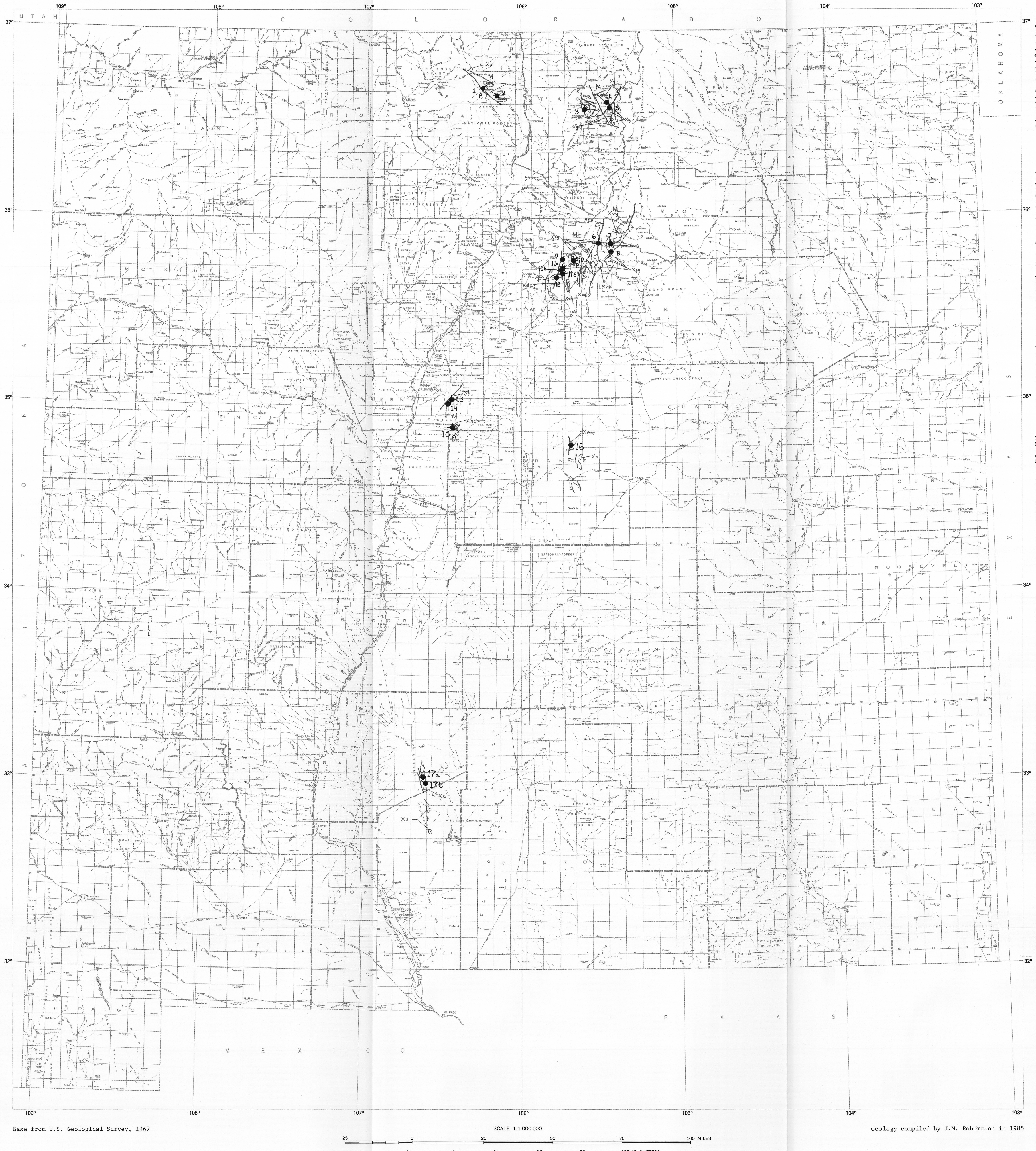
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1853-A
VOLCANOGENIC MASSIVE-SULFIDE MAP SERIES



EDITOR'S NOTE

This map is one of several planned or published preliminary and interim products of a study of the distribution and setting of volcanogenic massive-sulfide occurrences in the western United States. "Volcanogenic massive sulfides" refers to occurrence types that are inferred to be associated with the development of ancient island arc or rift systems in a mainly subaqueous environment. Most massive-sulfide occurrences on this map were probably deposited in ancient island arc environments and are considered to be "proximal" with respect to their emplacement near centers of volcanic activity.

The distribution of favorable host rocks for massive-sulfide deposits and the structures that apparently control their distribution are also shown on the map. The host rocks are not necessarily formal stratigraphic units and they commonly contain several lithologic types. They are shown here to delineate areas that may have some potential for undiscovered massive-sulfide deposits.

SUMMARY OF VOLCANOGENIC MASSIVE-SULFIDE OCCURRENCES IN NEW MEXICO

INTRODUCTION

New Mexico volcanogenic massive-sulfide occurrences, which typically contain pyrite and pyrrhotite accompanied by variable amounts of base-metal sulfides and precious metals, are found within mainly subaqueous, compositionally bimodal metavolcanic successions of Early to Middle Proterozoic age that are exposed primarily in the north-central part of the state. Host rocks include both mafic and felsic volcanic rocks or their volcaniclastic equivalents, silica-rich chemical sediments, and locally developed carbonate horizons. Some host rocks display variably preserved relict volcanic and(or) sedimentary textures, but the majority are metamorphic rocks having original textures and mineralogies substantially changed. In addition, many host rocks experienced significant premetamorphic chemical alteration that further obscures their origins. For these reasons, the "Host rock lithology" column in table 1 first lists a metamorphic rock description and then, in parentheses, suggests a possible volcanic or chemical-sediment protolith.

With the exception of the Pecos mine and a subsurface deposit partially outlined by recent drilling at Jones Hill, New Mexico occurrences shown on this map do not exhibit enough of the classic features of volcanogenic massive-sulfide deposits to make their classification (or origins) unequivocal. Nonetheless, these occurrences are included because they might be genetically, spatially, chronologically, or in some combination of ways related to volcanogenic massive-sulfide-forming systems and are therefore deserving of further study.

The following two sections 1) outline the general geologic setting and character of New Mexico's Proterozoic volcanic terranes, which host volcanogenic massive-sulfide occurrences, and 2) describe the general features of two occurrences--the Pecos mine and Jones Hill--which display the most complete and convincing collection of "classic" volcanogenic massive-sulfide features of any of the New Mexico examples.

GEOLOGIC SETTING

The mafic volcanic-dominated successions that host a majority of the massive-sulfide occurrences in New Mexico, informally termed greenstone belts or terranes, apparently accumulated during two relatively short intervals in the Early Proterozoic: 1760-1740 Ma and 1730-1710 Ma (Bowring and others, 1984; Reed, 1984; Bowring and Condie, 1982). The remaining massive-sulfide occurrences are associated with slightly younger (1660-1650 Ma) volcanic successions that are dominated by felsic volcanic and volcaniclastic rocks.

Broadly speaking, ages of exposed volcanic successions appear to decrease from north to south within the state. Older (1760-1740 Ma) greenstone terranes are exposed in the Tusas Mountains (Moppin Metavolcanics) and the northern Sangre de Cristo Mountains (Gold Hill volcanic rocks); younger (1730-1710 Ma) greenstone terranes are exposed in the southern Sangre de Cristo Mountains (Pecos greenstone belt) and Manzanita Mountains (Tijeras Greenstone). The youngest (1660-1650 Ma) rhyolite-dominated terranes are exposed in the southwesternmost Sangre de Cristo Mountains (Dalton Canyon volcanic rocks), the Pedernal Hills (Pedernal volcanic rocks), and the San Andres Mountains (unnamed). In detail, however, this southward younging trend is not quite so simple. Recent mapping, for example, along with a growing body of lithologic descriptions, geochemical analyses, and U-Pb zircon ages indicates that more than one "generation" of Precambrian volcanic rocks are present in the Tusas and southern Sangre de Cristo Mountains. It is probable that at least two age groups of volcanic rocks are also present in the Manzanita and northern Manzano Mountains (Cavin and others, 1982), although discontinuous outcrops and numerous granitic intrusions make exact stratigraphic interpretations in this area especially difficult. The extent to which other Proterozoic volcanic terranes in New Mexico may contain more than one age-group of volcanic rocks is, at present, unknown.

A typical greenstone terrane consists of metamorphosed, subaqueous basalts and locally important felsic volcanic rocks, iron formation, and volcaniclastic sediments. Volcanic rocks comprise a compositionally bimodal suite of basalt (up to 90 percent) and dacite-rhyodacite-quartz latite-rhyolite (up to 30 percent, but generally much less). Mafic volcanics are metamorphosed to mostly fine-grained, massive to well-foliated amphibolites that locally display relict amygdules, pillows, and pillow breccia. Felsic volcanic rocks are mainly porphyritic flows and crystal-rich volcaniclastics. A complex of concordant to discordant, hypabyssal intrusions of tonalite-trondhjemite and diabase-gabbro intrudes, and may be locally overlain by, portions of the volcano-sedimentary pile. Volcanic and subvolcanic rocks have undergone regional metamorphism of upper greenschist to lower amphibolite grade and show the effects of at least two periods of penetrative deformation. The metamorphic sequence is cut by pretectonic to syntectonic (1755-1650 Ma) granitic rocks and quartz porphyries and by syntectonic to post-tectonic, mainly anorogenic (1500-1450 Ma) granitic rocks.

A typical rhyolite-dominated terrane consists of metamorphosed, felsic volcanic and volcaniclastic rocks, commonly porphyritic, and their reworked epiclastic equivalents; lesser amounts of mafic volcanic rocks and related sedimentary rocks (graywacke and sub-graywacke); locally significant amounts of arkosic, subarkosic, and argillaceous sedimentary rocks; and thin, discontinuous ferruginous quartzite or metachert horizons (Moench and Erickson, 1980; Armstrong and Holcombe, 1982; Cavin and others, 1982). On the basis of limited geochemical data, volcanic rocks comprise a compositionally bimodal suite with the dacite-rhyodacite-rhyolite end member typically accounting for 50-75 percent of the total. The mafic end member is apparently mainly basaltic and contains little or no andesite, although mafic volcanic protoliths are not well documented in these terranes. Many mafic as well as felsic volcanic units display strong textural evidence of pyroclastic origins, both with and without subsequent reworking. Commonly, the volcano-sedimentary pile is intruded by an apparently synvolcanic suite of hypabyssal rocks ranging in composition from tonalite to quartz porphyry and aplite. Rhyolite-dominated terranes appear to have experienced the same deformational and regional metamorphic history as the older greenstone terranes.

GENERAL FEATURES OF NEW MEXICO'S PROTEROZOIC VOLCANOGENIC MASSIVE-SULFIDE DEPOSITS

Unequivocal volcanogenic massive-sulfide deposits are not common in New Mexico and are essentially restricted to the Pecos greenstone belt of the southern Sangre de Cristo Mountains. There, two occurrences, at the Pecos mine and at Jones Hill, display most of the classic features of such volcanogenic deposits and may be used collectively as a "yardstick" against which the rest of the occurrences listed in table 1 may be measured. What follows is based in large part on the work of Riesmeyer (1978), Robertson and Moench (1979), and Riesmeyer and Robertson (1979).

Host Rocks

Both the Pecos mine and Jones Hill deposits are associated with felsic, mainly pyroclastic, volcanic rocks whose internal textures and apparently limited lateral extent suggest that they probably represent local eruptive centers. These rocks are now quartz-sericite, quartz-chlorite-talc, quartz-chlorite-actinolite, and quartz-biotite schist and phyllite whose minor and trace element chemistry suggests a volcanic protolith composition in the dacite to rhyodacite range. Layered to massive chert, or its recrystallized metamorphic equivalent, containing trace to substantial amounts (greater than 25 modal percent) of hematite and(or) magnetite, may locally form part of the immediately enclosing host rocks at the Pecos mine and is present, but less abundant, in the Jones Hill area. Carbonate (± calc silicates), on the other hand, is closely associated with some of the sulfide ore at Jones Hill, whereas it is not so common in the Pecos mine.

Ore Deposits

Ore at the Pecos mine is mainly confined to several adjacent, strata-bound, lens-shaped bodies that are broadly conformable with the compositional layering and tectonite fabric of the enclosing multiply deformed volcanic rocks. Ore bodies at Jones Hill display a similarly conformable geometry, although the details are complicated by post ore, Phanerozoic (plus Precambrian?) faulting. Mineralogy is relatively simple: pyrite and pyrrhotite are the volumetrically dominant sulfides; chalcopyrite, sphalerite, and galena constitute the major economic sulfides and are accompanied by variable amounts of silver (associated with galena), gold (associated mainly with chalcopyrite), and arsenopyrite.

Representative ore types are based almost entirely on samples from the Pecos mine and include both massive and stringer ore. Massive ore, containing more than 50 volume-percent sulfide (Sangster and Scott, 1976), may be subdivided into 1) massive, structureless ore, dominated by pyrite and sphalerite in varying proportions; 2) banded ore, dominated by sphalerite and pyrite in alternating layers (averaging 1-cm thick) with or without intercalated selvages of host rock, along with lesser amounts of chalcopyrite and galena; and 3) breccia ore, typically consisting of volcanic host rock fragments in a matrix of sphalerite and pyrite. Stringer ore contains substantially less than 50 volume-percent sulfides and commonly consists of veinlets and stringers of quartz and chalcopyrite ± tourmaline along with lesser amounts of pyrite, pyrrhotite, and sphalerite.

Alteration

Alteration associated with ore at both the Pecos mine and Jones Hill is almost entirely limited to the stratigraphic footwall of each deposit and consists largely of chloritization and less abundant silicification. In addition to chlorite, talc is a common member of the chloritic alteration assemblage at Jones Hill (for a general discussion see Roberts and Reardon, 1978). Medium-grade regional metamorphism has, in places, further modified the original mineralogy of the chloritized rocks through the development of tremolite-actinolite and biotite. Secondary (and(or) primary?) carbonate is only a minor phase at the Pecos mine, but it is more widespread at Jones Hill where both carbonate and calc silicates are locally important. Tourmaline is a common accessory in ore as well as in adjacent host rocks. The Mg-rich variety, dravite, has been identified in one sample from the Jones Hill area (for a general discussion see Slack, 1980).

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EXPLANATION

SAMPLE LOCALITY--Numbers are refered to in table 1; "p" indicates a deposit that is producing or has produced ore

Copper — Silver
Gold — Zinc
Lead — Other metals--See table 1

IRON SULFIDE MINERALS ONLY

M — MAFIC-DOMINATED VOLCANIC ROCKS

F — FELSIC-DOMINATED VOLCANIC ROCKS

CONTACT

FAULT

VOLCANIC TERRANES

Xdc	Dalton Canyon volcanic rocks	1660-1650 Ma
Xp	Pedernal volcanic rocks	1660-1650 Ma(?)
Xu	Unnamed volcanic rocks	1660-1650 Ma(?)
Xhc	Greenstone at Hell Canyon	1730-1710 Ma(?)
Xpg	Pecos greenstone belt	1730-1710 Ma
Xt	Tigeras Greenstone	1730-1710 Ma(?)
Xg	Gold Hill volcanic rocks	1760-1750 Ma
Xm	Moppin Metavolcanics	1760-1750 Ma

TABLE 1.--Volcanogenic massive-sulfide occurrences in New Mexico

Map no.	Name	Location	Age*	Host-rock lithology	Mine workings	Metals#	Remarks*
1	Hopewell Lake area	Lat: 36° 42′ 3″ Long: 106° 14′ 35″	>1750 Ma (21)	Quartz-sericite-chlorite ± carbonate phyllite and schist (felsic to intermediate volcanic and volcaniclastic rocks)	Adits, shafts, dumps, trenches	Au (Ag, Cu, Pb, Zn)	Minor Ag, Cu, Pb, Zn. Total reported production probably less than $200,000, mainly from Au placers. (2)
2	Bromide/Payroll mine	Lat: 36° 39′ 26″ Long: 106° 10′ 2″	>1750 Ma (21)	Quartz-chlorite-sericite ± carbonate phyllite and schist (intermediate to mafic volcanic and volcaniclastic rocks)	Adits, shafts, pits, dumps	Ag, Cu (Au)	Minor Au. Total reported production less than $50,000, primarily from Ag-Cu ore. (2)
3	La Virgen prospect	Lat: 36° 34′ 34″ Long: 105° 34′ 59″	~1750 Ma (4)	Amphibole-biotite schist; chlorite-sericite schist (mafic volcanic and volcaniclastic rocks)	Open cuts, adits, trenches, dumps	Zn, Cu, Pb	Occurrence crosscut by numerous white Tertiary rhyolite dikes.
4	Gold Hill area	Lat: 36° 37′ 24″ Long: 105° 26′ 18″	~1750 Ma (4)	Quartz-mica phyllite and schist (felsic volcanic and volcaniclastic rocks)	Outcrop	---------	No reported production. (6)
5	Bull-of-the-Woods (Highline)/Frazer mines	Lat: 36° 35′ 50″ Long: 105° 26′ 35″	~1750 Ma (4)	Quartz-mica phyllite and schist (felsic volcanic and volcaniclastic rocks)	Shafts, adits, dumps, trenches	Cu	Little production from either property. (21)
6	Maestas Creek area	Lat: 35° 51″ 45″ Long: 105° 29′ 25″	~1720 Ma (3)	Amphibolite with minor calc-silicate horizons (mafic volcanic rocks with interlayered impure carbonate horizons)	Pits, shafts, dumps	Cu, (Mo)	Minor Mo. No reported production. (20)
7	Upper Rociada area	Lat: 35° 50′ 51″ to 35° 52″ 15″ Long: 105° 23′ 58″ to 105° 25′ 42″	~1720 Ma (3)	Calc-silicate rocks; chert; quartz-mica schist (impure carbonate horizons intercalated with felsic volcaniclastic rocks)	Adits, pits, dumps, outcrop	Zn, Pb, Cu, (Ag)	No reported production. (11)
8	Sapello River area	Lat: 35° 47′ 40″ Long: 105° 24′ 27″	~1720 Ma (3)	Quartz-feld-mica gneiss; quartz-mica schist (felsic volcanic and volcaniclastic rocks)	Pits and trenches	---------	No reported production. (11)
9	Doctor Creek area	Lat: 35° 46′ 55″ Long: 105° 43′ 15″	~1720 Ma (3)	Quartz-biotite ± chlorite phyllite; hornblende schist (metasiltstone and metagraywacke...volcaniclastic?)	Adits, pits, dumps	Cu	No reported production.
10	Pecos mine	Lat: 35° 45′ 30″ Long: 105° 40′ 7″	1720 Ma (3)	Quartz-sericite ± chlorite phyllite with variable amounts of biotite, actinolite and tourmaline; quartz-magnetite and quartz-hematite rock (felsic volcanic and volcaniclastic rocks, ferruginous cherts)	Underground mine, extensive dumps, outcrop	Zn, Pb, Cu, Ag, Au	Mine was active from 1927-39. Reported production was 2.3 million tons averaging 12.9% Zn, 4.0% Pb, 0.8% Cu, 0.11 oz/ton Au, and 3.4 oz/ton Ag. (11) (16)
11a	Jones Hill prospect	Lat: 35° 43′ 58″ Long: 105° 43′ 52″	1720-1710 Ma (3)	Quartz-sericite ± chlorite and biotite phyllite and schist (felsic volcanic and volcaniclastic rocks)	Underground workings, dumps, outcrop	Cu, Zn, Pb, Au, Ag	No reported production.
11b	Hill 9359 (altitude 9,359 ft.)	Lat: 35° 43′ 15″ Long: 105° 43′ 52″	~1720 Ma (3)	Quartz-sericite ± chlorite schist; quartz-hematite and quartz-magnetite rocks (felsic volcanic and volcaniclastic rocks, ferruginous cherts)	Pits, outcrop	Cu	No reported production.
11c	Macho Canyon prospects	Lat: 35° 42′ 37″ Long: 105° 44′ 13″	~1720 Ma (3)	Quartz-sericite ± chlorite phyllite and schist; quartz-feldspar-mica granofels (felsic volcanic and volcaniclastic rocks)	Pits, adits, dumps, outcrop	Pb, Zn, Ag, (Cu)	No reported production.
12	Dalton Canyon prospects	Lat: 35° 41′ 6″ to 35° 41′ 41″ Long: 105° 45′ 30″ to 105° 46′ 32″	1660-1650 Ma	Quartz-biotite-chlorite phyllite and schist; quartz-sericite schist (siliceous graywacke, felsic volcanic and volcaniclastic rocks)	Adits, pits, dumps outcrop	Cu, Ag, Zn, Pb (W)	Contains some W mineralization as amphibole-quartz-scheelite ± calcite and chalcopyrite veins and fracture fillings in amphibolite and quartz-biotite-chlorite phyllite. (9)
13	Tijerjas Canyon-York mine	Lat: 35° 2′ 6″ Long: 106° 10′ 2″	~1720 Ma (?)	Amphibolite; quartz-chlorite schist; calc-silicate rocks (mafic volcanic and volcaniclastic rocks ± impure carbonate horizons)	Pits, shafts, dumps	Cu, (Zn, Au)	No reported production. (8)
14	Tijerjas Canyon-Great Combination and Mary M mines	Lat: 35° 01′ 40″ to 35° 01′ 28″ Long: 106° 26′ 28″ to 106° 26′ 52″	~1720 Ma (?)	Amphibole-biotite schist; chlorite-sericite schist (mafic volcanic and volcaniclastic rocks)	Adits, dumps	Au, (Cu, Ag)	Reported production of 5 tons of Au ore. Earlier, unreported production probably comparable. Contained minor amounts of Ag and Cu. (7)
15	Hell Canyon-Milagros-Star and Cerro Del Oro mines	Lat: 34° 53′ 13″ to 34° 53′ 58″ Long: 106° 25′ 48″	~1720 Ma (?)	Epidote-actinolite-hornblende hornfels; chlorite phyllite; quartz-mica phyllite (mafic volcanic and volcaniclastic rocks)	Opencut, pits, shafts, trenches, dumps	Cu, Au, Ag	Production 1880-1910: approx 2000 tons of Cu ± Au ore 1975-1976: 2,348 oz Au, 3,333 oz Ag by heap leaching. (23)
16	Pedernal Hills prospects	Lat: 34° 47′ 25″ Long: 106° 40′ 25″	1660-1650 Ma (?)	Quartz-sericite ± chlorite phyllite and schist; calc-silicate rocks; quartz-hematite and quartz-magnetite rocks (felsic volcanic and volcaniclastic rocks with interlayered impure carbonate and ferruginous cherts)	Pits, trenches, outcrop, drill holes	Cu	No reported production. (1) (10)
17a	Sufur Canyon prospects	Lat: 33° 02′ 04″ Long: 105° 29′ 25″	1660-1650 Ma (?)	Quartz-sericite ± chlorite schist and phyllite; amphibolite (mafic to intermediate volcanic and volcaniclastic rocks)	Adits, pits, dumps	Cu	No reported production. Prospect is on White Sands Missile Range and is inaccessible. (12)
17b	Grandview Canyon prospects	Lat: 32° 59′ 01″ Long: 106° 41′ 28″	1660-1650 Ma (?)	Quartz-sericite ± chlorite schist and phyllite; amphibolite (mafic to intermediate volcanic and volcaniclastic rocks)	Adits, pits, dumps	Bi, W, Cu	Contains W (scheelite) and Bi mineralization. 1500 lbs of ore shipped in 1918 (70.2% Bi). Prospect is on White Sands Missile Range and is inaccessible. (12)

*References are indicated by numbers, such as "(3)", and are listed at the end of the map text.
#Metals listed in order of decreasing importance. Metals in parentheses are minor.

METALLOGENIC MAP OF VOLCANOGENIC MASSIVE-SULFIDE OCCURENCES IN NEW MEXICO

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VOLCANOGENIC MASSIVE-SULFIDE MAP SERIES
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