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6/26/85

(602) 398-2106

Bob Johnson

Ed Mueller - Pacific Cyprus - Vancouv

$250,000 down
300,000 shares
200,000 work in 1st year
5% NSR

- picked up Margarita property from Mrs. Wallace Trust
- now administered by Nephew

Quit claim back to Wallace today

Johnson still has

Old Glory + 8 claims - trying to promote this

250,000 tons - 500,000 tons @ .08

Old hole 350'-410' - .31 opt Au - ~400' NE of pit

has drilled ~ 22 air track holes in Old Glory pit area

In the southern PRC, the Spokane dome mylonitic zone is 4 km thick, and fades structurally upward and downward into amphibolite-grade metamorphic rocks without a concordant detachment fault or chloritic breccia. Kinematics of the mylonites determined from ubiquitous S and C surfaces and asymmetric porphyroclasts indicate that movement was top-to-the-east on the eastern and western limbs of the dome. Muscovite, sillimanite, and locally andalusite were stable during the later stages of mylonitization. Locally within Spokane dome, thin (0.5 m), top-to-the-west, non-penetrative ductile shears cut the earlier top-to-the-east mylonites and probably correlate with the Newport fault.

Thick, mid-crustal ductile shearing and shallower detachment faulting represent contrasting structural styles in the PRC. Mylonitization may represent Mesozoic intracontinental shearing caused by the accretion of microplates to the west. The Newport fault fits a model of Eocene crustal stretching which accompanied the uplift of the PRC.

MESOZOIC THRUST SHEETS OF THE HARQUAHALA AND LITTLE HARQUAHALA MOUNTAINS, WESTERN ARIZONA | № 65059

RICHARD, Stephen M., Univ. of Calif., Santa Barbara, CA 93117, REYNOLDS, Stephen J., and SPENCER, Jon E., Arizona Bureau of Geology and Mineral Technology, 845 N. Park Ave., Tucson, AZ 85719

A basal parautochthon and three overlying, stacked thrust sheets in the western Harquahala (WHM) and Little Harquahala (LHM) Mountains, western Arizona, consist of (in ascending order): (1) quartz-phyric rhyodacite to rhyolite volcanic and hypabyssal rocks overlain by approximately 2 km of feldspathic-lithic, feldspathic, and volcaniclastic sandstone, conglomerate, and siltstone, correlated with the McCoy Mountains Formation (MMF). Volcaniclastic sandstone and andesitic to dacitic volcanic rocks intercalated in the middle part of this section indicate that volcanism continued during deposition of the MMF in this area. (2) heterogeneous igneous and metamorphic rocks overlying the MMF thin from a minimum of 250 m thick in the NE to zero in the SW. (3) Precambrian granitic rocks nonconformably overlain by a complete, cratonic Paleozoic section (1000m) overlain by Jurassic(?) dacite to rhyodacite volcanic rocks (900m) and lithic feldspathic sandstone (750m). Two phases of folding in these rocks predate thrusting: large, NE-trending, subhorizontal folds, overturned to the SE are refolded about steeply-plunging, north-trending axes. Metamorphic grade in the Paleozoic rocks increases from unmetamorphosed in the SW LHM to lower greenschist in the WHM. (4) Precambrian schists and granitic rocks make up the highest thrust sheet.

Schistosity is only weakly developed along faults in the LHM, while thin mylonite zones with N-S-trending stretching lineation are present in the WHM. S-C fabrics within mylonite zones indicate transport of upper plates to the south. These thrusts represent the northeastern edge of the Cordilleran fold - thrust belt in western Arizona, but are unusual because they are directed away from rather than toward the interior of the North American continent.

STRUCTURAL CONFIGURATION OF THE SANTA CLARA AVENUE OIL FIELD, VENTURA BASIN, CALIFORNIA | № 60055

Richards, Matthew E., Dept. of Geology, Oregon State University, Corvallis, Oregon 97331

The nonmarine Sespe Formation of Oligocene age has produced 7 million barrels of oil which is trapped by a Miocene mafic igneous intrusion, which cuts across bedding. Throughout most of the oil field, the Miocene and older beds dip about 15° to 25° northwest. The intrusion is probably related to the outpouring of Conejo Volcanics throughout much of the southern Ventura basin. The Pacific Farms #1 well penetrated 4000 feet of igneous rocks below 5100 feet, whereas wells less than 500 feet to the northwest penetrated Sespe Formation over this interval. The western wall of the intrusive body is located by 10 wells which pass repeatedly through the Sespe - intrusive contact. Structure contours on the intrusive contact with the Sespe on the northwest show that the contact varies from N45°E 85°±20°SE in the southern portion of the field, to N90°E 85°S in the northern end of the field. The southeast wall of the intrusion is not cut by wells, but its location is controlled by a well about 4000 feet southeast of the northwest wall. If the intrusive contact is rotated to its position when it was intruded prior to tilting of the middle and late Miocene Modelo Formation, the Sespe overhangs the igneous body along a contact with paleo-dip of 80°NW. Two wells penetrate large inclusions of Sespe within the intrusion. The cause of lateral closure in the field is not yet known but may be related to early Miocene normal faulting of the Sespe Formation.

STRATIGRAPHY AND GEOLOGIC HISTORY OF THE PAJARITO MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA | № 66905

RIGGS, Nancy, Department of Geosciences, University of Arizona, Tucson, AZ 85721

Detailed geologic mapping in the Pajarito Mountains west of Nogales indicates that rhyolitic crystal tuff exposed in most of the range is Jurassic in age. The stratigraphic section comprises 3000 m of crystal tuff, unconformably overlain by up to 1000 m of Glance-equivalent coarse conglomerate and 200 m of Bisbee Formation sandstone, siltstone, algal limestone, and conglomerate. This package is in fault contact with mid-Tertiary andesitic to rhyolitic flow, tuff, and volcaniclastic sedimentary rocks. Although previous workers have assigned a Cretaceous age to the basal crystal tuff, a pre-earliest Cretaceous age is indicated by the stratigraphic position of the tuff below Glance-equivalent conglomerate. In addition, the presence of locally interstratified cross-bedded arkosic sandstone within the crystal tuff suggests correlation with the early Jurassic Ali Molina Formation.

The geologic history of the Pajarito Mountains begins with Jurassic volcanism between 200-150 m.y. ago, represented by the rhyolitic crystal tuff. High-angle block faulting and erosion of the arc are reflected in the late Jurassic-early Cretaceous coarse conglomerate. Early Cretaceous Bisbee subsidence and sedimentation are represented by probable lake sediments. Thrust faulting and northeast-trending mineralized shears may record crustal shortening associated with the Laramide orogeny. Following mid-Tertiary volcanism, northwest- and northeast-trending high-angle faults juxtaposed Tertiary and Mesozoic strata. Finally, uplift along a north-northeast-trending high-angle fault exposed a section of older Mesozoic rocks on the east and younger Cenozoic rocks on the west.

WHOLE-ROCK STRONTIUM ISOTOPIC AGES OF MESOZOIC PLUTONS IN THE WEST WALKER RIVER AREA, EAST-CENTRAL CALIFORNIA | № 65102

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Strontium isotopic data for 270 whole-rock samples from 12 Mesozoic granitoids within a 30-km radius of the confluence of the West Walker and Little Walker Rivers, east-central California, yield 2 Late Jurassic ages of 161.3 ± 4.5 m.y. and 155.0 ± 3.0 m.y. and 10 Late Cretaceous ages ranging from 96.9 ± 0.9 m.y. to 82.4 ± 1.1 m.y. Initial $^{87}Sr/^{86}Sr$ values range from 0.70412 to 0.70637. These units include three of four plutons described in detail and three of four others mentioned briefly that are termed older felsic and mafic plutons in GSA Special Paper 176 (Schweickert, 1976). Since the theme of the Special Paper is the assignment of a probable Early Jurassic age to the older plutons in support of a conceptual tectonic model, it is worth emphasizing that none of the whole-rock Sr ages of the units termed older plutons are older than Late Jurassic and two are Late Cretaceous.

An argument for the Early Jurassic age of the shallowly emplaced China Garden pluton is the conjecture that it erupted a nearby dacitic tuff thought to be part of a volcano-sedimentary sequence lithologically and structurally similar to fossiliferous Upper Triassic to upper Lower Jurassic strata 25 km north. The Sr data do indicate contemporaneity of the pluton with the dacitic tuff and also with an underlying rhyolite intruded by the pluton. A Late Cretaceous 10-point whole-rock isochron of 90.4 ± 1.5 m.y. for the rhyolite is the youngest age yet determined for Mesozoic volcanic rocks in the Sierra Nevada.

Much of the shallow-level Late Jurassic Desert Creek pluton has undergone albitization, resulting in Rb loss. A suite of progressively altered granite samples from one locality in the pluton gives a rotated six-point whole-rock isochron of 87.4 ± 1.9 m.y., matching the age of the adjacent Late Cretaceous porphyritic granite of Taylor Valley.

LATE HOLOCENE RECURRENT FAULTING ON THE GLEN IVY NORTH STRAND OF THE ELSINORE FAULT, SOUTHERN CALIFORNIA | № 65536

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Sediments exposed in test trenches across the Glen Ivy North strand of the Elsinore fault zone consist of stratified clayey silt, silt, sand, and gravel with several interbedded 0.1 to 2cm thick peat horizons, three of which have been dated. Lateral slip is demonstrated by stratigraphic mismatch across individual fault strands, offset sand and gravel channels, the anastomosing nature of the individual strands, and the local and regional fault geometry, geology, and geomorphology. At least four individual fault strands show vertical separations of up to 50cm and provide evidence for the following late Holocene seismic events: one or two earthquakes since 1660 A.D. $^{+300}_{-100}$, one or two between 1275 A.D. $^{+100}_{-65}$ and 1660 A.D. $^{+300}_{-100}$, one between 1260 A.D. ±40 and 1275 A,D. $^{+100}_{-65}$, and at least three prior to 1260 A.D. ±40. These data yield a recurrence interval for groundbreaking earthquakes of about 200 - 300 years, which combined with previous estimates of the long term horizontal slip rate of 1 to 7 mm/yr, suggest typical earthquake magnitudes of 6 to 7.

PLEISTOCENE VERTEBRATES FROM DOWNTOWN SAN FRANCISCO, CALIFORNIA | № 60750

RODDA, Peter U. and BAGHAI, Nina L., Department of Geology, California Academy of Sciences, San Francisco, CA 94118

Well-preserved, disarticulated cranial and post-cranial elements of Mammuthus columbi (Columbian Mammoth) and Bison latifrons (Giant Bison) were recovered from gravelly, sandy clay of the Colma Formation at the south base of Telegraph Hill in San Francisco, California. The fossils were recovered from the middle of a 12-foot-thick sequence of interbedded sand and clay exposed in an excavation at the intersection of Pacific and Columbus Streets. The animals apparently were buired in a boggy environment at the south base of a steep hillside underlain by Franciscan shale.

68A

Cordillera

Mike Greeley 9/23/85

Dro Blanco - Bill Ewing - head Rayrock Mines
- [redacted] Hilard Crow - partly owned by Teck

John Kenason - consult. geol
Al " - civil eng. } lease on Montana Mine tails
tails run 1.6 oz/

Ken McLaughlin - BattleAx Mining Co. - Cerro Colorado Mine
Mary G mine area

V. of Coronado Nat. Mon - 3 patented claims
qtz. vein

. Dives SE to Arizona Klondyke, just SE of Gold Prince
all of Big Dyke - Big Dyke is gold-bearing near Dives, barren at Gold Prince
Gold Prince ~ 1000 tons/mo. to Douglas | Dyke from 20' to 100' wide
Phelps Dodge underground - trackless

primary copper industry in 1984
Cliff Hicks - new copper report ; ~~1984~~

Bul 430

SOME OCCURRENCES OF MOLYBDENITE IN THE SANTA RITA AND PATAGONIA MOUNTAINS, ARIZONA.

By F. C. Schrader and J. M. Hill.

LOCATION AND GENERAL DESCRIPTION.

The Santa Rita and Patagonia mountains constitute one of the most prominent mineral-bearing desert ranges of the Southwest. Beginning near the transcontinental line of the Southern Pacific Railroad about 20 miles southeast of Tucson, the range extends southward in Pima and Santa Cruz counties, with a length of 45 miles, to the international boundary, which it crosses about 12 miles east of Nogales. The northern two-thirds of the range, extending to Sonoita Creek, which cuts across it, is known as the Santa Rita Mountains and the remainder as the Patagonia Mountains.

The range is generally rugged and near the middle part of its course culminates in Old Baldy, at 9,432 feet above the sea. It is drained by Santa Cruz River, which flows in a northwesterly direction via Tucson into the Gila, which in turn joins the Colorado at Yuma.

In a reconnaissance of the mineral deposits of the mountains during the season of 1909 the occurrences of molybdenite (sulphide of molybdenum, MoS_2) herein described were encountered at the following more or less widely separated localities, as indicated on the accompanying map (fig. 12): Helvetia, Madera Canyon, Providencia Canyon, Duquesne, and near the international boundary Of these the most important is Helvetia.

DESCRIPTION BY LOCALITIES.

HELVETIA.

Helvetia, the most important mining camp in this part of Arizona, is situated 27 miles southeast of Tucson, in the northern part of the Santa Rita Mountains, on the west slope at an elevation of about 4,300 feet. (See fig. 12.) Here molybdenite occurs at two localities—the Leader mine and the Ridley mine.

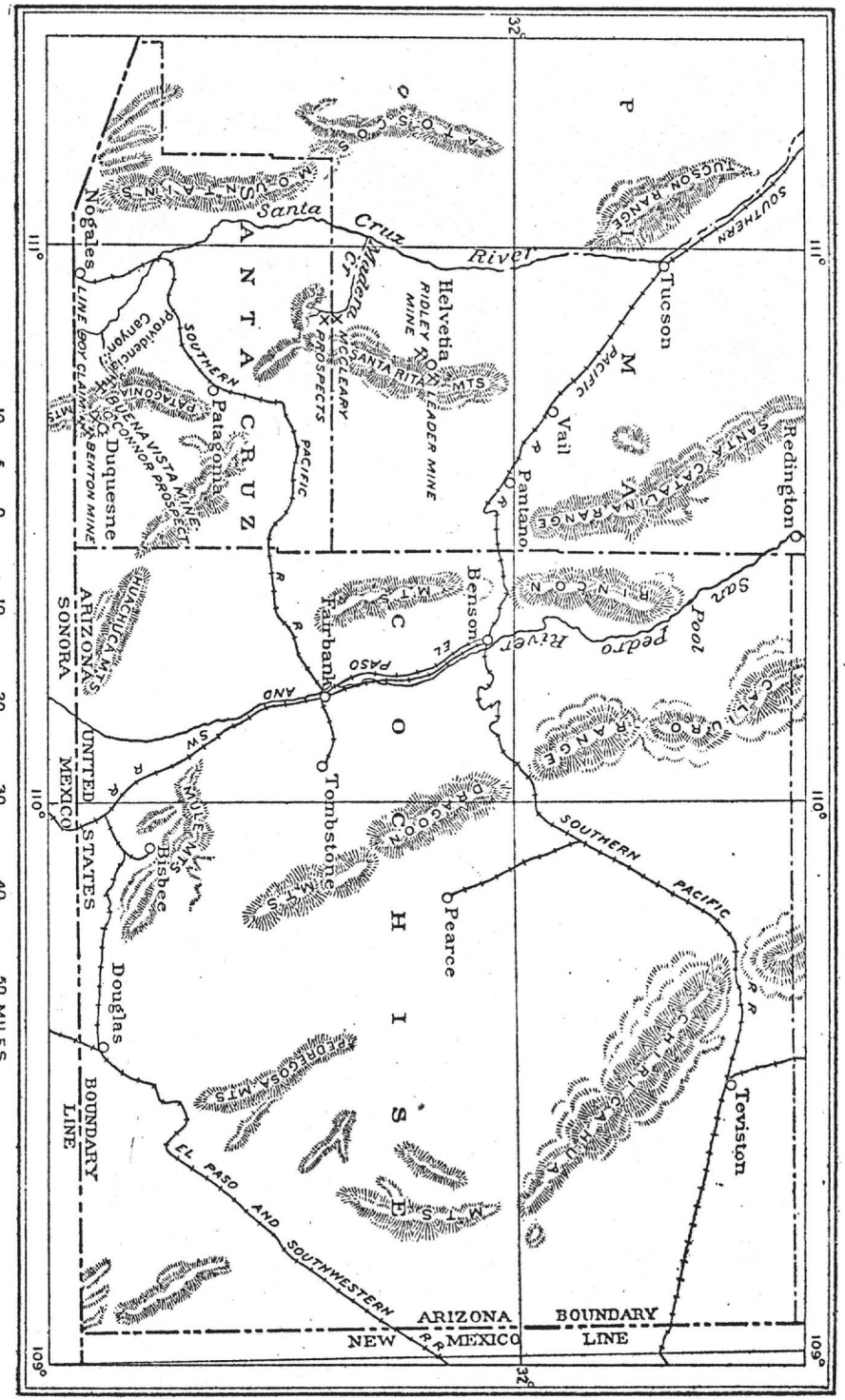

Figure 12.—Index map of southeastern Arizona, showing location of molybdenite deposits in Santa Rita and Patagonia mountains.

LEADER MINE.

The Leader mine, one of a group of copper mines owned and operated by the Helvetia Copper Company, is situated east of the town and a few hundred feet above it, at an elevation of about 4,700 feet, in altered Paleozoic limestone, close to the northeastward dipping contact with underlying granite. Both pre-Cambrian and post-Carboniferous granitic rocks are present. The latter include aplite dikes as well as granite porphyry.

The workings in the main are on what is known as the tunnel level, which follows the contact for some distance, extending in a northerly direction. The molybdenite occurs at a point about 150 feet in from the mouth of the tunnel, in dull-brownish and greenish to yellowish mineralized garnetiferous silicified limestone and quartz.

The rock is more or less massive. It varies from fine to medium grained and is composed essentially of pale-greenish garnet, which corresponds to grossularite and occurs in grains and imperfect crystals. The mineral next in abundance is quartz, which seems to be of two periods. The remaining secondary metamorphic minerals observed are calcite, magnetite (or ilmenite) and epidote, which are present only in small amount. The latest mineral in general is quartz. After the rock had been severely crushed and fractured the cracks and openings became filled with quartz, which occurs in macroscopic and microscopic lenses, irregular bodies, and veins. The smaller veins have in general a direction roughly parallel with the ore bed and connect variously with the larger bodies or lenses, in places forming a closely woven reticulating meshwork, with garnet filling the interspaces.

At the tunnel level a tabular vein or seam of copper ore with quartz gangue inclines eastward at an angle of about 40° and is opened on the incline by what is known as the Molybdenite winze. In the vicinity of the level the vein is only a few inches in width, but with it, on either side, is associated from 1 to 3 feet or more of the above-described mineralized limestone, which contains chalcopyrite, pyrite, coarse calcite, and quartz, and which is a low-grade copper ore.

In the incline at a depth of 35 or 40 feet below the level, however, conditions change. Here molybdenite occurs in both the vein and the inclosing rock, mingled with the chalcopyrite and pyrite. In the next 8 or 10 feet below the dip flattens somewhat, the chalcopyrite and pyrite decrease greatly, and there is a more than corresponding increase in the amount of molybdenite, so that the deposit is there a relatively pure molybdenite ore, and seems to constitute a body or ore bed at least 3 or 4 and probably 6 or 7 feet in thickness. Owing to the presence of water in the shaft sunk at the end of the incline, examination could not be made across the entire bed. So far as observed there seemed to be no detrimental intermingling of chalcopyrite.

The molybdenite occurs in lenses, irregular bodies or bunches, and crystal aggregates embedded in and associated with both the rock and the quartz. It is mostly fine-grained, but some of the crystal plates range up to one-half inch or more in maximum diameter.

Bodies of the molybdenite inclosed in the middle of some of the quartz veins indicate that deposition of this ore probably continued after that of the quartz, with which the molybdenite seems to be in the main contemporaneous. Like the quartz, it was probably deposited by thermal solutions that accompanied or followed the intrusion of the aplite dikes or granite porphyry.

A considerable amount of molybdenite can be seen on a large dump of low-grade copper ore at the entrance to the mine, and a smaller pile of 8 or 10 tons of molybdenite ore is reported to average 6½ per cent of molybdenum. At the time of visit in 1909 the company was planning to mine the deposit commercially and expected to produce ore with a very much higher percentage of molybdenum.

RIDLEY MINE.

The Ridley mine, owned and worked for copper by C. B. Ridley, of Helvetia, is located in the foothills a mile southwest of Helvetia at an elevation of about 4,060 feet. The topography in this vicinity is gentle. The country rock is the pre-Cambrian (?) granite and it is freely intruded by dikes and masses of aplite which, as shown by the croppings to the north of the mine, are associated with the vein. The mine is situated on a tabular quartz vein that contains the ore and dips about 50° E. It is developed by an incline on the vein to a depth of 150 feet and contains short drifts on two levels, one of which is near the bottom of the shaft and the other 55 feet above it. The vein varies in thickness from 2 to 5 feet and averages about 4 feet. Some of the quartz is drusy. The better ore occurs in the lower part of the mine. Here it is mostly contained in a 10 to 18 inch pay streak on the hanging-wall side of the vein. It consists of alternating bands of quartz and sulphides—pyrite, chalcopyrite, argentiferous galena, and sphalerite—and is said to run about 6½ per cent in copper and 30 ounces in silver and $1.50 in gold to the ton.

In the south drift on the lower level a little molybdenite is scattered through the ore, and in the sump at water level, between the pay streak and the granite hanging wall, occurs a band from one-eighth inch to 4 inches in width, composed of sericitic mica, quartz, pyrite, and fine-grained molybdenite. In places this material seems to constitute a good molybdenum ore. Its concentration, however, may be difficult owing to its mixture with mica.

MADERA CANYON.

Madera Canyon drains the northwestern part of the Old Baldy section of the Santa Rita Mountains, about 10 miles south-southwest of Helvetia and 35 miles south of Tucson. In the foothill part of its course, where the creek and wagon road cross the Pima-Santa Cruz county line, a short distance above White House, as indicated on the accompanying map (fig. 12), occur a group of molybdenite prospects commonly known as the McCleary prospects, from the name of the owner. They range from about 4,500 to 5,000 feet in elevation and trend nearly north and south along the creek, extending half a mile on either side of the county line. The deposits probably have a much wider extent in an east-west direction, for the prospects here described have only accidentally been brought to light by the erosion of the creek across a seemingly small portion of the area.

In this part of its course the creek, a fine, clear mountain stream, about 2 feet wide by 3 inches in depth, flows in a trench but 5 to 15 feet deep. The topography is gentle and the prospects are all easily accessible.

The country rock is pre-Cambrian (?) granite. It has been fractured by dynamic disturbances, and along the more prominent of the resulting joints and fault fissures occur quartz veins containing the prospects. These veins vary from 1 foot to 12 feet or more in width and are mostly compound veins or stockworks. They are in the main associated with intrusive aplite or allied dikes, with which, as at Helvetia, the deposits are probably genetically connected.

The most important exposures, as shown in prospect shafts and tunnels, will be described in downstream order from south to north.

The most southerly of the prospect holes is situated on the west side of the creek at an elevation of 4,990 feet. It is on a small, somewhat iron-stained quartz vein that carries pyrite, chalcopyrite, and flaky molybdenite and dips 70° N. A 20-foot dike of aplitic granite forms the hanging wall.

Just south of the road forks, in the creek bank, at an elevation of 4,765 feet, in a fine-grained phase of the granite, a 4-foot vein of iron-stained honeycombed quartz dipping steeply to the north is opened by a shaft which was filled with water at the time of visit, but is reported to be 40 feet deep. On the surface the vein exposes a little flaky molybdenite and a very minor amount of pyrite and chalcopyrite.

On the east side of the creek, about 200 feet from the road, at an elevation of 4,675 feet, the granite is traversed by a stockwork several feet in width, composed mainly of massive iron-stained dark smoky quartz veins. It strikes N. 60° E. and the dip is vertical or steep

to the north. The quartz is in part drusy or comby. It is concentrated along the north or hanging-wall side of the fissures, where it is from 6 inches to 2 feet in width and contains a little pyrite and a less amount of chalcopyrite. Associated in part with the pyrite and chalcopyrite and occurring also independently of these minerals, exposed at many places on the joint planes, are flakes of molybdenite that are locally concentrated in masses one-fourth inch thick and covering an area of about a square inch. Flaky aggregates and small bodies of pure molybdenite also occur in the druses and otherwise inclosed in the quartz, as at Helvetia. Associated with the larger masses of the molybdenite and also with limonite on the joints near the surface is a soft yellowish earthy material which looks like clay, but which on examination was found to be ferrous iron sulphate. At the mouth of the 10-foot tunnel driven on this prospect, dipping steeply to the southeast, occurs what seems to be a dike of fine-grained aplitic granite, with which the molybdenite is probably genetically connected.

The most northerly and apparently the most important prospect of the group is on the east side of the creek, at an elevation of 4,560 feet. Here in the granite is exposed a stockwork of quartz veinlets 3 to 7 feet wide. It dips about 60° NNW. and is traceable for a distance of 1,500 feet eastward from the opening. The granite between the veinlets is very much altered. It is soft, is of a yellowish-red color, due seemingly to iron staining, and contains pyrite crystals and flakes of molybdenite. The quartz forming the veinlets of the stockwork is smoky and coated with limonite and a little molybdenite. Some walls of open fissures are coated or glazed with a black sinter-like substance, which is mostly silica but contains manganese and molybdenum. It is particularly abundant on the south or foot wall.

PROVIDENCIA CANYON.

GENERAL DESCRIPTION.

Providencia Canyon heads about 2 miles northwest of Washington, in the southern part of the range, drains a considerable portion of the western slope, and joins the Santa Cruz 6 miles northeast of Nogales. The molybdenite prospects here described are in the foothill portion of its course, in the general region of the Golden Rose and Buena Vista mines, 10 miles north-northeast of Nogales, 5 miles west of Washington, and about 5 miles north of the international boundary, at elevations between 4,200 and 5,000 feet.

The topography is rough, being of the type formed from an area of igneous rocks scored by canyons and gulches in an arid climate, but the canyons or washes form avenues of approach to the mines.

The country rock is pre-Cambrian (?) granite, faulted and intruded by dikes and masses of quartz diorite generally, with granite porphyry

occurring near by. As in Madera Canyon, it has suffered considerable dynamic disturbance, and the resulting fault fissures locally contain mineral-bearing quartz veins or lodes. The granite also locally contains metallic minerals in considerable amount.

In the northwestern part of the triangular area bounded by Sycamore Canyon on the south and east and Providencia Canyon on the northwest, just southeast across Providencia Canyon from the Golden Rose mine, the granite is uniformly impregnated with evenly disseminated small macroscopic crystals, aggregates or masses, and grains of chalcopyrite and pyrite, and contains sparingly molybdenite, having much the same habit as the other minerals. These mineralogical conditions are very constant throughout the mile or more of the northwest slope of the mountain examined opposite the Golden Rose mine, where in prospecting for copper the ground has been opened at intervals by shafts and tunnels from 10 to 80 feet in depth, and the same conditions are reported to prevail over most of the area above described, which occupies 2 square miles or more and rises 800 feet above the canyon.

From cursory examination these minerals seem in all respects to be primary constituents of the granite, but as such occurrence is unusual, decision on this point must await further examination.

Hess,[a] from investigations of the same minerals in other fields, concludes that the minerals are probably not primary and that the molybdenite in the places he cited was deposited possibly by a gaseous solution that had greater power than a liquid solution to penetrate the dense granite.

BUENA VISTA MINE.

The Buena Vista mine, owned by the Banco del Oro Mining Company, of Magdalena, Sonora, Mexico, is located about three-fourths mile southeast of the Golden Rose mine and the locality above described. It is in the pre-Cambrian (?) granite, on a fault or shear zone, with intrusive quartz diorite outcropping on the ground and granite porphyry occurring near by.

The zone comprises half a dozen or more fault fissure veins and associated lodes of more or less mineralized crushed rock, all of which dip about 60° SSE. The veins range from 6 inches to more than 6 feet in width. The two most important are about 100 feet apart. The vein filling is quartz with here and there associated calcite. The mine contains about 2,000 feet of work. It is developed principally by three tunnels on suitably spaced levels between approximately 4,700 and 5,000 feet in elevation. Two of the tunnels are drifts on the main vein. The other is a crosscut which opens a parallel vein.

[a] Hess, F. L., Some molybdenum deposits of Maine, Utah, and California: Bull. U. S. Geol. Survey No. 340, 1908, pp. 231-239.

In the lower drift, which is 415 feet in length, the main vein contains about 5 inches of white quartz and calcite that carries chalcopyrite, pyrite, and a little flaky molybdenite. The ore is separated from both walls by gouge. In the face of the crosscut tunnel, which is 45 feet above the lower tunnel, is a 4-foot zone of crushed granite and quartz carrying pyrite, chalcopyrite, and a little flaky molybdenite.

DUQUESNE.

The well-known mining camp of Duquesne, south of Washington, lies on the east slope of the Patagonia Mountains, about 2 miles north of the international boundary and about 15 miles east-northeast of Nogales. At the southwestern border of the camp, about one-fourth mile west of the Belmont mine, on ground owned by Captain O'Connor, of Duquesne, occurs ore which shows galena, chalcopyrite, pyrite, and a little molybdenite, associated with drusy quartz. The deposit is in the country-rock granite just west of the contact of this rock with limestone. The granite is intruded or cut by masses of granite porphyry. Both rocks are much shattered and are traversed in all directions by a large number of the drusy quartz veins. The property is developed by several shafts, but these could not be entered at the time of visit, as they were full of water.

SAN ANTONIO CANYON.

Molybdenite is contained in two openings, the Benton mine and the Line Boy prospect, near the international boundary, in San Antonio Canyon, at the east foot of the Patagonia Mountains, about 2 miles south of Duquesne and 15 miles east of Nogales. The more important of these is the Benton mine.

BENTON MINE.

The Benton mine, owned by Dennis Coughlin and partners, of Duquesne, is situated about three-fourths mile northeast of post 113 of the international boundary line, on open ground, at an elevation of about 5,200 feet. It is developed principally by a 155-foot tunnel. The country rock is granite, intruded by granite porphyry and aplitic granite. The granite porphyry contains the values of the mine, which consist of low-grade copper and gold ore. The ore occurs chiefly in a dike of this rock 60 feet wide, which is impregnated with pyrite, chalcopyrite, and a little flaky molybdenite. Its contact with the granite is marked by a sericitic zone a few feet in width.

LINE BOY PROSPECT.

The Line Boy prospect, owned by Captain O'Connor, of Duquesne, is located just north of post 113 of the international boundary, about three-fourths mile southwest of the Benton mine, at an elevation of

about 5,400 feet. It is developed to a depth of 80 feet by three shafts and a tunnel.

The country rock is gray granite, intruded by a north-south dike of granite porphyry 300 feet in width. The ore deposits are contained in the granite, which near the dike is impregnated with pyrite, chalcopyrite, molybdenite, and a little bornite. The metallic minerals are particularly abundant along the contact of the two rocks and are concentrated in joint planes and fissures, locally with a little associated quartz. In one place occurs a 3-foot band of fine-grained, friable, and relatively pure specularite.

The molybdenite occurs also unassociated with the other sulphides, in the form of comparatively pure lumps or crystals, in places one-eighth of an inch thick and more than half an inch in diameter, in a coarse siliceous, sericitic phase of the granite. It also, with quartz in about equal amount, forms veinlets of considerable continuity that traverse less acidic portions of the granite and range from microscopic width to one-sixteenth inch. It is also present in small amount in microscopic to very small macroscopic veinlets or seams traversing a dense phase of the granite. The veinlets are parallel, ten or twelve being contained in a single thin section made for microscopic study. They contain and are associated with microscopic druses.

ORIGIN OF THE DEPOSITS.

At all the localities here described the molybdenite, whether found in veins, as impregnations in the rock, or in other forms, occurs in granite or in quartz veins cutting the granite. All the deposits, besides being intimately associated with considerable quartz, are also more or less intimately associated with granitic intrusive rocks—aplite, granite porphyry, and allied acidic rocks. From the constancy of these conditions it seems probable that some genetic relation exists between the deposits and the intrusive rocks, and that the deposits were probably formed by precipitation from thermal solutions whose circulation accompanied or followed the intrusions.

FUTURE PROSPECTS OF THE DEPOSITS.

The only one of the above-described localities at which molybdenite seems to be present in workable quantities is at Helvetia, notably in the Leader mine. However, as all the deposits occur under geologic conditions favorable for molybdenite and are still in the prospect stage, it is possible that with development some others may prove to be of economic value. At the time of visit the Madera Canyon prospects were being exploited for molybdenite. An important point in the selection of deposits for development is the absence of chalcopyrite, for this mineral is difficult to separate from molybdenite and thus reduces its market value.

GENERAL OCCURRENCE OF MOLYBDENITE.

According to Crook,[a] the molybdenite at fifty or more localities in different parts of the world which have been described occurs in a great variety of rocks, including practically all the main groups, but its occurrence with granite is by far the most usual and typical. Hillebrand[b] also states that molybdenite accompanies the more acidic rocks and is a well-known constituent of some granites.

According to Crook, "the association with sulphides and oxides is that most characteristic of the occurrence of molybdenite in quantity in veins." In small quantities the mineral is not at all uncommon in the fissure veins of the Cordilleran States. The deposit at Crown Point, Wash.,[c] economically one of the most important in the United States, is a quartz vein in which molybdenite occurs in association with chalcopyrite.

USES AND PRODUCTION OF MOLYBDENITE.

Molybdenite is important as the main source of molybdenum, whose chief use in recent years is that of an alloy in the manufacture of steel. Other uses[d] of molybdenum in its different compounds are, as ammonium molybdate, to determine phosphorus in iron; as fireproofing material; as a germicide; as a disinfectant; as sodium molybdate, to color pottery and porcelain blue and to dye silks and woolens; as molybdenum tannate, to color leather; and, as "molybdenum indigo," to color india rubber.

According to Hess,[e] the price of molybdenum ordinarily ranges between 20 and 30 cents a pound for material carrying 92 per cent of molybdenum sulphide. The production of molybdenite ore in the United States is small, being in ordinary years less than 50 tons carrying 92 per cent of molybdenum sulphide.

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[a] Crook, A. R., Molybdenite at Crown Point, Wash.: Bull. Geol. Soc. America, vol. 15, 1904, pp. 283-288.

[b] Hillebrand, W. F., Distribution and quantitative occurrence of vanadium and molybdenum in rocks of the United States: Bull. U. S. Geol. Survey No. 167, 1900, p. 53.

[c] Landes, Henry, Ann. Rept. Washington Geol. Survey, 1901, vol. 1, pp. 41, 92, 93. Crook, A. R., Bull. Geol. Soc. America, vol. 15, 1904, p. 285. Pratt, J. H., Mineral Resources U. S., 1899 to 1902, U. S. Geol. Survey.

[d] Hess, F. L., Molybdenum: Mineral Resources U. S., for 1908, pt. 1, 1909, pp. 745-747.

[e] Op. cit., p. 747.

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NOTE ON THE OCCURRENCE OF TUNGSTEN MINERALS NEAR CALABASAS, ARIZONA.

By J. M. Hill.

In the latter part of June, 1909, the writer made a short visit to the tungsten deposits about 3 miles south and a little east of Calabasas, Ariz., a station on the Nogales branch of the Southern Pacific Railroad, 10 miles north of Nogales. Information on this occurrence was also obtained from Messrs. Taylor, Peck, and Reagan, of Nogales, the two latter men owning claims in the vicinity.

The presence of wolframite was first noted about 1906, and a few prospect holes sunk at that time led to mild excitement. Little work has been done on the deposits. The deepest shafts are about 30 feet and the greater number are less than 10 feet in depth. Mr. Reagan has shipped about 1,000 pounds of ore which he states assayed more than 50 per cent tungstic acid, and about 400 pounds of ore of the same grade is still on the ground, together with several hundred pounds of lower-grade material.

The low north end of the tongue of land between Santa Cruz River and Nogales Wash is underlain by a very coarse, in many places porphyritic, granodiorite of light-gray color, that weathers to a flesh pink or dull red. In this rock are pink orthoclase crystals up to half an inch in diameter; the striations on plagioclase are plainly visible, and blebs of quartz and some dark micaceous mineral can be distinguished.

The granodiorite is cut by intrusive rocks of two types. One of small extent and of little importance so far as the ore deposits are concerned is a fine granular rock composed of orthoclase, quartz, some plagioclase (possibly andesine), and an insignificant amount of biotite.

The dikes that are most closely associated with the wolframite deposits are of the same type, but apparently of two ages of intrusion, possibly very close together. One set strikes N. 75° W. and dips at rather high angles to the north. The other and later system strikes N. 25° W. and is vertical or has a very steep dip to the west.

None of these dikes are over 6 feet across and most of them are between 2 and 4 feet. Some of them are traceable for 1,500 to 2,000

feet, but the greater number are shorter. The whole tongue is a grill of dikes in which those trending east and west are the more numerous. At one place four dikes, each about 2 feet wide, were seen within 100 feet, all striking N. 75° W. These were crossed by two north-south dikes.

The rock is a greenish-black, dense, fine-grained lamprophyre. Under the microscope it appears holocrystalline with trachytic texture. The most important constituents are an undeterminable plagioclase with index of refraction probably less than Canada balsam, long needle-like altered greenish crystals of hornblende, and a minor amount of quartz. The rock is largely altered to chlorite and a little epidote and contains some hematite, probably derived from magnetite, which is fairly abundant in the rock. It is cut by veinlets of calcite. Some phases are rather coarsely porphyritic, and in these the weathered surfaces are pitted, the casts being coated with iron oxide or filled with calcite.

The contacts of these dikes with the granodiorite are extremely sharp. The latter is apparently little changed except for a fraction of an inch. Along this belt, though the original constituents of the granodiorite are still visible, there is also a great deal of epidote and a chloritic mineral developed from both feldspars and ferromagnesian minerals. For one-fourth of an inch from the contact the intrusive rock is very dense, fine grained, and black; inside of this there is a belt of varying width, dependent on the size of the dike, that is much epidotized and chloritized; and in the center the rock is unaltered.

The deposits are veins showing beautiful comb structure, and in places repeated bands of quartz and wolframite. The usual order from the wall inward is quartz, wolframite. Here and there this order is reversed, and it may be that the deposition was more or less simultaneous, as wolframite crystals are seen in some of the quartz layers, and vice versa. Postmineral movement is shown by the gouge-covered wall, but the veins were not much crushed by this disturbance. In a number of places the quartz is cemented to the wall by a thin layer of greenish siliceous material, which is very dense, like a silicified shale, and may be the intrusive rock that has been altered by the solutions which formed the veins.

The principal gangue mineral is quartz, but there are some small crystals of calcite. The walls and gouge are in many places iron stained.

The only metallic minerals are wolframite, a dark reddish-black heavy mineral with metallic luster and brownish streak, and a very minor amount of scheelite. The wolframite is in part fairly well crystallized, but mostly rather massive. In the crystallized form, in the larger veins, the crystals have apparently grown into an open space that has later filled with white vitreous quartz. The wolfram-

calcite of the Cobalt ores is notably ferruginous. Silver-bearing solutions after reacting with simple arsenides in accordance with any one of the above equations would carry sulphuric acid. By subsequent reaction with the ferruginous calcite, this acid solution would create spaces in which silver might be deposited and coincidently ferrous sulphate is formed and this salt is known to be an effective precipitant of silver.

In conclusion, chemical reactions that from experimental results are known to take place if acidic sulphate solutions carrying silver and iron are brought in contact with the minerals characteristic of the Cobalt ores appear adequate to explain all of the replacement phenomena described in this paper. It is probable that few geologists would deny to downward enrichment a rôle in the genesis of the silver ores of Cobalt, Ontario, and similar ores elsewhere. In so far as downward enrichment has been operative it has probably involved reactions of the order here indicated.

The study of reactions that would take place if the same suite of primary minerals were brought in contact with silver-bearing solutions having properties analogous to those of hypogene ore-bearing solutions offers an attractive field for geochemical research.

THE GEOLOGIC DISTRIBUTION AND GENESIS OF THE METALS IN THE SANTA RITA–PATAGONIA MOUNTAINS, ARIZONA.[1]

FRANK C. SCHRADER.

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[1] Published with the permission of the Director of the U. S. Geological Survey. A fuller account appears in the recently published U. S. Geological Survey Bulletin 582, which is based on a field reconnaissance made by J. M. Hill and the writer.

LOCATION.

The Santa Rita and Patagonia mountains are situated in southern Arizona in Pima and Santa Cruz counties, and in the Patagonia and Nogales topographic quadrangles of the United States Geological Survey. Forming an irregular belt about eight miles in average width the mountains extend from near the main line of the Southern Pacific Railroad east of Tucson, southward to the Mexican boundary, nearly fifty miles distant. Patagonia, an important distributive and shipping point for mining districts, is located on the Benson-Nogales branch of the railroad where it crosses the south-central part of the range.

MINING DISTRICTS.

Beginning on the north the range is subdivided into the Empire, Helvetia, Greaterville, Old Baldy, Tyndall, San Cayetano, Wrightson, Red Rock, Harshaw, Palmetto, Patagonia, and Nogales districts, each district having its own several camps or settlements. The chief producers and those in which the mines and deposits are the more abundantly distributed, are the Helvetia, Empire and Greaterville districts on the north, the Tyndall district, on the west-central slope of the range, and the Harshaw and Patagonia districts on the south.

SURFACE FEATURES.

The mountains are of the Great Basin type. On either side they overlook broad detritus-filled valleys. They are mostly rugged and near the center of the range culminate in Old Baldy, a knoblike peak at 9,432 feet in elevation or about 7,000 feet above the adjoining Santa Cruz Valley on the west. Longitudinal faulting has played an important part in the orogeny. The gentler slopes are on the east, the scarps and steeper slopes on the west.

The mountains form a nearly continuous range, though toward the south they are traversed by the trenchant valley of Sonoita Creek. The portion to the north of the valley is known as the Santa Rita and that to the south as the Patagonia Mountains.

The mountains are drained by the Santa Cruz River, which flows northward into the Gila.

GEOLOGY.

The range consists of a granitic axis of probable pre-Cambrian age, flanked by overlapping and locally highly tilted Cambrian ? to Cretaceous sedimentaries, which except the Cretaceous have been invaded by Mesozoic intrusives and all covered by Tertiary volcanics. The structure in general is monoclinal with the dip gently to the east and the trend northwesterly. Areally, the igneous rocks are dominant. In a generalized section the principal sediments in natural or descending order are as follows:

SEDIMENTARY ROCKS IN THE SANTA RITA AND PATAGONIA MOUNTAINS, ARIZONA (GENERALIZED SECTION).

			Thickness.
Cenozoic	Quaternary	Alluvium (silts, sands and gravels along present streams)	100 feet.
		Gravels and sands (valley fill)	
Chiefly Mesozoic	Chiefly Cretaceous	Red shales, sandstones and conglomerates (chiefly Comanche series)	6,000 feet.
	Unconformity		
Paleozoic	Carboniferous (Pennsylvanian)	Thin-bedded dark limestones	4,000 feet.
		Heavy light-colored limestones	
	Unconformity		
	Devonian (Middle Devonian)	Thin-bedded gray limestone	
	Unconformity		
	Cambrian?	Conglomerate Quartzite Shale Schist	4,000 feet.

Economically, the most important of the sedimentary rocks are the Paleozoic limestones. They occur in relatively moderate-sized areas throughout the range and are locally highly altered by contact metamorphism. In a few instances, as at the

Flux mine, near Patagonia, and at the Duquesne-Washington camp, the limestones have been largely engulfed by the invading magmas.

The principal igneous rocks in partial columnar and age order, beginning with the youngest, are as follows:

IGNEOUS ROCKS IN THE SANTA RITA AND PATAGONIA MOUNTAINS, ARIZONA.

				Thickness.
Lava flows	Quaternary	Basalt		6 feet.
	Tertiary	Tuffs and agglomerates		2,500 feet.
		Rhyolite		
		Andesite		
		Quartz latite porphyry		
		Rhyolite		
Granitic intrusives	Mesozoic	Acidic	Rhyolite porphyry	
			Aplite and aplitic rocks	
			Granite porphyry	
			Younger quartz monzonite	
			Quartz diorite	
			Older quartz monzonite	
			Granite	
		Basic	Diabase	
			Gabbro	
			Syenite rocks	
			Lamprophyric dike rocks	
Pre-Cambrian?			Granite (basal)	

Of the igneous rocks the Tertiary effusives are most abundant. They occur in areas ranging up to 10 miles or more in extent and cover most of the south-central part of the range They consist chiefly of normal rhyolites and andesites with associated tuffs and breccias and occur as heavy flows and beds; in the vicinity of Old Baldy a thickness of 2,100 feet is exposed. To the southwest near the Alto mine in the Tyndall district effusive features are not so marked and the quartz latite assumes a holocrystalline texture.

In places, the lavas are hydrothermally altered by sericitization, silicification, and propylitization.

The most important of the igneous rocks, however, with reference to the ore deposits are the Mesozoic acidic intrusives. These granitic rocks seem to have a common origin and probably represent differentiations of the same mother magma. They

include masses of intermediate composition and range from quartz diorite through quartz monzonite and granodiorite to granite. A petrographic characteristic running throughout the series is the monzonitic or dual feldspar feature of their composition.

The rocks occur as stocks, dikes and small batholithic masses, which range up to twenty miles in length. The most abundant and important are the granite, quartz diorite, quartz monzonite, and granite porphyry. Areally they occur in about equal amount.

The granite occurs chiefly in the northern part of the range in the Empire, Helvetia, Greaterville, Old Baldy, and Tyndall districts, the quartz diorite in the west-central part in the Tyndall district and the quartz monzonite and granite porphyry in the southern and south-central parts in the Patagonia, Palmetto, and Harshaw districts. Some younger quartz monzonite is also associated with the quartz diorite in the west-central part in the Tyndall district.

Granite.—The granite in general is a reddish coarse to medium-grained, somewhat porphyritic rock. It is composed principally of orthoclase (or microline), quartz, and biotite, but also contains oligoclase, hornblende and a little augite. Apatite, zircon, and magnetite occur sparingly as accessories and in places also pyrite and chalcopyrite.

Older Quartz Monzonite.—The older quartz monzonite as seen in the Duquesne-Washington camp is a greenish-gray, black-spreckled granitoid rock with a reddish tinge and weathers reddish brown. It is medium to coarse grained and locally porphyritic. It is fairly fresh and is composed principally of oligoclase-andesine, quartz, orthoclase, biotite, hornblende, augite, and magnetite and contains considerable pyrite and some titanite. The plagioclase, which is the main constituent of the rock, is especially fresh.

Quartz Diorite.—The quartz diorite is important economically in that it contains more mineral deposits than any other formation. It contains nearly all the deposits in the Tyndall and

Wrightson districts and in the southwestern part of the Old Baldy district. It is a dark iron-gray massive fine to medium-grained granitoid rock, with usually a pinkish or reddish hue. It is composed principally of oligoclase-andesine with subordinate brown biotite, mostly altered to pale-green chlorite, a nearly equal amount of hornblende, a moderate amount of orthoclase and quartz, nearly all interstitial, a little augite, considerable magnetite, and accessory pyrite, apatite and titanite.

In some localities the rock contains considerable tourmaline and much magnetite, as at the McCleary mines, in the Old Baldy district. In the uncommon basic forms, which approach gabbro, the plagioclase ranges to labradorite, augite is the principal mafic mineral, and the orthoclase and quartz become relatively inconspicuous or absent. A native silver-bearing augite diorite in the west-central slope of the range described by Bond[2] seems to belong to this facies, and certain iron ore deposits described later in the Patagonia district seem to represent still more basic magmatic differentiations of this rock.

Younger Quartz Monzonite.—Microscopic examination of specimens collected at points well distributed throughout the diorite belt shows that much of the rock which cannot well be differentiated from the diorite in the field is a quartz monzonite similar to the older quartz monzonite above described. It differs macroscopically however from the older quartz monzonite in being finer grained and less granitoid.

In places it is medium grained and reddish gray, has a crude or indistinctly banded structure, and macroscopically shows considerable biotite. The microscope shows it to be composed principally of oligoclase-andesine and orthoclase in about equal amount, biotite, mostly in large foils, and a subordinate amount of quartz, with a little hornblende, magnetite and pyrite.

Granite Porphyry.—Granite porphyry and aplite or their allied forms occur in an extensive series of variations, and some forms have undergone pronounced alteration by silicification and other processes.

[2] Bond, Josiah, "A Silver-bearing Diorite in Southern Arizona," *Eng. and Min. Jour.*, Vol. 39, p. 1268, 1910.

The rocks range from typical granite porphyry and aplite to those composed almost wholly of quartz with only very minor amounts of feldspar. They are widely distributed in small stocks and radial dikes intruded into the pre-Mesozoic, rarely into the Mesozoic, sediments; also into the granite, and to a less extent into the quartz monzonite and diorite.

The granite porphyry is a light-colored coarsely porphyritic granitoid rock composed chiefly of phenocrysts of feldspar, mainly orthoclase, and of quartz, and locally biotite or muscovite, embedded in a finer granitic or microcrystalline groundmass which is likewise composed mostly of orthoclase and quartz. Apatite, zircon, pyrite, cupriferous pyrite and titanite occur as accessories. The rock is locally pegmatitic and has an agglomerate-like structure, and some of it is graphic.

The rock is widely distributed and occurs in nearly all the districts. It comprises many types and is generally associated with ore deposits. A prominent exposure containing numerous prospects occurs two miles east of Helvetia in the form of a stock about a third of a mile in diameter. In the western part of the Harshaw district and adjoining portions of the Palmetto district it occupies about 9 square miles and contains the principal mineral deposits in this part of the range, including those of the Three R, Thunderer, Standard, Sunnyside, and other mines.

Aplite and Aplitic Rocks.—The granitic intrusives and surrounding Paleozoic sediments in various parts of the range are cut by many dikes and some small stocklike masses of rock. They are reddish or flesh colored, fine to medium granular, and are composed almost wholly of orthoclase and quartz, a little sodic plagioclase, and a negligible amount of muscovite, biotite, or other dark minerals, with zircon and apatite usually present as accessories. The alkalic feldspar may be represented in part by microline or microperthite or both. In places these rocks are slightly prophyritic and contain glassy-faced phenocrysts of the feldspar.

From the typical aplite thus described these rocks, according

to their mineral composition, range on the one hand through granitic aplite to aplitic granite or even to granite, and on the other through alaskite aplite, alaskite, and alaskite porphyry to almost pure quartz.

Rhyolite Porphyry.—Dikes of rhyolite porphyry regarded as probably Mesozoic and which may be a magmatic differentiation phase of the granite porphyry, in places cut the Paleozoic sedimentaries and the intrusive granite as at the Copper Camp in the Empire district and the granite in the Old Baldy and Tyndall districts.

Rock Alteration.—Many of the acidic intrusive rocks are altered by development of sericite, quartz, sulphides, alunite, epidote and chlorite.

THE METALS AND METALLIFEROUS DEPOSITS.

The valuable metals in the deposits of the range are gold, silver, copper, lead, zinc, iron, tungsten and molybdenum. There are about a thousand small mines and prospects scattered throughout the mountains, their character and distribution depending in large measure upon the rock formations in which they occur, and the rocks with which they are genetically associated. Most of the deposits were examined and data collected adequate to show the approximate distribution of the deposits and their metals in each rock formation.

GEOLOGIC DISTRIBUTION OF THE METALLIFEROUS DEPOSITS IN THE SANTA RITA AND PATAGONIA MOUNTAINS, ARIZONA.

Rock formation or group.	Per cent. of deposits.	Per cent. of the deposits genetically connected with later intrusive rocks.
Quartz diorite	30	14
Paleozoic sedimentary rocks	25	25
Granite	10	4
Older quartz monzonite	8	5
Granite porphyry	10	2
Younger quartz monzonite	3	2
Tertiary volcanics	14	2
	100	54

The lower limit of the oxidized zone is irregular and ranges from less than 100 to 300 feet in depth, but sulphides are usually near the surface. Water occurs in most of the mines and ground water level stands at depths of about 250 feet. The surface deposits yielded chiefly rich silver ores, but in depth the deposits gave way to ores of copper, lead, and zinc. The primary ore minerals are mainly pyrite, galena, argentite, chalcopyrite, tetrahedrite, gold, and sphalerite. Much of the pyrite is cupriferous, much is auriferous and some of it as well as the chalcopyrite and tetrahedrite seems to be also argentiferous. The galena generally is argentiferous and some is also auriferous. Much of the argentite apparently contains gold. The deposits occur chiefly as fissure veins but also as replacement, contact metamorphic, and shear zone, deposits. The term replacement deposits as used in this paper refers to replacement deposits formed at lower temperatures than the contact metamorphic deposits.

The main gangue minerals in the veins are quartz, barite, fluorite, rhodochrosite, and other carbonates.

Important agencies in determining the position of the deposits were the intrusion of the igneous masses along the contact zone, faulting and contraction of the igneous masses on cooling by means of which channels in the form of fissures, shear zones, shrinkage cracks, and joint planes, were opened up. These permitted circulation of the ore-bearing solutions and furnished repositories for the ores. The importance of these fractures is emphasized in the quartz diorite which, though normally a tight and unpromising looking rock for mineral, contains more deposits, mines, longer and larger veins, than any other formation. Secondarily, barrier reefs or sills have also played an important part in arresting, or otherwise influencing the circulation of the depositing solutions.

Potent agencies in determining the metallic nature of the deposits were: (1) the character of the host rock, and (2) the character of the mineralizing solutions; (3) conditions of temperature and pressure.

The deposits occur in two large and contrasting groups that

differ in age and represent at least two distinct periods of mineralization. The older and more important group occurs in association with the Mesozoic granular intrusives and in part with the Paleozoic sedimentary rocks, and is of Mesozoic (probably early Cretaceous) age. The younger group occurs in or associated with the Tertiary volcanic rocks and is of Tertiary age.

Older Deposits (Cretaceous).

The older deposits first attracted attention to the mineral wealth of the area and have furnished most of its production. They embrace the larger number of the deposits of the area and are widely distributed thoughout the range.

They contain gold, silver, copper, lead, zinc, iron, tungsten, and molybdenum. As they nowhere occur in the known Cretaceous rocks of the area they are here referred to the early Cretaceous.

These deposits seem to belong to the same general period as the batholiths of California and western Nevada with whose intrusion ore deposits have been widely formed. They were probably deposited chiefly by ascending thermal solutions that circulated as a close after-effect of the intrusion of the Mesozoic magmas.

The older deposits are mainly fissure veins and contact metamorphic deposits, but also replacement and shear zone deposits. They have suffered considerable erosion, and their general nature, together with the alteration of the intruded sedimentary rocks, and the relative coarse texture of the granites at or near the contact, leads to the inference that as a whole the deposits were probably formed originally at considerable depth in the deep vein zone. Also the presence of considerable tourmaline and molybdenite and the occurrence of pegmatite in places point to the magmatic origin of the mineralizing solutions. These conditions denote that at least some of the deposits were formed at high temperatures, and that pneumatolytic action played a part in their genesis.

Deposits in Sedimentary Rocks.—The deposits in the sedimentary rocks occur almost entirely as contact metamorphic de-

posits and ordinary replacement deposits, and excepting a few of minor importance found in the Cambrian sediments, are found in the Paleozoic limestone. They seem to be genetically connected with the igneous intrusives about as follows:

	Per Cent.
Granite	40
Aplite	20
Granite porphyry	18
Rhyolite porphyry	7
Older quartz monzonite	6
Lamprophyric rocks	5
Diabase	1
Diorite	1

Contact Metamorphic Deposits.—The contact metamorphic deposits comprise nearly all the deposits in the sedimentary rocks. They were among the first to be formed as they, and the Paleozoic sedimentary and Mesozoic intrusive rocks with which they are connected, are cut by later veins and associated complementary dikes. They are also slightly earlier than the ordinary replacement deposits which generally adjoin them. In this group belong most of the copper deposits in the Helvetia and Empire districts, and also those of the Duquesne-Washington camp in the Patagonia district, described by Professor Crosby.[3]

The deposits occur principally in or near the contact zone of the Paleozoic limestone with the Mesozoic intrusive rocks, particularly the granitic rocks. Along this zone which ranges up to 200 feet or more in width, their formation was accompanied by contact metamorphism, mineralization, and the development of a garnetiferous zone with the usual assemblage of a dozen or more contact minerals. Among the minerals observed mostly in the Duquesne-Washington camp are garnet (andradite and grossularite), pyroxene (diopside, wollastonite, and hedenbergite), amphibole (hornblende, tremolite, actinolite, and gedrite), calcite, dolomite, quartz, epidote, pyrite, magnetite, pyrrhotite, specularite, ilmenite, molybdenite, arsenopyrite, tourmaline, and others.

[3] Crosby, W. O., "The Limestone-granite Contact-deposits of Washington camp, Arizona," *Trans. Amer. Inst. Min. Eng.*, Vol. 36, p. 626, 1906.

These minerals are mostly exomorphic but some are also endomorphic, especially those of the amphibole group. The following is an analysis of a specimen of garnet from the Empire mine which seems to be representative of the garnet in the Duquesne-Washington camp. It shows it to be the calcium-iron variety, andradite. Mineralogically, the garnet is an aluminous andradite and is found by molecular calculation to consist of an isomorphous mixture of about 85 per cent. andradite and 15 per cent. grossularite.

ANALYSES OF GARNET (ANDRADITE).

(From the Empire mine, Duquesne, Ariz., W. T. Schaller, analyst.)

SiO_2	37.16
Al_2O_3	3.47
Fe_2O_3	28.11
CaO	30.23
MgO	.51
FeO	None
MnO	Present
	99.48

The deposits occur in irregular bodies in a zone from 1 foot to 40 feet or more in width, principally in the Carboniferous limestone. They are mainly copper-bearing, but they generally contain a little silver and gold and some of them also lead and zinc. The chief primary ore minerals are chalcopyrite and cupriferous pyrite, together with a subordinate amount of galena, sphalerite, argentite, pyrrhotite molybdenite, and gold. These sulphides generally appear at or near the surface, but the oxidized zone, which extends to depths of 200 to 300 feet, contains also secondary or oxidized minerals, particularly the common carbonates and oxides of copper, manganese and iron, chloropal, silver chloride, chrysocolla, etc., and the secondary sulphides chalcocite, chalcopyrite, and bornite. To this class belong most of the productive copper deposits which have been worked and have yielded nearly all the copper production especially in the Helvetia and Duquesne-Washington camps. The present workable deposits are apparently chiefly the result of concentration or secondary

enrichment. They consist of malachite, azurite, chalcocite, chalcopyrite, chalcanthite, etc., derived from the chalcopyrite and cupriferous pyrite which occur as contact-metamorphic minerals and as primary or accessory constituents in the intrusive granitic rocks.

The deposits were formed in part directly by magmatic influence of the molten batholith or stock in its peripheral contact with the limestone and other sedimentary rocks, but mainly by the accompanying hydrothermal solutions and pneumatolytic activities that replaced the limestone depositing therein the ores and their associated minerals.

A conclusion reached in the study of this class of deposits is that the intrusive rocks and the attending solutions, especially in the Duquesne-Washington camp, were the principal contributors to the ferruginous mineral constituents of the contact zone, as well as bearers of the ore minerals. It is also concluded that the metallic materials were not derived in any considerable amount from the surrounding limestone nor for any great extent beyond the contact-metamorphic zone. This is indicated on the one hand by the purity of the bordering limestone and by its wholly unaltered condition at many places very near the contact, and on the other hand, by the abundance of silica and ferruginous minerals. The only possible source adequate to account for the silica and iron seems to be the intrusive older quartz monzonite. This, being rich in biotite and hornblende and containing considerable augite and magnetite and some pyrite, could readily supply the iron element, for whose concentration in the deposits the fluid magma and its accompanying hydrothermal solutions and pneumatolytic gases, containing the ingredients, were admirably adapted. The abundant quartz occurring in or associated with the deposits and the metamorphic zones is largely accounted for by the siliceous character of the quartz monzonite magma. This conclusion essentially agrees with the conclusions of others who have investigated similar deposits.[4]

[4] Stewart, C. A., "The Geology and Ore Deposits of the Silver Bell Mining District, Arizona," *Trans. Amer. Inst. Min. Eng.*, Vol. 43, pp. 240–288, 1913.

Similar, though not so marked metamorphic phenomena prevail in the Helvetia and other camps where deposits likewise occurring in the Paleozoic limestone owe their origin to the granite, granite porphyry, aplites and alaskitic rocks. In the Empire district, granite, and rhyolite porphyry in the form of dikes appear to be genetically associated with the deposits.

Replacement Deposits.—The replacement deposits are commonly associated with the contact-metamorphic deposits but are apparently in most cases later in age. Like the contact-metamorphic deposits they occur mostly in limestone in association with the intrusive rocks. In some cases they are difficult to differentiate from the contact-metamorphic deposits, since all gradations occur between the two. Mineralogically, however, they are without the characteristic contact-metamorphic minerals and generally they differ from the contact-metamorphic deposits in their metalliferous content. Instead of copper, as in the contact deposits, their principal metallic constituents are lead and silver, and among the secondary minerals are the common oxides of manganese and iron, siderite, jarosite, vanadinite, and wulfenite.

To this class apparently belong in large part the important deposits at the Mowry mine in the Patagonia district, the Total Wreck mine in the Empire district, and the Flux mine in the Harshaw district and some of the mines at Helvetia.

The Mowry deposits produced lead and silver to the value of 1½ million dollars in the early 60's and have since been worked intermittently with good results. They are situated on a fault fissure contact of quartz monzonite and Pennsylvanian limestone. The quartz monzonite is regarded as intrusive into the limestone which is locally altered to fine-grained marble, but the usual metamorphic minerals and silication phenomena are absent. The limestone dips steeply away from the contact and at a depth of

Spurr, J. E., Gerry, G. H., and Fenner, Clarence N., "Study of a Contact Metamorphic Ore Deposit, the Dolores Mine at Matehuala, S. L. P. Mexico," Econ. Geology, Vol. 7, pp. 444–484, 1912.

Umpleby, J. B., "The Genesis of the Mackay Copper Deposits, Idaho," Econ. Geology, Vol. 9, No. 4, pp. 307–358, June, 1914.

about 350 feet in the mine it is underlain by an altered basic rock corresponding to gabbro which also seems to be intrusive.[5]

The ore deposits are best developed in the limestone next to the quartz monzonite. They extend as upright tabular bodies in more or less solid form 600 feet or more along the contact and 100 feet laterally into the limestone. Beyond this occur inclined ore beds or sills ranging up to 20 feet in thickness dipping conformably with the bedding of the limestone.

The deposits consist mainly of lead and silver minerals, such as galena, cerusite, anglesite, and bindheimite, all contained in a manganiferous–ferruginous gangue composed principally of massive psilomelane, pyrolusite and hematite. The manganese and iron together form about one fifth of the ore bodies in volume. There is but little quartz and a remarkable feature is the absence of zinc, especially as zinc is a common mineral in the neighboring mines. The ore is mostly oxidized down to or below the 300-foot level. Scarcely any sulphide other than galena was found above this level. Copper anl iron sulphides first appeared on the 400-foot level where also vanadinite and arsenopyrite sparingly occur.

The Mowry deposits seem to have been formed by metasomatic replacement through the agency of mineral-bearing solutions that circulated along the contact fault. The ore deposition extended from the monzonite contact into the limestone. The solutions were probably thermal and deposited the ore minerals at considerable depth in the limestone, chiefly as sulphides of lead, silver, iron, and manganese. Subsequently, in the lowering of the surface by erosion these sulphide ore minerals became oxidized and concentrated to their present state. Silver leached from the overlying now eroded deposits doubtless contributed to their enrichment.

Inasmuch as the Mowry rocks and ores are similar to those of Leadville, Colo.,[6] a similar origin may be ascribed to them.

[5] Data on the lower levels of the mine, which were under water at the time of visit, were kindly supplied by the Mowry Mines Company.

[6] Argall, Philip, "Siderite and Sulphides in Leadville Ore Deposits," *Min. and Sci. Press*, Vol. 109, pp. 50–54 and 128–135, July–December, 1914.

Thus it is concluded that the quartz monzonite at Mowry is the probable source of the deposits.

Vein and Shear Zone Deposits.—Vein deposits in the sedimentary rocks are few and are usually associated with contact-metamorphic deposits, where they occupy small fissures of apparently the same class as those occupied by complementary dikes of the main intrusive. Some, however, occur in the Paleozoic rocks away from contacts and in connection with rhyolite porphyry and lamprophyric dikes. The deposits of the Verde Queen and Chief mines in the Empire district are examples of these. The metals are chiefly copper and lead, with minor quantities of gold and silver. A few deposits also occur in the Cambrian ? schist and quartzite where, as in the later Paleozoic rocks, the principal metalliferous content is copper and the deposits are genetically closely connected with lamprophyric intrusives; the deposits of the Lucky Ledge and other mines in the Old Baldy district are examples of this class.

Deposits in the Acidic Intrusive Rocks.—The deposits in the intrusive rocks occur almost wholly in those of acidic character. They are found in all the acidic rocks but are relatively more plentiful in the quartz diorite, as in the Tyndall district, and the granite porphyry and quartz monzonites, as in the Palmetto district, than in the other formations. They occur chiefly as fissure veins but also as shear zone and replacement deposits.

The deposits probably owe their origin to solutions which circulated through the fissures following the intrusion of the inclosing rocks, or of closely connected complementary dikes. In some instances the presence of considerable tourmaline and molybdenite point to the magmatic origin of the mineralizing solutions, and suggest that certain of the deposits have been formed at high temperatures.

In the fissure vein and shear zone deposits, where the gangue is siliceous, the principal primary ore mineral is generally galena but where the gangue is basic or composed chiefly of crushed or sheared rock as at the Three R mine, chalcopyrite and other copper-bearing minerals predominate. This is especially true in

the quartz diorite and the monzonites. These conditions are essentially in harmony with those that prevail in the granite, where the deposits are mostly siliceous and the dominant metals are lead, gold, and silver.

Veins.—The veins are numerous and widely distributed. They are particularly plentiful on the west slope of the Santa Rita Mountains and in the Patagonia Mountains. They range from 1 foot to 20 feet or more in width, 6 feet being perhaps the average width, and they are commonly separated from the wall rock by a few inches to a foot or more of kaolin gouge. In places they parallel the dominant jointing or fault system, with steep or vertical dips, but more commonly they occupy independent cross or diagonal fissures and in a general way lie approximately parallel with the axis of the range. Many are persistent, some have a length of a mile or more and a known vertical range of nearly 1,000 feet, and some have been opened to the depth of 500 feet. They occur mostly in fault fissures but some appear to occupy shrinkage cracks due to contraction of the rock on cooling. The croppings are frequently prominent and consist chiefly of vein quartz and altered silicified rock heavily stained with oxides of iron and manganese, copper, and lead carbonates.

The gangue or filling of the veins is chiefly quartz, with fluorite and barite. It frequently contains rhodochrosite and in a few mines magnetite is the dominant constituent. The primary ore minerals are chalcopyrite, cupriferous pyrite, pyrite, galena, argentite, native silver, gold, tetrahedrite, bornite, arsenopyrite, sphalerite, specularite, siderite, molybdenite, wolframite, and scheelite.

The deposits also contain oxidized minerals, such as cerargyrite, bromyrite, stephanite, pyromorphite, cerusite, anglesite, malachite, azurite, chalcanthite, native copper, psilomelane, pyrolusite, hematite, limonite, bindheimite, utahite, and others, and the secondary sulphides, chalcocite, chalcopyrite, bornite, and covellite.

In places the ore is not restricted to the fissure but extends in

irregular bodies laterally several feet or more into the wall rock. This has locally been metasomatically replaced and silicified by the ore-bearing solutions, and the deposits thus merge into those of the replacement type, later described.

The distribution of the deposits in any given formation is largely dependent upon the location of fissures and other openings that afforded channels and repositories for the depositing solutions. The deposits are more numerous at or near the margin of the host formation which represents the zone of maximum fracturing and lower temperature and pressure, and consequently that of maximum circulation and precipitation. This is shown in the quartz diorite along its north contact with the granite in the Tyndall district; also in a narrow belt of the same rock in the Old Baldy district, and to some extent in several areas of granite porphyry in the southern part of the range. It is also noticeable in several instances that smaller areas or stocks particularly of granite porphyry in the Helvetia and Tyndall districts contain more deposits in proportion to their size and periphery than larger areas.

Away from the marginal zone of fracture and segregation the deposits are sporadically distributed. For instance, the Tia Juana vein from 10 to 40 feet in width and 2½ miles in length lies in the center of a large area of quartz diorite 4 miles in width.

Shear Zone Deposits.—The shear zone deposits occur in the same formations as the fissure veins, and in some cases are associated with them. To this class belong the Florida mine in the Old Baldy district and the recently notably productive Three R mine near Patagonia, both copper mines. In the Three R mine the shear zone, which is from 40 to 100 feet in width, lies in granite porphyry heavily impregnated with pyrite, and a little chalcopyrite. Within the zone there is a concentration of these minerals forming crude stock works or bunches of ore and veins in the sheared and altered rock. In the deeper part of the mine there have been concentrated by processes of secondary enrichment bodies of workable ore consisting of chalcocite, bornite, chalcopyrite and covellite, replacing the sheared and altered alunitized rock; below these secondary ores lies the zone of primary sulphides.

The progress of enrichment, as shown by microscopic study of ores from this mine by Graton and Murdoch,[7] consists of several steps approximately in the order of bornite, covellite, chalcocite, and chalcopyrite, though all of these minerals are not invariably present. With this process the results of later studies made by Probert[8] in the mine essentially agree.

Deposits in the Granite.—In the granite which is exposed mainly in the Empire, Helvetia, Greaterville, Old Baldy, and Tyndall districts, the deposits occur mostly in quartz veins or siliceous shear zones and contain chiefly lead, gold, and silver, but sometimes copper and molybdenum in workable amount. Few of the deposits appear to have genetic connection with later rocks such as granite porphyry, aplite, diorite, and rhyolite porphyry which are intruded in the granite.

The primary ore minerals are galena, argentiferous galena, argentite, pyrite, chalcopyrite, sphalerite, and free gold, more rarely tetrahedrite. The most important secondary or oxidized minerals are cerargyrite, cerusite, copper carbonates, and in a few cases zinc carbonate. Gold and silver are both present, one or the other predominating. The gold in the Greaterville placers, which have produced more than $7,000,000 and still contain by estimate much more, seem to have been derived chiefly from this class of deposits which occur in the granite in the adjoining upper slope of the range. In certain instances the granite is probably pre-Cambrian but it could not be differentiated from the Mesozoic rock. The veins are mostly small with low ore tenor in depth and the metallic minerals sporadically distributed in the gangue.

In a few of the deposits which seem to be genetically connected with later intrusives, copper, or copper and lead are the dominant metals, with gold and silver next in importance.

[7] Graton, L. C., and Murdoch, Joseph, "The Ores of Copper: Some Results of Microscopic Study," *Am. Inst. Min. Eng. Trans.*, Vol. 46, No. 77, pp. 754–755, figs. 5 and 6, 1913.

[8] Probert, F. R., "The Three R Mine, Patagonia District, Ariz.," *Min. and Sci. Press*, Vol. 109, No. 5, p. 176, 1914.

Molybdenum stands next to copper and lead in value in the Elephant Head deposits, where they are associated with rhyolite porphyry, and in the Ridley Mine at Helvetia where granite is intruded by aplite dikes. The primary ore minerals are chiefly chalcopyrite, galena and molybdenite. Sphalerite is frequently conspicuous but it is not present in workable amount.

In half a dozen or so of the deposits the only valuable metal is molybdenum. It occurs mostly as flaky pieces of molybdenite associated with a little pyrite and chalcopyrite in quartz veins or stock works. This is especially true in the Old Baldy district, where in some cases the deposits seem to be genetically connected with intrusive aplite dikes.

Though some molybdenite occurs in nearly all the geologic formations of the range the home of this mineral seems to be chiefly in the granite and the older quartz monzonite. It also occurs to a lesser extent in the contact or replacement deposits of the sedimentary formations where intruded by either of these two rocks, as in the Leader mine at Hevetia. A sketch of the general occurrence of molybdenite in the range appears in an earlier paper.[9]

Deposits in the Older Quartz Monzonite. Vein and Shear Zone Deposits.—In the older quartz monzonite, found chiefly in the southern part of the range in the Patagonia, Palmetto, and Nogales districts, the deposits occur almost entirely as vein and shear zone deposits. About 60 per cent. of them appear to be genetically connected with later intrusives, of which 50 per cent. is with the quartz diorite, and 10 per cent. with the granite porphyry. Copper is the principal, almost the only metal. Forty per cent. of the deposits contain copper only, the dominant primary ore minerals in nearly all cases being chalcopyrite and pyrite. Bornite and molybdenite are present in some cases in subordinate amount. The gangue minerals are chiefly quartz and calcite, kaolin, brecciated, altered and silicified rock. The secondary or oxidized minerals are chiefly the oxides of iron and

[9] Schrader, F. C., and Hill, J. M., "Some Occurrences of Molybdenite in the Santa Rita and Patagonia Mountains, Arizona," U. S. Geol. Survey Bull. 430, pp. 158–159, 1910.

manganese and the secondary sulphides are chalcocite, chalcopyrite, bornite, and covellite.

In the Patagonia district in the west slope of the Patagonia Mountains in the triangular area occupying a square mile or more bounded by Sycamore Canyon on the south and Providentia Canyon on the northwest, the quartz monzonite is impregnated with uniformly disseminated grains of chalcopyrite, pyrite and bornite, and some molybdenite. These minerals, particularly the pyrite and chalcopyrite, both macroscopically and microscopically seem to be primary, of magmatic origin, and to have crystallized out from the original magma similarly and contemporaneously with the rock minerals. They are very persistent throughout the area and are observed through a vertical range of 800 feet.

In about 30 per cent. of the deposits in the older quartz monzonite lead is the dominant metal with silver or copper next and gold in a few of them. The primary ore minerals are chiefly galena, argentiferous galena, chalcopyrite, pyrite, and argentite. The secondary or oxidation minerals are cerusite, cerargyrite, limonite and manganese dioxide.

In 10 per cent. of the deposits, notably those in the Nogales district at Mount Benedict, the mines are worked for gold. Here the metals in order of importance occur as gold, lead, silver, and copper. The primary ore minerals are pyrite, chalcopyrite, galena, argentiferous galena, argentite, gold, wolframite, and stibnite. The secondary or oxidized minerals are cerargyrite, proustite, pyrargyrite, cerusite, and the oxides of iron and manganese. The gold is mostly associated with the pyrite, chalcopyrite, galena, cerusite, and stibnite.

A few of the deposits contain only lead and silver, the chief ore mineral being argentiferous galena, and a few contain only lead and copper, the ore minerals in this case being galena and chalcopyrite.

In some of the deposits, notably those at the Reagan camp and vicinity in the northern part of the Nogales district, the only important metal is tungsten. This occurs mainly as wolframite and subordinately as scheelite. The wolframite and scheelite

occur in narrow quartz veins contained in dark lamprophyric dikes, and in the adjoining quartz monzonite country rock which the dikes abundantly intrude. A small amount of calcite is present as a primary gangue mineral mingled with the vein quartz. Apparently the only secondary or oxidation mineral present is a little hematite which stains the fissure walls and gouge and in places is pseudomorphic after wolframite.[10]

Contact-Metamorphic Deposits.—Ores which may be regarded as a form of contact-metamprphic deposits occur at several localities in the older quartz monzonite where it has been invaded by the younger of the Mesozoic intrusives. Of this class the Line Boy deposit in the southern part of the Patagonia district on the International Boundary is an example. Here, a small stock-like mass of granite porphyry intrudes the quartz monzonite. From the stock a 10-foot dike of the porphyry extends radially outward into the quartz monzonite, which it has sericitized and otherwise altered along the contact. The metallic minerals, pyrite, chalcopyrite, and molybdenite, with a little bornite, calcite and quartz, are abundantly developed along the contact and are concentrated in joint planes and small fissures. The quartz monzonite is partly impregnated with them. Along the hanging-wall side of the dike occurs a sheet of specularite 3 feet wide and a 6-foot vein of copper ore containing principally chalcopyrite with much bornite.

Deposits in the Quartz Diorite.—In the quartz diorite, which lies mainly on the central west slope of the range in the Tyndall and Old Baldy districts, the deposits occur mainly as veins with also a few scattering shear zone and replacement types. They contain the metals copper, silver, lead, gold, zinc, molybdenum, and iron. The primary ore minerals are chalcopyrite, galena, argentiferous galena, argentite, auriferous pyrite, molybdenite, magnetite, sphalerite, specularite, bornite, and chalcocite (?). Secondary or oxidation minerals now present are malachite, azurite, chrysocolla, cuprite, cerargyrite, bromyrite, embolite, cerusite,

[10] For a fuller description of these tungsten deposits see Hill, J. M., "Note on the Occurrence of Tungsten Minerals near Calabasas, Arizona," U. S. Geol. Survey Bull. 430, pp. 164–166, 1910.

pyromorphite, anglesite, smithsonite, marcasite, the common oxides of iron and manganese, and the secondary sulphides chalcocite, chalcopyrite and covellite, and stephanite and dyscrasite.

The primary gangue is chiefly quartz and barite, with a little calcite, rhodochrosite, and tourmaline, but in many cases now contains also considerable carbonate, especially manganese and iron, also iron oxides, kaolin, and altered rock material.

The presence of tourmaline common in the Old Baldy district and not rare in the Patagonia district indicates that some of the deposits are of the high temperature type.

In about 50 per cent. of the deposits copper is the dominant metal and in 25 per cent. it is the sole metal. Its most common associate metal is silver, with lead a close second. In a few cases only, gold, silver, or lead is the only associated metal. In about 40 per cent. of the deposits lead is the dominant metal with the second place shared about equally by copper and silver.

In about 10 per cent. of the deposits silver is the dominant metal, and in most of these cases it is associated with lead, the two metals commonly occurring in argentiferous galena. In a few deposits, however, as at the Salero and Montezuma mines the silver occurs chiefly in argentite and cerargyrite with copper as the only associated metal. Zinc, except as an associate metal, is rare, and when present in commercial quantity, it occupies third place with lead and copper.

The few iron deposits in the quartz diorite consist chiefly of massive bodies of magnetite and quartz or of specularite and quartz, as in those of the Specularite Prospect near Gross camp in the Patagonia district, which have been used for flux.

Of the deposits observed in the quartz diorite formation only about 44 per cent. appear to be directly connected genetically with later intrusives. Of these 22 per cent. are associated with granite porphyry, 16 per cent. with rhyolite porphyry, and 2 per cent. each with aplite, younger quartz monzonite, and andesite.

In the deposits associated with the intensive granite porphyry the metals in order of abundance are copper, lead, silver, and gold, with gold in a few cases in the lead. In those associated

with the rhyolite porphyry, the metals are copper, lead, gold, and silver, the two latter occupying subordinate positions. In the deposits associated with the younger quartz monzonite the dominant metals are silver and copper, in those associated with the andesite, silver, gold, lead and copper.

The genesis of deposits apparently not connected with later intrusives such as the Tia Juana vein described on page —, and whose metals are silver, copper, and lead is provisionally referred to mineralizing thermal solutions derived from and circulated as an after-effect of the intrusion of, the quartz diorite magma itself.

Deposits in the Granite Porphyry.—In the granite porphyry, found chiefly in the southern part of the range in areas from three to five miles in extent, the deposits are chiefly veins and shear zone replacements, containing copper, lead and silver in the order given. They include those of the Three R mine described on page —, the Happy Jack, Sunnyside, and in part those of the Alto and other mines. In 60 per cent. of the deposits copper ranks first with the second place about equally divided between lead and silver. In 25 per cent. lead holds first place, with silver second, and in 15 per cent. silver is first with copper second. The primary ore minerals are chiefly chalcopyrite, pyrite, cupriferous pyrite, galena, argentiferous galena, tetrahedrite, argentite, and molybdenite. The ores contain also the secondary or oxidation minerals, malachite, azurite, cerargyrite, bromyrite, pyromorphite, the hydrous oxides of iron and manganese, and the secondary sulphides chalcocite, bornite, chalcopyrite, and covellite. The gangue is chiefly quartz and altered rock with barite, alunite, specularite, calcite, other carbonates, and kaolin.

The deposits are rarely connected with later intrusives which seem adequate to account for their origin, though in the Happy Jack mine the enclosing formation is cut by greenish altered dikes which appear to be andesite, and at the Three R mine by light colored aplitic dikes.

The deposits in most cases seem to have been formed by

thermal solutions that were derived from and followed the intrusion of the granite porphyry magma itself. Its favorableness as a repository for workable deposits is largely attributed to its feldspar phenocrysts which, being relatively more soluble with their cleavage edges exposed to attack, stand foremost in affording avenues of penetration for the mineralizing solutions and gases.

Deposits in the Younger Quartz Monzonite.—The younger quartz monzonite occurs chiefly as small stocks intruding the older quartz monzonite and the quartz diorite, mostly in the Patagonia and Tyndall districts.

The few deposits in this formation occur chiefly as veins and shear zone replacement deposits. Their dominant metal is copper with gold and silver also present in some veins. The principal primary ore minerals are chalcopyrite, cupriferous pyrite, argentite, and bornite.

The primary minerals also include sphalerite, specularite, magnetite, gold, and molybdenite. The ores contain the usual oxidized minerals and secondary sulphides, chalcocite and chalcopyite.

The gangue is mainly quartz, altered and replaced rock with tourmaline present in places. Among the most important of the deposits are those of the Four Metals and Omara mines in the Patagonia district and the Carrie Nation mine in the Old Baldy district. The Four Metals and Carrie Nation deposits are of the replacement shear zone type.

The Four Metals deposit occurs in a fault shear zone 1200 feet or more in width in which the greatly shattered and altered rock is impregnated and replaced by the deposits, of which the most important occur within a width of 500 feet. Copper is the sole metal of economic importance. The primary and chief ore mineral is chalcopyrite. Some chalcocite, which may be primary, is also present, as are also pyrite and cupriferous pyrite, and a little galena, argentite, and gold. In the Omara deposits which are quartz veins the dominant metal is gold with silver second and copper third.

The depositing solutions may have been derived from the magma of the inclosing younger quartz monzonite itself, which as a small stock intrudes the older quartz monzonite and contains disseminated cupriferous pyrite and chalcopyrite apparently as primary constituents.

Deposits Associated with the Lamprophyric Rocks.—Excepting the silver-gold deposits in the Blue Jay mine in the Helvetia district, the only metals observed in or genetically connected with the lamprophyric rocks, which occur chiefly as dikes, are those of copper in the Old Baldy district described under deposits in the sedimentary rocks, and tungsten in the Nogales district described under the older quartz monzonite.

Younger Deposits (Tertiary).

The younger group of deposits occurs in or associated with the Tertiary effusive volcanic rocks which occupy most of the south-central part of the range. Excepting a small belt of quartz latite porphyry covering about 8 square miles in the Tyndall district on the west, the rocks are almost entirely andesite and rhyolite, which occur in approximately equal amount and are disposed in large areas. The rhyolite is the older formation but the andesite is locally cut by dikes of a younger rhyolite. About 50 per cent. of the deposits occurs in the andesite, 40 per cent. in the rhyolite, and 10 per cent. in the quartz latite porphyry.

This group of ore deposits is regarded as late Miocene and possibly Pliocene. It belongs to the late Tertiary epoch of metallization and to the great group of metalliferous deposits in the Tertiary volcanic rocks throughout the west, formed near the surface by ascending thermal solutions.

Veins.—The deposits occur in irregular and branching veins which are chiefly fissure veins, and also to some extent as replacement deposits. The great group to which they belong is in general throughout the west gold-silver-bearing quartz veins. In the present region, however, the deposits are chiefly base metal veins and contain principally copper, lead, silver, and gold; in this respect similar to certain deposits described by Purington and others in the San Juan region, Colorado.[11]

The gangue is mostly quartz but it frequently contains also barite, fluorite, calcite, rhodochrosite, rhodonite, and altered and replaced rock, kaolin, and occasionally epidote and gypsum.

The primary ore minerals are chalcopyrite, pyrite, tetrahedrite, bornite, chalcocite, galena, argentiferous galena, argentite, proustite, sphalerite, molybdenite, specularite, and gold. Secondary or oxidation minerals contained in the ores are malachite, azurite, chrysocolla, cuprite, tenorite, cerargyrite, bromyrite, embolite, wulfenite, cerusite, marcasite, and the secondary sulphides chalcocite, chalcopyrite, and bornite.

A constancy in association of certain minerals giving rise to two types of veins is noticeable. These types are (1) tetrahedrite-rhodochrosite veins, and (2) quartz-galena-sphalerite ? veins. In the first type usually rhodochrosite, and in some instances rhodonite, is present in deposits in which tetrahedrite is a leading or an important ore mineral, as in those of the Jersey Girl and other prospects.

In the second type, which are quartz-galena veins, sphalerite is present but rarely in commercial quantity.

Though these types of deposits may not be identical to those of the "tetrahedrite-rhodochrosite veins" and the "quartz-galena zincblende veins" of the Lake City district, Colorado, described by Irving and Bancroft,[12] and later discussed by Lindgren,[13] their general similarity to them is very marked.

The deposits of the group are numerous and relatively but little developed. About a score, however, have become producers, among them the Rhode Island, La Plata, Gringo, and other important mines.

In more than 50 per cent. of the deposits the dominant metal is

[11] Purington, Chester W., U. S. Geol. Survey Geol. Atlas, Telluride Folio (No. 57) and folios Nos. 60, 120, 130, 131, 153, and 171 in the San Juan region, Colorado.

[12] Irving, J. D., and Bancroft, H., "Geology and Ore Deposits near Lake City, Colorado," Bull. U. S. Geol. Survey No. 478, p. 47, 1911.

[13] Lindgren, Waldemar, "Mineral Deposits," p. 505, 1913.

copper, in 25 per cent. silver, in 17 per cent. lead, and in 7 per cent. gold. Gold is present in 25 per cent. of the deposits and in a few, as those of the Gringo and Silver Cave mines in andesite and the Helena mine in rhyolite, it is the only workable metal.

In the deposits in andesite taken as a whole the rank of the metals is copper, lead, silver, and gold, with copper dominant in about 50 per cent., silver and lead in 25 per cent., and gold in 20 per cent.

In the deposits in rhyolite, copper is the dominant metal in nearly every case, with silver and gold, rarely lead, occupying second place. In several cases copper is the sole metal and in a few cases silver and gold, rarely lead, each stand first.

In the quartz latite porphyry, copper is the dominant metal in about 60 per cent. of the deposits, with silver and lead each in 20 per cent., gold and zinc occurring only as subordinate or associate metals.

From the foregoing description it appears that copper shows a decided preference for the rhyolite as does also, to a less extent, silver and gold. The same, excepting gold, is to a less extent true for the quartz latite porphyry, while lead appears to find its best repository in the andesite. Aside from these preferences the deposits do not seem to be dependent upon any particular kind of rock or formation nor do they seem to be dependent upon intrusives.

The deposits seem to have been formed by ascending thermal solutions which circulated mainly as a close after-effect of the eruptions of the containing lavas themselves. They were formed in fissures and fractures that resulted from the effects of volcanism or post-volcanic crustal adjustment and contraction of the lavas upon cooling. Their distribution in the volcanic rocks has accordingly been determined chiefly by the more or less accidental position of fissures and fractures that were accessible to the depositing solutions. A subordinate, though in some instances, an important feature was the lower temperature which accelerated precipitation and deposition from solutions that circulated in the more rapidly cooling border zone of the lavas,

particularly where they lay in contact with the older formations. This is illustrated by the marginal position of many deposits, for instance, in the quartz latite porphyry in the Tyndall district, where this rock is in contact with and locally intrudes the granite porphyry just west of the Salero and Alto camps, and the quartz diorite farther north toward Josephine Canyon.

Replacement Deposits.—The replacement deposits belonging to the Tertiary group occur in two forms, (1) ore beds, and (2) replacements adjoining fissure veins.

1. *Ore Beds.*—The ore beds occur in certain flows and intrusive sheets of the lavas notably of the rhyolite. Of those occurring in flows, the deposits a few miles south of Patagonia furnish good examples. Here over a wide area the rhyolite composing Red Mountain and the surrounding region is heavily impregnated with pyrite, and chalcopyrite, both of which seem to be primary. The weathered surface of the rock is often coated with malachite, chalcocite, and bornite. For instance, at the Invincible mine in which the valuable metal is gold in quartz veins, concentrates from the enclosing pyritic rhyolite were found to average 3 per cent. in copper, 33 per cent. iron, and 35 per cent. sulphur.

On the Aztec ground the copper minerals, notably chalcocite, chalcopyrite, bornite, and malachite, are particularly concentrated as replacement deposits, probably in part by processes of secondary enrichment, in a 12-foot wide replacement body. In the bed some of the ore is banded and consists of tabular shoots or veins an inch in width composed of relatively pure chalcocite and chalcopyrite.

In the Morning Glory mine in the Patagonia district the so-called vein having a dip of 40° appears to be a replacement ore bed representing an 8-foot sheet or sill of rhyolite intruded into the Paleozoic limestone. The ore minerals are chiefly pyrite and chalcopyrite with some sphalerite and a little hematite and specularite. The gangue minerals consist of quartz, a little calcite, and barite. Chalcocite is sparingly present as a secondary sulphide. The dominant metal is copper, with also silver and zinc present in workable amount.

In replacement deposits, similar to those of the Morning Glory mine, occurring in sheets of rhyolite similarly intruding quartzite and shale in the Harshaw district, at the Hardshell, Hermosa, and Salvador mines, the metals are respectively lead and silver, or silver alone.

2. *Replacements Adjoining Fissure Veins.*—The replacements adjoining fissure veins consist of deposits which have metasomatically replaced the adjoining wall rock. They are irregular especially in lateral extent and contain essentially the same class of ore and minerals as the vein. The gangue is generally siliceous and the veins are enclosed by silicified or propylitically altered wall rock. The Gringo mine in andesite and the Helena mine in rhyolite, both gold mines, are examples.

SUMMARY.

The metalliferous deposits occur in two great dissimilar groups. (1) Older deposits (Cretaceous) and (2) Younger deposits (Tertiary). About 54 per cent. of them appear to be genetically connected with intrusives later than the enclosing formation.

OLDER DEPOSITS.

The older deposits are genetically connected with or occur in the Mesozoic acidic intrusive rocks, the granite, quartz monzonites, quartz diorite, granite porphyry, rhyolite porphyry, and aplites. Most of these contain as disseminated primary constituents pyrite and chalcopyrite carrying silver and gold. The genetic connection of the deposits with these rocks is also shown by the common occurrence of contact metamorphic deposits as in the Duquesne-Washington and Helvetia camps.

The presence of tourmaline, molybdenite, arsenopyrite, and other minerals commonly of deep-seated origin, and the strong metamorphism induced in the sedimentary host rocks, indicate that the deposits were probably formed at considerable depth, in the deep vein zone. With lowering of the surface by erosion, oxidation and descending meteoric waters have locally played an important rôle in concentrating the deposits, by processes of secondary enrichment, into workable ore bodies.

The most universal and widely distributed metal is copper. It is not only dominant in the contact metamorphic deposits and prominently associated with the lesser siliceous granitic rocks, the quartz diorite and the quartz monzonites, but it is also prominent in association with granite porphyry. The diorite seems to be the dominant silver-bearing formation while the granite leads in gold.

In the deposits in the sedimentary rocks which are chiefly contact-metamorphic deposits, the dominant metals are copper and silver, with molybdenum third in importance in some instances where the intrusive rock is granite, and zinc where the intrusive is the older quartz monzonite. Copper is also the dominant metal in vein and shear zone deposits genetically connected with lamprophyric intrusives in the early Paleozoic quartzite and schists. In replacement deposits in the limestone where genetically connected with intrusives the dominant metals are lead and silver, sometimes in a basic psilomelane-pyrolusite-hematite gangue.

The deposits in the acidic intrusive rocks occur mainly as quartz-barite veins and to a small extent as shear zone replacements.

In the deposits in granite, the dominant metals are gold, silver, and lead, but where the deposits are genetically connected with aplite or allied intrusives the order tends to be copper, lead, gold, silver, and molybdenite, and in some of the deposits molybdenite is the only metal.

In the deposits in the older quartz monzonite, which are mainly vein and shear zone deposits, copper is preëminently the dominant metal with lead second, and gold third. In 40 per cent. of the deposits including those genetically connected with granite porphyry, copper is the only metal present. In 30 per cent. lead ranks first, with silver or copper a strong second, and gold third, while in 10 per cent. of the deposits which are included in those which are genetically connected with the intrusive quartz diorite or allied rocks, the mines are worked for gold which is, however, associated with minerals of lead, silver, and copper, and with stibnite. In a few of the (vein) deposits genetically

connected with and partly contained in lamprophyric dikes, tungsten is the only metal.

In about 50 per cent. of the deposits occurring in the quartz diorite as in those of the older quartz monzonite, copper is the dominant metal, with silver commonly a close second, followed by lead and gold, with zinc, except as an associate metal, rare; in about 40 per cent. lead is the dominant metal with second place shared about equally by copper and silver; in about 10 per cent. silver is dominant; in a few iron is the only metal. Only 44 per cent. of the deposits appear to be in genetic connection with later intrusives in the quartz diorite; of these the most important is granite porphyry. In deposits connected with this rock the rank of the metals is not materially changed except that lead is moved to second place at the expense of silver, and in a few of the deposits gold ranks first. The quartz diorite beside containing about 30 per cent. of the deposits of the range, also as has been shown plays the rôle of later intrusive in genetic connection with 50 per cent. of the deposits occurring in the older quartz monzonite.

In the deposits in the granite porphyry which are chiefly vein and shear zone deposits, containing copper, lead, and silver, copper is the chief metal; in 60 per cent. of them it ranks first, in 25 per cent. lead is first, and in 15 per cent. silver is first, with copper second.

In the deposits in the younger quartz monzonite the dominant metal is copper, with gold and silver also present in some veins, and the rock itself like the older quartz monzonite in places contains primary minerals of copper.

YOUNGER DEPOSITS.

The younger deposits occur chiefly in and are genetically connected with the Tertiary effusive volcanic rocks. They were formed relatively near the surface by ascending thermal solutions resulting from the magmas of the inclosing or associated rocks. They are regarded as of late Miocene or early Pliocene age. In these deposits, which occur chiefly as branching fissure veins

in andesite, rhyolite and quartz latite porphyry, an unusual feature is their generally base metal character and the tendency of the deposits to occur in two types, (1) tetrahedrite-rhodochrosite veins, and (2) quartz-galena-sphalerite veins. Copper is the dominant metal in the rhyolite areas some of which appear to contain pyrite and chalcopyrite. Some of the deposits, however, contain only gold and silver, and a few only gold.