GEOLOGY OF THE MONTE CRISTO VEIN AREA,
BLACK ROCK MINING DISTRICT, YAVAPAI COUNTY, ARIZONA

by

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STATEMENT OF AUTHOR

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LIST OF ILLUSTRATIONS
The geology of the Constellation area is relatively complex. Precambrian granitic gneiss and mafic schist act as hosts to Proterozoic pegmatites. Tertiary volcanic rocks intrude and overlie the older pegmatites and metamorphic rocks. Epithermal-type quartz veins emplaced along the strike of the diabasic dikes incorporate brecciated dike material, crosscut all of the older rock types, and carry significant values of copper, gold, and silver.

The Monte Cristo vein/fault zone further complicate this picture. This unusual silver-nickel-cobalt-arsenide-bearing vein strikes across the trend of the other known structures in the area, although outcrop is limited. Surface sampling detected none of the reported arsenide mineralization, although anomalous amounts of rare-earth elements give the vein a qualitative geochemical "fingerprint". Excepting generalizations, determination of the relative age of the Monte Cristo vein and its relationships with outcropping units will have to wait until underground exploration is again possible.
CHAPTER 1

INTRODUCTION

The Constellation area of the Black Rock mining district has seen mining activity in the past, as is attested to by the shadowy adits and gray waste dumps which dot the area. Of most interest has been the Monte Cristo mine, renowned for seventy years as an inconsistent but high-grade native silver producer. The association of arsenides of cobalt, nickel, and silver with native silver at the Monte Cristo mine has attracted the attention of many geologists who have noted the similarity of this mineralogy to that of the Cobalt district, Ontario, and parts of the Erzgebirge District, German Democratic Republic. Before conclusions may be reached with respect to the implications of the underground mineralogy, however, the hitherto-neglected geology of the area surrounding the mine should be evaluated.

Purpose

The purpose of this study is to provide a comprehensive description of the geology of the area immediately surrounding the Monte Cristo mine and to develop a geologic history which will reasonably account for the features observed in the area. The Monte Cristo mine itself is flooded to within several tens of
meters of the surface, making all but the first level inaccessible. Descent to the waterline is possible, but little useful information is revealed in this section of the mine. For this reason, this study will concern itself only with the surface geology of the area. This work will provide a background for later, more detailed study of the mineralization in this region.

**Method of Treatment**

Approximately 250 hours of mapping during the spring and fall months of 1982 was done at a scale of 1:6000 on a topographic map enlarged from the Morgan Butte U.S.G.S. 7.5' sheet. The actual mapped area covers approximately 4 square kilometers; of this area, greater than 80 percent is outcrop.

Thin sections were used to determine the composition and character of the rock types encountered in the area. As many are of a metamorphic nature, petrography was especially important with respect to the identification of mineral assemblages and hence determination of metamorphic grade. Whole-rock analyses helped to distinguish rocks of similar derivation and to differentiate rocks of a sedimentary origin from those of an igneous origin where metamorphism had destroyed relict primary textures. Fire assay, neutron activation, and supplemental atomic absorption analyses of mineralized dike-vein material from the many veins which occur in the area allowed identification of those veins that are of economic interest. Identification of the types and amounts of
metals present in the different veins allows correlation of those veins with similar metal ratios into genetically-related groups. Determination of the general age of the most predominant rock type found in the area allows the placement of this specific locality within the geologic time-scale of surrounding rocks in the region.

**Location and Accessibility**

The Black Rock Mining District is at the extreme southern end of Yavapai County in central Arizona approximately 11 miles northeast of Wickenburg (Figure 1). The area mapped covers parts of sections 4, 5, and 9 in T. 8 N., R. 3 W. and sections 32 and 33 in T. 9 N., R. 3 W. The area is accessible by means of a dirt and gravel road which is well maintained for the first 15 kilometers outside of Wickenburg; the last 7 kilometers should be attempted only in a vehicle with relatively high clearance. The climate is that of the high Sonoran desert - hot and dry in the summer and cool and dry the rest of the year, excepting for occasional heavy seasonal rainstorms. The elevation at the Monte Cristo mine collar is approximately 1055 meters, with slightly more than 340 meters of relief within the map area. This combination of factors creates conditions which make fieldwork possible - even pleasant - for about 8 months of the year.

**Previous Work**

The first, and only, publication dealing exclusively with the Monte Cristo area was published in 1922 and is entitled
Figure 1. Location map of Constellation area, Black Rock Mining District, Yavapai County, Arizona.
"Primary Native Silver Ores Near Wickenburg, Arizona, and Their Bearing on the Genesis of the Silver of Cobalt, Ontario", by E. S. Bastin. The actual research for this work was carried out in 1913, but publication was delayed by WWI. This paper was principally concerned with the underground ore petrology - which is described in detail - and its similarities to the silver ore of Cobalt, Ontario. Only one page is devoted to the surrounding rocks.

A 1924 article in the Arizona Mining Journal by Colonel Dean Burgess briefly mentioned "the famous and mysterious Monte Cristo Mine". This article stated that the workings presently extended below 1100 feet and that the native silver from this mine "are show specimens and of very large size". Copies of several letters, all from the mid-1930's, describe "a mining enterprise so attractive.... that the Monte Cristo can be developed into one of the outstanding producers of the country" (Ralph H. Speaker, late 1930's). Most of these reports were apparently based on 1911 assay results of up to "25,000 oz./Ton of silver" (sic). Much of the Monte Cristo's reputation rests on these figures, which document the discovery of a small but high-grade lens of native silver in 1911. Although similar figures were being quoted nearly 25 years later, there is no indication that more than one such bonanza silver discovery was ever made. "Promoter - inflation" may have also been responsible for some of the reported
extraordinary ore grades, as most of the early correspondence was generated by mining promoters eager to make a sale.

The Monte Cristo headframe, mine buildings, and much of the underground timbers burned in 1969, the apparent victims of arson. Southcan Mining Ltd. of Vancouver, British Columbia, dewatered and retimbered the mine in 1974. Underground mapping, sampling, and diamond core drilling were carried out over the next five years. Unfortunately, Southcan's records are incomplete and ambiguous, and little useful information can be gleaned from their reports. Callahan Mining Corporation of Phoenix, Arizona, has recently relogged the core from one drill hole. Efforts at underground investigation have been curtailed due to reflooding of the mine.
CHAPTER 2

REGIONAL GEOLOGY

The Black Rock mining district is located in the Wickenburg Mountains, an area of irregular ridges and narrow canyons located slightly west of the center of the Morgan Butte quadrangle. This area, just to the west of the rugged Bradshaw Mountains, falls within the physiographic division of Arizona known as the Central Mountain Region. Jagger and Palache (1905) are the first geologists to have recorded their observations of this general area, although their reconnaissance did not extend as far west as the Black Rock district. More recently, Jahns (1952) discussed the White Picacho Pegmatite District immediately to the south of the map area, and Rehrig, Shafiqullah, and Damon (1980) discussed the general geology of the Vulture Mountains, approximately 18 miles to the southwest of the area of interest. Much of the following geologic summary will be drawn from Jahn's work, as this area is closest to the map area, although pertinent data from other sources and from Reynolds' (1980) condensation of the geology of west-central Arizona will be included.

The oldest rocks in central Arizona are the Precambrian metamorphosed igneous and sedimentary rocks of the Yavapai Series, a rock name with no specific time-stratigraphic implications in this particular portion of Arizona (Figure 2). The Yavapai Series
Figure 2. Sketch map of general occurrences of Yavapai Series-age rocks (solid) and Arizona Pegmatite Belt (dashed) with F - Flagstaff, P - Phoenix, and W - Wickenburg (from Jahns, 1952 and the Arizona Bureau of Mines, 1962).
ranges widely in composition: thinly foliated quartz-mica schist, quartz-mica-hornblende schist and gneiss, amphibolite, feldspathic hornblende schist, and granitic gneisses. The metamorphic rank of these rocks varies locally from chlorite to amphibole-rank, although the prevailing degree of regional metamorphism is indicated by the presence of such minerals as hornblende, garnet, biotite, and calcic plagioclase. The general trend of the steeply dipping foliation in these rocks is from west-northwest to northeast, making them concordant with the foliation of most of the known Precambrian rocks in northern Arizona. Relict structures, such as graded bedding and cut-and-fill relations, are cited as evidence that much of the Yavapai Series protolith was sedimentary in nature, although no such primary features have been observed in the area mapped by the author. Isotopic dating of the foliated rocks in this area has so far been inconclusive (Shafiqullah and others, 1980). Biotite in a foliated monzonite porphyry from a dump within the map area yielded a potassium-argon age of 111 ± 3 Ma, an age said to be "highly suspect" (Shafiqullah, personal communication, 1982). Simple granitic and aplitic pegmatites of presumed Precambrian age are also common features in this area, which falls on the northern boundary of what Jahns has designated as the Arizona Pegmatite Belt (see Figure 2, page 8).

Intrusive masses of porphyritic rhyolite, diorite, and gabbro are local phenomena thought to be related to quartz
porphyry occurrences within the Spud Mountain Volcanics of the Jerome area. These latter rocks constitute what are believed to be the youngest Precambrian rocks in the area.

The Laramide orogeny is represented by the 68.4 Ma Wickenburg Batholith (Rehrig, Shafiqullah, and Damon, 1980), a granodioritic pluton which crops out to the southwest of the map area but which extends to the northeast for an undetermined distance. Three intrusive phases of this batholith have been clearly identified; an early diorite border phase, a light-gray equigranular main granodiorite phase, and a later porphyritic quartz monzonite stage. Intrusive rocks in the map area with a granitic appearance may be related to the Wickenburg Batholith plutonism and so be of Laramide age. The general description of the Bradshaw Granite - "a coarse plutonic rock which has in places a gneissic and in places a coarse granular texture, with zones where the rock becomes highly schistose and would better be called a mica gneiss" (Jagger and Palache, 1905) - fits many of the locally foliated rocks in the area. However, outcrops of identifiable Bradshaw Granite are found at least 15 kilometers away to the northeast. The author is unaware of any concrete evidence to link the plutonic rocks in this particular region with the late Precambrian plutonism which produced the Bradshaw Granite.

Except for the Laramide-initiated igneous activity, the Paleozoic and Mesozoic units which characterize the geology of
adjacent areas of Arizona are entirely missing from the Constellation area, where preserved volcanic and sedimentary accumulations of Tertiary age rest nonconformably directly upon Precambrian rocks. The volcanic rocks are composed of interlayered coarse volcanic agglomerates, flow breccias, and tuffs of rhyolitic, latitic, andesitic, and basaltic composition. Most of these volcanic rocks have been eroded away, but good exposures may still be observed in several washes where these volcanic rocks may be observed to represent dikes and feeders, presumably to now-absent volcanic flows. The following Tertiary sedimentary rocks are found in the general Wickenburg area: red to brown arkose and pebble conglomerate, tuffaceous sandstone and arkose, bouldery volcanic agglomerate, and flow and fault breccias which locally contain fragments of all the surrounding older rocks.
CHAPTER 3

DETAILED GEOLOGY

Granitic Gneiss

The rock type most commonly encountered in this area (Figure 3, in pocket) is a granitic gneiss with a rubidium-strontium whole-rock minimum age of 1734 Ma, there being no error limits on this date due to mineral-separation limitations. This general rock type crops out over approximately three-quarters of the map area. Its appearance changes with topography, ranging from very weathered, grusy, and crumbly in most of the area to apparently fresh and resistant along the steepest slopes and washes (Figure 4). The general composition and degree of foliation changes somewhat over the 3 square kilometers, although these variations were not considered to be distinct and significant enough to attempt their distinction as separate map units. The strike and dip of the foliation of the gneiss ranges from west-northwest to northeast, structural attitudes which are similar to those in Precambrian terranes elsewhere in Arizona and which are probably the result of Precambrian deformation (Rehrig, Shafiqullah, and Damon, 1980). Every other rock type in the area is observed to cut the gneiss, with most contacts appearing sharp and distinct. The gneiss acts as a brittle host to the faulting and mineralization of the Monte Cristo vein as well. Layers of a
Figure 4. Granitic gneiss exhibiting isoclinal folding in roadcut on east side of road as one enters the map area.
more mafic material, to be described in the following section, are often layered within the gneiss, creating a narrow migmatitic zone. Where these different layers are contorted, especially where they are associated with narrow veins of pegmatitic material, the overall appearance is persuasively sedimentary. Close inspection reveals none of the primary sedimentary structures one would associate with such layering, however, and it will be developed later that it is the author's belief that the field relations are consistent with an igneous protolith.

Thin sections reveal the full extent of compositional variations (Figure 5). Quartz remains the most uniformly distributed mineral across the map area, varying only between 35 and 40 percent. In every thin section, quartz is observed to occur as subhedral to anhedral, 0.5 - 2.0 mm grains which are severely strained and sutured. Feldspar content ranges between 40 and 55 percent, but what is more important are the relative amounts of potassium feldspar and plagioclase. Potassium feldspar dominates the gneiss in most instances - microcline, the most abundant potassium feldspar, constitutes up to 55 percent of the rock and all of the feldspar present. However, plagioclase is occasionally observed to dominate the feldspar content by as much as a 3:1 ratio. In most instances, the feldspars occur as subhedral to anhedral, normally-zoned laths which are essentially equigranular with the quartz grains. Ragged, broken flakes of biotite constitute 5 - 10 volume percent of the gneiss. The
Figure 5. Thin section of granitic gneiss showing biotite flakes, twinned feldspars, and anhedral quartz crystals. Thin section taken from rock used for age-date determination, from wash in east-central section of the map area. Field of view is 6.5 x 4.5 mm.
presence and degree of alignment of this biotite determines the extent of foliation in any one sample. Individual flakes are not particularly aligned, but overall the flakes are typically segregated into narrow bands of only several millimeters width. Relatively random orientation of the biotite accounts for the absence of foliation in some samples. Fine-grained, euhedral muscovite is occasionally present and may constitute up to 5 percent of the gneiss. Even where present in a sample with strong foliation, muscovite remains unaligned. Fine-grained chlorite and epidote are both present in small amounts, commonly as alteration products of biotite.

The compositional ranges detailed above represent variations within rock types from quartz monzonite/quartz latite to granite/rhyodacite to grandiorite/dacite. In the following chapter on petrology, the compositional variations within this rock type will be documented and discussed.

**Black Schist**

The most enigmatic of all the rock types in this area is that which the author has loosely termed 'black schist'. This metamorphic rock is found interlayered with, and in lenses and pods enclosed by, the granitic gneiss (Figure 6). It has experienced the same deformation as has the gneiss; the variably-developed metamorphic fabric is continuous from one rock type to the other, and in locations where the black schist is interlayered
Figure 6. Lens of black schist enclosed by granitic gneiss.
with granitic gneiss, folding has affected both in the same manner. The majority of the contacts of the black schist with the granitic gneiss are fairly clear and definite. In the southwestern section of the map area, the black schist is present as the prevailing country rock. The contacts of the granitic gneiss with this large area of black schist are either gradational or so intricately interfingered as to make the actual determination of a boundary very difficult. The mapped contact represents a locus of points where the granitic gneiss is no longer the predominant country rock. Foliation in the black schist is like that of the granitic gneiss, west-northwest to north-east, except in the southwestern section where the strikes of the foliation remain the same but the dips become progressively flatter to the northwest. The black schist is cut by all of the remaining rock types in the area. The granitic gneiss is intercalated with the black schist in the manner described above and lenses of black schist are elongate with their long axes concordant with the foliation. The continuity of foliation and deformation between the black schist and the granitic gneiss suggests that the black schist is also of Precambrian age.

The term "black schist" encompasses significant differences in composition and fabric; composition ranges from coarse-grained (hornblende) amphibolite through spotted amphibole gneiss to biotite schist. The latter form is most commonly encountered and is responsible for the term 'black
None of these forms have been mapped independently, as they have each been observed to grade into one another over the space of a single outcrop (Figure 7). In fact, most of the lenses of black schist are between three and thirty meters long, and so have not been mapped as separate units within the granitic gneiss. Each of these forms will be described in detail in the following paragraphs.

Outcrops of the amphibolite are relatively rare within the map area, although there seems to be no limit to the amount of amphibolite float. The amphibolite itself is massive, but in no instances does it constitute the entire outcrop. Rather, the amphibolite preferentially occurs adjacent to narrow silicic veins which are ubiquitous within the black schist rock type. These veins, which are composed largely of potassium feldspar—mostly in the form of microcline—and quartz, appear to emanate from the linear pegmatites, although the veins themselves may be folded (Figure 8). These veins cut both the black schist and granitic gneiss, but they may appear more abundant in the black schist due to differences in color contrast. The amphibolite appears largely as selvages around these veins, although in places the amphibolite may occur with no obvious vein association; in other instances, these veins are present in black schist with no amphibole association. The weakly foliated amphibolite is composed of 90–96 percent anhedral, allotriomorphic-granular hornblende laths which range in size from 0.3 to 0.4 mm, the larger laths being
Figure 7. Outcrop showing transition from spotted gneiss to black schist, from wash in east-central section of the map area.

Figure 8. Sketch of silicic vein leading away from pegmatite (based on photographs).
found nearer the veins. The fresh hornblende crystals exhibit weak alignment. The balance of the rock is composed of approximately equal amounts of anhedral quartz and plagioclase which fill interstices around the hornblende laths. Garnets are present in trace amounts. Thin sections reveal that crystals along the contact between the amphibolite and the silicic veins show no alignment or preferred orientation.

The spotted amphibole gneiss is the most conspicuous of the forms of black schist, it being a black rock with distinct white augen of plagioclase feldspar. It occurs in discrete outcrops with only occasional transitions to biotite schist evident, although when this transition is present it may occur within one rock over a distance of several centimeters (see Figure 7, page 20). The spotted gneiss is composed of 45 percent anhedral, 0.3 - 1.5 mm hornblende laths, 50 percent subhedral to anhedral twinned plagioclase crystals, and 5 percent subhedral, strained quartz crystals. The hornblende laths are strongly aligned and the long axes of the 5 - 10 mm feldspar augen are concordant with foliation. Relatively few of the silicic veins cut the spotted gneiss.

The biotite schist is by far the most prevalent form of the black schist. Not as resistant as the amphibolite and spotted gneiss, this dark rock often crumbles to pieces upon hammer impact. It is composed of 20 percent subhedral, broken biotite flakes, 50 percent anhedral plagioclase tablets, 25 percent
anhedral quartz crystals, 2 - 3 percent relict hornblende laths, and 2 percent opaque minerals consisting largely of magnetite. The flakes of biotite are all aligned, giving this rock a strong schistosity. Generally conformable silicic veins are present in great abundance within the biotite schist, often exhibiting tight recumbent folds. Biotite flakes are noticeably larger and more concentrated along the selvages of these veins although this edge effect is restricted to within several millimeters of the quartz-rich veins.

The implications of these observations will be discussed in a later chapter. Whole-rock analyses of the different forms of the black schist will aid interpretation of these puzzling rocks.

**Pegmatites**

Pegmatites are ubiquitous in this area, constituting anywhere from 5 to 80 percent of the country rock. They crosscut both the granitic gneiss and the various forms of the black schist, varying in width from 0.2 to 7 meters and possessing strike lengths of up to several kilometers. They are themselves cut by the hornblende porphyry and diabasic dikes, as well as by the rhyolite and all faulted-mineralized structures (Figure 9). Occasional small drag folds are present immediately adjacent to contacts between pegmatite and granitic gneiss. Alteration, however, is limited to the black schist and consists of the conversion of biotite to amphibole within millimeters of the
Figure 9. Pegmatite in outcrop, with diabasic dike crosscutting pegmatite and granitic gneiss, in roadcut several hundred meters west of the Monte Cristo mine.
contact. Small, folded quartz and potassium feldspar "stringer" veins accompany the pegmatites. There is no evidence to contradict an igneous origin for these pegmatites.

The larger ridge-forming pegmatites are exceptionally linear in appearance and trend in one of two directions, depending upon their location relative to the Monte Cristo mine headframe (Figure 3, in pocket). Those pegmatites directly to the east trend generally N70W and dip steeply to the southwest, whereas the pegmatites to the north, west, and south of the mine all trend N55E and dip between 60 and 75 degrees to the southeast. This change of trend and linearity has significant implications for post-pegmatite faulting, which will be discussed in a later chapter.

The mineralogy of the pegmatites is simple, they being composed of varying amounts of quartz, potassium feldspar, and black tourmaline. In only one instance was biotite observed in a pegmatite. The black, iron-bearing tourmaline schorl occurs as euhedral crystals ranging in size from fractions of a millimeter to three millimeters, which constitute from 5 to 80 percent of the pegmatite in any one location. Tourmaline abundance varies along the strike length of each pegmatite, with areas of high-tourmaline density in one pegmatite density reflected by increased tourmaline content in adjacent pegmatites. The potassium feldspar occurs as subhedral to anhedral salmon-colored crystals up to several millimeters in length. Under the microscope, at least 80 percent
of the feldspar is observed to be microcline, the remainder being albite. Gray-to-clear quartz, which exhibits significant strain shadows, occurs as anhedral to subhedral crystals which fill in around the earlier-formed feldspar and tourmaline. The ratio of quartz to feldspar is generally about 1:1, although pegmatites are present in which either quartz or feldspar is greatly predominant. Graphic granite is commonly present inside the border, constituting up to 30 percent of some pegmatites.

**Dike Rocks**

Numerous greenish-brown dikes are apparent in the roadcuts as one enters the map area. Although they are rarely over 3 meters wide, these mafic dikes contrast markedly with the generally felsic country rock to such a degree that many are detectable on 1:12000 air photos. The dikes strike to the west-northwest and range in dip from 47°SW to just past vertical. They crosscut the granitic gneiss, black schist, pegmatites and, in one location, the rhyolite. Many of these dikes have been faulted, brecciated, and mineralized along their length, indicating that either original dike material was intruded along previously existing zones of sub-parallel shears or the dikes acted as zones of weakness along which movement occurred and later mineralizing solutions flowed. The timing of faulting, with respect to both the emplacement of the dikes and the overall picture of known
tectonic stresses in central Arizona, will be discussed in a later chapter.

In outcrop, all of the dikes in this area look very similar. Often resistant enough to form small ridges of 0.1 to 1.0 meters relief, these aphanitic, greenish-brown dikes weather to form very characteristic rounded pebbles and boulders (Figure 10). Fresh surfaces are medium to dark gray. Round, calcite-filled vesicles 0.5 - 3.0 mm in diameter can easily be distinguished without the aid of a hand lens. The remainder of the rock is generally too fine-grained for mesoscopic identification. Thin sections reveal that the dikes consist of two distinct end-member compositions although the two are indistinguishable in hand sample. An attempt was made to differentiate the dike-types by thin-section and to map each as an individual unit. However such differentiation is clearly inappropriate - two thin sections taken from one single dike exhibit the two distinctly different characteristics, indicating that both types are simply variations between the two end-member types which will be described here.

Approximately one quarter of the dikes have hornblende as the dominant mafic mineral and are best classified as diorite/andesite. The subhedral to euhedral hornblende crystals constitute up to 55 percent of the rock; most are ragged and altered to epidote (< 10 percent), chlorite (< 10 percent), and shreds of calcite (< 5 percent). Subhedral plagioclase feldspar
Figure 10. Diabasic dike cropping out to form a small ridge.
laths (< 10 percent), ranging in composition from An32 to An64, have been largely replaced by sericite, and small amounts of anhedral quartz may be found in the interstices. Calcite-filled vesicles are relatively rare in these dikes. Where occasionally present, they tend to be smaller in size than those in the other dikes. Small apatite prisms are the major accessory mineral. The texture is subophitic, with the subhedral feldspar subordinate to the hornblende.

The remaining three quarters of the dikes are composed of small, euhedral plagioclase laths and abundant, round, calcite-filled vesicles in a groundmass which has undergone extensive propylitic alteration. Plagioclase constitutes approximately 50 percent of the rock, with the groundmass (40 percent) and amygdules (10 percent) accounting for the balance. Fine-grained chlorite dominates the groundmass and rims the vesicles, with amorphous mineraloids and 2-3 percent fine-grained montmorillonite giving the groundmass a "dusty" appearance. It is impossible unequivocally to identify the mineral which the clays are replacing, but several faint outlines suggest that the original mafic mineral may have been an amphibole. Quartz is present only occasionally in the very center of the amygdules. The texture resembles that of a diabase, with interstitial hornblende subordinate to the plagioclase.

The second of the two diabasic rock types described may be a more weathered and altered version of the first. Depth of
intrusion may also have been an important factor in determining the rate of crystallization of the melt, gas vesicle abundance, and the present extent of alteration, all of which could produce the variations observed in these rocks. Nothing in the field relations suggest that these dikes do not share a common source. Comparison with similar dikes in western Arizona, to be discussed in a later chapter, allows inference of a Tertiary age for these dikes.

**Rhyolite**

Tertiary rhyolite crops out at three locations within the field area (Figure 3, in pocket). The most extensive occurrence is found as resistant ridges along the sides of Slim Jim Wash, a steep, sand-floored wash which forms the major drainage for the Constellation area (Figure 11). The rhyolite extends along the wash for a kilometer; occasional irregular dikes extend out and away from the immediate wash area. The second appearance of rhyolite is as a narrow, resistant dike trending parallel to, and several hundred meters southwest of, the rhyolite along Slim Jim Wash. The dike can be traced for nearly the same distance as the rhyolite of the wash. The third and least extensive occurrence is found in the southwest portion of the field area. This irregular pod of rhyolite is not as conspicuous as is the rhyolite in the other two locations, a fact which is due largely to the increased pegmatite density in this area. The appearance in this section of
Figure 11. Rhyolite along the sides of Slim Jim Wash, looking to the northwest. This outcrop of rhyolite is the largest within the map area.
The rhyolite in these three locations is somewhat different, as will be described in the following paragraphs.

The rhyolite along Slim Jim Wash is conspicuously porphyritic. Fresh surfaces are grayish-white, with visible phenocrysts of quartz and, less clearly, potassium feldspar. Weathered surfaces are yellowish-gray and do not appear obviously porphyritic. It is composed of 5 - 15 percent euhedral, 0.5 - 2.0 mm glomeroporphyritic quartz crystals, 0 - 8 percent shreds of deep green actinolite, and 85 percent microcrystalline, felsitic, devitrified groundmass. Close inspection reveals the groundmass to consist of interlocking quartz and potassium feldspar crystals forming a granophyric-spherulitic texture. Tablets of feldspar have been converted to calcite and sericite, with subordinate montmorillonite. Hairline fractures which cut the rhyolite are filled with actinolite which is nearly identical in appearance to that which occurs as phenocrysts. Flow banding is common.

In the other two locations, the rhyolites are similar to each other in appearance. Both are grayish-white, fine-grained, and almost aplitic on fresh surfaces. Weathered surfaces are yellowish-gray grading to a limonitic orange along fractures. Both consist of roughly equal amounts of quartz and potassium feldspar, now sericitized. One thin section from the rhyolite in the southwestern area was so altered as to have had the original texture completely destroyed and to have been replaced with a chalcedonic-chloritic spherulitic groundmass. The subhedral,
normally-zoned potassium feldspar has been extensively altered to sericite and some montmorillonite. The subhedral strained and sutured quartz crystals are only slightly altered by sericite. Opaque minerals are present in trace amounts, with associated limonite staining. Flow in both areas is defined by continuous 1 - 2 mm wide bands of differing quartz-feldspar ratios.

In order to evaluate the consanguinity of these two sets of rhyolites, the following lines of evidence must be considered:

1. Besides the distinctly non-porphyritic texture, there exist two other conspicuous differences between these rhyolites and that in the Slim Jim Wash area; the absence of calcite as an alteration mineral and the total absence of amphiboles in the former.

2. All three outcrops occur within one kilometer of each other, and reconnaissance outside the field area indicates that further outcrops of rhyolite are not common.

3. Two of the occurrences, although somewhat dissimilar in microscopic appearance, exhibit a similar trend and extent of outcrop.

4. All three have flow-banding.

5. All three exhibit the same cross-cutting relationships with the surrounding rock types, namely, that the granitic gneiss, black schist, and pegmatites are observed to be cut by the rhyolite. The diabasic dikes and quartz-vein mineralization are observed to cut the rhyolite.
6. Slickensides within the rhyolite are observed at all three locations.

7. General outcrop appearance and color are similar in all three outcrops.

Item 1 notwithstanding, these similarities and field relations suggest that these rhyolites are related, probably cogenetically.

**Hornblende Diorite Porphyry**

The hornblende diorite porphyry is the most restricted in occurrence of all the rock types encountered. It is present in one approximately 200-meter-long dike in the northwest corner of the map area. The rock is light gray in outcrop; fresh surfaces are a darker gray with striking black euhedral hornblende crystals scattered randomly throughout the finer-grained groundmass. Thin sections reveal a composition of 20 percent euhedral 0.2 - 10 mm hornblende laths in an intergranular matrix of 1 - 2 percent magnetite and 70 percent euhedral to subhedral normally-zoned plagioclase laths. Small amounts of chlorite and associated calcite, with traces of epidote, replace the hornblende; interstitial anhedral quartz furnishes the remaining components. The feldspar matrix has been altered somewhat to sericite and lesser fine-grained amorphous mineraloids. The cores of the feldspar grains are much more extensively altered than are the more sodic rims, which appear to be fresh.
It is unfortunate that the occurrence of this rock type is so limited, as the relatively unaltered hornblende crystals would have made excellent subjects for potassium-argon age determination. The dike is observed to cut only rocks of presumed Precambrian age, so its age can only be described as Cambrian or younger.
CHAPTER 4

PETROLOGY

X-ray fluorescence whole-rock analyses of the granitic gneiss and the black schist, both of which rocks were described in the previous chapter, were conducted. The results of these analyses are presented in Table 1. Barth norm calculations (Barth, 1962) were then executed for each sample using the analytical results from Table 1. The normative minerals, and their appropriate igneous classification, are presented in Table 2 (page 37) and plotted on an IUGS igneous rock classification diagram (Figure 12, page 38). Before these classifications may be assumed to be correct, however, it should be demonstrated that an igneous origin is most likely for these two metamorphic rocks.

Granitic Gneiss

The following evidence suggests to the author that the gneissic country rock is an orthogneiss, that is, one of igneous origin:

1. No relict sedimentary structures were observed on outcrop scale in the field or in hand samples.

2. Thin-sections did not reveal the presence of andalusite, cordierite, sillimanite, or any of the many alumino-silicate metamorphic minerals which might be expected in a normally alumina-rich gneiss of sedimentary origin (Spry, 1979).
Table 1. Whole-rock analyses of granitic gneiss and black schist. Whole-rock analyses obtained by X-ray fluorescence of rock chips and conducted by X-Ray Assay Laboratories of Toronto, Canada.

<table>
<thead>
<tr>
<th>SAMPLE NUMBER</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>Fe₂O₃</th>
<th>MnO</th>
<th>TiO₂</th>
<th>P₂O₅</th>
<th>Cr₂O₃</th>
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<tr>
<td>MG-1</td>
<td>70.2</td>
<td>14.2</td>
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<td>0.84</td>
<td>4.40</td>
<td>2.35</td>
<td>3.70</td>
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<td>0.09</td>
<td>0.01</td>
<td>0.93</td>
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<td>0.27</td>
<td>0.08</td>
<td>0.01</td>
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<td>0.64</td>
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<td>0.02</td>
<td>1.00</td>
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<td>8.72</td>
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Error limits: ± 0.08%
Table 2. Barth norm compositions of apparent igneous rock equivalents of Black Rock Mining District 'granitic gneiss' and 'black schist'.

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<tr>
<th>IGNEOUS CLASSIFICATION</th>
<th>SAMPLE NUMBER</th>
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<th>IL</th>
<th>OR</th>
<th>AB</th>
<th>AN</th>
<th>MT</th>
<th>COR</th>
<th>EN</th>
<th>FS</th>
<th>QTZ</th>
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<td>GABBRO</td>
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<td>MONZODIORITE</td>
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<td>15.44</td>
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</table>
Figure 12. IUGS igneous rock classification diagram (Streckeisen, 1973) with compositions of Black Rock Mining District rocks shown.
3. Microscopic examination did reveal the presence of normal-type plagioclase zoning - calcic cores to sodic rims - in the abundant plagioclase feldspar laths.

4. The accessory minerals - euhedral zircon and ilmenite - are consistent with an igneous origin.

5. SiO$_2$ and Al$_2$O$_3$ values are nearly identical over the several kilometer-square Constellation area. It is highly unlikely that these values would remain so constant, were the gneiss the metamorphosed products of sediments. Taking these facts into consideration, it is reasonable to conclude that an igneous classification is appropriate for the granitic gneiss. From the calculations, it is obvious that a range of compositions, from granite to granodiorite, is represented by the gneiss samples. Reference to the preceding description indicates that this chemical determination agrees well with the petrographic identification.

Furthermore, an attempt was made to place the granitic gneiss into the I- and S-type granitic classification proposed by Chappell and White (1974). Evidence in support of the I-type classification for the gneiss includes:

1. High SiO$_2$: 70.85 wt%.

2. High Na$_2$O: 3.77 wt %.

3. The absence of alumino-silicates such as cordierite and sillimanite.

4. Sr$^{87}$/Sr$^{86}$ assumed to be 0.7040.
Evidence in support of the S-type classification for the gneiss includes:

1. Mol $\frac{Al_2O_3}{(Na_2O + K_2O + CaO)} = 1.49$
2. The absence of hornblende in the gneiss.
3. The presence of both biotite and muscovite.

In addition, two of the four samples analyzed have CIPW normative corundum $> 1$ wt %, an indicator of S-type affiliation, whereas the other two samples have CIPW normative corundum $< 1$ wt %, indicative of I-type granites. Clearly, this classification scheme provides no new useful information with respect to the petrogenesis of the granitic gneiss, as neither I- nor S-type is appropriate for this gneiss.

**Black Schist**

Para-amphibolites are known to occur where impure limestones with abundant iron and magnesium have been exposed to 'amphibolite-grade' conditions (Spry, 1979) although such paragneisses "are difficult to distinguish from ortho-amphibolites derived from basic igneous rocks" (Walker et al, 1959). However, field relations suggest that the Black Rock area black schist is of igneous origin. Nowhere are relict sedimentary structures apparent, interlayering of the black schist with the granitic gneiss is neither continuous nor rhythmic, and relatively thick lenses of the black schist within granitic gneiss do not imply the
plasticity of deformation one might expect from a sediment. Microscopic examination revealed none of the characteristic alumino-silicate metamorphic minerals which one would expect to find if this rock were of sedimentary origin (J. Ganguly, personal communication, 1982). Also to be accounted for is the spotted gneiss, which grades into both the biotite schist or amphibolite end-members of the black schist rock type. In a section entitled Metamorphism of Basic Igneous Rocks, Spry (1979) offers the following explanation:

"Textures in amphibolites depend to a certain extent on the relative proportions of amphibole and plagioclase. Metamorphism of more mafic types produces an amphibole-rich rock with the plagioclase dispersed as regular 'round-grained' crystals, giving a rock of very characteristic spotted appearance. It seems likely that the plagioclase originally had an elongate, lenticular form and that it was converted to a new, spherical, low surface energy shape during post-tectonic crystallization."

The presence of amphibolite-facies metamorphosed rocks suggests that relatively high-grade metamorphic conditions existed at one time in the past (Winkler, 1979). It has been shown that the anorthite content of the plagioclase in amphibolites increases with increasing temperatures of metamorphism (Winkler, 1979). The plagioclase in these rocks ranges from An42 to An72, suggesting temperatures of metamorphism in the 600° - 700° range.

On the assumption that the black schist is also of igneous origin, the classification provided by the Barth norm calculations
indicates a range of compositions for this rock type (Figure 12, page 38). The amphibolites plot in the gabbro/basalt field, while the biotite schist ranges from a monzogabbro/andesite to a quartz monzodiorite/quartz andesite. These differences in composition may be accounted for by slight compositional variations within the original mafic igneous rock or by the effects of metamorphic segregation. Further conclusions will be drawn in the final chapter of this report.
CHAPTER 5

MINERALIZATION

The original goal of this thesis was to map and then geochemically analyze the Monte Cristo vein. Early in this project, field work revealed the presence of numerous quartz veins in the immediate Constellation area. These quartz veins are of two distinct appearances: solid bull quartz veins and iron-stained quartz veins with open-space filling textures. The Monte Cristo vein and each of the quartz vein types will be described in the following paragraphs.

The Monte Cristo vein can be identified with certainty only at the entrance to the Boardinghouse Tunnel, which is located approximately 30 meters to the south of the mine headframe. The vein is found along the east wall as one faces the adit, and is surrounded by 2-3 meter wide zone of sheared, incompetent granitic gneiss. The vein itself is 1-2 meters wide, trends N25°W, and dips 52° to the southwest. Coarse-grained barite, quartz, and calcite, in decreasing order of abundance, constitute the majority of the vein material. Pyrite is present as a major accessory mineral with minor chalcopyrite and tell-tale copper staining. No evidence of erythrite (cobalt-bloom) or annabergite (nickel-bloom)
was observed, although small fragments of erythrite float were
found on an early field trip. Neutron activation revealed the
presence of several unusual elements, specifically hafnium,
rubidium, and barium, in unexpectedly high concentrations within
and immediately adjacent to the Monte Cristo vein. No
quantitative determination was made of the amounts of these
elements present, however, as these elements do not appear in any
of the other samples analyzed in this study, their presence may be
a significant geochemical indicator of the unusual Monte Cristo
vein mineralization.

The more interesting of the two quartz vein types is that
which is accompanied by extensive iron-staining. Open-space
filling is also ubiquitous in these veins, although the average
size of most quartz crystals is 1 cm or less. Replacement
textures are also well developed, where chalcopyrite and possibly
calcite have dissolved to leave behind delicate boxwork textures
now lined with saccharoidal quartz. At the edges of these veins,
which are generally less than 1 meter in width, are selvages of
sheared and brecciated diabasic dike and granitic gneiss material
which have been recemented with quartz vein filling material.
These areas, which average 1-2 meters in width, are commonly
pyritic and heavily stained black by manganese, red and brown by
iron, and green by copper oxide minerals. These quartz veins are
always associated with one or more of the diabasic dikes and have
the identical trend as the immediately adjacent dikes.
The second of the two types of quartz veins consists of 0.5 - 1.0 meter wide solid, white, bull quartz veins. These veins do not commonly show evidence of open-space filling, show only rare casts after pyrite, and are iron-oxide-stained only along hairline fractures. Vein selvages are commonly narrower than they are adjacent to the preceding vein type and usually consist of only sheared and brecciated granitic gneiss. These veins trend in the same general direction as the other quartz vein set, but are not apparently contiguos to the diabasic dikes. In most cases observed, such dikes are present within 10 meters of these veins.

Results of analyses of vein samples are shown in Table 3. The silver, gold, and cobalt values were obtained by the author by neutron activation analysis of powdered samples. The copper values were determined by atomic absorption of the same powdered samples.

It is obvious that several of the veins contain appreciable amounts of copper, gold, and silver; high values of one metal are commonly associated with elevated amounts of the other two metals in the same sample. In most cases, the veins with distinguished assay values are those quartz veins with open-space filling and considerable staining. Excepting the Monte Cristo vein, the six main veins in the area — the Amethyst, Mountain View, Mahoney, Copper Neley, Colorado, and Rowland veins (Figure 3, Crowther, undated) — are all of this type. The one notable exception, sample 158, consists almost entirely of
Table 3. Selected element analyses of vein samples.

Ag, Au, and Co samples analyzed by neutron activation with sample values calculated by calibration with standard samples analyzed by fire assay by Copper State Analytical Lab, Inc., of Tucson, Arizona. Cu values obtained by atomic absorption by Skyline Labs, Inc., of Tucson, Arizona.

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<th>SAMPLE NUMBER</th>
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<th>Au (ppm) (±12%)</th>
<th>Cu (ppm) (±10%)</th>
<th>Co (ppm)</th>
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<td></td>
<td></td>
<td>400</td>
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*All samples, with the exception of 10A and 11A, were contaminated with Co in the grinding process. Samples 153 and 169 contain more Co than can be accounted for by contamination.

10,000 ppm = 1%

- indicates too little element for detection
brecciated diabasic dike rock and pyrite with very little visible quartz. The association of the quartz veins and diabasic dikes and possible implications of this association will be discussed in the following chapter. The Monte Cristo vein is conspicuous for its lack of silver and cobalt. One can only presume that the reported values of these two elements (Bastin, 1922) were produced from deeper levels within the mine.
CHAPTER 6

INTERPRETATION

Very little interpretation of the observations revealed by this study has been essayed to this point. The purpose of this chapter is to synthesize all the pertinent information into a cohesive and reasonable, although incomplete, geologic history of the Constellation area.

The petrology of the granitic gneiss is not entirely homogeneous, locally ranging in composition from granite/rhyodacite to grandiorite/dacite, reflecting probable effects of metamorphic assimilation, segregation, or both. The rubidium-strontium age of the granitic gneiss is 1734 Ma, which places the gneiss in the mid-Proterozoic. This particular date also places the gneiss within the general "Yavapai Schist" classification (Jagger and Palache, 1905), but makes it more recent than the Yavapai Series, a provincial time-stratigraphic term defined in the Prescott-Jerome area as the time interval from 1770 ± 10 to 1820 + Ma (Anderson, Blacet, Silver, and Stern, 1971).

The black schist rock type is also a metamorphic rock of original igneous protolith. Whole-rock analyses suggest that its original composition was in the monzodiorite/gabbro-dacite/basalt...
range. The foliation of the black schist is concordant and continuous with that of the granitic gneiss. This fact implies that the black schist is also of mid-Proterozoic age.

With the given information, several different interpretations may be made with respect to the origin of these two contiguous rock types. Recent literature (Donnelly and Hahn, 1981) supports the explanation that the granitic gneiss and the black schist are the metamorphic vestiges of originally interlayered rhyodacites-dacites and basalts-latites. Most of the Precambrian rocks in this general area of Arizona which possess ages in the interval 1700 - 1800 Ma represent a thick assemblage of submarine volcanic, volcaniclastic, and epiclastic rocks. Reconstruction of the primary depositional environment indicates that multiple centers of mafic to felsic volcanism were once present (Donnelly and Hahn, 1981) which would account for the different igneous compositions observed in the Constellation area.

The author believes that the petrographic evidence favors a further explanation. Coeval with the above-mentioned volcanic rock are 'granitic'-bodies, of diverse actual composition (Donnelly and Hahn, 1981). In fact, the Brady Butte Granodiorite found in the northern Bradshaw Mountains, approximately 50 kilometers to the north, is similar in both its granioritic composition and 1770 ± 10 Ma age to the granitic gneiss of the Constellation area (Anderson, Blacet, Silver, and Stern, 1981). It is the author's interpretation that the granitic gneiss was
originally one of the afore-mentioned coeval granitic bodies, similar to the Brady Butte Granodiorite, and that the black schist represents the now-deformed and metamorphosed remnants of the mafic volcanism referred to by Donnelly and Hahn. The regional metamorphism, which locally reaches amphibolite-grade, may represent the effects of the end of this orogenic/volcanic episode which comprised part of the Mazatzal Revolution (Wilson, 1939).

The White Picacho Pegmatite District (Jahns, 1952) lies approximately eight miles directly to the south of the map area. This district contains many large, lenticular pegmatite bodies within igneous and metamorphic rocks of Precambrian age. Most of the pegmatites described in this area are notable for their abundance of lithium-containing minerals such as amblygonite, spodumene, and lepidolite. Included in Jahns' description of the individual pegmatite occurrences is a now-famous generalized model of the characteristic distribution of zones within them (Cameron, Jahns, McNair, and Page, 1949). The pegmatites of the Constellation area, although narrower and much greater in strike length, follow this model to some extent:

1. The Border Zone. This zone, the outermost zone of the Constellation pegmatites, ranges in thickness from absent to a meter or more wide. In general, this zone consists only of quartz and potassium feldspar and is aplitic in appearance.

2. The Wall Zone. The size of this zone is directly dependent on the size of the pegmatite, varying from centimeters
to meters in thickness. It is composed of potassium feldspar, quartz, and small tourmaline crystals. Graphic granite and granitic textures make this zone immediately recognizable.

3. The Intermediate Zone. Composed of the same three minerals as the wall zone, this region consists of the largest crystals in the pegmatite, some reaching up to several centimeters in size. Tourmaline crystals are often continuous from the wall zone to this one, increasing in size as they extend inwards.

4. The Core. This zone is composed of coarse-grained quartz crystals, and is present in only the largest pegmatites in the map area.

Slight drag folds in the gneiss adjacent to the pegmatites and GCZP-type zoning (Guilbert and Park, in press) provide evidence of an igneous origin. Were the pegmatites concordant with the gneissic foliation, it would be tempting to consider them as the "last gasp" of the plutonic system which produced the granitic rock. However, although locally concordant in trend with the foliation of the granitic gneiss, their overall cross-cutting trend is consistent with a formation clearly removed in time from the foliation-producing metamorphic event. Jahns' report on the White Picacho pegmatites states that "the pegmatites are among the youngest of the Precambrian rocks in the district". It is not possible to date the tourmaline of the pegmatites in the map area, but cross-cutting field relationships place them between the granitic gneiss and the rhyolite in age. These facts, together
with a lack of contradictory evidence, leads to the conclusion that the pegmatites of the Constellation area are also of younger Proterozoic age.

There is little information to document the geologic history between the time of the pegmatite emplacement and Tertiary volcanism. Assuming for the moment that both the rhyolite and the diabasic dikes are of Tertiary age, then it is certain that at least one episode of faulting must have preceded the Tertiary volcanism. The following evidence supports this assertion:

1. The pegmatites in fully one-quarter of the area of study are rotated with respect to the majority of the pegmatites in the Constellation area. Pegmatites in both sectors are parallel to each other, exceedingly linear in appearance, and not offset in any manner except that of the distinct change of trend. This change occurs across the main valley to the southeast of the Monte Cristo mine, an area which is cut by dikes and quartz veins, but which is also conspicuous for its absence of pegmatites. It is possible that the pegmatites in this linear valley have been faulted and brecciated into oblivion.

2. It is likely that the diabasic dikes were intruded along pre-existing parallel zones of weakness. If this were not the case, it seems intuitively reasonable that the dikes would appear to emanate from a common origin.

The rhyolite in this area is a small vestige of the volcanism which was ubiquitous to the southwest in Tertiary
times. No age-date was obtained from this material, but there is no evidence to suggest an older age; the rhyolite is somewhat altered, but locally appears fresh, especially where porphyritic. This rhyolite is cut in one location by the diabasic dikes which are almost unquestionably of Tertiary age. Isotopic ages of rocks with similar field relationships and general appearance near Wickenburg have been determined to range from 18.2 to 16 Ma (Rehrig, Shafiqullah, and Damon, 1980).

The diabasic dikes which are abundant in this area are believed to be related to those in the Harquahala and western Harcuvar Mountains (Reynolds, 1982). The rocks of each of these separate dike swarms are similar in appearance and crosscutting relationships (Reynolds, personal communication, 1983), both dip steeply and have nearly identical trends (Figures 13a and 13b), and both are associated with copper-gold mineralization. Potassium-argon ages of biotite and hornblende from the westerly dike swarm average 25 Ma (Shafiqullah and others, 1980).

The quartz veins in the Constellation area are therefore of post-25 Ma age, as they have been injected along the strike of the diabasic dikes and, in many places, contain abundant brecciated fragments of these dikes. Brecciated fragments of rhyolite may also be found in the veins where the dikes and accompanying quartz veins crosscut the rhyolite. There is no field evidence of movement along these fault planes post-dating formation of the quartz veins. Thin sections reveal, however,
Figure 13a. Strike of middle Tertiary microdiorite dikes in western Harcuvar Mountains, west-central Arizona (Reynolds, 1982).

Figure 13b. Strike of presumed Tertiary diabasic dikes in the Constellation area.
that most of the quartz in these veins is highly strained. The sense of faulting which occurred in this area and which allowed for the formation of these quartz veins is enigmatic - a strong vertical component of motion is suggested by the continuity of the linear pegmatites across most of the area. Some horizontal movement is indicated along faults, the topographic expressions of which are now narrow washes or gullies which are perpendicular to the predominant trend of the fault-dike swarm and which act to offset the diabasic dikes and quartz veins, although no more than tens of meters.

It is the author's belief that the Monte Cristo vein is in no way related to the many diabasic dikes and quartz veins which crosscut the area. Its ore petrology, mineralogy, and trend are completely different from any other structure in the Constellation area, as well as in the general west-central Arizona area. The vein is also difficult to trace - projections of the vein, based on its strike and dip as measured at the entrance to the Boardinghouse Tunnel, yield sites where only undisturbed gneiss is present. It is possible that the trend of the Monte Cristo vein is not linear, in which case the author suggests that the Monte Cristo vein may be observed in a tractor-cut approximately one-half kilometer to the southwest of the mine itself. This 50 meter-long cut exhibits no recognizable vein material, but is highly faulted along its entire length. The general trend of the fault at this location is N36W, dipping 51° to the southwest. The
The author originally dismissed this fault zone as being a possible extension of the Monte Cristo vein, due to the significant differences in strike and dip evident over a relatively short distance. Neutron activation results, however, revealed the presence of hafnium, rubidium, and barium anomalies in samples taken from the Monte Cristo vein itself and from the fault zone exposed in this cut which are unlike any results obtained from any of the remaining samples. These elements are occasionally independently present in other samples, but only in these particular samples are all three of these uncommon elements significantly elevated. No standards were run with which to quantitatively calculate the values of these elements.

Slickensides on the recognizable portion of the Monte Cristo vein reveal a strong component of horizontal movement. As none of the diabasic dikes or quartz veins are offset along the projection of the Monte Cristo vein/fault in this immediate area, movement on the Monte Cristo fault zone must have occurred prior to their formation. Less than one hundred meters from the northwest end of the vein are dozens of linear, apparently undisturbed pegmatites. Projection of the Monte Cristo vein/fault just one hundred meters to the northwest requires that any movement along its length must have occurred prior to the formation of the pegmatites, suggesting a possible Precambrian age for the Monte Cristo fault: Little data are apparent on the surface with which to suggest its age more accurately.
Imperfect reports from drill core from one Southcan Ltd.-

sponsored drill hole appear to further complicate the geologic
picture of the area. Intense argillic and sericitic alteration of
both the granitic gneiss and black schist was encountered,
increasing downwards to a depth of 268 meters, at which depth
quartz monzonite porphyry was intersected. The hole was continued
to a depth of 287 meters, remaining in quartz monzonite porphyry
with occasional felsic dikes and intense sericitic alteration.
The quartz monzonite porphyry is relatively devoid of
mineralization (Bouley, 1982). Certainly this development adds
much to complicate the already complex geologic picture of this
area.
CHAPTER 7

CONCLUSIONS

The geology of the Constellation area in west-central Arizona is relatively complex. Precambrian granitic rock—petrologically an orthogneiss—covers most of the area. Within this gneiss are lenses and pods up to several hundred meters in length of a mafic schist. This schist, which locally grades into amphibolite, is also of igneous protolith. These two rock types are the result of the regional metamorphism of a pre-existing granitic pluton which, prior to metamorphism, had been intruded by mafic dikes from surrounding volcanic centers active during the mid-Proterozoic Mazatzal Revolution.

The conspicuous, tourmaline-bearing pegmatites in this area are representative of a later Precambrian igneous event, the general effects of which extend for several hundred kilometers to the northwest and southeast of this location. So numerous are the pegmatites in this area that Jahns (1952) was prompted to name it the "Arizona Pegmatite Belt". The pegmatites in the Constellation area are relatively narrow, possess a northeast trend, and are quite linear in occurrence.

The rhyolite and dikes of diabasic material are the vestiges of the Tertiary volcanism which was so abundant in the Southwest. The rhyolite, which post-dates the diabasic dikes,
appears to emanate from a source within the mapped area itself, specifically Slim Jim Wash. The diabasic dikes are comparable in appearance, trend, and crosscutting relationships to other "microdiorite" dikes in western Arizona (Reynolds, 1982). They were apparently intruded along a zone of parallel, northwest-trending faults and are the product of a region-wide volcanic event.

Epithermal-type quartz veins are the most recent geologic feature in this area. Emplaced along the same fault planes as the diabasic dikes, a majority of these veins incorporate brecciated fragments of these dikes along the vein selvages. Copper, gold, and some silver mineralization is found in these veins, the highest values generally occurring in those veins with the greatest dike involvement.

The Monte Cristo vein and fault zone, the original source of interest of this study, falls unclearly into the geologic picture of this area. To begin with, the vein is difficult to trace - the trend of the vein as indicated on Figure 3 (in pocket) is only approximate. The appearance, gangue mineralogy, and measured trend are quite different from those of the other veins in this area, and no trace of the reported cobalt and nickel arsenides was detected from surface sampling. Crosscutting relationships, or more appropriately a lack thereof, suggest that the vein predates the Tertiary volcanism, and possibly also the pegmatite-emplacement episode. The apparent lack of correlation
between the Ag-Co-Ni mineralization and the diabasic dikes in the area by analogy does not support a presumed relationship between the Nipissing Diabase and the ore minerals of the Cobalt District, Ontario. General comparison of the Constellation area with the Erzgebirge District, German Democratic Republic, yields significant similarities in metamorphic country rock, ore mineralogy, and ore petrography, but no mafic igneous-rock association. In the Erzgebirge District, field associations point clearly to a genetic association of the ores with granitic intrusives (Bastin, 1939). Such intrusives are present in the Constellation area, but any genetic association remains unclear. The author believes that many of these questions could be answered were the underground workings of the mine accessible to inspection.
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FIGURE 3. SURFACE GEOLOGY MAP OF THE CONSTELLATION AREA, BLACK ROCK MINING DISTRICT, YAVAPAI COUNTY, ARIZONA.
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