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GENERAL GEOLOGY OF CHLORIDE MINING DISTRICT, SIERRA AND CATRON COUNTIES, NEW MEXICO

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Abstract—The Chloride mining district has been an area of intermittent precious- and base-metal mining activity for the past hundred years. Metal values in excess of $18,000,000 have been produced from the district. Tertiary volcanic and volcaniclastic rocks of the Mogollon–Datil volcanic field host epithermal vein-type deposits. The oldest Tertiary unit in the Chloride district is the Rubio Peak Formation. Rubio Peak overlies Paleozoic rocks with angular unconformity and is divisible into a lower, sediment-dominated sequence overlain by a volcanic-dominated sequence. Very large exotic blocks of Paleozoic rocks occur as landslide deposits within the lower Rubio Peak Formation. Overlying Rubio Peak are Kneeling Nun Tuff, sandstone of Monument Park–Caballo Blanco Tuff–tuff of Koko Well, basaltic andesite of Poverty Creek, tuff of Little Mineral Creek–tuff of Stiver Canyon, and Moccasin John Rhyolite. Strike–slip faulting along north–northeast trends cut only Rubio Peak and older rocks. High-angle normal faults along north, northwest, north–northeast to northeast and east trends cut the entire stratigraphic section. Epithermal vein deposits occupy all fault trends. Vein deposits consist of quartz, calcite, (fluorite, barite) gangue material with sulfide mineralization occurring in structurally controlled shoots. Sulfide mineralization occurred in two stages in the southern portion of the district; an older stage of Pb, Zn, Cu, (Ag) mineralization, followed by stage of Cu, Ag mineralization. A single stage of Ag, Au, (Cu) mineralization occurred in the northern part of the district. Vein mineralization is spatially and temporally related to emplacement of Moccasin John-type intrusives.

INTRODUCTION

The Chloride mining district (previously Apache, Phillipsburg, and Black Range districts) is located along the eastern flank of north-central Black Range, Sierra County, New Mexico (Fig. 1). Precious- and base-metal epithermal mineralization occurs within fissure-filling vein systems hosted by volcanic and volcaniclastic rocks of the mid-Tertiary Mogollon–Datil volcanic field. The mining district lies almost exclusively within the Gila National Forest, bordering upon the Gila Wilderness Area. Terrain is rugged and, although NM-59 traverses the northern part of the district, access is limited to four-wheel drive and foot travel through much of the remainder of the mining district.

Approximate production from the district for the period 1880–1932 is estimated at $1,000,000 in gold and silver (minor copper, lead, and zinc) (Harley 1934). During the period 1932–1982, only small amounts of direct shipping ore were produced from the district, with no available production estimates. In 1982–1985, St. Cloud, U.S. Treasury, Great Republic, and Minnehaha mines produced just over two million ounces of silver, nine thousand ounces of gold, and three thousand tons of copper, in addition to several thousand tons each of lead and zinc. The bulk of this production was from the St. Cloud and U.S. Treasury mines.

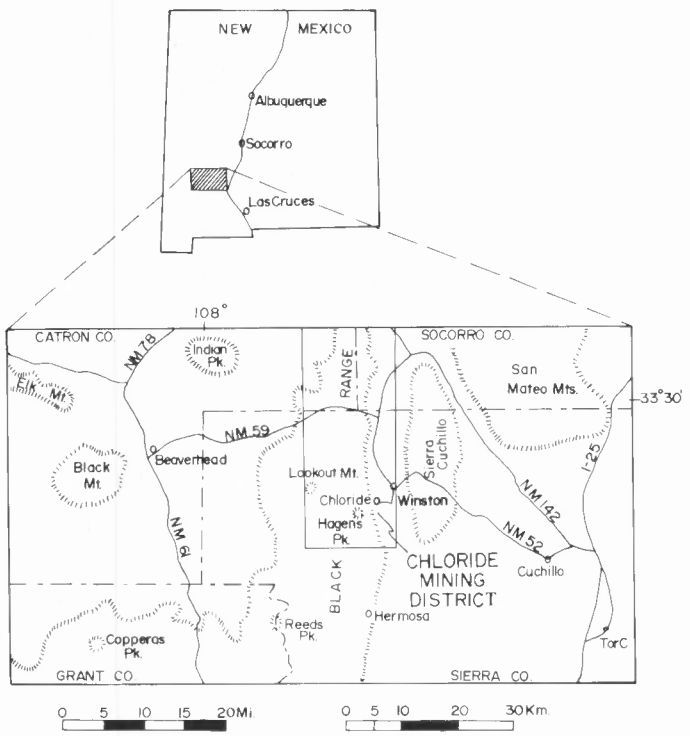


FIGURE 1—Location map of Chloride mining district.

PREVIOUS WORKS

Silliman (1882) visited the mining district during its boom days of the 1880's and early 90's. He was impressed by the greater than 13 km length of the Great Master Lode and its high-grade black streaks that assayed 50–60 oz/ton gold and over 200 oz/ton silver.

Gordon (Lindgren et al. 1910) later visited the region and briefly described the history, geology, and mineral deposits. He described the general stratigraphy and structure of the district and included a sketch map showing unsurveyed claim locations in relation to major drainages and prominent landmarks. Two vein systems recognized by Gordon are Au, Ag, (Cu) mineralization along north–south trends and Ag, Cu mineralization along east–west trends.

The most extensive report on geology and past mining activity to date for the Chloride mining district was published by Harley (1934). He presented geologic descriptions of many mines in the district that are presently inaccessible. He also re-emphasized the north–south and east–west vein systems recognized by Gordon in Lindgren et al. (1910).

The preliminary geologic map of the Winston quadrangle by Maxwell & Heyl (1976) shows epithermal-vein systems in the southwestern portion of the district as well as some of the major allochthonous Paleozoic limestone blocks of the region. They interpreted these exotic blocks to be either of Magdalena Group or of San Andres Limestone and to have been emplaced by gravity-sliding mechanisms. Maxwell & Heyl (1980) described the mineralization and structure of deposits in the Hermosa, Chloride, and Phillipsburg mining areas, the latter two of which are incorporated into the Chloride mining district in this report. They also recognized two vein categories in the Chloride (Phillipsburg) area: (1) an older series of northwest-trending en echelon fault zones with fissure veins containing Cu, Pb, Zn, Ag, Au mineralization; and (2) north–northeast-trending veins with quartz, calcite, and fluorite mineralization "cut by thin dark-gray to black reticulate seams containing Au, Ag and minor Cu."

Larsen (1975), Winston (1975), Woodard (1982), and Abitz (1984) completed M.S. theses on geology and geochemistry of volcanic rocks in and around the Chloride district. Freeman & Harrison (1984) briefly described the regional geology and some of the recent mining activity within the district.

TERTIARY STRATIGRAPHY

A composite stratigraphic section for Tertiary rocks of the Chloride district is shown in Fig. 2. The section consists almost entirely of volcanic and volcaniclastic rocks that accumulated in a continental-basin environment from mid-Eocene(?) into Miocene time. Local intermediate and silicic flow–dome complexes and dikes intruded the section and, in part, contributed to its aggregation.

Rubio Peak Formation

The oldest Tertiary unit in the Chloride district is the Rubio Peak Formation of Jicha (1954). As used by Elston et al. (1975), this formation consists of the intermediate volcanic and volcaniclastic sequence that occurs between the lowermost Tertiary unconformity and the unconformity at the base of the Kneeling Nun Tuff. Thickness of the Rubio Peak Formation in the Chloride district varies from 800 to 900 m. Reported radiometric dates for Rubio Peak Formation are 44.7 ± 1.9 my, 38.0 ± 1.5 my, 37.6 ± 2.0 my, 37.3 ± 2.3 my, 36.7 ± 2.3 my, and 32.6 ± 2.1 my (Seager et al. 1982). Within the Chloride district, the Rubio Peak Formation is divisible into a lower section of dominantly proximal alluvial-fan deposits overlain by an upper section of dominantly intermediate lava flows, ash-flow tuffs, and distal alluvial-fan deposits. Early Chadronian vertebrate fossils have been found by Lucas (this guidebook) in sedimentary deposits of the upper Rubio Peak Formation (Turkey Creek, SW¼SE¼ sec. 24, T10S, R9W, and SW¼SW¼ sec. 14, T10S, R9W).

Debris-flow and mud-flow facies volumetrically dominate the lower Rubio Peak Formation; occurring as massive, poorly to non-bedded, matrix-supported deposits containing subrounded, heterolithic clasts of aphanitic and porphyritic, intermediate volcanic rocks. Clasts range from cobbles to large boulders, with individual horizons containing abundant clasts of Paleozoic limestone up to about 10 m in thickness. Interbedded with debris-flow and mud-flow deposits are thick, horizontally bedded, poorly to moderately sorted sandstones. These deposits generally lack cross-stratification and other fluvial sedimentary features and are perhaps the product of hyperconcentrated flood flows as described by Smith (1986).

Poorly sorted, clast-supported, boulder to cobble conglomerates with minor sandstones commonly occur at the base of the Rubio Peak Formation. These deposits contain clasts of Permian Abo Formation, holocrystalline monzonitic rocks, various intermediate volcanic rocks, and Paleozoic limestone. Basal conglomerates grade upward into debris-flow and mud-flow deposits.

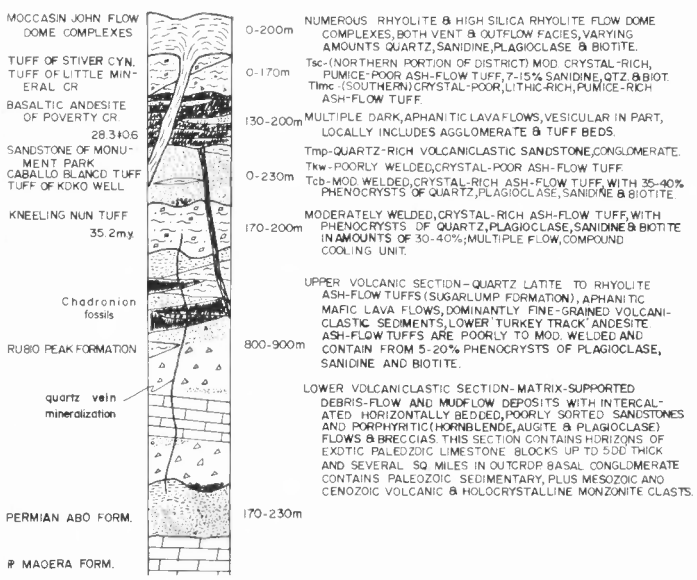


FIGURE 2—Composite Tertiary stratigraphic column for Chloride mining district.

Exotic blocks of Pennsylvanian Madera Limestone, up to 170 m thick and several square kilometers in outcrop, rest upon both debris-flow and sandstone facies of the lower Rubio Peak Formation. The lower contact of the limestone blocks is locally brecciated and commonly contains abundant gouge material. Clastic dikes and thin clastic sills commonly cut lower portions of exotic blocks. Northeast- and north-trending synclinal and anticlinal folds in the limestone blocks are possibly indicative of transport directions.

Upper Rubio Peak rocks consist of porphyritic and aphanitic intermediate lava flows and rhyolite to quartz-latite ash-flow tuffs with intercalated volcaniclastic intervals. Intermediate flow rocks contain varying amounts of plagioclase (An_{30-50}), clinopyroxene, and hornblende and in outcrops exhibit generally massive cores with commonly autobrecciated tops and bases. Source areas were probably local flow–dome complexes that remain unidentified.

In the Chloride district, three ash-flow-tuff sheets are found in the upper Rubio Peak Formation. These tuffs are time-stratigraphic equivalents of the Sugarlump Tuff of Jicha (1954) and Jones et al. (1967), Sugarlump Latite and Rhyolite of Elston (1957), and Sugarlump Formation of Seager et al. (1982). R.E. Clemons reported a K–Ar date on a basal member of the Sugarlump Formation in City of Rocks State Park of 36.9 ± 1.5 my (Elston 1976).

In the Chloride area, the oldest of the three Sugarlump Tuffs is a moderately welded, pumice-rich, lithic-rich, crystal-poor ash-flow tuff. Bluish-green alteration of pumice is common in this tuff. The middle tuff is a poorly welded, crystal-poor, pumice-rich ash-flow tuff with 5–10% phenocrysts of plagioclase and minor biotite. This tuff is highly susceptible to silicic alteration and at several altered localities pyrite dissemination with varying anomalous amounts of Au and Ag mineralization are found.

The upper Sugarlump Tuff is herein informally referred to as tuff of Wildhorse Canyon for exposures in the center of sec. 32, T9S, R9W along Wildhorse Canyon. At that locality, the tuff is sandwiched between two dark aphanitic basaltic andesite flows directly beneath Kneeling Nun Tuff. Tuff of Wildhorse Canyon is a moderately to poorly welded, moderately crystal-rich ash-flow tuff. Phenocrysts constitute 10–25% of the rock with subequal amounts of plagioclase and sanidine, and 1–2% biotite.

The upper contact of the Rubio Peak Formation with overlying Kneeling Nun Tuff is an unconformity commonly marked by a thin volcaniclastic interval called the sandstone of Cliff Canyon by Woodard (1982). This unit consists of fine-grained, well-sorted, thin- to medium-bedded sandstones and shales, with a local basal conglomerate containing andesitic clasts.

Kneeling Nun Tuff

Throughout the Chloride mining district, outflow facies of Kneeling Nun Tuff overlies Rubio Peak Formation. Kneeling Nun Tuff was named by Jicha (1954) and Kuellmer (1954) in the southern Black Range and was extended into the northern Black Range by Erickson et al. (1970). The source area for Kneeling Nun Tuff is the Emory cauldron (Elston et al. 1975), the northern margin of which is within 13 km (southwest) of the Chloride district. From the margin of the Emory cauldron, a continuous outflow sheet of Kneeling Nun Tuff can be traced northward through the entire 32 km length of the mining district. Kneeling Nun Tuff was miscorrelated to Hells Mesa Tuff in the Poverty Creek area by Coney (1976) and in the Lookout Mountain area by Woodard (1982).

A radiometric date of 34.2 my (recalculated using new IUGS constants) was reported for the Kneeling Nun Tuff by McDowell (1971). McIntosh et al. (this guidebook) report a slightly older $^{40}Ar/^{39}Ar$ age, 35.2 my, from outcrops along Poverty Creek in the northern part of the Chloride district.

Kneeling Nun Tuff is a multiple-flow, compound-cooling unit of poorly to moderately welded, crystal-rich, ash-flow tuff. As much as 45% phenocrysts of quartz, sanidine, plagioclase, and biotite occur within the tuff; it is normally zoned from a quartz-rich, biotite-poor

basal member to a quartz-poor, more biotite-rich upper member. Total thickness throughout the mining district is consistently 170–200 m.

Sandstone of Monument Park–Caballo Blanco Tuff–tuff of Koko Well

In the north-central Black Range various units directly overlie Kneeling Nun Tuff. The most common of them is the regionally extensive basaltic andesite of Poverty Creek. The name sandstone of Monument Park was proposed by Woodard (1982) for volcaniclastic and pyroclastic rocks that locally occur between Kneeling Nun Tuff and basaltic andesite of Poverty Creek. Included within this stratigraphic interval in the Chloride district are fine-grained sandstones and siltstones, minor conglomerates, Caballo Blanco Tuff, and tuff of Koko Well. All members are relatively conformable with Kneeling Nun Tuff and appear to represent deposition in shallow, broad depressions on a plateau of Kneeling Nun Tuff.

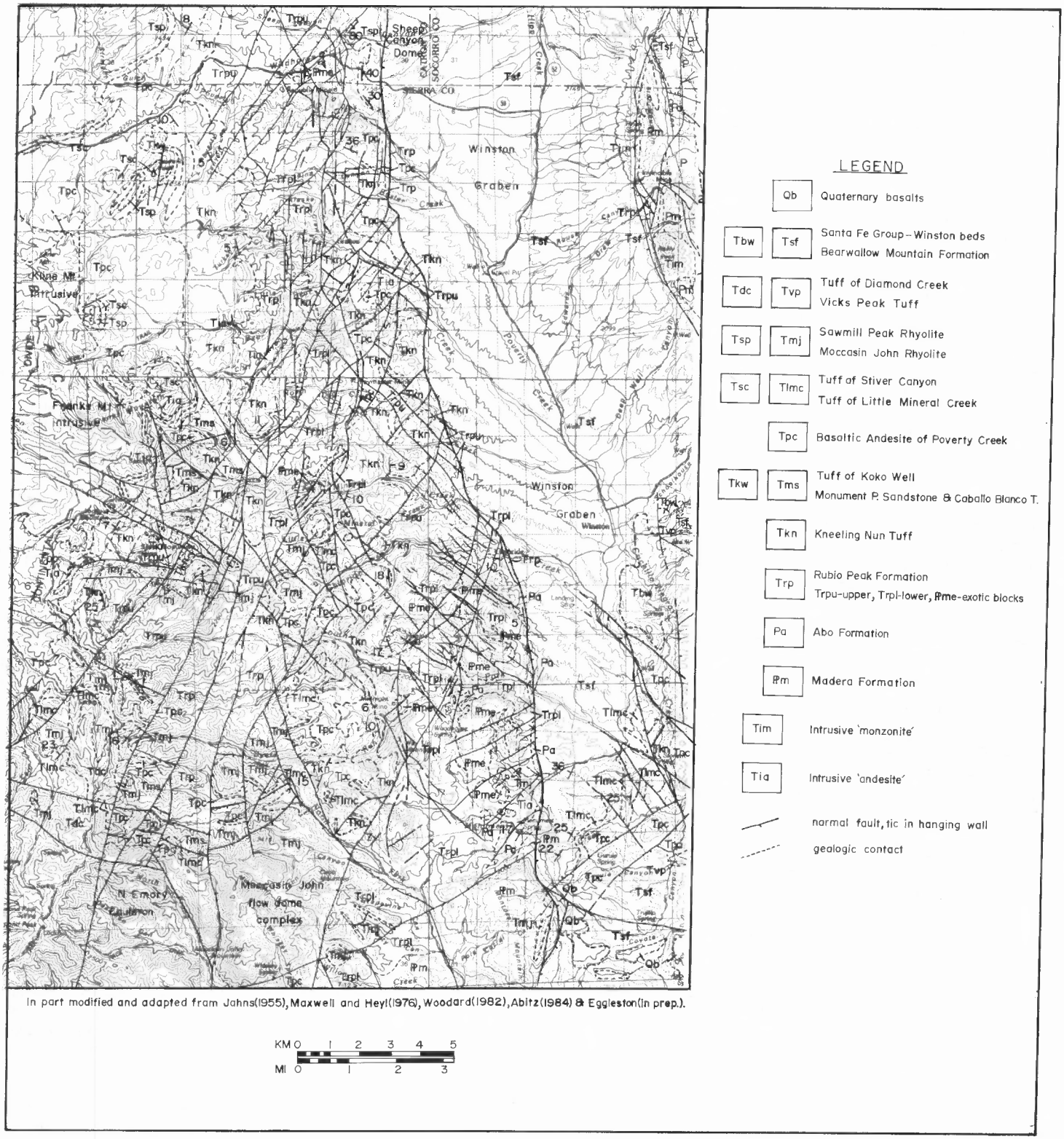


FIGURE 3—Generalized geologic map of the Chloride mining district.

Volcaniclastic rocks in this stratigraphic interval occur largely in the western portion of the district, pinching out to the north and east. Sandstone and siltstone layers contain rounded to subrounded grains of quartz, sanidine, plagioclase, and minor biotite. Conglomerates contain clasts of Kneeling Nun Tuff.

Interbedded within these volcaniclastic rocks is Caballo Blanco Tuff of Elston (1957), a moderately welded, crystal-rich ash-flow tuff with 35–40% phenocrysts of quartz, sanidine, plagioclase, and biotite. This unit occurs in small, meager outcrops along the southwestern margin of the mining district. It was first identified in the Chloride area by Abitz (1984) and has a radiometric age of 29.8 ± 0.8 my (Elston 1976).

In the northern part of the Chloride district, around the base of Sawmill Peak, a poorly welded, crystal-poor, pumice-rich ash-flow tuff occurs between Kneeling Nun Tuff and basaltic andesite of Poverty Creek. An informal name of tuff of Koko Well is proposed by Eggleston (in preparation) for this tuff from exposures in SW1/4 sec. 6, R10W, T10S at Koko Well, along NM-59. Stratigraphic relationships between tuff of Koko Well and Caballo Blanco Tuff are presently unknown.

Basaltic andesite of Poverty Creek

Elston et al. (1973) gave the name basaltic andesite of Poverty Creek to the formation exposed in SW1/4 sec. 6, T10S, R10W, along the northwestern margin of the Chloride mining district. Stratigraphic correlation of Poverty Creek to Bear Springs Basalt of Jicha (1954) and Elston (1957) was made by Elston (1976). A K–Ar age of 28.3 ± 0.6 my is given by Woodard (1982) for basaltic andesite of Poverty Creek in the Chloride district. This formation is also believed to be stratigraphically equivalent to andesite of Mimbres River and andesite of Hermosa area of Ericksen et al. (1970), and to T4ba unit of Seager et al. (1982) in the southern Black Range. A 28.1 ± 0.6 my radiometric date is given for the T4ba unit by Seager et al. (1982).

In the Chloride area, basaltic andesite of Poverty Creek is a complex unit containing multiple, dark, aphanitic lava flows, interbedded volcaniclastic sedimentary rocks, and red, scoriaceous intervals. Sparse phenocrysts of augite, biotite, and quartz are found in the fine-grained flows. Thickness of this unit is 130–200 m. Numerous feeder dikes (and flow–dome complexes?) for the Poverty Creek flows are found in the Chloride district. Feeder dikes most commonly have northeast and north–northeast trends.

Tuff of Little Mineral Creek–tuff of Stiver Canyon

The stratigraphic interval overlying basaltic andesite of Poverty Creek is occupied by two distinct ash-flow tuffs. Tuff of Little Mineral Creek (Woodard 1982) unconformably overlies Poverty Creek in the southeastern portion of the Chloride district and tuff of Stiver Canyon (Woodard 1982, Eggleston & Norman 1983) unconformably overlies Poverty Creek in the northwestern portion of the district. Stiver Canyon is the younger of the two units, as it overlaps Little Mineral Creek in the Lookout Mountain area. The age of this stratigraphic interval is tightly constrained between 28.9 my (upper limit of Poverty Creek date from Woodard 1982) and 28.46 my ($^{40}Ar/^{39}Ar$ age for Vicks Peak Tuff from McIntosh et al. in this guidebook). Vicks Peak Tuff overlies tuff of Little Mineral Creek just outside the Chloride district.

Tuff of Little Mineral Creek is a poorly welded, lithic-rich, pumice-rich, crystal-poor ash-flow tuff. Red and gray, aphanitic flow-banded rhyolite angular lithics make up 10–50% of the tuff of Little Mineral Creek and range in diameter to several centimeters. Sparse broken crystals of quartz and sanidine occur in a highly pumiceous matrix. Intervals of fluvial reworking and air-fall deposits are common in this unit. Zeolithic alteration of volcanic glass to clinoptilolite (and other zeolite minerals) is locally extensive in tuff of Little Mineral Creek (Bowie & Barker in this guidebook).

Tuff of Stiver Canyon is a poorly to moderately welded, crystal-poor to moderately crystal-rich ash-flow tuff. Lithics and pumice are both rare; crystal content varies from 7 to 20% of sanidine, quartz, and minor biotite. Thickness of this unit in the Chloride mining district ranges up to 200 m.

Northwest of the Chloride district, tuff of Stiver Canyon contains a basal interval of conglomerate, sandstone, and mudstone (Eggleston & Norman 1983). In the Lookout Mountain area, about 25 m of basal aphanitic rhyolite flows and breccia, densely welded, lithic-rich, crystal-rich ash-flow tuff with phenocrysts of quartz and sanidine, and angular rhyolitic lithic fragments have been included with Stiver Canyon by Woodard (1982).

Moccasin John Rhyolite

Ericksen et al. (1970: E31) used the name rhyolite of Moccasin John area for "distinctive rhyolite sequence (that) crops out on Moccasin John Mountain and in the area drained by Moccasin John Creek and the North Fork of Palomas Creek." Among other possibilities, they suggested that the Moccasin John area constituted a flow–dome complex, although they were uncertain of its stratigraphic position.

In the Chloride mining district, lava flows of Moccasin John Rhyolite overlie tuff of Little Mineral Creek. Numerous other small flow–dome complexes and dikes of Moccasin John-type rhyolite occur in the Chloride district, the most important of which is the Chloride Creek dome (Fig. 4). Additional flow–dome complexes of possible affinity to Moccasin John Rhyolite are Franks Mountain intrusive (Woodard 1982), Kline Mountain intrusive (Eggleston & Norman 1983), and Sheep Creek dome at the north end of the mining district. Kline Mountain intrusive has a Rb–Sr age of 27.6 ± 1.2 my (Eggleston in preparation). Stratigraphically, these rhyolite flow–dome complexes are probably equivalent to Swartz Rhyolite of Elston (1957) in Mimbres Valley and a younger rhyolite (T4r map unit) of Seager et al. (1982) in the southern Black Range. Swartz Rhyolite has a reported K–Ar age of 26.8 ± 0.5 my (Elston 1976).

Moccasin John Rhyolite consists of highly contorted flow-banded domes and lava flows with common interbedded perlitic tuffs and tuf-

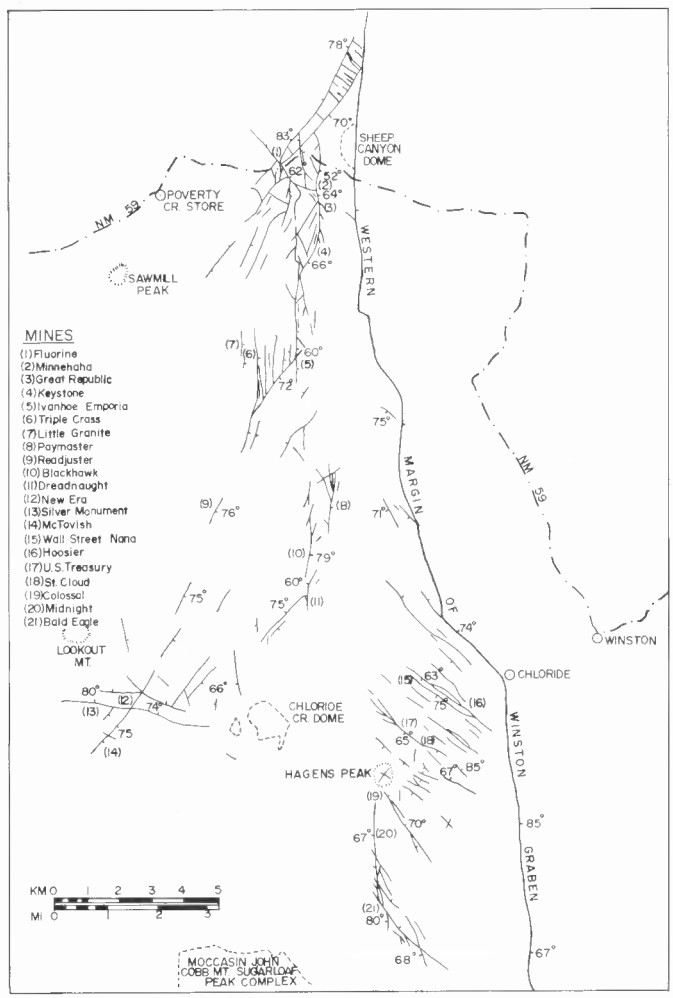


FIGURE 4—Major vein systems of Chloride mining district.

faceous sedimentary rocks. Carapace breccias exist around flanks of Moccasin John complex. Varying amounts of phenocrysts, from 1 to 30% quartz, sanidine, plagioclase, and biotite, and an abundance of volcanic glass and spherulites are characteristic of Moccasin John Rhyolite. Generally, this unit contains sparse phenocrysts. Hydrothermal alteration (silicification, kaolinization, alunitization) is common in the upper portions and/or along the margins of all Moccasin John flow domes in the Chloride district.

Late Cenozoic stratigraphy

Late Cenozoic volcanic rocks younger than Moccasin John Rhyolite form but a single exposure (Dolan Peak Rhyolite of Coney 1976) in the entire Chloride district. Reference is given to Eggleston & Norman (1983) and Eggleston (in preparation) for details of younger Tertiary volcanic stratigraphy in the Taylor Creek region immediately west of the Chloride district.

Gravels of the Santa Fe Group occur in fault contact with units of the entire stratigraphic section in the Winston graben, along the east side of the Chloride district. Where exposed at the graben's south end, the base of Santa Fe Group-Winston beds (Jahns 1955, Chapin et al. 1978) consists of coarse boulder conglomerates interbedded with coarse-grained sandstones and rests with angular unconformity upon tuff of Little Mineral Creek. Clasts consist of volcanic-rock types representative of the entire Tertiary section; no pre-Tertiary rock types have been found in the "Winston beds."

Two mafic-flow intervals lying unconformably within the "Winston beds" have K–Ar ages of 18.3 ± 0.4 my and 4.8 ± 0.10 my (Seager et al. 1984). Upper "Winston beds" have yielded Quaternary fresh-water mollusks and vertebrate fauna of early Pleistocene age (Chapin et al. 1978).

STRUCTURE

Regional tectonics

The structural fabric of the Chloride mining district and environs is the result of complex interaction between dynamic, regional-tectonic forces and local, magmatically influenced structures. Regional Cenozoic tectonics influencing structural deformation in southwestern New Mexico includes: (1) Laramide compression and strike–slip faulting along west–northwest to northwest trends (Seager 1983, Seager et al. in this guidebook); (2) Laramide compression and dextral strike–slip faulting along north–northeast to northerly trends (Chapin & Cather 1982, Seager 1975, Kelley & McCleary 1960, Nelson et al. in this guidebook); (3) late Oligocene to Miocene extension associated with development of the Rio Grande rift, forming north–northeast- and northwest-trending basins and initially characterized by emplacement of 28–29 my old, high-Sr basaltic-andesite flows (Chapin & Seager 1975, Seager et al. 1984, Eaton 1979); (4) late Miocene and Pliocene extension, forming north-trending basins and uplifts (Seager et al. 1984, Smith et al. 1985, Zoback et al. 1981, Eaton 1979); and (5) northeast-trending transverse shear zones (Chapin et al. 1975). Both Laramide and Rio Grande rift deformations can be divided into two stages corresponding to orientation of stresses.

Structure

Structures in the Chloride district display elements of all regional tectonic trends mentioned above, with the exception of compressional features (Fig. 3). This exception could be due to the extensive cover of post-Eocene volcanic rocks and overprinting of younger extensional deformation. However, sparse pre-Eocene rocks that crop out in the district reveal no indication of intense folding or thrust faulting; fault and dike trends in these older rocks are similar to trends in younger rocks.

The oldest faulting in the Chloride district occurred as strike–slip motion along north–northeast trends as indicated by slickenside striations and riedel shears along fractures in the southwestern part of the district. Strike–slip movement occurred only in Rubio Peak Formation and older rocks. Offset of a large, exotic limestone block suggests approximately 1.2 km of right-lateral motion during lower Rubio Peak time on one of the strike–slip faults. No date exists for lower Rubio Peak rocks in this area and, therefore, age of faulting is not well constrained.

The dominant structural style found in the Chloride mining district is high-angle normal faulting along north, northwest, north–northeast to northeast, and lesser east trends. Normal faults along these trends cut older strike–slip faults as well as rocks from the entire stratigraphic section and are the principal hosts for epithermal vein deposits in the mining district. Normal faulting occurred before, during, and after vein mineralization. Normal faulting began after Poverty Creek deposition, nearly coincidental with intrusion of Moccasin John Rhyolite flow–dome complexes.

Earliest normal faulting produced a series of north–northeast-elongated horsts and grabens that were later truncated by the north–northwest-trending Winston graben, the westernmost structural basin in this region related to the Rio Grande rift (Chapin & Seager 1975). The western boundary fault of the Winston graben, adjacent to the Chloride district, consists of a series of segments along north, north–northwest, and northwest trends. Slickenside striations along north trends reveal nearly total dip–slip motion, as a result of east–west extension. Slickenside striations along northwest and north–northwest segments show varying degrees of oblique–slip motion, consistent with an east–west extensional direction. Fault motions indicated by slickenside striations along most of the vein systems in the Chloride district are sympathetic to motion along the western margin of the Winston graben.

The southern end of the Chloride mining district is marked by a northeast-trending transverse zone along the Santa Rita lineament of Chapin et al. (1978). This zone is a structural-domain boundary similar to the transverse shear zone along the Morenci lineament in the Socorro–Magdalena area described by Chapin et al. (1978). The Santa Rita lineament in north-central Black Range is a few kilometers wide zone that acts as a hinge line for structural blocks tilted in different directions on opposite sides of the lineament. An excellent example is the Winston graben, a structure that is tilted down to the northwest with its hinge along the Santa Rita lineament. Major magmatic activity has occurred locally along this transverse zone from mid-Eocene time to about 4.5 my ago. Local magmatic centers along this zone include: Sierra Cuchillo intrusive (K–Ar age of 50.1 ± 2.6 my, Chapin et al. 1975); Willow Springs dome; North Emory cauldron (outflow dated by K–Ar at 34.3 ± 1.0 my corrected, McDowell 1971; and by $^{40}Ar/^{39}Ar$ at 35.2 ± 0.1, McIntosh et al. in this guidebook); and Moccasin John–Cobb Mountain–Sugarloaf Peak rhyolite flow–dome complexes.

Collapse and resurgence of the northern part of Emory cauldron and collapse of Moccasin John and other flow–dome complexes have influenced, and have been influenced by, local structures in the southwestern part of Chloride district. Faults along the structural margins of these volcanic centers are traceable for kilometers into the Chloride district and in places host vein mineralization. Small rhyolite domes, such as Chloride Creek dome, have locally arched country rock and produced radial and tangential fractures, many of which host epithermal vein deposits.

EPITHERMAL VEIN DEPOSITS

Epithermal mineral deposits in the Chloride mining district occur as open-space, fissure-filling veins with or without disseminated mineralization in adjacent wallrocks. Vein deposits consist dominantly of quartz, calcite (fluorite, barite) gangue material, with lesser sulfide and native-metal mineralization occurring in distinct, structurally controlled shoots. Rocks of the Rubio Peak Formation are the primary hosts for vein deposits, with a few occurrences in Kneeling Nun Tuff. Basaltic andesite of Poverty Creek occurs in the hanging wall of one northern vein, but its emplacement there is believed to be post-mineralization.

Quartz occurs as multiple pulses of coarse-grained to vuggy to cryptocrystalline and as milky white, clear, or amethystine varieties. Calcite, fluorite, and barite mineralization always occur as latest-stage vein filling. Quartz and adularia mineralization occur concurrently with sulfide and gold mineralization.

Districtwide sulfide mineralogy is varied in both vertical and lateral dimensions. In a vertical direction, both upper precious-metal and lower

base-metal horizons described by Buchanan (1981) for epithermal systems are recognized in individual deposits of the Chloride district. Most of the Au mineralization found in the Chloride district occurs in the upper precious-metal horizon of individual deposits. Regional lateral-zonation patterns are also recognized, portions of which were noted by Lindgren et al. (1910), Harley (1934), and Maxwell & Heyl (1980). For discussion of regional zonation patterns, the Chloride mining district is divided into southern and northern portions

Southern Chloride district

Cu–Ag mineralization in the southern part of the district is localized within a circular belt, 3–8 km in radius, centered on the Chloride Creek dome (Fig. 4). Veins radiate away from this dome along west, north, and northwest trends. Mineralogy in this Cu–Ag stage consists of bornite, chalcocite, argentite, minor chalcopyrite, and native silver along Silver Monument and New Era vein systems west of the Chloride Creek dome; bornite, chalcocite, and argentite along Dreadnaught and Black Hawk vein systems north of Chloride Creek dome; and bornite, digenite, chalcocite, covellite, and betehkenite along St. Cloud–U.S. Treasury, Hossier, Colossal, and Midnight (Pye Lode) vein systems southwest of Chloride Creek dome. Ag in this stage is largely contained by primary Cu minerals as lattice substitutions. For similar mineralization at Butte, Montana, Brimhall et al. (1984) indicate possible Ag contents in chalcocite–digenite up to 926 ppm, bornite up to 1,075 ppm (0.1 wt%) and covellite up to 10,000 ppm (1 wt%).

An older stage of Pb, Zn, Cu (Ag) mineralization occurs in vein systems in the southeastern portion of the Chloride district. Mineralogy in this first-stage mineralization consists of galena, sphalerite, and chalcopyrite (polybasite, pyrargyrite, pyrite). This stage is much poorer in precious-metal content than the second-stage mineralization, except in shallow areas where secondary processes greatly increase tenor, such as at the Bald Eagle mine.

The first and second mineralization stages overlap each other in portions of the Hoosier, St. Cloud–U.S. Treasury, Colossal, and Midnight–Bald Eagle (Pye Lode) vein systems. A mineral paragenesis typical of these vein systems is given in Fig. 5. Whether the two stages are genetically related, or represent two distinct, unrelated mineralizing pulses is unknown. Vein textures in the St. Cloud–U.S. Treasury system clearly show a temporal difference in the two stages of mineralization, and K–Ar ages indicate as much as 2.5 my difference. Stage 1 mineralization at the Bald Eagle mine yielded a date of 28.9 ± 1.1 my, while stage 2 mineralization at the Silver Monument, Hoosier, and St. Cloud mines yielded dates of 26.3 ± 1.1 my, 26.9 ± 2.0 my, and 26.5 ± 1.1 my, respectively (M. Bauman, unpubl. report for FRM Minerals 1984). There exists a great similarity between stage 1 mineralization in the Chloride district and sulfide mineralization in the Palomas (Hermosa) mining district 8–11 km to the south. Palomas mineralization is described by Jicha (1954b), Jahns (1957), and Shepard (1984). It seems quite possible that Chloride district stage 1 mineralization and Palomas mineralization are representatives of a distinct hydrothermal event associated with the Moccasin John flow–dome complex located midway between the two mining districts.

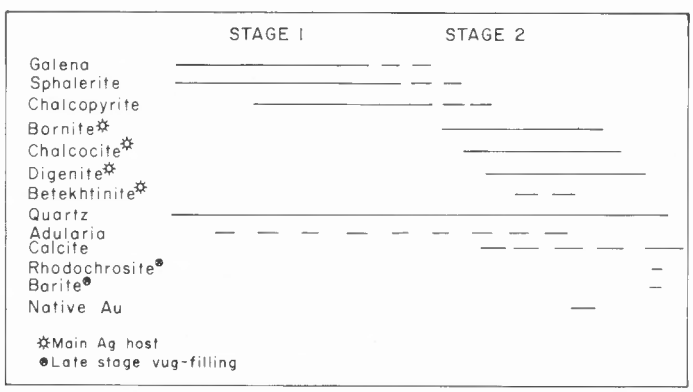


FIGURE 5—Mineral paragenesis for vein systems in southeastern Chloride mining district.

Of all the complexities in Chloride district mineralization, the most obvious and extreme variation is in the amount of lead and zinc sulfide occurrences. These metals are present in large quantities in the southeastern part of the district and virtually absent throughout the remainder of the district. Cu, Ag (Au) mineralization is ubiquitous to the entire district in some form.

A possible explanation for Pb, Zn variation is offered by Shikazono (1985), who studied Neogene vein-type deposits in Japan and noted Cu–Pb–Zn-rich mineralization in association with organic-bearing sedimentary rocks. Au, Ag mineralization, on the other hand, was found by Shikazono (1985) to occur dominantly in association with only volcanic rocks.

These ideas are consistent with observations for the area of high Pb, Zn mineralization on the Chloride district. Paleozoic sedimentary rocks are interpreted from geophysical data as existing beneath a relatively shallow volcanic cover in this area when compared to the rest of the district (Ericksen et al. 1970). This interpretation is also supported by detailed geologic mapping conducted by this author (unpubl. data).

Northern Chloride district

Epithermal vein systems in the northern part of the district exist along dominantly north trends with lesser northeast and northwest trends. The longest continuous vein system in the district, the Great Master Lode, occurs in this area, winding along north and northeast trends for more than 11 km. Vein adularia at the Minnehaha mine, on the Great Master Lode, yielded a K–Ar age of 26.2 ± 1.2 my, nearly identical to dates for stage 2 mineralization in the southern half of the district (M. Bauman, unpubl. report for FRM Minerals 1984).

Northern gangue mineralogy differs slightly from that in southern vein systems in that a moderate amount of fluorite and barite occur in the north and are virtually absent in the south. Sulfides in northern vein systems occur primarily as dark, very fine-grained bands, pods, and streaks. Mineralogy is principally acanthite, tetrahedrite, and pyrite with lesser bornite, chalcopyrite, and native Au occurrences. A rhyolite flow–dome complex located in Sheep Canyon is possibly a control for northern epithermal mineralization, as the Chloride Creek dome appears to be for southern mineralization.

TERTIARY GEOLOGIC HISTORY

1. Oldest Tertiary rocks found in the Chloride mining district are volcaniclastic alluvial-fan deposits of the lower Rubio Peak Formation. These deposits are proximal to mid-proximal facies typified by mass-movement processes of debris flows, hyperconcentrated flood flows, and gravity slides. Lower age restrains for these deposits are unknown, but paleontologic data place the upper volcaniclastic rocks in the Chadronian (earliest Oligocene) (Lucas in this guidebook). These rocks are interpreted as intermontane-basin accumulations shed from middle Tertiary volcanic centers overprinted on a Laramide uplift, similar to the L-shaped Sierra uplift of Eardley (1962) to the east and south of the district. Rubio Peak Formation rests on progressively older Paleozoic rocks south of the district; and paleoflow directions for lower Rubio Peak rocks in the district are from the east (Cather in preparation). Volcanic source areas for lower Rubio Peak volcaniclastic rocks are possibly marked by the north-trending chain of quartz-monzonite to monzonite intrusions that extends from Copper Flats (73.4 my, Hedlund 1974) northward through Salado Mountain intrusive, Double S Peaks intrusive, Sierra Cuchillo intrusive (50.1 ± 2.6 my, Chapin et al. 1975), and Kelly Peak intrusive.

2. The occurrence of exotic Paleozoic limestone blocks of enormous size within rocks of lower Rubio Peak Formation is an intriguing geologic phenomenon. Interpretation of geologic evidence by this author supports Maxwell & Heyl's (1976) gravity-slide origin for these blocks. Emplacement processes are envisioned as similar to those occurring along the Heart Mountain detachment fault, northwest Wyoming (Pierce 1941, 1957), and gravity-slide blocks in the Canelo Hills, southeastern Arizona (Davis et al. 1979).

Exotic limestone blocks occur at the same stratigraphic horizon across an area in excess of 150 km^2, throughout the length of the Chloride district. Individual blocks range upward to 170 m in thickness and 5 km^2 in outcrop. Bedding-plane faults and open-space breccias formed near the base of most blocks during sliding. A shale seam at the base of an exotic limestone block exposed in the St. Cloud mine incorporated fragments of underlying volcaniclastic rocks during transport. These features, plus highly fragmented, rotated areas along the base of large blocks suggest gravity sliding rather than the passive rafting expected from debris-flow deposition. Small limestone blocks around the margins of larger blocks do occur incorporated in debris-flow deposits that accompanied gravity sliding.

3. The stratigraphic interval from upper Rubio Peak Formation through basaltic andesite of Poverty Creek contains deposits of volcanic rocks intercalated with distal-alluvial-fan deposits. Volcanic rocks in this interval alternate between rhyolite and quartz-latite ash-flow tuffs and dark, aphanitic basaltic-andesite flow rocks. These volcanic rocks are representatives of the extensive Oligocene volcanism that began upon termination of Laramide basinal deposition (Smith et al. 1985) in response to cessation of compressional forces throughout the Cordillera in late Eocene time (Coney 1972). In the Chloride district, this transition is marked by change in volcanic rocks from intermediate stratovolcano derivatives to silicic ash-flow-tuff outflow sheets and basaltic-andesite flows and flow–dome complexes. Sugarlump Tuff members of the Rubio Peak Formation and Kneeling Nun Tuff are the major ash-flow-tuff units within this stratigraphic interval. The basaltic andesite of Poverty Creek is the most extensive and youngest mafic unit; it marks the beginning of regional extension along the Rio Grande rift.

4. The high-silica tuff of Little Mineral Creek and Moccasin John Rhyolite flow–dome complex together with the underlying basaltic andesite of Poverty Creek represent a fundamental petrologic transition noted by many (Lipman et al. 1972, Christiansen & Lipman 1972, Rhodes et al. 1972) as occurring in the 27 to 29 my bracket throughout the Cordillera, virtually concurrent with earliest extension along the Rio Grande rift (Chapin & Seager 1975, Eaton 1979, Seager et al. 1984). Tuff of Little Mineral Creek is interpreted as a lithic-rich pyroclastic deposit derived from initial eruptions of the Moccasin John Rhyolite flow–dome complex. Such early pyroclastic deposits are probably the result of either excessive build-up of volatiles or of interaction between magma and ground water (Sheridan 1979, Burt & Sheridan 1981). This pyroclastic volcanism and later extrusion of rhyolitic lavas resulted in collapse around major vent areas.

5. Hydrothermal convective cells generated by intrusion of rhyolitic magma associated with Moccasin John Rhyolite flow–dome complex, Chloride Creek dome, Sheep Canyon dome (and others?) appear to be responsible for epithermal vein deposits of the Chloride mining district. Mineralized fault structures are largely those active during doming and/or collapse of flow–dome complexes. Regional zonation of mineralization is believed to be related to location of these rhyolitic intrusions (as well as to the dominant lithologies through which hydrothermal systems operate).

6. Post-mineralization, high-angle normal faulting refractured vein systems and initiated new fault structures sympathetic to the Winston graben and Rio Grande rift.

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