New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/49

A reinterpretation of ore zoning in the Organ district, Dona Ana County, New Mexico

Virgil W. Lueth and Virginia T. McLemore

1998, pp. 279-285. https://doi.org/10.56577/FFC-49.279

in:

Las Cruces Country II, Mack, G. H.; Austin, G. S.; Barker, J. M.; [eds.], New Mexico Geological Society 49 th Annual Fall Field Conference Guidebook, 325 p. https://doi.org/10.56577/FFC-49

This is one of many related papers that were included in the 1998 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

A REINTERPRETATION OF ORE ZONING IN THE ORGAN DISTRICT, DOÑA ANA COUNTY, NEW MEXICO

VIRGIL W. LUETH and VIRGINIA T. McLEMORE
New Mexico Bureau of Mines and Mineral Resources, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801 USA

Abstract—Metal and mineralogical zoning is defined in the northern portion of the Organ district. Zoning is present along the structurally-controlled Merrimac-Hilltop and Torpedo-Bennett mineralization trends. Copper-molybdenum porphyry-type deposits at the Torpedo mine and Organ copper deposit gave rise to copper skarns that are immediately adjacent to the porphyry systems. An outward progression continues to zinc skarns followed by zinc-lead replacement deposits and lead-zinc replacements, with significant silver values, that occur farthest from the mineralization source. Pb/Cu and Cu/Zn ratios best define metal zoning and fluid flow directions for sulfide-bearing deposits. High Cu/Zn and low Pb/Cu ratios are located at the source of hydrothermal fluids. The variation of the ratios is a function of relative solubilities between metal complex species. Gaps in the zoning sequence, represented by a lack of observed or developed mineral deposits represent areas of highest exploration potential. Fluorite-barite deposits in the Organ district are genetically unrelated to porphyry copper mineralization based on age constraints.

INTRODUCTION

Changes in ore or gangue mineralogy during the course of crystallization of minerals in moving fluids produces the patterns recognized as zoning. Zoning can be defined on a number of scales ranging from regional (metallogenic) to microscopic. This study attempts to define zoning at a district-wide scale. District zoning is commonly observed as a grouping of minerals formed more or less in sequence in a ore depositional system (Barnes, 1975). Metal and mineral zoning is observed in many mining districts but is not necessarily present in all. Generally, district zoning is recognized by a particular sequence of minerals in a concentric or linear distribution about a point source. These patterns can range from relatively simple to complex with overlapping or missing mineralogical and/or metal zones. All deposit types, igneous, metamorphic, or sedimentary, can display zoning patterns. Within the Organ district, zoning apparently formed from a magmatic-derived or moderated hydrothermal system.

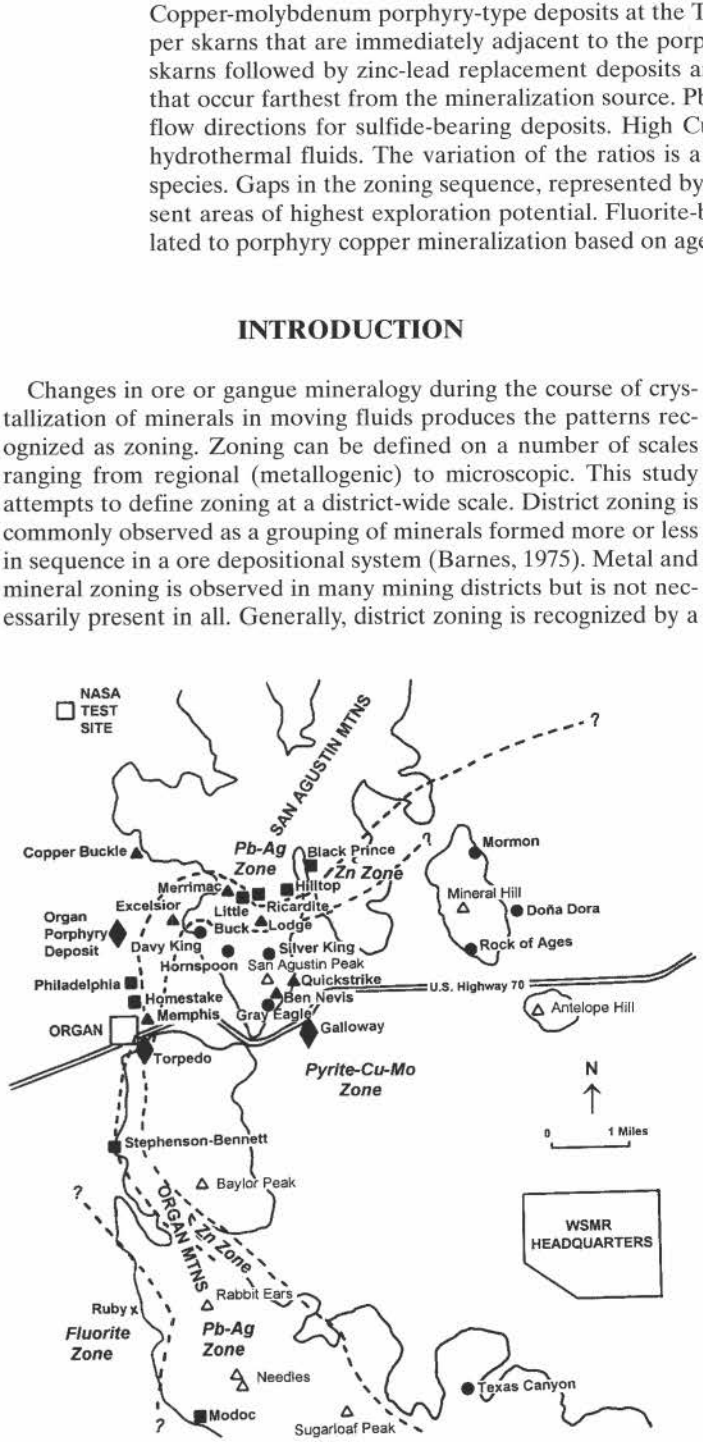

FIGURE 1. Map of mineral deposits and metal-ore zoning in the Organ district. Dashed lines represent metal zones based on Dunham (1935) as presented by Seager (1981). Symbols indicate type of deposit: ◆ porphyry; ▲ skarns; ■ carbonate replacement; ● vein; ✖ fluorite replacement. Figure modified from Seager (1981).

The geology of the Organ Mountains and the southern San Andres Mountains was first described in detail by Dunham (1935) and was updated in a comprehensive geological report by Seager (1981). The former paper characterized the ore deposits in some detail. Seager (1981) concentrated his study on the structural and lithologic features of the district with a summary of economic geology derived mainly from the reports of Dunham (1935) and Albritton and Nelson (1943), with additions from surface observations. Other published reports on the mineral deposits of the district include Lindgren et al. (1910), Soulé (1951), Glover (1975), McAnulty (1978), Macer (1978) and McLemore et al. (1996). The description of a porphyry copper-molybdenum deposit, north of the town of Organ (Fig. 1), was made by Newcomer (1984) and Newcomer and Giordano (1986). An initial reinterpretation of zoning was described by Lueth (1988) in conjunction with trace element geochemistry of galena and the recognition of tellurium mineralization in the northern portion of the district (Lueth et al., 1988; Lueth, 1989). A discussion of other mineralization centers in the district was presented by McLemore et al. (1996) and McLemore and Lueth (1997), but not discussed in detail. This paper is intended to clarify zoning in the district in light of recent geological and geochemical data.

GENERAL GEOLOGY

The Organ Mountains are a west-tilted fault block composed of rocks that range in age from Proterozoic to Quaternary. Proterozoic gneisses and granites are exposed on the north and eastern portions of the range. Paleozoic sedimentary rocks, dominantly marine, lie unconformably on a Proterozoic granitic basement. The maximum thickness of the Paleozoic section is 2591 m (Seager, 1981). The section is dominated by carbonate rocks that were deformed during the Laramide compressional event. The Paleozoic carbonate units are important host rocks for skarn and replacement ore deposits in the district. Oligocene volcanic rocks, that unconformably overlie the Paleozoic rocks, are coeval to the Organ batholith. The batholith was emplaced in three main phases

TABLE 1. Classification of ore deposits in the Organ district ranked according to "intensity factors" of Dunham, 1935. Top of the table represents highest intensity.

Deposit Name	Deposit Type	Host Rocks	Ore Assemblage	Gangue Assemblage	Reference
Organ Porphyry	Porphyry Cu-Mo	Tertiary granite	py-cpy-moly	qtz-kf-ser	Newcomer & Giordano, 1978
Torpedo	Cu Breccia Pipe	limestone	py-cpy	qtz-kf	Soulé, 1951
Excelsior	Cu skarn	limestone	py-cpy-pyrr	gnt-qtz-act	Lueth, 1988
Memphis	Cu-Zn skarn	limestone	py-cpy-sph-te	gnt-qtz-act	Dunham, 1935
Merrimac	Zn skarn	limestone	py-sph-cpy	gnt-qtz-act	Dunham, 1935
Lodge	Zn skarn	limestone	py-sph	gnt-qtz-act	Dunham, 1935
Hornspoon	Base metal vein	Tertiary granite	py-sph-gal-ss	qtz-kf-chl	Lueth, 1988
Homestake	CO_3 replacement	limestone	py-sph-gal	qtz-cal	Albritton & Nelson, 1943
Little Buck	CO_3 replacement	limestone	py-sph-gal-te	qtz-cal-fl	Lueth, 1988
Ricardite	CO_3 replacement	dolomite	gal-sph-py-te	qtz-cal-tc	Lueth, 1988
Hilltop	CO_3 replacement	dolomite	gal-sph-py-te	qtz-cal-fl-tc	Lueth, 1988
Black Prince	CO_3 replacement	dolomite	gal-sph	cal	Lueth, 1988
Stephenson-Bennett	CO_3 replacement	limestone	gal-sph-py	qtz-cal-gl	McLeMore et al., 1996
Modoc	CO_3 replacement	limestone	gal-sph	qtz-cal	McLemore et al., 1996
Bishop Cap	CO_3 replacement	limestone	fl-bar	qtz-cal	Seager, 1981
Hayner	CO_3 replacement	limestone	fl-bar	qtz-cal	Seager, 1981
Texas Canyon^{+}	Au-Ag vein	Tertiary granite	py-cpy-tetr-ar	qtz-bar	Dunham, 1935
Dona Dora^{+}	Au-Ag vein	PC granite	py-gal-sph	qtz-sid	Dunham, 1935
Mormon^{+}	Au-Ag vein	PC granite	py-cpy	qtz-hem	Dunham, 1935
Rock of Ages^{+}	Au-Ag vein	PC granite	py-cpy	qtz	Dunham, 1935

+ not assigned to any particular zone by Dunham (1935)

Mineral abbreviations: act - actinolite, ar - argentite, bar - barite, cal - calcite, chl - chlorite, cpy - chalcopyrite, fl - fluorite, gal - galena, gnt - garnet, hem - hematite py - pyrite, pyrr - pyrrhotite, qtz - quartz, te - tellurides, tetr - tetrahedrite, ss - sulfosalts, sid - siderite, sph - sphalerite, tc - talc,

shortly after caldera-style eruption of the volcanic rocks (Seager and Brown, 1978; Seager and McCurry, 1988). The main phase of the batholith, the Sugarloaf Peak quartz monzonite, was dated by the ^{40}Ar/^{39}Ar method at 33.1 ± 0.1 Ma (McLemore et al., 1995). Uplift and tilting of the range occurred during the middle Miocene in response to tectonism in the Rio Grande rift (Kelly and Chapin, 1997). Weathering and erosion incised the mountain range and deposited detritus into the adjacent basins.

ORE DEPOSITS

The Organ Mountains are host to a wide variety of ore deposit types. This variety is characterized by deposits ranging from magmatic to placer types. An estimated total production value for the district exceeds $2.7 million dollars (McLemore et al., 1996). The majority of deposits are thought to have a genetic link to the intrusion and crystallization of the Organ batholith (Dunham, 1935; Albritton and Nelson, 1944; Seager, 1981; McLemore and Lueth, 1996). The genetic link of ore deposits to magmatic activity in the district provides a constraint for the determination of district zoning.

Ore deposits studied during the course of this study are presented in Table 1. A large number of minor deposits were not utilized because of their small size and lack of applicable analytical data. Pegmatite deposits were not included, because they represent no economic source of metals in the district. Despite Dunham's (1935) description that pegmatites at the Gray Eagle, Ben Nevis, and Quickstrike mines produced some silver, Lueth (1988) determined that the complex pegmatites of Dunham were actually roof pendant skarns hosted by the main intrusion, based on the calcsilicate assemblages and fluid inclusion temperatures. Analogously, the "simple" pegmatites of Dunham (1935) represent endoskarns adjacent to the margins of the pluton. Potassium feldspar from the Quickstrike mine yielded an age of 32.2 ± 01 Ma (McLemore et al., 1995).

Copper-molybdenum porphyry deposits

The largest deposits in the Organ district are porphyry copper-molybdenum stockwork types. The Organ porphyry deposit crops out north of the town of Organ and has been explored through extensive drilling (Newcomer and Giordano, 1986). The copper breccia pipe at the Torpedo mine is also typical of porphyry copper mineralization. Molybdenum mineralization is also present at the Galloway mine and in a breccia zone near Aguirre Springs. Significant disseminated pyrite mineralization is also in the San Agustin pass area and in the vicinity of Granite Peak (Seager, 1981, McLemore and Lueth, 1997). These occurrences were not deemed significant although they were noted by Dunham (1935). Porphyry mineralization typically consists of early-stage pyrite-chalcopyrite-molybdenite in veinlets and disseminations, followed by a more diverse late-vein assemblage of pyrite-chalcopyrite-sphalerite-galena. Ore mineralization is accompanied by widespread potassic and quartz-sericite alteration and localized argillic and propylitic alteration (Newcomer and Giordano, 1986). The Organ porphyry deposit occurs in the lead-zone of Dunham and is inconsistent with his zoning pattern.

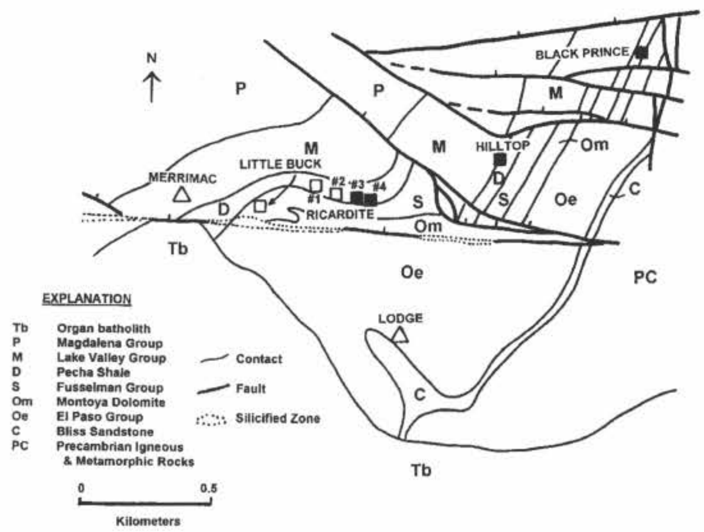

FIGURE 2. Generalized geology along the Merrimac-Hilltop mineralization trend. Geology modified from Seager (1981). Arrow points in the direction of fluid flow inferred from metal ratios. Symbols indicate type of deposit: ▲ - skarn (open = zinc skarn), ■ - replacement (open = zinc dominant)

Skarn deposits

Skarn deposits are developed along the margin of the Organ batholith and associated with faults outside the intrusive mass. Both copper and zinc types are present (Lueth, 1988). These deposits are characterized by extensive development of calcsilicate minerals, typical of skarns. Copper skarns at the Memphis and Excelsior deposits tend to contain a greater proportion of andradite over diopsidic pyroxene compared to zinc skarns. Zinc skarn mineralization is present at the Lodge and Merrimac mines. The northern portion of Memphis mine displays characteristics similar to zinc skarns. Sulfide mineralization generally occurred late in the skarn development and is accompanied by retrograde alteration of the calcsilicate minerals by hydrous alteration assemblages (clays, epidote, and actinolite). Retrograde alteration tends to be more abundant in copper skarns. All skarn types were mined for their base metal content. Ore mineralogy of the copper skarns consists of pyrite-pyrrhotite-chalcopyrite ± sphalerite and galena. Zinc skarns have an ore assemblage of pyrite-sphalerite-chalcopyrite ± galena.

Carbonate replacement deposits

Carbonate replacement deposits are common in the district and are represented by two subtypes based on dominant ore minerals, lead-zinc and fluorite-barite. Lead-zinc replacement deposits are hosted by Paleozoic limestones or dolomites and tend to occur along fault zones in areas more removed from the batholith. The distribution of impermeable rocks (shales and intrusive dikes) and fold structures profoundly influence the localization of these deposits. They are characterized by their dominantly lead and zinc mineralogy (galena and sphalerite) and lack of calcsilicate alteration of the host rocks. Significant silver was produced from the lead-zinc replacement deposits at the Little Buck, Ricardite, Hilltop, Black Prince, and Stephenson-Bennett mines. Minor amounts of calcsilicate mineralization are present in some deposits, but it is volumetrically insignificant. The second type of replacement deposit involves fluorite-barite mineralization represented at the Ruby mine and Bishop Cap area. The fluorite-barite deposits differ from the lead-zinc types in ore mineralogy (generally lacking sulfides) and locally extensive silicification of the carbonates that accompanied mineralization. Fluorite-barite replacement deposits are also significantly removed from magmatic activity.

Vein deposits

Vein deposits are present within the batholith proper and in Proterozoic rocks. Dunham (1935) considered all veins to be contemporaneous and a similar conclusion was drawn by Seager (1981). Three sets of veins are present; one trending east–west, another with a northeasterly trend, and the weakest trending northwest. All veins have steep dips. Ore mineralogy appears to vary in each set. East–west veins (e.g., Hornspoon and Doña Dora) contain an assemblage of pyrite-sphalerite-galena-sulfosalts (Lueth, 1988). Northeasterly veins (e.g., Davy King and Texas Canyon) are typically chalcopyrite- and quartz-rich with significant gold assays (Dunham, 1935). The northwesterly trend (Mormon and Poor Man's Friend) contains an assemblage similar to the east-west veins and may represent a conjugate set. The veins tend to be thin and display multiple episodes of mineralization. The veins in the Proterozoic granites locally occur in shear zones on the margins of altered diabase dikes. Veins hosted by the batholith display thin chlorite alteration envelopes. All veins were developed for their precious metal content.

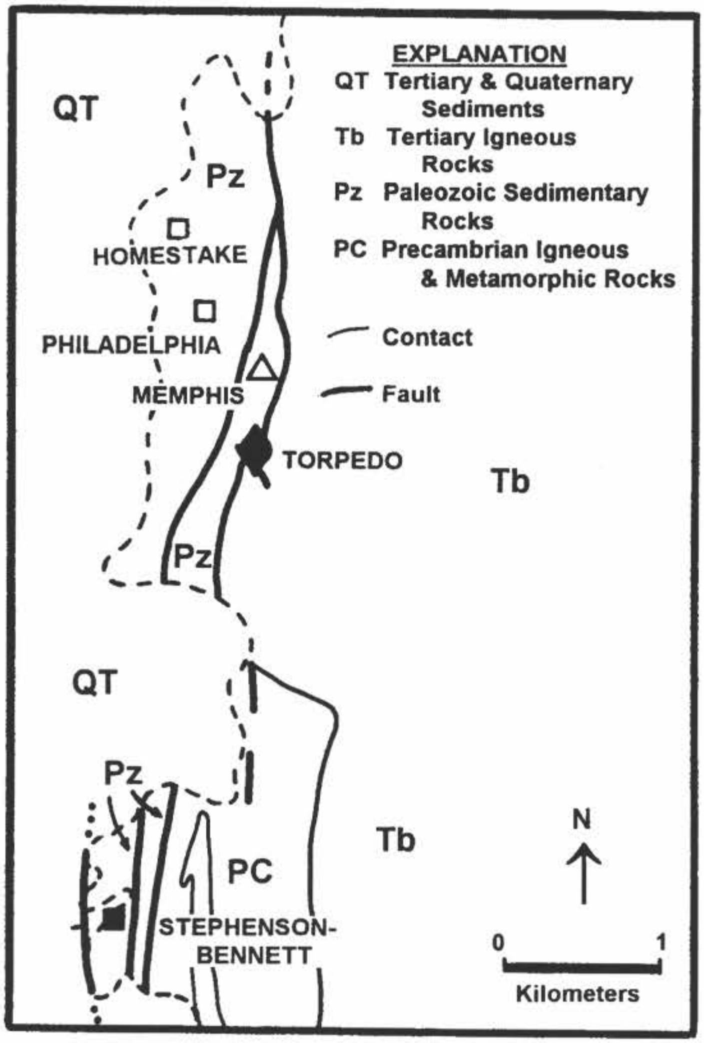

FIGURE 3. Generalized geology along the Torpedo-Bennett fault zone. Geology modified from Seager (1981). Arrow points in the direction of fluid flow inferred from metal ratios. Symbols indicate type of deposit: ◆ porphyry, ▲ - skarn (open = zinc skarn), ■ - replacement (open = zinc dominant)

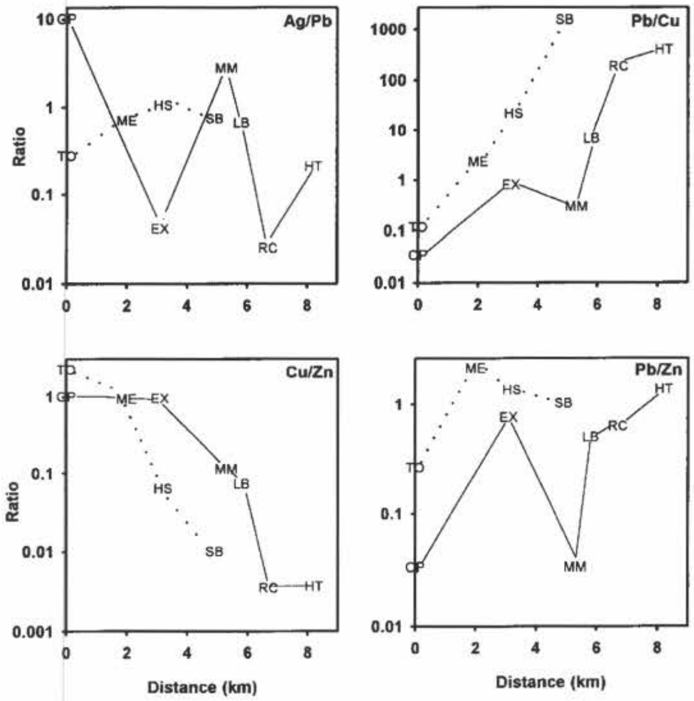

FIGURE 4. Comparison of metal ratios to distance along specific mineralization trends. Dotted line represents the Torpedo-Bennett trend. Solid line represents deposits along the Merrimac-Hilltop trend. Data and mine abbreviations from Table 2.

DISTRICT ZONING

Zoning of ore metals in the Organ district was first described by Dunham (1935). Utilizing the concept of an "intensity factor" (based on a combination of structural, temperature, pressure, and mineral assemblage data, e.g., Lindgren, 1933) and the depth-zone concepts of Graton (1933), Dunham interpreted a zoning pattern that was concentric about the Organ Batholith (Fig. 1). The listing of ore deposits in Table 1 follows the concepts applied by Dunham (1935, fig. 7, p. 138). The resulting interpretation of the zoning pattern has remained essentially unchanged since that time, although a number of studies have been carried out in the district subsequently. Seager (1981), in a reappraisal of the geology of the district, mentions a number of areas of mineralization unknown to Dunham, thereby establishing the potential need for a re-interpretation of zoning in the district.

A number of different methods for establishing zoning patterns in the Organ district were explored. These include: a review of mineral distributions, calculation of metal ratios from available assay data, and a resynthesis of the methods first employed by Dunham (e.g., Lindgren's intensity factors and Graton's depth-zone concepts). Determination of metal ratios for the mines was made from published assay values, private reports, or government surveys. Methods of ore sampling are variable, consisting of grab samples, smelter returns, and drill core assays. Accordingly, only assays of channel, smelter shipment, or drill core samples were utilized for metal-ratio determinations. The values used (Table 2) represent averages for all analyses from a particular mine.

Lueth (1988) noted that the distribution of the largest ore deposits within the Organ district lie along two distinct structural trends (Figs. 2 and 3). Zoning, based on "intensity factors," is well illustrated along at least one east-west structure (Merrimac-Hilltop trend) and apparent along the north-south-trending Torpedo-Bennett fault zone (TFZ). This zoning was also recognized by Dunham (1935, fig. 7, p. 138.).

Data amenable to metal-ratio analysis are lacking for many of the smaller vein-type deposits. The ore mineral assemblages are

TABLE 2. Assay data and ratio calculations for some of the ore deposits in the study area.

Deposit Name	Label	Deposit Type	Distance (km)	Cu	Pb	Zn	Ag	Cu/Zn	Pb/Zn	Ag/Pb	Pb/Cu	Data Reference
Merrimac-Hilltop Trend												
Organ Copper deposit	OP	Porphyry Cu-Mo	0	0.30	0.01	0.30	0.10	1.00	0.03	10.00	0.03	5
Excelsior	EX	Cu skarn	3.1	35.10	28.00	37.00	1.00	0.95	0.76	0.04	0.80	1
Merrimac	MM	Zn skarn	5.3	1.07	0.32	16.00	0.69	0.07	0.02	2.17	0.29	1
Lodge	LO	Zn skarn	6.3	1.42	1.20	10.77	0.56	0.13	0.11	0.46	0.84	2
Little Buck	LB	Zn repl.	5.8	1.82	12.40	24.70	16.60	0.07	0.50	1.34	6.81	1
Ricardite	RC	Pb repl.	6.7	0.08	17.52	24.02	3.95	0.00	0.73	0.22	219.06	1,2
Hilltop	HT	Pb repl.	8.2	0.23	36.31	23.38	8.49	0.01	1.55	0.23	157.86	1,2,3
Stephenson-Bennett Fault Zone												
Torpedo	TO	Cu breccia pipe	0	3.71	0.30	2.60	0.95	1.42	0.12	3.13	0.08	3
Memphis	ME	Cu-Zn skarn	2	2.54	7.33	13.62	3.59	0.19	0.54	0.49	2.88	1
Homestake	HS	Zn repl.	3.2	0.55	7.17	3.20	13.92	0.17	2.24	1.94	13.03	1,2
Stephenson-Bennett	SB	Pb repl.	4.9	3.05	19.58	6.50	11.77	0.04	3.01	0.06	6.41	1
Vein Deposits												
Hornspoon	HN	Polymetallic	na	0.92	4.20	11.67	11.48	0.08	0.36	2.73	4.59	2
Texas Canyon	TC	Au-Ag	na	1.38	1.60	0.23	6.66	5.89	6.86	4.16	1.16	2
Dona Dora	DD	Au-Ag	na	0.08	0.60	0.83	0.01	0.09	0.72	0.02	7.71	1,4
Mormon	MO	Au-Ag	na	4.12	0.10	0.10	3.95	41.18	1.00	39.54	0.02	1
Rock of Ages	RA	Au-Ag	na	0.26	0.04	0.01	2.76	26.00	4.00	69.00	0.15	1,4

References: 1, Dunham (1935); 2, Albritton & Nelson (1943); 3, Soule (1951); 4, McLemore et al. (1996); 5, this study similar in all E–W-trending vein deposits, consisting of sphalerite, galena, pyrite, and occasional silver-bearing sulfosalts. This assemblages constrasts to the northeasterly trending veins hosted by Proterozoic rocks that consist of chalcopyrite and quartz with high gold values. Only the Davy King and Texas Canyon (both northeast-trending veins) deposits hosted by the batholith have similar assemblages to northwest-trending veins found in the older host rocks. Northwesterly trending veins hosted by Proterozoic rocks have assemblages similar to the east–west, base-metal veins in the batholith.

A comparison of metal ratios among deposits with compatible geochemical data allows for the interpretation of a metal zoning pattern in the Organ district. Metal ratios from Table 2 are plotted according to distance along the Merrimac-Hilltop and Torpedo-Bennett trends (Fig. 4). The Pb/Cu and Cu/Zn ratios display systematic variation along the respective trends. This behavior indicates these ratios can be used as a "zoning index" (Goodell and Petersen, 1974) or a "progress variable" (Lueth et al., 1990). The log Pb/Cu provides the best "progress variable" since it maintains slope along the entire trend. The flat slopes on either end of the Cu/Zn curve limit its usefulness. The irregular pattern of the Ag/Pb and Pb/Zn ratios limits their utility unless they are compared to one of the progress variables to monitor the onset of crystallization of a particular species. The log Ag/Pb shows the greatest variation and is most sensitive to changes in ore chemistry, a feature used by Lueth (1989) to map trace element variation in polymetalllic ores.

Zoning along the Merrimac-Hilltop trend

The Merrimac-Hilltop trend is localized along an unnamed fault that intersects the Torpedo-Bennett fault and continues east to a thrust fault at Black Prince Canyon (Fig. 2). Metal zoning along the trend is readily apparent in deposit mineralogy (Table 1) and metal ratios (Table 2; Fig. 4). Increasing Pb/Cu values away from the Organ porphyry deposit is consistent with an evolving fluid as it migrates away from its source region (Gross, 1956; Goodell, 1970; Goodell and Petersen, 1974). Cu/Zn values decrease while Pb/Zn values generally increase away from the "source" porphyry system. This is probably a function of relative solubilties of the metal complexes in the hydrothermal fluid as determined by Hemley et al. (1992) and Hemley and Hunt (1992). Minor variability in the aforementioned ratio patterns corresponds to mineralization at the Merrimac and Little Buck mines. Four factors may account for this variation, individually or in combination: (1) changing host rock lithology from limestone to dolomite, (2) intersection with a second episode of mineralization, e.g., the quartz-fluorite-telluride veins described by Lueth et al. (1988), and Lueth (this guidebook), (3) changing depth of mineralization or, (4) the Merrimac is a proximal zinc skarn on the margin of the batholith and not associated with mineralization along the fault.

Zoning along the Torpedo-Bennett fault zone

Metal zoning along the Torpedo-Bennett fault zone (TFZ) (Fig. 3) is symmetric about the Torpedo copper breccia-pipe deposit (Fig. 4). All ratios are consistent with the concept of fluid migration away from the breccia pipe, which would plunge east after removal of Rio Grande-type tilting of the range. This orientation would suggest an origin of the pipe from the vicinity of San Agustin Pass, an area of disseminated pyrite mineralization similar to that found in copper-molybdenum-porphyry deposits. In addition, molybdenite and pyrite are present at the Galloway mine, immediately east of the pass. This area was suggested as a center of mineralization by McLemore et al. (1996) and McLemore and Lueth (1996).

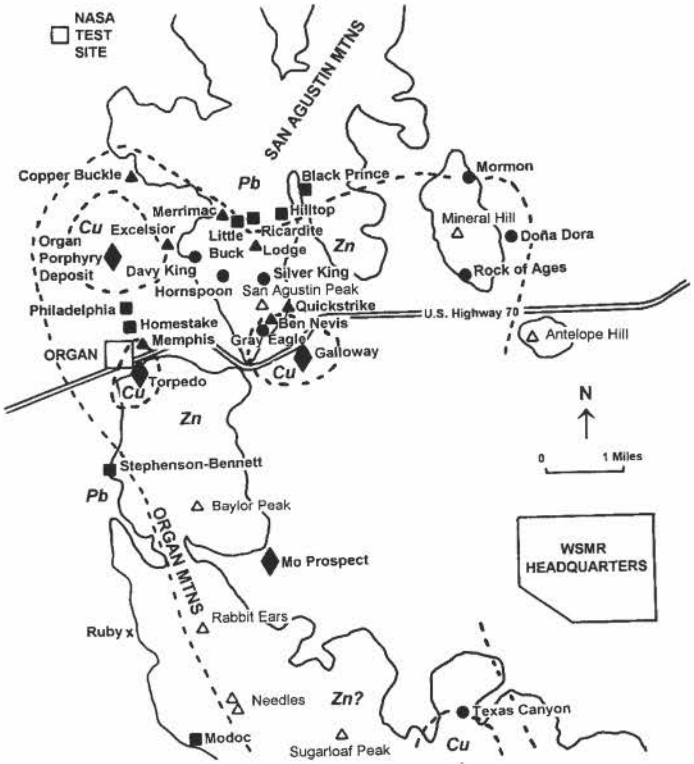

FIGURE 5. Metal zoning in the Organ district based on metal ratios and mineral distributions. Base map adapted from Seager (1981). Symbols from Figure 1.

Zoning of vein deposits

Metal zoning within vein deposits hosted by the batholith or Proterozoic rocks appears minimal. These deposits formed from similar hydrothermal fluids under the same physiochemical conditions as demonstrated by the consistent ore mineral assemblages. Taking into account the tilting of the range, these deposits represent a significant vertical section in the pluton over which mineralization is uniform, typical of polymetallic mesothermal vein deposits. Vein deposits in the Proterozoic rocks are even inferred to have formed at greater depths as compared to the polymetallic veins. The high copper and gold contents at the Texas Canyon, Davy King, and Rock of Ages deposits indicate these deposits may represent deep portions of a copper-gold porphyry system.

A new district zoning model

A reinterpretation of ore deposit distribution and mineralogy coupled with a metal-ratio study resulted in a new district zoning pattern. Instead of a concentric pattern about the Organ batholith (Fig. 1), zoning is centered about two, possibly three, porphyry-type deposits at the Torpedo mine, Organ deposit, and Granite Peak(?) (Fig. 5). A significant amount of hydrothermal alteration of the batholith is also present at these centers. However, zoning can only be established along structural trends that were utilized by the mineralizing fluids. Accordingly, low Pb/Cu and high Ag/Pb values at the Torpedo and Organ deposits indicate they are the source area for the mineralizing fluids. These ratios vary systematically along the mineralized structures away from the source. Metal zoning is a consequence of fluid evolution away from the copper-rich deposits.

Metal zoning in the Organ district can be quantified by comparing the two best zoning indicators, Pb/Cu and Cu/Zn (Fig. 6). The lines separating fields on this diagram are defined on the basis of observed mineral assemblages at particular deposits. The transition

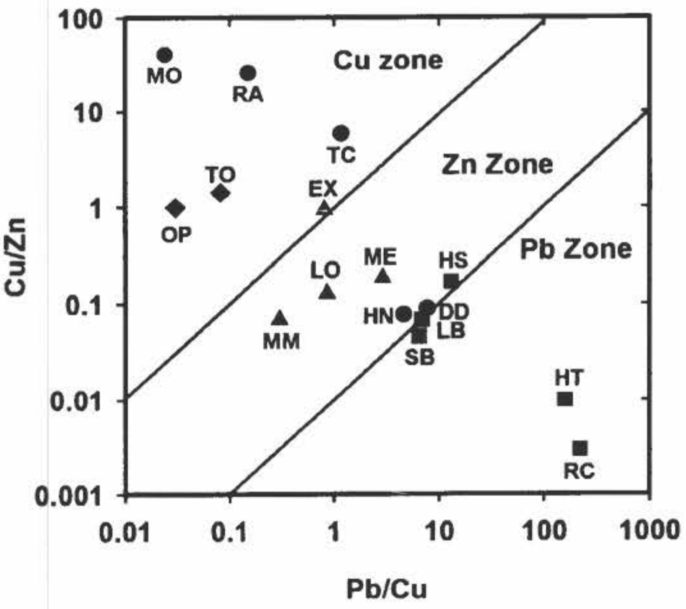

FIGURE 6. Comparison of zoning indices Pb/Cu and Cu/Zn. Data and mine abbreviations from Table 2. Symbols indicate deposit type: ◆ porphyry, ▲ skarns, ■ carbonate replacement, ● vein.

of the copper-to-zinc zones is defined at the Memphis mine. The Memphis has copper skarn characteristics in the southern workings and zinc skarn features on the north. The Zn-to-Pb transition takes place at the Ricardite mine, where zinc replacements are in the western workings and lead replacements dominate to the east.

The similarity of metal ratios at the Organ and Torpedo deposits, along with the presence of porphyry-type mineralization at San Agustin pass (Galloway mine), suggests these deposits may be genetically related. If so, they may represent faulted portions of the same large-scale deposit. Another area of intense pyrite mineralization that may represent porphyry-type mineralization exists near Granite Peak. We speculate that the Texas Canyon deposit on the east end of the district may be a product of this center, although geochemical data does not exist to adequately test this hypothesis. Mineralization in the vicinity of the Modoc mine may be related to this porphyry-type occurrence in the same way. A molybdenite-bearing breccia is hosted in the batholith and occurs immediately west of Aguirre Springs. This mineralization may be another center of porphyry-type mineralization within the batholith (Fig. 5).

The east–west and northwest-trending vein deposits (Hornspoon, Silver King, and Doña Dora) within the batholith represent epithermal-mesothermal, polymetallic-vein-type mineralization that is relatively uniform and plots in the zinc zone. These deposits occur along a deep cross section of the batholith, now exposed by tilting and uplift during Rio Grande rift tectonism. The northeast-trending, copper-rich, precious-metal veins in Proterozoic rocks and in Texas Canyon and the Davy King mine are part of the deeper portions of the porphyry system and are more intimately associated with copper mineralization based on metal ratios (Fig. 4). The Texas Canyon deposits may be related to the Organ Peak mineralization center. An interesting feature of many vein deposits involves their structural orientation and the location of the identified source areas for the hydrothermal fluids.. An extension of the vein and dikes orientations reveal a point of mutual intersection in the vicinity of the Organ copper deposit and/or the Torpedo mine. The apparent radial distribution of these mineralized structures may be a response to mineralization at the source areas. Similar deposits may be present to the west along the mountain pediment or under basin fill.

Fluorite-barite mineralization, which formerly represented the outer-most zone of mineralization in the Organ district, have no relationship to the porphyry copper mineralization. Seager (1981) indicated that this type of mineralization occurred much later and is associated with Rio Grande rift tectonism. A dating of hypogene jarosites, intimate with fluorite-barite ores at the Bishop Cap subdistrict yield a geologically significant ages between 5 and 6 Ma. The age of mineralization in the sulfide deposits in the Organ district is inferred to be Oligocene, 32.2 ± 0.1 Ma to 30.8 ± 0.1 Ma (McLemore et al., 1995). Fluorite-barite mineralization is a distinctly later stage of mineralization and is related to similar deposits up and down the Rio Grande rift (McLemore and Barker, 1985, Lueth and Goodell, 1996; Lueth and Heizler, 1997; Goodell et al., 1997).

CONCLUSIONS

A reappraisal of ore mineral distributions coupled with the study of metal ratios defines zoning in the Organ district. This pattern is centered about copper porphyry mineralization and is best illustrated by Pb/Cu and Cu/Zn ratios. Ratios are better exploration tools than grade because they indicate geochemical evolution of hydrothermal fluids as they migrate along structures. Accordingly, metal-ratio information derived from this study indicates a number of areas with good exploration potential. These include: the area between the Organ porphyry deposit and San Agustin Pass for porphyry-type mineralization; the area between the Torpedo and Stephenson-Bennett mines for zinc skarn or replacement deposits, and the area between Organ Peak and the Modoc mine for copper and zinc mineralization. However, much of the area occupied by the Organ district is part of the White Sands Missile Range, limiting accessibility to these areas, in addition to the significant increase in residential development on the west side of the Organ Mountains.

The character of vein mineralization in the batholith and Proterozoic rocks suggests these deposits have a low potential for significant metal production, although some mining has been done in the past. These deposits represent fracture zones deep in the porphyry system and are of limited extent.

Fluorite-barite deposits in the Organ district have no relationship to sulfide mineralization. These deposits represent a later stage of mineralization associated with rift development. They have characteristics similar to other deposits up and down the rift.

ACKNOWLEDGMENTS

This work was supported by the New Mexico Bureau of Mines and Mineral Resources, (Charles E. Chapin, Director and State Geologist). We would also like to thank Phil Goodell (University of Texas at El Paso) for years of discussions concerning the district and his constructive review of the manuscript. Andrew Campbell (New Mexico Tech) also provided an insightful review of the manuscript. Ben Donegan, Leonard Minerals, shared geological information about the Organ porphyry deposit. Special thanks are extended to Chuck O'Donnell (Bureau of Land Management) and Robert Myers (White Sands Missile Range) for providing access and coordinating fieldwork on the missile range. Sam Seek also arranged access to WSMR and range riders Rod Pino and Chris Ortega provided transportation on the range.

REFERENCES

Albritton, C. C. and Nelson, V. E., 1943, Lead, zinc, and copper deposits of the Organ district, New Mexico (with a supplement on the occurrence of bismuth): U.S. Geological Survey, Open-file Report 43, 39 p.

Barnes, H. L., 1975, Zoning of ore deposits: Types and causes: Transactions of the Royal Society of Edinburgh, v. 69, p. 295–311.

Dunham, K. C., 1935, The geology of the Organ Mountains: New Mexico Bureau of Mines and Mineral Resources, Bulletin 11, 270 p.

Glover, T. J., 1975, Geology and ore deposits of the northwestern Organ Mountains, Dona Ana County, New Mexico [M.S. thesis]: El Paso, University of Texas, 93 p.

Goodell, P. C., 1970, Zoning and paragenesis in the Julcani district, Peru [Ph.D. dissertation]: Cambridge, Harvard University, 118 p.

Goodell, P. C., Lueth, V. W. and Heizler, M. T., 1997, ^{40}Ar/^{39}Ar age of Rio Grande rift tectonism in the north Franklin Mountains, west Texas and southern New Mexico: Geological Society of America, Abstracts with Programs, v. 29, no. 2, p. 11.

Goodell, P. C. and Petersen, U., 1974, Julcani mining district, Peru: A study in metal ratios: Economic Geology, v. 69, p. 347–361.

Graton, L. C., 1933, The depth-zones in ore deposition: Economic Geology, v. 28, p. 513–555.

Gross, W. H., 1956, The direction of flow of mineralizing solutions, Blyklippen mine, Greenland: Economic Geology, v. 51, p. 415–426.

Hemley, J. J. and Hunt, J. P., 1992, Hydrothermal ore-forming processes in light of studies in rock-buffered systems: I. Iron-copper-zinc-lead sulfide solubility relations: Economic Geology, v. 87, p. 23–43.

Hemley, J. J., Cygan, G. L., Fein, J. B., Robinson, G. R. and D'Angelo, W. M., 1992, Hydrothermal ore-forming processes in light of studies in rock-buffered systems: I. Iron-copper-zinc-lead sulfide solubility relations: Economic Geology, v. 87, p. 1–22.

Kelly, S. A. and Chapin, C. E., 1997, Cooling histories of mountain ranges in the southern Rio Grande rift based on apatite fission-track analysis-a reconnaissance survey: New Mexico Geology, v. 19, p. 1–14.

Lindgren, W., 1933, Mineral Deposits, 4th ed.: McGraw-Hill, New York, 930 p.

Lindgren W., Graton, L. C. and Gordon, C. H., 1910, The ore deposits of New Mexico: U.S. Geological Survey, Professional Paper 68, 361 p.

Lueth, V. W., 1988, Studies of the geochemistry of the semimetal elements: Arsenic, antimony, and bismuth [Ph.D. dissertation]: El Paso, University of Texas, 173 p.

Lueth, V. W., 1989, Characterization of tellurium mineralization in the Organ district, New Mexico: Geological Society of America, Abstracts and Programs, p. A149.

Lueth, V. W. and Goodell, P. C., 1996, A remarkable deposit of jarosite: The product of rift basin dewatering: Geological Society of America, Abstracts with Programs, v. 28, no. 7, p. A–210.

Lueth, V. W., Goodell, P. C. and Pingitore, N. E., 1990, Encoding an ore system in bismuthinite-stibnite compositions, Julcani, Peru: Economic Geology, v. 85, p. 1462–1472.

Lueth, V. W., Goodell, P. C., Llavona, R., Mertig, H. and Sharp, W., 1988, Tellurium minerals of the Organ district, Doña Ana County, New Mexico (abstr.): New Mexico Geology, v. 10, p. 18.

Lueth, V. W. and Heizler, M. T., 1997, ^{40}Ar/^{39}Ar age and origin of jarosite mineralization at the Hansonburg district, New Mexico: New Mexico Geology, v. 19, p. 51.

Macer, R. J., 1978, Fluid inclusion studies of fluorite around the Organ cauldron, Doña Ana County, New Mexico [M.S. Thesis]: El Paso, University of Texas, 107 p.

McAnulty, W. N., 1978, Fluorspar in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 34, 61 p.

McLemore, V. T. and Barker, J. M., 1985, Barite in north-central New Mexico: New Mexico Geology, v. 7, p. 21–25.

McLemore, V. T. and Lueth, V. W., 1996, Lead-zinc deposits in carbonate rocks in New Mexico: Society of Economic Geologists, Special Publication, p. 264–276.

McLemore, V. T., Sutphin, D. M., Hack, D. R. and Pease, T. C., 1996, Mining history and mineral resources of the Mimbres Resource Area, Doña Ana, Luna, Hidalgo, and Grant Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 424, 251 p.

McLemore, V. T., McIntosh, W. C. and Pease, T. C., 1995, ^{40}Ar/^{39}Ar age determinations of four plutons associated with mineral deposits in southwestern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 410, 14 p.

Newcomer, R. W., 1984, Geology, hydrothermal alteration, and mineralization of the northern part of the Sugarloaf Peak quartz monzonite, Doña Ana County, New Mexico [M.S. thesis]: Las Cruces, New Mexico State University, 108 p.

Newcomer, R. W. and Giordano, T. H., 1986, Porphyry-type mineralization and alteration in the Organ mining district, south-central New Mexico: New Mexico Geology, v. 8, p. 83–86.

Seager, W. R., 1981, Geology of the Organ Mountains and southern San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 36, 97 p.

Seager, W. R. and Brown, L. F., 1978, The Organ caldera; *in* Chapin, C. E. and Elston W. E., eds., Field guide to selected cauldrons and mining districts of the Datil-Mogollon volcanic field, New Mexico: New Mexico Geological Society, Special Publication 7, p. 139–149.

Seager, W. R. and McCurry, M., 1988, The cogenetic Organ cauldron and batholith, south-central New Mexico: evolution of a large-volume ash flow cauldron and its source magma chamber: Journal of Geophysical Research, v. 93, p. 4421–4443.

Soulé, J. H., 1951, Investigations of the Torpedo copper deposits, Organ mining district, Doña Ana County, New Mexico: U.S. Bureau of Mines, Report of Investigation 4791, 10 p.

View looking west of the northern end of the Robledo Mountains. The high cliffs are Pennsylvanian limestones and the lower cliffs are alluvial-fan and axial-fluvial sediment of the Plio–Pleistocene Camp Rice Formation. Photograph by Greg Mack.