the west. Near the south boundary of the quadrangle, the base of the dacite just east of Mineral Creek is at about the same altitude as in Devils Canyon about 3 miles to the west, in the adjacent Superior quadrangle; but about midway between these points, the base is at some unknown depth below the bed of Mineral Creek and therefore at least 500 feet lower in altitude than to the east or west; however, these data have little value as evidence of fault displacement, because the local relief before the eruption of dacite was of a similar order of magnitude.

One of the most prominent structural features of the region is the Miami fault, of which a short segment crosses the quadrangle near the northeast corner. This fault forms the west and south boundaries of a downdropped block, which in an earlier report, on the geology of the Globe quadrangle (Peterson, 1954), was named the Globe Valley block. The outline of this block corresponds closely with that of the large roughly triangular outcrop of Gila conglomerate in the broad valley between Globe and Miami.

The segment of the fault outcrop within the quadrangle follows a curved but general northwesterly course and forms the boundary between Gila conglomerate on the northeast side and Solitude granite, Pinal schist, and Schultze granite on the southwest side. The dip of the fault is toward the northeast, probably 60° or more. About a quarter of a mile north of the quadrangle, the outcrop turns to a north-northeast course and can be followed for about 6½ miles, beyond which its identity is lost. East of the quadrangle, the fault continues southeastward and forms the northeast boundary of the Solitude granite for a distance of 2¼ miles, whence it strikes a little south of east and can be traced for about 7 miles. At a point 2 miles north of the quadrangle, the vertical component of displacement on this fault is known to be at least 1,500 feet. The displacement decreases both to the north and east of the Pinal Ranch quadrangle, so that the greatest movement is probably in or close to the segment shown on the map. This relation and the attitudes of crude bedding in the Gila conglomerate indicate that the downdropped hanging-wall block was tilted southwestward.

ECONOMIC GEOLOGY

Minor mineral deposits occur throughout the schist area of the Pinal Ranch quadrangle and to a lesser extent in the areas underlain by Schultze granite. They have attracted considerable attention from prospectors and mining companies. Only a few of the deposits have had any recorded production, however, although several others may have yielded small lots of selected shipping ore during the early days of mining.

The copper deposits have been the most productive. Their total recorded output amounts to about 12,500,000 pounds of copper and 3,500 ounces of silver, valued at about $2,177,000; of this output, nearly 99 percent came from the Gibson mine. This relatively small production is in marked contrast with the copper deposits of the neighboring Globe-Miami, Pioneer, and Mineral Creek districts, which have production records of approximately $1,307 million, $271 million, and $527 million respectively (Elsing and Heineman, 1936, p. 92 and 99 and U.S. Bur. Mines, 1932–59).

The large disseminated copper deposits of the Globe-Miami district on the north side of the Schultze granite stock are of a type generally regarded as having formed within the mesothermal temperature range, but at such shallow depths that supersaturation of the mineralizing solutions was relatively rapid. The ore minerals as well as the associated products of hydrothermal alteration, mainly clay and sericite, are mostly fine grained.

With a few exceptions, the deposits on the south side of the stock contain essentially the same assemblage of hypogene minerals as those on the north side but differ in the relative proportions and grain size of the minerals. They contain a greater proportion of pyrite to chalcopyrite, and many pyritic vein deposits seem to contain no chalcopyrite whatever.

The schist, which is the host rock of most of the deposits, is composed chiefly of quartz and sericite, the same minerals that are the usual products of hydrothermal alteration; and although some recrystallization may have occurred, it is extremely difficult to compare the effects of hydrothermal alteration. The veins in the granite, however, are bordered by alteration zones of coarse-grained sericite or muscovite.

These characteristics suggest that the deposits formed at greater depths than those that crop out in the Globe-Miami district, a condition in keeping with the deeper erosion of the premineral rocks of the Pinal Ranch quadrangle. If there were ever any deposits comparable to those of the Globe-Miami district, in size and copper content, which is doubtful, they have long since been eroded away, and only the pyritic roots remain.

The veins in the schist and granite north and northeast of Pinal Ranch have a decidedly hypothermal aspect. The vein fissures and fissure zones are but weakly mineralized along most of their recognizable extent, but locally they contain lenticular shoots of vein matter, which are surrounded by zones of highly altered rock that is best described as greisen.

The vein matter is mainly white glassy quartz, which encloses coarse granular pyrite, molybdenite, wolframite and scheelite, a little chalcopyrite, and locally a little tourmaline. Each metallic mineral generally occurs alone as discrete masses or aggregates of crystals and is rarely in contact or even closely associated with any other metallic mineral.

The greisen is a soft cellular aggregate of random-oriented interlocking books of coarse muscovite. Minute grains of fluorite are scattered throughout the aggregate but are not easily recognizable in hand specimens. The greisen commonly encloses irregular masses of white quartz; and in some places, usually along narrow parts of the veins, quartz grains form an integral part of the aggregate. A semiquantitative spectrographic analysis of the mica showed the presence of lithium in the order of only 0.015 percent.

COPPER DEPOSITS

The great Miami-Inspiration ore body lies in a broad arc astride the north edge of a lobe of Schultze granite that projects into the schist from the northeast side of the stock. Similar lobes form the southeast and southwest extremities of the granite outcrop in the Pinal Ranch quadrangle, and these too seem to have exerted some degree of control on the localization of mineralization. Although many small deposits containing mainly quartz, pyrite, and chalcopyrite are scattered throughout the schist area south of the stock, all the deposits that have been productive or have shown promise enough to attract noteworthy exploration are contained within an east-trending zone about 1 mile wide which extends across the full width of the quadrangle and overlaps the extremities of the granite lobes. This zone bears no obvious relation to the local structural trends.

An extensive though low-grade deposit of disseminated pyrite and chalcopyrite occurs in the schist bordering the south side of the east lobe (9), but all the other deposits south of the stock are of the vein or lode type. With the sole exception of the Ellis vein (10), all the veins strike northeast, and those in schist are roughly conformable with the bedding and foliation. The relation of the vein faults to the structure of the schist has been described in an earlier section of this report.

In those segments of the vein faults that are conformable with the bedding of the schist, the sulfides were deposited as very thin films in zones of slippage that commonly are as much as 15 feet wide; whereas along the shorter segments cutting across the bedding, mineralization was commonly confined to a single fracture, along which a well-defined vein or shoot was deposited. In a few of these, the vein minerals were sufficiently concentrated to be ore.

Supergene enrichment probably was an important factor in raising the copper content of a few deposits to economic grades, particularly the Summit, Pasquale, Lorraine, and the Cole and Goodwin deposits. In general, however, the high relief and rapid erosion in this area largely prevented the formation of noteworthy secondary chalcocite zones. Along most of the veins, pyrite and chalcopyrite are present in the outcrops or within a few feet of the surface. A little chalcocite formed along late fractures, but general replacement of the hypogene minerals is not common.

GIBSON MINE

Production of the Gibson mine (8) during the main period of operation, 1906–18, is estimated (Elsing and Heineman, 1936, p. 92) at 12 million pounds of copper valued at $2.1 million. The ore was handsorted and hauled by wagon 14 miles over crude mountain roads to the smelter at Globe. During this period, the mine was operated successively by S. L. Gibson, Gibson Copper Co., Summit Copper Co., and the Gibson Consolidated Copper Co. Since 1918 the mine has been inaccessible, and the small production recorded (U.S. Bur. Mines, 1937–53)—about 260,000 pounds of copper—was from ore sorted from the mine dumps.

Several veins crop out on the Gibson property, the most prominent of which are the Summit and the Pasquale. The outcrops of these two veins are roughly parallel and have general strikes about N. 25° E. They are about 300 feet apart just south of the mine dumps, which largely conceal the outcrops of the most productive segments of the veins. A third vein, known as the Intermediate, is between the two main veins, but so far as can be determined it was not productive.

The subsurface vein structure can be roughly deduced from a composite level map and cross sections made by the Summit Copper Co. about 1911. The map does not show some of the early shallow workings, and undoubtedly some of the latest workings are not recorded. A brief description of the mine and ore bodies was published in the "Copper Handbook" (Stevens, 1911, p. 1618–1620).

The mine has six principal levels served by an inclined shaft sunk on the Summit vein. Level 6 is about 430 feet in vertical depth below the collar of the shaft. Other levels are at vertical intervals ranging from 60 to 80 feet. The levels are also connected with a vertical shaft sunk from a point about 125 feet northwest of the outcrop of the Pasquale vein. This shaft intersects the Pasquale, Intermediate, and Summit veins at depths of 125, 260, and 525 feet, respectively, below the collar. Several drift adits of unknown extent explore the southwestern parts of the veins.

The Summit vein is said to be virtually concordant with the bedding and foliation of the schist. Its general dip is about 55° NW., but in detail the dip is very irregular and is affected by several minor rolls or folds in the bedding. Apparently the more pronounced rolls were favorable locations for the replacement of the schist by vein matter. The ore occurred in three lenticular shoots separated by intervals in which the vein fracture is obscure and practically barren of vein minerals.

The Pasquale vein, though roughly parallel in strike, differs from the Summit in that it dips about 35° NW. and occupies a more clearly defined fracture zone that is not conformable with the bedding of the schist. This vein also contained three ore shoots that have been stoped.

The ore shoots of the Summit vein had the form of lodes composing a seam of solid vein matter 8 to 15 inches wide, which averaged 20 to

30 percent copper, and many small discontinuous sulfide veinlets. The Pasquale vein was more intensely and more continuously mineralized than the Summit, and the walls were more sharply defined and regular. The mineralized fault zone was from 5 to 10 feet wide and had a core of solid vein matter from a few inches to 3 feet wide.

COLE AND GOODWIN DEPOSIT

The Cole and Goodwin deposit (11) is a short irregular shoot of vein matter formed by replacement of sheared schist. The shear zone seems to be parallel in strike with the bedding of the schist but is probably slightly discordant in dip. Toward the southwest, the ore shoot ends at a small offset in the shear zone which probably is caused by a minor premineral crossfault. The offset segment is but slightly mineralized. The vein matter is quartz, pyrite, and chalcopyrite, and some chalcocite and copper carbonates.

The deposit is developed by an inclined shaft which is said to be 480 feet deep. It is reported (Stevens, 1911, p. 1078–1079) that in 1908 the mine produced 50,263 pounds of copper; and in 1939 and 1940, shipments of a few hundred tons of ore yielded 32,000 pounds of copper and 380 ounces of silver (U.S. Bur. Mines, 1939–1940).

AMERICAN MINE

The American mine (5) is situated at the southwest extremity of the Schultze granite outcrop. Its production as reported in the Minerals Yearbook (U.S. Bur. Mines, 1934–51) is 76,300 pounds of copper, 1,773 ounces of silver, and 5 ounces of gold recovered from 760 tons of ore; however, most of the development had been done by 1908, and some early production may not have been recorded.

Practically all the development has been on the Myah vein, which has a general strike of N. 43° E. and dips 55° NW. to vertical. The principal ore shoot is developed by a drift adit and an inclined shaft from which drifts have been driven on the 65-, 130-, and 180-foot levels. The workings are now inaccessible below the 65-foot level.

The vein was formed by replacement of sheared granite along a minor fault zone. As seen on the 65-foot level, it is a composite of small discontinuous stringers of quartz, pyrite, and chalcopyrite and ranges in width from a few inches to about 3 feet. Undoubtedly replacement by vein minerals was more complete in those parts of the vein, mostly southwest of the shaft, that have been stoped.

A drift toward the northeast on the 130-foot level found a small pocket or shoot of ore that contained tetrahedrite-tennantite as well as pyrite and chalcopyrite. In 1934, about 34 tons of ore mined from this shoot yielded 10,325 pounds of copper and 1,236 ounces of silver.

Other properties containing similar pyrite-chalcopyrite deposits that have undergone noteworthy exploration and development include the Lorraine (6) and Crenshaw (7), both of which have yielded some shipping ore; the Red Rock (13); Catclaw (12); and Doak (15). The Doak and some of the Catclaw veins contain a little galena and sphalerite.

MADERA PROSPECT

The Madera prospect (9) lies between the southeast extremity of the Schultze granite outcrop and the mass of Madera diorite to the south; it is an isthmuslike outcrop of Pinal schist which in much of the area extending from the Ellis vein at the east to the west boundary of secs. 14 and 23, T. 1 S., R. 14 E. has the characteristics of "capping" formed by oxidation and leaching of included grains and veinlets of metallic sulfides. The boxwork and residual limonite indicate a great preponderance of pyrite, but the former presence of some copper sulfides is proved by copper stains in a few places where veinlets are especially large or abundant.

In 1948, five churn-drill holes were sunk to explore beneath the outcrops that appeared most promising. Three of the holes passed through the usual zones typical of disseminated-sulfide deposits that have undergone near-surface alteration by weathering: an oxidized and partly leached zone overlying a zone of chalcocite enrichment that grades downward into rock containing only primary sulfides. The intersections of the enriched zone, totaling 125 feet in length, averaged about 0.42 percent copper; whereas the protore, represented by intersections totaling about 1,000 feet in length, averaged about 0.14 percent copper.

The other two holes showed disseminated sulfides of fairly uniform copper content and slight replacement by chalcocite throughout their length.

Although no part of the deposit can be regarded as ore, the total volume of mineralized rock nevertheless contains a large amount of copper.

The Ellis vein (10) at the east end of the mineralized area contains quartz, pyrite, chalcopyrite, and also a relatively large proportion of both fine- and coarse-grained molybdenite. It is one of the very rare examples in this region of a hypogene vein deposited in a northwest-trending facture.

POWERS GULCH DEPOSIT

In a strip extending for a distance of about 1 mile along the edge of the dacite west of Powers Gulch (1), the schist is lightly stained by copper silicates and carbonates. These copper minerals occur as impregnations and discontinuous veinlets ranging from paper thin to nearly an inch in width. The schist host rock shows no evidence of hydrothermal alteration or of the former presence of sulfide minerals except in two small, widely separated areas, one of which is just north of the northwest corner of the quadrangle and the other is near the granite that crops out at the edge of the dacite about 4,500 feet to the south.

Although the copper content of the schist is too low to be of economic importance, this widespread occurrence of exotic copper minerals has attracted considerable attention as a possible indication of a hypogene copper deposit nearby. In 1930–31, diamond-drill holes were sunk through the adjacent dacite, two in the Haunted Canyon quadrangle near the common corner of the quadrangles and three opposite the granite outcrops at the south end of the mineralized area. The holes passed through 488 to 1,235 feet of dacite and through 70 to 410 feet of the underlying schist and granite.

Most of the samples recovered from the schist and granite were described in the driller's logs as "capping" and contained less than 0.3 percent copper. In one intersection 156 feet long, the samples averaged 0.54 percent copper, with assays ranging from 0.3 to 1.2 percent. No sulfides were found in any of the samples.

In 1956, the copper-bearing schist was sampled by 10 short drill holes distributed in an interval of about 4,500 feet near the edge of the dacite. The 10 drill holes totaled about 2,060 feet in length and averaged about 0.15 percent copper. In general, the copper content of the rock decreased with depth, and most of the holes bottomed in practically barren rock.

The absence of Whitetail conglomerate between the schist and the dacite indicates that this area stood relatively high during the period of erosion that preceded the dacite eruption; therefore, a hypogene copper deposit would have been exposed to weathering during this time and could have been enriched.

TUNGSTEN AND MOLYBDENUM DEPOSITS

SWEDE MINE

The Swede vein (2) traverses an irregular tongue of schist that probably is a pendant projecting into the granite at the western edge of the stock. The vein was deposited along a shear zone which, at least in some segments, is slightly discordant with the bedding of the schist. Along most of its extent the zone is a poorly defined stockwork of thin, discontinuous quartz-pyrite veinlets. Replacement by vein matter is most complete along a segment in which the shear zone is intersected by two narrow dikes that are offshoots of the main granite mass. This segment contains a small ore shoot which has been developed by an adit crosscut and drifts. A few tons of tungsten concentrate have been recovered from ore mined from a stope between the adit level and the surface.

The remaining part of the mineralized zone that is exposed in the drifts and at the edges of the stope has a central core of massive white quartz flanked by zones of coarse greisen as much as 18 inches wide. Masses of coarse granular pyrite, platy crystals of wolframite partly altered to scheelite, rounded clots and thin seams of molybdenite, a few small clusters of tourmaline prisms, and a little chalcopyrite are scattered at random in the massive quartz.

The similarity of the greisen to that formed by alteration of granite and the sharp contact between the greisen and the schist wallrock suggest that the segment of the vein containing the ore shoot was formed by replacement of granite porphyry intruded along this part of the shear zone by way of the previously mentioned dikes.

CLARK PROSPECT

The Clark prospect (4) explores a small deposit or shoot formed by replacement along an obscure shear zone that cuts the granite at the edge of the stock. The deposit is an irregular stockwork of subparallel and interlacing veinlets of quartz, which incloses the same assemblage of minerals that is present in the Swede deposit. The granite wallrock within the stockwork is largely altered to greisen composed almost entirely of muscovite. Fluorite occurs sparsely as minute grains in the greisen and in vugs in the quartz.

BRONX PROPERTY

The veins on the Bronx property (3) were formed by replacement of granite, and they are like the Swede and Clark deposits except that no tungsten minerals have been recognized and molybdenite is present in greater abundance. During the early months of World War I, Frederick Weise mined about 50 tons of high-grade molybdenite ore from one of the shoots. The ore was contracted to the German Government; but before the shipment could be made, the stockpile, which extended part way across a narrow gulch, was swept away by a flash flood.

In the shoot from which the ore was mined, molybdenite occurs as irregular foliated masses as much as 2 inches across in the outer parts of the central quartz core, as coarse flakes in the inner parts of the greisen envelope, and as selvages along many quartz veinlets traversing the less completely replaced granite on the hanging-wall side of the quartz core.

From a review of the literature on the tungsten deposits of Burma, Turner (1919, p. 636) concluded that molybdenite appeared to be characteristic of a zone at or below the bottom of the wolframite zone. Ke-Chin Hsu (1943, p. 442) observed a similar zoning in some deposits of China. The Bronx deposits crop out well within the granite stock and therefore probably were formed in a higher temperature zone than the wolframite veins at the edges of the mass.

SAMSEL DEPOSIT

The Samsel deposit (14) is a composite vein deposited along a shear zone in schist that seems to be about parallel with the bedding in strike but steeper in dip. The outcrop of the shear zone shows slight mineralization for a strike length of about 3,500 feet; lenses of vein matter, some as much as 4 feet in width, crop out discontinuously.

As seen in several shallow pits and in one opencut 20 feet deep, the vein matter consists chiefly of white or grayish, generally granular quartz containing many small drusy cavities. The quartz includes variable amounts of pyrite as discrete cubic grains and coarsely granular masses, and locally it contains scatterd platy and prismatic crystals of wolframite partly altered to scheelite. Minor amounts of gold and silver are present in unknown combinations. The outcrops are oxidized and variably stained with limonite and manganese oxides. Several tons of tungsten concentrate (Wilson, 1941, p. 28) have been produced from an opencut on the vein.

A crosscut adit about 125 feet below the outcrop intersected a mineralized fault zone which may be the Samsel vein. The vein matter is chiefly quartz and coarsely granular pyrite with selvages composed of very fine grained quartz and molybdenite. Chalcopyrite is present in very minor amounts.

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