Geology and mineralization of the Kingston mining district, New Mexico

Peter A. Sanders and Thomas H. Giordano

1986, pp. 287-292. https://doi.org/10.56577/FFC-37.287

in:

Truth or Consequences Region, Clemons, R. E.; King, W. E.; Mack, G. H.; Zidek, J.; [eds.], New Mexico Geological Society 37th Annual Fall Field Conference Guidebook, 317 p. https://doi.org/10.56577/FFC-37

This page is intentionally left blank to maintain order of facing pages.

GEOLOGY AND MINERALIZATION OF THE KINGSTON MINING DISTRICT, NEW MEXICO

PETER A. SANDERS and THOMAS H. GIORDANO
New Mexico State University, Las Cruces, NM 88003

Abstract—The Kingston district, mined in the past for Ag, Zn, Pb, Cu, and Mn, is located in Sierra County, on the east flank of the southern Black Range. Mapping on a scale of 1:24,000 has revealed a complete stratigraphic section from Precambrian to Permian. These rocks are the dominant units exposed within the district. Other major exposures include Tertiary volcanic rocks which overlie the Permian and older rocks, and Tertiary rhyolite and andesite intrusives which invade all rock units stratigraphically below the lower Oligocene Kneeling Nun Tuff. Major structural features within the Kingston mining district demonstrate that the district is situated on the eastern structural margin of the Emory cauldron. Base- and precious-metal mineralization is typically hosted by lower Paleozoic carbonate rocks and appears to be controlled on a district scale by two major structural-margin faults of the Emory cauldron. Mineralization in the district occurs as vein and replacement deposits, with the strongest mineralization occurring in proximity to quartz fissure or shear zones composed of brecciated and silicified carbonate rocks. There appears to be a general district-wide zonation; to the south and west deposits are rich in copper, while to the north and east manganese-mineral assemblages predominate. Primary ore and gangue mineralogy throughout the district is simple, with pyrite, sphalerite, chalcopyrite, galena, and acanthite being the dominant sulfides and quartz, calcite, and rhodochrosite being the dominant non-sulfide gangue minerals. Geologic and petrologic data suggest that mineralization was post-cauldron or, at the earliest, contemporaneous with cauldron development, and that movement of fluids and localization of the ore were controlled by the structural-margin fracture system of the Emory cauldron.

INTRODUCTION

The Kingston mining district is in Sierra County, approximately 80 km east of Silver City and 15 km west of Hillsboro, on the east flank of the southern Black Range (Fig. 1). The study area as outlined in Fig. 1 includes nearly the entire Kingston mining district. The first claims in the district were established in 1880. Jones (1904) reported production for the period from 1880 to 1904 to be 6 million oz of silver, most of which was produced prior to the collapse of the silver market in 1893. This production made the Kingston district the largest silver producer in New Mexico for that period. From 1904 until 1957 an estimated 126,000 oz of silver were produced, as well as more than 500,000 lbs each of lead and zinc, and 100,000 lbs of copper (Harley 1934, Howard 1967). Manganese ore was shipped from 15 mines from 1943 to 1958. A total of 5,536 tons of ore at an average grade of 34.5% Mn was produced (Farnham 1961). Since 1958 only minor production of lead, zinc, copper, manganese, and silver has occurred.

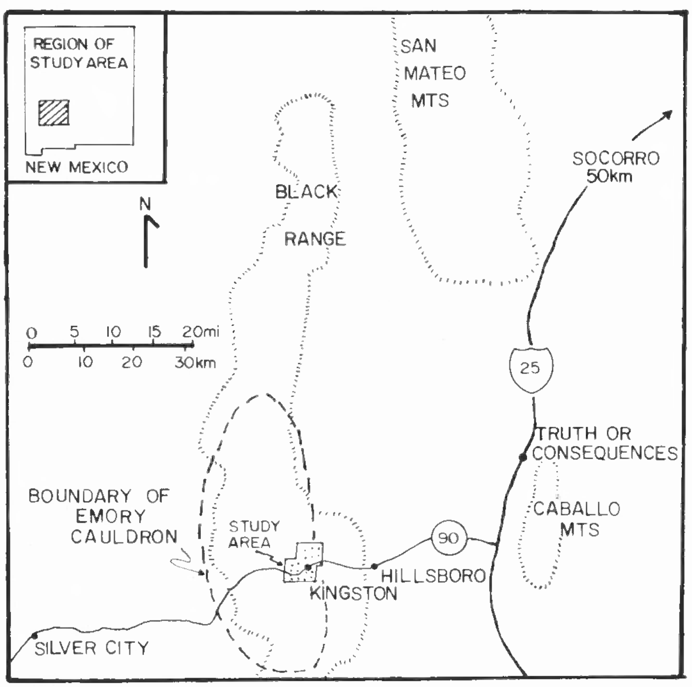

FIGURE 1—Location map of study area including the Kingston mining district in southwestern New Mexico. Modified from Elston et al. (1976).

The level of past mining activity along with the rich mining histories of many other districts on the east flank of the Black Range suggest that potential for discovery of economic mineralization still exists within the Kingston district. Despite this potential, little work has been carried out on the structural controls for mineralization and even less is known about the geochemistry of the base- and precious-metal deposits. In this paper four aspects of the Kingston mining district are considered. First, the geology—in terms of stratigraphy, structural setting, and regional geology—is discussed. This is followed by a discussion of the relationship between structural and stratigraphic controls for mineralization and the structure of the Emory cauldron. Next, primary mineralization and district zoning are evaluated. Lastly, the timing of mineralization is discussed.

PREVIOUS WORK

Discussions of the Kingston ore deposits have been given by many authors (Jones 1904, Lindgren et al. 1910, Harley 1934, Hill 1946, Farnham 1961, Thompson 1965, Howard 1967, Erickson et al. 1970, Hedlund 1977a, Eveleth & North 1980, Canby & Evatt 1985). Most of the descriptive information gathered on the district prior to 1934 was obtained as part of regional reconnaissance surveys of the geology and mineral deposits in the western United States. The studies published after 1934, with the notable exception of Canby & Evatt (1985), are basically a recapitulation of the earlier reports. Kuellmer (1954) mapped across the Black Range along NM-180 (now NM-90). He noted an extremely thick rhyolite-tuff sequence (Kneeling Nun Tuff) and related intrusive rocks. On the west side of the range he noted a "xenolith zone" and suggested that this was a vent agglomerate zone from which the Kneeling Nun Tuff was extruded. Aeromagnetic work done in the early 1970's defined an elliptical occurrence of magnetic lows in the region of the southern Black Range. This magnetic signature was subsequently interpreted as the definition of the wall of a major resurgent cauldron (Erickson et al. 1970, Erickson & Wedow 1976, Hedlund et al. 1979). Petrologic, structural, and geophysical data presented by Elston et al. (1975) and Seager et al. (1978) provided substantial evidence for a resurgent cauldron in the southern Black Range, which they named the Emory cauldron. Subsequent mapping by Seager et al. (1982)

and Hedlund (1977b) further defined the southern portion of the Emory cauldron.

REGIONAL GEOLOGY

The Black Range lies along a transitional boundary between the Datil–Mogollon volcanic field to the west and the Rio Grande rift, part of the Basin and Range province, to the south and east (Fig. 1). The Emory cauldron, which is located in the southern portion of the Black Range, is elliptical, approximately 55 km long and 25 km wide, with its long axis trending parallel to the axis of the Black Range. The eastern structural margin of the cauldron passes just east of Kingston, within the study area. Throughout much of the Tertiary the region was characterized by episodic volcanism (Elston & Bornhorst 1979, Seager et al. 1984). In late Eocene to early Oligocene andesitic to latitic volcanism occurred, and by middle Oligocene large calc-alkaline cauldrons such as the Emory cauldron formed. By latest Oligocene high-silica cauldrons were forming in the Datil–Mogollon volcanic field to the west, while to the east bimodal volcanic sequences of basaltic andesites and rhyolites were erupting.

STRATIGRAPHY

Although the study area has been highly faulted, mapping on a scale of 1:24,000 (Sanders in preparation) has revealed a complete stratigraphic section from Precambrian to Permian rocks. Mesozoic rocks have been completely eroded, while upper Eocene to upper Oligocene volcanic and intrusive rocks represent the Tertiary. Precambrian through Permian rocks are the dominant units exposed within the Kingston district as shown on the generalized geologic map (Fig. 2). Other major exposures include Tertiary volcanic rocks which overlie the Permian and older rocks and Tertiary rhyolite and andesite intrusives which invade all rock units stratigraphically below the Kneeling Nun Tuff (Fig. 3). At many localities the correct stratigraphic position is difficult or impossible to determine because of extreme alteration and deformation. This is particularly true for the lower Paleozoic dolomites which tend to become very brecciated, bleached, or silicified near intrusions and major fault zones.

Precambrian basement

Several distinct Precambrian units are exposed in the Kingston mining district. A small outcrop of Precambrian rock located about 0.75 km northeast of Kingston contains both metagraywacke and granite. The metagraywacke appears similar to those described by Kuellmer (1954) in the south Percha Creek area. Field evidence suggests that the granite intruded the metagraywacke, a relationship noted by Erickson et al. (1970) for similar rocks northwest of the study area. The major Precambrian exposures in the Kingston mining district occur north of this small outcrop and are composed of granite, with U–Pb on zircon ages of 1,600 ± 100 my (Stacey & Hedlund 1983), and minor metadiabase dikes up to 6 m wide.

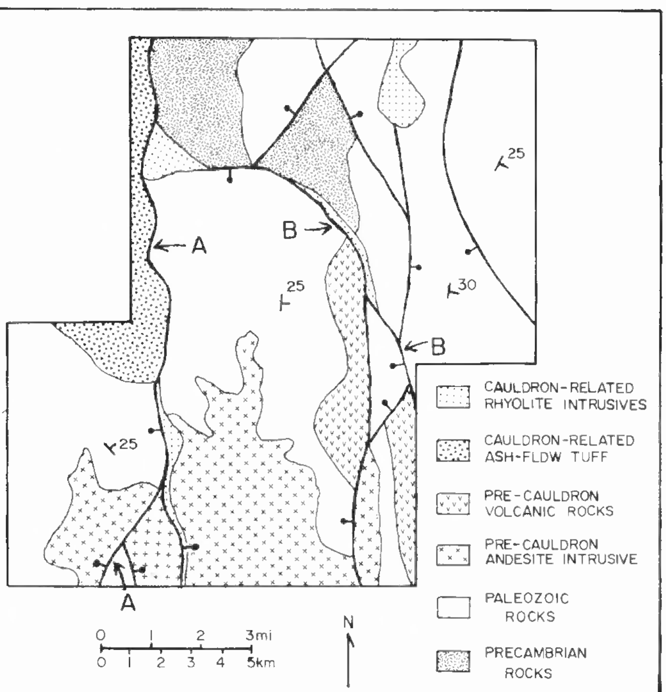

FIGURE 2—Generalized geologic map of the Kingston mining district. Modified from Sanders (in preparation).

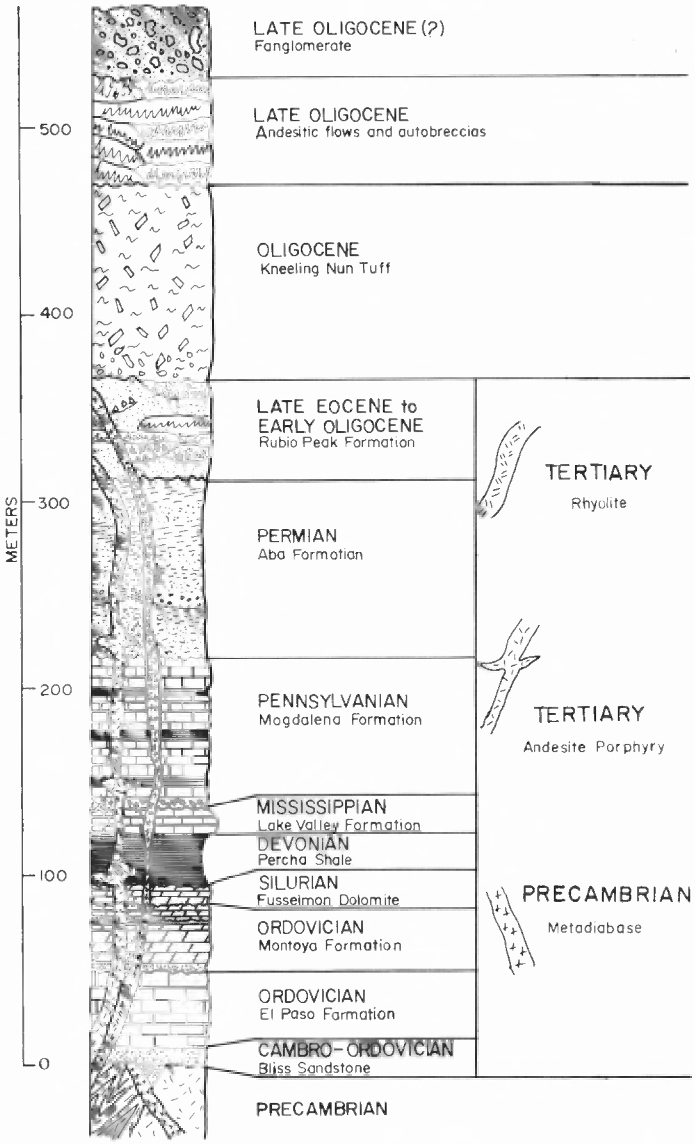

FIGURE 3—Generalized stratigraphic column for Kingston mining district.

Sedimentary rocks

Cambro-Ordovician

The Bliss Sandstone unconformably overlies the Precambrian granites and metamorphic rocks in the area. It consists of a lower orthoquartzite approximately 3–6 m thick, overlain by 18–23 m of ferruginous sandstones, siltstones, and shales. The high iron content in the Bliss gives it a distinct dark-brown to purplish-black appearance in outcrop. In the study area, the Bliss Sandstone is exposed in the western portion of Pickett Springs Canyon and the western portions of Sawpit and Carbonate Canyons. It generally forms a prominent dark sandstone ledge. The upper contact of the Bliss is gradational with the overlying El Paso Formation.

Ordovician

In the Kingston area, the El Paso Formation is limestone 85–91 m thick (Kuellmer 1954). It is distinctively thin- to medium-bedded, with abundant light-brown, thin, way silt laminae parallel to bedding. On weathered surfaces the limestone appears gray to bluish gray and fresh surfaces are generally black to dark gray. It is generally fine-grained and locally contains sparse gastropod-shell fragments. Outcrops of El Paso occur at the same locations as the Bliss Sandstone and along the Middle Percha Creek approximately 1.6 km due west of Kingston and in Ladrone Gulch, approximately 0.8 km northwest of Kingston.

The Montoya Formation disconformably overlies the El Paso Formation. Four distinct members (Cable Canyon Sandstone, Upham Dolomite, Aleman Member, and Cutter Dolomite) crop out at various locations in the study area. The Cable Canyon Sandstone is the basal unit and is massive-bedded, friable to well indurated and typically dolomite-cemented, although it may be locally cemented by silica. While it is plain white on fresh surfaces, it weathers dull light gray. It forms a distinctly lighter-colored slope between the darker Upham Dolomite above and El Paso Formation below. The Upham Dolomite is a massive-bedded, microcrystalline to coarsely crystalline dolomite. Weathered surfaces appear medium to dark gray, while fresh surfaces are generally lighter, medium gray. In some cases the Upham Dolomite appears very brecciated and veined by white calcite. The Upham Dolomite is generally a ledge-former approximately 23 m thick.

The Aleman Member, the most distinctive unit of the Montoya Formation, is approximately 30 m thick and generally forms a steep ridge. It is composed of thin, interbedded, medium-gray to dark-gray dolomite and medium-gray to black chert ribbons, which give the outcrops a distinctive banded appearance. The lower contact is gradational with the underlying Upham Dolomite. Near the top of the member, chert ribbons are disrupted and chert occurs as random, large, thin, breccia blocks in a dolomite matrix. Since this feature is only at the top of the member, it suggests at least a short hiatus before deposition of the overlying Cutter Dolomite. The Cutter Dolomite weathers light gray, light tan gray, or light yellowish gray and is slightly darker on fresh surfaces. It is generally fine-grained, with some beds having thin parallel laminations. Silicified brachiopods and colonial corals are present and vary in abundance from outcrop to outcrop. The Cutter Dolomite forms a steep slope with occasional ledges.

Silurian

Although the unconformity between the Cutter Dolomite and the Silurian Fusselman Dolomite is sharp in the Kingston area, distinguishing between the two requires patience and experience. The Fusselman Dolomite, no more than 18–26 m thick, is generally thick- to massive-bedded, but may have some thin-bedded strata. These thin-bedded strata weather medium to light gray and are distinguished from the Cutter Dolomite by: (1) lack of fossils, (2) more bluish gray color (the Cutter is more tan to yellowish gray), (3) tendency toward being vuggy, and (4) being situated between darker, thick- to massive-bedded dolomites above and below. In the Kingston area, the uppermost meter of the Fusselman Dolomite has been widely brecciated and silicified. This aspect of the Fusselman is most likely related to hydrothermal activity and will be discussed later in the context of hydrothermal mineralization.

Devonian

Unconformably overlying the Fusselman Dolomite is the Percha Shale, a grayish shale approximately 43 m thick. As the most incompetent formation in the Kingston area, it has been extremely deformed by faulting and is typically intruded by upper Eocene andesite-porphyry sills and dikes. It generally forms steep slopes covered by fine flakes.

Mississippian

In the Kingston area the Mississippian System is represented only by the Lake Valley Formation, which is divided into four members. The basal, Andrecito Member, lies unconformably on Percha Shale and is composed of fossiliferous, brownish-gray micrite. It is typically poorly exposed and is a slope-former below the cliff-forming Alamogordo Member. The lower contact is generally covered, but based on occurrence of float the Andrecito appears to be only 3–5 m thick. Overlying the Andrecito is the Alamogordo Member, a distinct dark-gray, microcrystalline, cliff-forming limestone approximately 9 m thick. It is unfossiliferous, with gray to black chert nodules. The Nunn Member conformably overlies the Alamogordo and is a tan-gray, fossiliferous micrite approximately 9–12 m thick. It generally forms a short slope between the two cliff-forming limestones above and below it. Above the Nunn is the Tierra Blanca Member, a massive-bedded, light-gray, medium- to coarsely crystalline limestone that forms prominent cliffs and varies in thickness from 0 to 23 m. This member contains abundant lenses of white chert as well as much crinoidal material. In parts of the Kingston district the Tierra Blanca has been removed by a pre-Pennsylvanian erosion event. In other parts of the district the Tierra Blanca displays many paleokarst features resulting from this erosion.

Pennsylvanian

The Pennsylvanian Magdalena Formation, estimated to be in excess of 198 m thick in the Kingston area, unconformably overlies the Lake Valley Formation. It consists of interbedded limestones and shales that typically form slopes with many small ledges. The limestones are highly variable in color, typically being some shade of gray. Some limestone beds are fossiliferous, while others contain chert nodules which range in color from orange and black to light and dark gray. The base of the Magdalena is marked by either a yellowish-brown to greenish shale or a chert breccia. Near the top of the formation are chert-pebble conglomerates. Many of these are laterally discontinuous and some contain abundant oncolites.

Permian

The Permian Abo Formation disconformably overlies the Magdalena Formation and consists predominantly of red shales and mudstones with rare, gray, chert–limestone conglomerate beds. The thickness of the Abo is estimated at 229 m. In the west-central portion of the map area the Abo has been intruded by both andesite and rhyolite dikes and is very altered, typically to a light-tan color.

Igneous rocks

Tertiary volcanic and related volcaniclastic rocks

The Tertiary sequence contains rocks representing three distinct periods of volcanic activity. The earliest of these periods is represented by the Rubio Peak Formation which unconformably overlies either the Abo or Magdalena Formation. In the Kingston area it is andesite to latite in composition and consists of interbedded flows, tuffs, laharic breccias, and related volcaniclastic rocks. Generally the upper part has been eroded, but, where overlain by Kneeling Nun Tuff, it is estimated to be 128 m thick. It is highly altered to an assemblage which includes calcite, sericite, chlorite, hematite, leucoxene, and epidote (Kuellmer 1954). K–Ar ages on hornblende suggest that the Rubio Peak Formation is latest Eocene to earliest Oligocene (36.7 ± 1.4 my, Loring & Loring 1980; 37.3 ± 2.3 my, Marvin & Cole 1978).

The Kneeling Nun Tuff is a compositionally zoned, generally pinkish-brown, crystal-rich ash-flow tuff containing up to 40% phenocrysts. Although the top of the Kneeling Nun has been removed by erosion, an estimated thickness of 259 m still exists in the northwestern portion of the map area. This great thickness suggests it is part of the cauldron facies. Seager et al. (1984) reported an age of 34.2 my recalculated from McDowell (1971).

The last period of Tertiary volcanism is represented by the Ranger Station andesite, an informal map unit of Ilchik (1981). It is a dark-gray to purplish andesite with associated laharic breccia and occurs in the southeast corner of the map area where the only outcrop is approximately 140 m thick. It resembles the Rubio Peak Formation, but typically is lighter gray and may contain small blocks and cobble conglomerates of Kneeling Nun Tuff. Above the Ranger Station andesite is Tertiary fanglomerate consisting of clasts up to cobble size, which were derived predominantly from the Kneeling Nun Tuff. The small outcrop in the map area lacks sedimentary structures and has an estimated thickness of 102 m.

Tertiary intrusive rocks

In the southern part of the map area, a large sill of intermediate composition intrudes the Paleozoic section. It replaces Percha Shale, Lake Valley Formation, and basal section of the Magdalena Formation. Large blocks of the Tierra Blanca Member of the Lake Valley Formation appear to be in correct stratigraphic position, yet are entirely surrounded by the sill. Megascopically, the intrusive is green. It has been extremely propylitized and many phenocrysts have been replaced. This intrusive has been called a quartz-monzonite porphyry by Kuellmer (1954), an andesite porphyry by Seager et al. (1978), and a quartz-latite porphyry by Maggiore (1981). Modal analysis based on petrographic work done by Kuellmer (1954) suggests the rock is of quartz-latite composition. However, in hand specimen it appears more mafic and is here considered an andesite porphyry. In addition to the large sill, andesite porphyry also intrudes Paleozoic rocks and basal section of the Rubio Peak Formation as smaller sills and dikes. The age of the andesite porphyry is uncertain. Fission track dates on zircon yielded an age of 34.0 ± 2.8 my (Maggiore 1981), which is similar to the age of the Kneeling Nun Tuff. However, field relations suggest the andesite-porphyry intrusive is coeval with the Rubio Peak Formation.

Rhyolite occurs as dikes and small plugs along north- to northwest-trending faults related to the cauldron. For the most part, these intrusions can be considered the Mimbres Peak Formation, rhyolites which intruded the moat sequence and along ring fractures of the cauldron. These rhyolite intrusives are usually flow-banded with a procelain-like texture and are typically white to reddish tan. They contain up to 15% phenocrysts of quartz and sanidine and locally have a spherulitic texture. In the study area dikes have been observed to intrude all but the Kneeling Nun Tuff and younger rocks. The Mimbres Peak Formation has been dated at 32.0 ± 1.0 my (Elston et al. 1973).

STRUCTURAL SETTING

The major structural features within the study area demonstrate that the Kingston district is on the eastern structural margin of the Emory cauldron. Two major faults (labeled A and B in Fig. 2) bound the structural margin of the Emory cauldron. In the northwest corner of the study area one main northwest-trending fault bifurcates into two major faults. Where the one main fault occurs, Kneeling Nun Tuff is downdropped against Precambrian granite. South of the bifurcation the westernmost structural-margin fault (fault A) trends in a southerly direction, while the easternmost fault (fault B) trends eastward for approximately 2 km and then bends south–southeastward. The westernmost structural-margin fault has the greatest displacement occurring along its northern extent. Here the Kneeling Nun Tuff is dropped down against Montoya Formation, a stratigraphic separation of some 740 m. Farther south this westernmost structural-margin fault bends slightly southwestward and dies out into a resurgent horst of the cauldron just south of the study area (Seager et al. 1982). Maximum offset along the easternmost structural-margin fault juxtaposes Rubio Peak Formation on the west against Precambrian rocks on the east, some 730 m of stratigraphic separation. The easternmost structural-margin fault extends south–southeasterly out of the study area and is exposed as the structural-margin fault in Tierra Blanca Canyon (Seager et al. 1982).

MINERALIZATION

Structural and stratigraphic controls

On a district scale, mineralization within the Kingston district appears to be controlled by the two major structural-margin faults. Most of the mineralization occurs in an area between these faults or in close proximity to them, as shown by the density of major mining claims in this area (Fig. 4). All major mines in the study area are associated with one or more of these major claims (Harley 1934, Lindgren et al. 1910). Locally, the deposits occur at the intersections of east–northeast-trending fractures with west–northwest-trending fractures which parallel the structural-margin faults. Most of the base- and precious-metal mineralization in the Kingston district is hosted by lower Paleozoic carbonate rocks. Favorable horizons within these units include the Fusselman Dolomite, particularly just below the contact with the overlying Percha Shale, the lower members of the Montoya Formation including the Upham Dolomite and Aleman Member, and possibly the upper part of the El Paso Formation (Hedlund 1977a, Canby & Evatt 1985). The bulk of past production was most likely from the Fusselman Dolomite (Jones 1904, Harley 1934, Hedlund 1977a). In most other mining districts on the flanks of the Emory cauldron mineralization also occurs in the lower Paleozoic carbonate rocks. For example, similar mineralization occurs in the Hermosa district (Shepard 1985), Lake Valley district (Jicha 1954), and Carpenter and Tierra Blanca districts (Harley 1934, Hedlund 1977a). These similarities suggest that regionally the lower Paleozoic carbonate rocks were the favorable units for mineralization.

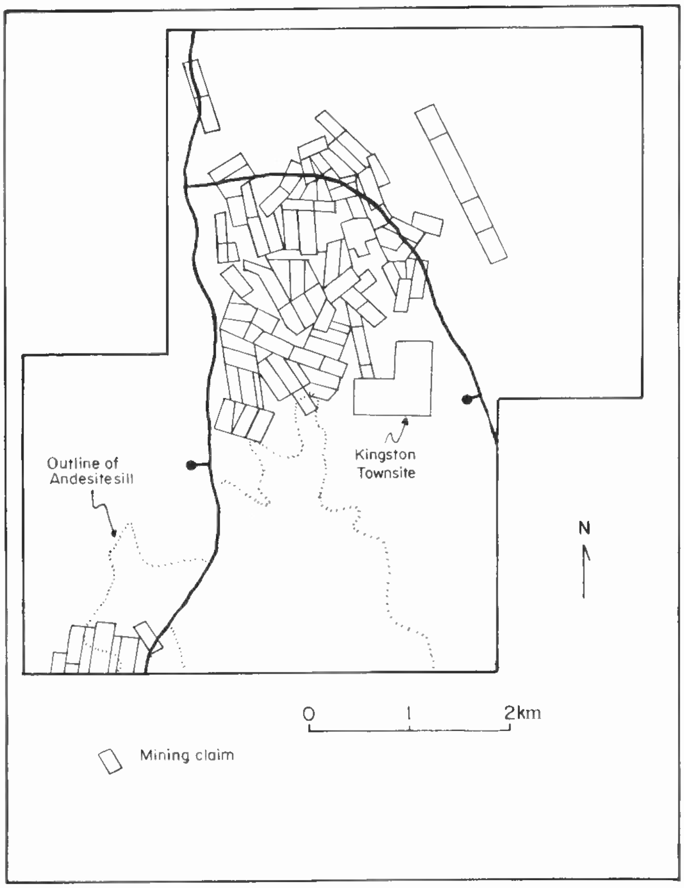

FIGURE 4—Map of major mining claims in Kingston mining district and their spatial relationship to structural margin faults of the Emory cauldron and large Tertiary andesite sill. Locations of mining claims are taken from Harley (1934) and Lindgren et al. (1910).

Mineralization in the district occurs as vein and replacement deposits, typically as blanket-type manto bodies replacing host carbonates, but also as pipe-like bodies at fracture intersections. The strongest mineralization occurs in proximity to quartz fissure or shear zones composed of brecciated and silicified carbonate rocks. Dump samples and the nature of accessible mine workings suggest that early production was most probably from oxidized and secondarily enriched manto deposits. Vein and replacement deposits are best developed along the west–northwest-trending fractures, although they are also developed along the east–northeast-trending fractures. Typically, deposits extend for only short distances, usually no greater than 70–100 m along strike and 10–

70 m in width. Many separate mineralized bodies are located along the same structure.

Silicification

In many sections of the district, particularly near major faults, the upper Fusselman Dolomite, the Upham Dolomite, and the Aleman Member have been silicified or completely altered to jasperoid. In the Carbonate Creek area, the Percha Shale and the Magdalena and Lake Valley Formations are also in part replaced by jasperoid (Canby & Evatt 1985). There is a poor spatial correlation between this silicification, and base- and precious-metal mineralization. Silicification appears to be related to an early stage of district-wide hydrothermal activity which occurred prior to base- and precious-metal mineralization (Lovering 1972). Canby & Evatt (1985) report that Kneeling Nun Tuff has been deposited on eroded jasperoid surfaces in the Carbonate Creek area. This suggests a lower age limit of early Oligocene for jasperoid formation.

District zoning and ore mineralogy

Primary mineralization and district zoning of the Kingston mining district were evaluated using available published information on the geology and mineralogy of major mines in the district and information obtained from reconnaissance surveys of inactive mines, prospects, and mine dumps. Within the district there appears to be a general district-wide zonation, as shown in Fig. 5. To the south and west chalcopyrite is common in deposits, while to the north and east manganese-mineral assemblages occur and chalcopyrite is rare or absent. This zoning may reflect an outward gradation of the system from the inner cauldron margin to the outer cauldron margin.

Primary ore and gangue mineralogy throughout the district is simple, with variations reflecting mainly the district zoning and host-rock composition. At the Gray Eagle mine (Fig. 5), dump samples suggest that primary mineralization occurs as quartz veins containing pyrite, sphalerite, chalcopyrite, galena, and acanthite. Secondary chrysocolla and malachite were observed in some of the samples. At the Brush Heap mine all workings were caved, but mineralization is reported to occur in quartz veins, breccias, and as bedded replacement deposits (Eveleth & North 1980). From dump samples it appears that veins from the Brush Heap mine contain pyrite, sphalerite, galena, and chalcopyrite in a quartz–calcite gangue. Cerargyrite has also been reported from the Brush Heap mine (Hedlund 1977a). Gold, polybasite, cinnabar, and realgar have been reported from the Carbonate Creek area (Canby & Evatt 1985). At the Black Colt mine, whose workings were accessible in part to the authors, sphalerite, galena, and pyrite occur in blanket replacement deposits as disseminations in a massive, fine-grained mixture of rhodochrosite and calcite (Sanders & Giordano 1985, Sanders in preparation). In a major fissure vein transecting this blanket deposit, sphalerite, galena, and pyrite occur with quartz, rhodonite, and rare alabandite. Minor chalcopyrite is present, mostly as exsolution blebs in sphalerite.

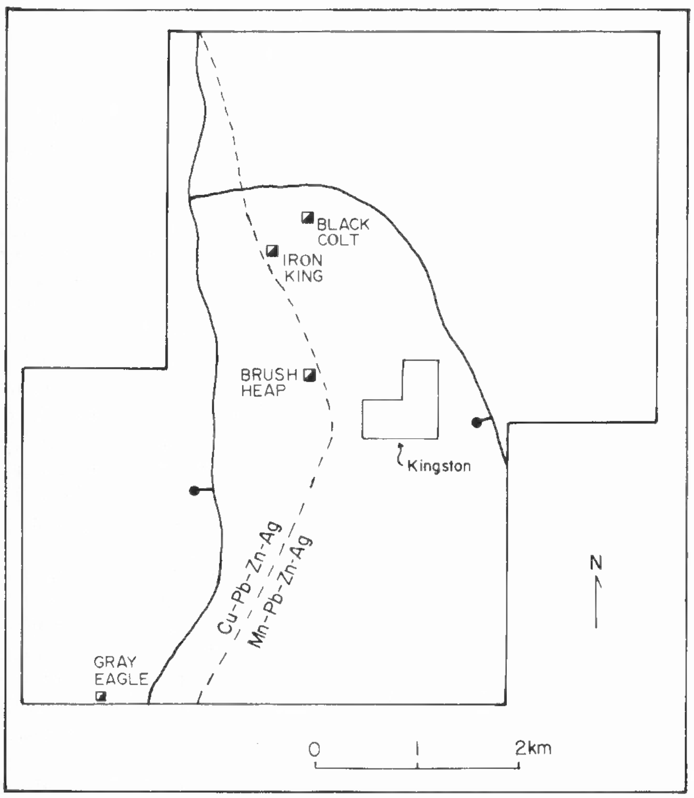

FIGURE 5—Metallic zoning in the Kingston mining district in relation to structural margin faults of the Emory cauldron.

Timing of mineralization

The spatial relationship of the ore deposits in the Kingston mining district to the Emory cauldron has been pointed out by Elston et al. (1976) and Elston (1978). The structural and other geological characteristics of the Kingston mining district outlined in this paper provide additional evidence for this relationship. As shown in Fig. 4, there is a well-defined correlation between areas of most intense base- and precious-metal mineralization and the structural-margin faults of the cauldron. There is at best a poor correlation between mineralized areas and the large andesite-porphyry sill in the south-central part of the district. Prior to 1970 many believed that mineralization in the district was related to this sill. However, cauldron-related faults cut the sill, which has been extensively propylitically altered and in some cases completely silicified along these faults with no base- or precious-metal mineralization present. These features suggest that the andesite-porphyry sill is pre-cauldron in age and is neither temporally nor genetically related to the base- and precious-metal mineralization in the district.

Exploratory drilling (Hill 1946), conducted by the U.S. Bureau of Mines in the early 1940's near the Gray Eagle mine (Fig. 5), indicated that there is minor sulfide mineralization associated with rhyolite intrusives. It is likely that these rhyolites represent ring dikes or other intrusive bodies related to the post-resurgent phase of the Emory cauldron and that they were derived from the same magma source as the Mimbres Peak intrusives. The apparent close temporal relationship between feldspar-rich silicic bodies and cauldron-margin faults suggests that these rhyolites may be genetically related, although not necessarily similar in age, to the ore-forming process responsible for mineralization in the Kingston district. Stacey & Hedlund (1983) reported similarities in lead-isotope ratios for ore leads from the Kingston district and rhyolite-porphyry plugs from the Carpenter district 20 km to the southwest. They suggest that these rhyolite-porphyry intrusions, which are also believed to be related to the post-resurgent phase of the Emory cauldron, may be a surface expression of an unexposed pluton responsible for the base- and precious-metal mineralization in the Kingston and Carpenter districts. These lead-isotope data suggest that lead from rhyolites related to the post-resurgent phase of the Emory cauldron and from mineralization in the Kingston mining district may have a similar source.

The exact timing of mineralization in relation to cauldron development as well as source or sources of ore fluids and constituents cannot be unequivocally established from the data available. Nevertheless, structural and petrologic evidence presented in this paper suggests that mineralization was post-cauldron or, at the earliest, contemporaneous with cauldron development, and that movement of fluids and localization of ore were controlled by the fracture system of the Emory cauldron's structural margin.

ACKNOWLEDGMENTS

The authors wish to thank the New Mexico Bureau of Mines & Mineral Resources, the New Mexico Geological Society, and the Donors of the Clemons Field Scholarship Fund administered by the Department of Earth Sciences, New Mexico State University, for their financial support of this study. We also thank Mr. Floyd Ingram for allowing access to The Black Colt mine and Drs. William R. Seager and Russell E. Clemons for their assistance in certain aspects of this research and for kindly reviewing this manuscript.

REFERENCES

Canby V.M. & Evatt R.L. 1985. Geology, character, and controls of epithermal silver mineralization in the Carbonate Creek area, Kingston, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Circular 199: 25–31.

Elston W.E. 1978. Mid-Tertiary cauldrons and their relationship to mineral resources, southwestern New Mexico: a brief review.—New Mexico Geological Society, Special Publication 7: 107–113.

Elston W.E. & Bornhorst T.J. 1979. The Rio Grande rift in context of regional post-40 my volcanic and tectonic events. *In* Riecker R.E. (ed.), Rio Grande rift: tectonics and magmatism.—American Geophysical Union, Washington, DC, pp. 416–438.

Elston W.E., Seager W.R. & Clemons R.E. 1975. Emory Cauldron, Black Range, New Mexico: source of the Kneeling Nun Tuff.—New Mexico Geological Society, Guidebook 26: 282–292.

Elston W.E., Rhodes R.C. & Erb E.E. 1976. Control of mineralization by mid-Tertiary volcanic centers, southwestern New Mexico.—New Mexico Geological Society, Special Publication 5: 125–130.

Elston W.E., Damon P.E., Coney P.J., Rhodes R.D., Smith E.I. & Bikerman M. 1973. Tertiary volcanic rocks, Mogollon–Datil province, New Mexico and surrounding region: K–Ar dates, patterns of eruption, and periods of mineralization.—Geological Society of America, Bulletin, 84: 2259–2273.

Erickson G.E. & Wedow H. Jr. 1976. Tertiary extrusive sheets and related intrusions in the Black Range, New Mexico.—New Mexico Geological Society, Special Publication 5: 63–67.

Erickson G.E., Wedow H. Jr., Eaton G.P. and Leland G.R. 1970. Mineral resources of the Black Range Primitive Area, Grant, Sierra and Catron Counties, New Mexico.—U.S. Geological Survey, Bulletin 1319-E: 162 pp.

Eveleth R.W. & North R.M. 1980. Reconnaissance report, Brush Heap mine, Kingston mining district, Sierra County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Open-file Report 165: 24 pp.

Farnham L.L. 1961. Manganese deposits of New Mexico.—U.S. Bureau of Mines, Information Circular 8030: 176 pp.

Harley G.T. 1934. The geology and ore deposits of Sierra County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 10: 220 pp.

Hedlund D.C. 1977a. Mineral resources map of Hillsboro and San Lorenzo quadrangles, Sierra and Grant Counties, New Mexico.—U.S. Geological Survey, Miscellaneous Field Studies Map MF-900B, scale 1:48,000.

Hedlund D.C. 1977b. Geologic map of the Hillsboro and San Lorenzo quadrangles, Sierra and Grant Counties, New Mexico.—U.S. Geological Survey, Miscellaneous Field Studies Map MF-900A, scale 1:48,000.

Hedlund D.C., Watts K.C., Alminas H.V. & Wynn J.C. 1979. Background information to accompany folio of geologic, mineral resource, geochemical, aeromagnetic, and gravity maps of the Hillsboro and San Lorenzo quadrangles, Sierra and Grant Counties, New Mexico.—U.S. Geological Survey, Circular 808: 26 pp.

Hill R.S. 1946. Exploration of Gray Eagle, Grandview and Royal John Claims, Grant and Sierra Counties, New Mexico.—U.S. Bureau of Mines, Report of Investigations 3904: 31 pp.

Howard E.V. 1967. Metalliferous occurrences in New Mexico: phase 1, state resources development plan.—New Mexico State Planning Office, Santa Fe, 270 pp.

Ilchik S.E. 1982. Geology of part of the Black Range between Kingston and Hillsboro, Sierra County, New Mexico (M.S. thesis).—New Mexico State University, Las Cruces, 49 pp.

Jicha H.L. 1954. Geology and mineral deposits of Lake Valley quadrangle, Grant, Luna, and Sierra Counties, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 37: 93 pp.

Jones F.A. 1904. New Mexico mines and minerals.—New Mexico Printing Co., Santa Fe, 346 pp.

Kuellmer F.J. 1954. Geologic section of the Black Range at Kingston, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 33: 100 pp.

Lindgren W., Graton L.C. & Gordon C.H. 1910. The ore deposits in New Mexico.—U.S. Geological Survey, Professional Paper 68: 268–270.

Loring A.K. & Loring R.B. 1980. K–Ar ages of middle Tertiary igneous rocks from southern New Mexico.—Isochron/West, no. 28: 17–19.

Lovering T.G. 1972. Jasperoid in the United States—its characteristics, origin, and economic significance.—U.S. Geological Survey, Professional Paper 710: 164 pp.

Maggiore P. 1981. Deformation and metamorphism on the floor of a major ash-flow tuff cauldron: the Emory cauldron Grant and Sierra Counties, New Mexico (M.S. thesis).—University of New Mexico, Albuquerque, 133 pp.

Marvin R.F. & Cole J.C. 1978. Radiometric ages: compilation A, U.S. Geological Survey.—Isochron/West, no. 22: 3–14.

McDowell F.W. 1971. K–Ar ages of igneous rocks from the western United States.—Isochron/West, no. 2: 1–16.

Sanders P.A. (in preparation). Geology and mineralization of the Kingston mining district, New Mexico; with detailed work on the Black Colt mine (M.S. thesis).—New Mexico State University, Las Cruces.

Sanders P.A. & Giordano T.H. 1985. Geology of the Kingston mining district, with detailed work on the Black Colt mine.—New Mexico Bureau of Mines & Mineral Resources, Circular 199: 55.

Seager W.R., Clemons R.E. & Elston W.E. 1978. Second-day road log from intersection of I-25 and NM-90 to Silver City, with side trip to Tierra Blanca Canyon.—New Mexico Geological Society, Special Publication 7: 33–48.

Seager W.R., Clemons R.E., Hawley J.W. & Kelley R.E. 1982. Geology of northwest part of Las Cruces $1° \times 2°$ sheet, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Geologic Map 53, scale 1:125,000.

Seager W.R., Shafiqullah M., Hawley J.W. & Marvin R.F. 1984. New K–Ar dates from basalts and the evolution of the southern Rio Grande rift.—Geological Society of America, Bulletin, 95: 87–99.

Shepard M.D. 1985. Geology and mineralization of the Hermosa mining district, Sierra County, New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Circular 199: 17–24.

Stacey J.S. & Hedlund D.C. 1983. Lead-isotopic composition of diverse igneous rocks and ore deposits from southwestern New Mexico and their implications for early Proterozoic crustal evolution in the western United States.—Geological Society of America, Bulletin, 94: 43–57.

Thompson A.J. 1965. Mineral and water resources of New Mexico.—New Mexico Bureau of Mines & Mineral Resources, Bulletin 87: 437 pp.