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# MINERAL DEPOSITS IN EDDY COUNTY, NEW MEXICO, AND THEIR RELATIONSHIP TO KARST PROCESSES

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**Abstract.**—Mineral deposits in Eddy County are commonly hosted in voids present in carbonate rocks. The first reported commercial mining in Eddy County was of bat guano from Carlsbad Cavern in 1904. Since then, more than $7 billion worth of mineral production has come from 3 types of deposits in 5 mining districts in Eddy County. Only one of these districts, Carlsbad potash district, accounted for nearly all production from Eddy County. It is unlikely that the metal deposits in Eddy County will ever produce because of small size, low grade, remoteness from existing processing facilities, and location/proximity with National Forest and National Park lands. Currently only potash, salt, and aggregate pits (caliche, sand and gravel) are active, and production of these commodities is likely to continue in the future. Stable isotope studies by Hill (1995, 1996) and Lueth et al. (2005) suggest that $H_2S$ was likely derived from the biochemical reduction of sulfate from Permian evaporite sedimentary rocks, including the potash deposits in the Permian basin. The coincidence between the age determinations in Mississippi Valley-type and Rio Grande rift deposits in central New Mexico was likely a result of changes in elevation in the host rocks due to significant pulses of tectonic uplift during Rio Grande rifting.

## INTRODUCTION

Karst terrains provide ideal cavities for many types of mineral deposits. More than 80 mining districts in New Mexico, 5 of them in Eddy County, are in carbonate rocks and most have some indication of karst prior to, during, or after mineral deposition (McLemore and Lueth, 1996). Many of these deposits could not have formed without some karstification. Mineralization and alteration are strongly controlled by secondary porosity such as faults, fractures, brecciation, and dissolution features produced as a result of karstification. Furthermore, the evaporite and carbonate rocks in karst terrains are potential commodities themselves. New Mexico is known for large reserves of limestone, gypsum, potash, and halite. The Carlsbad potash district is the largest potash producing area in the United States; salt also is produced from the district. Limestone and caliche are quarried throughout New Mexico for aggregate, cement, concrete, crushed stone, dimension stone, and specialty uses. Guano (a source of nitrate) also was mined from caves throughout the Guadalupe Mountains in the late 1800s and early 1900s.

The purpose of this paper is to summarize the geology, geochemistry, and production of the mineral deposits in Eddy County (Tables 1, 2, Fig. 1) and relate the mineral deposits to karst processes. Only one of these districts is a significant, world class mineral deposit; the Carlsbad potash district. Detailed geology and stratigraphy of the districts are described elsewhere in this guidebook and in cited references. This work is part of ongoing studies of mineral deposits in New Mexico and includes updates and revisions of prior work by North and McLemore (1986, 1988), McLemore et al. (2005a), McLemore and Lueth (1996), New Mexico Bureau of Mines and Mineral Resources et al. (1998), and McLemore (2001).

Published and unpublished data were inventoried and compiled on existing mines and mills within Eddy County. Mineralized areas were examined and sampled in 1980-1982, 1997, and 2005. Information on the mining districts and individual mines are included in the New Mexico Mines Database (McLemore et al., 2005a, b). Metal mineral production by district in Eddy County since the late 1800s is listed by district in Table 2. Mining and production records are generally poor, particularly for the earliest times, and many early records are conflicting. Production figures are subject to change as new data are obtained.

## DESCRIPTION OF DEPOSITS

Three types of mineral deposits are found in Eddy County: potash, Mississippi Valley-type (MVT), and stratabound, sedimentary-copper deposits. The potash deposits are evaporite deposits found in Permian sedimentary rocks.

Mississippi Valley-type (MVT) deposits are low-temperature, predominantly lead/zinc deposits generally found in carbonate rocks near the margins of marine sedimentary basins without any

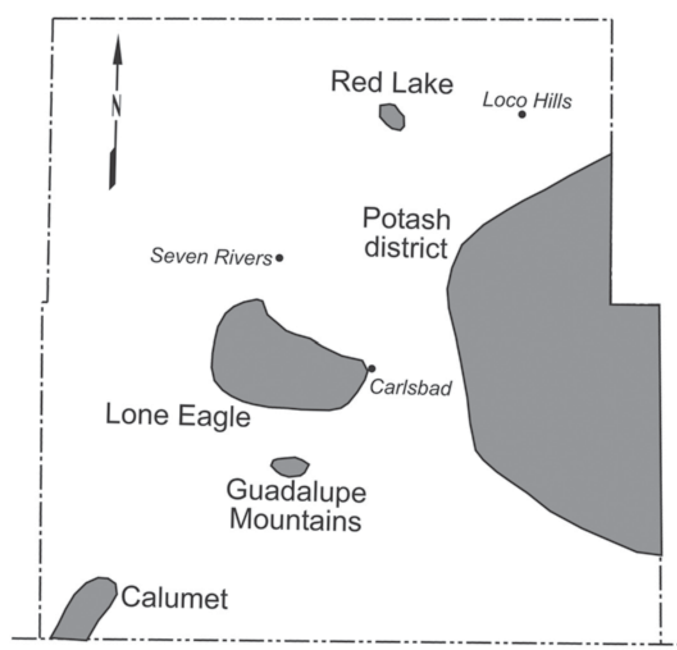


FIGURE 1. Mining districts in Eddy County, New Mexico.

TABLE 1. Mining districts in Eddy County, New Mexico. Names of mining districts are after File and Northrop (1966) wherever practical, but many districts have been combined and added. District identification number is from the New Mexico Mines Database (McLemore et al., 2005a, b). Estimated value of production is in original cumulative dollars and includes all commodities in the district, except aggregate (sand and gravel) and crushed and dimension stone. Production data complied from Lindgren et al. (1910), Anderson (1957), U. S. Geological Survey and Bureau of Mines Mineral Yearbooks (1900-1993), and Energy, Minerals and Natural Resources Department (1986-2003). Types of deposits are after North and McLemore (1986) and McLemore (2001). * district contains a significant deposit. Locations of districts are in Figure 1. Under commodities, commodities in parenthesis are occurrence only, other commodities listed were produced. Au-gold, Cu-copper, Pb-lead, Ag-silver, Zn-zinc, U-uranium.

| District Id Number | District Name (Aliases) | Year Of Discovery | Years Of Production | Commodities Produced (Present) | Estimated Cumulative Value Of Production (In Original Dollars) | Type Of Deposit | References |
|---|---|---|---|---|---|---|---|
| DIS038 | Carlsbad potash* (Lea County) | 1925 | 1931-present | potash, salt (halite, clay) | >7 billion | potash, salt | Barker and Austin (1996) |
| DIS037 | Calumet (extends into Texas) | 1900s | none | (Cu, Pb, Zn, Ag, Au) | — | Mississippi-Valley type, sedimentary copper (30b) | Hayes et al. (1983) |
| DIS039 | Guadalupe Mountains (Two Ladies) | 1900s | 1900s | Pb (Zn, Ag) | <1,000 | Mississippi-Valley type | Thompson (1983), Hill (1993, 1996) |
| DIS040 | Lone Eagle (Golden Eagle, Lucky Strike, Great Eagle, Ammon) | 1905 | 1905-1956 | Cu, Ag (U, Au) | 8,000 | sedimentary-copper, limestone uranium, Mississippi-Valley type, sandstone uranium | Soulé (1956), Motts (1962), Hill (1993, 1996) |
| DIS041 | Red Lake | ? | 1900s | Cu, Ag (Pb, Zn) | <1,000 | Mississippi-Valley type | North and Tuff (1986), Hill (1993), North and McLemore (1986) |

associated volcanic or intrusive activity. The Rio Grande Rift (RGR) barite-fluorite-galena deposits differ from MVT deposits by their smaller size, predominant barite and fluorite mineralogy, lack of predominant zinc minerals, and association with smaller, continental rift basins (McLemore and Lueth, 1996). Three oxidized MVT deposits are located adjacent to the Permian basin in southeastern New Mexico (North and McLemore, 1986, 1988; Hill, 1993, 1995, 1996; McLemore and Lueth, 1996; New Mexico Bureau of Mines and Mineral Resources et al., 1998; McLemore, 2001). The MVT deposits in New Mexico consist of open-space fillings in breccia zones with little or no replacement. The deposits are small, highly oxidized, and contain only minor amounts of lead, silver, and zinc; barite, gold and fluorite are rare to absent.

Geochemical and stable-isotope data suggest basin brines, possibly related to migration of oil and gas deeper within the basin during the Oligocene-Miocene uplift of the Delaware Basin, could have formed these MVT deposits (Hill, 1995, 1996). These deposits are similar to barite deposits at Seven Heart Gap in Culberson County, Texas, where a similar origin by basin brines is envisioned (McAnulty, 1980). Economic potential for base and precious metals in these deposits is low (North and McLemore, 1986, 1988; New Mexico Bureau of Mines and Mineral Resources et al., 1998; McLemore, 2001).

Stratabound, sedimentary-copper deposits containing Cu, Ag, and locally Au, Pb, Zn, U, V, and Mo are found throughout New Mexico, including Eddy County. These deposits have also been called "red-bed" or "sandstone" copper deposits by previous workers (Soulé, 1956; Phillips, 1960; Cox and Singer, 1986, #30b). They typically occur in bleached gray, pink, green, or tan sandstones, siltstones, shales, and limestones within or marginal to typical thick red-bed sequences of red, brown, purple, or yellow sedimentary rocks deposited in fluvial, deltaic or marginal-marine environments of Pennsylvanian, Permian, or Triassic age. The majority of sedimentary-copper deposits in New Mexico occur at or near the base of these sediments; some deposits such as those in the Zuni Mountains and Nacimiento districts, are in sedimentary rocks that unconformably overlie mineralized Proterozoic granitic rocks. The mineralized bodies

TABLE 2. Reported and estimated base and precious metals production by district in New Mexico. — no reported production. W withheld or not available. From Soulè (1956), North and McLemore (1986) and U. S. Geological Survey and U. S. Bureau of Mines Mineral Yearbooks (1900-1993).

| District Id Number | District | Years | Ore (Short Tons) | Copper (Lbs) | Silver (Oz) | Lead (Lbs) | Estimated Value ($) |
|---|---|---|---|---|---|---|---|
| DIS039 | Guadalupe | ? | — | — | — | W | <1,000 |
| DIS040 | Lone Eagle | 1905-1956 | 517 | 35,236 | 21 | — | 8,000 |
| DIS041 | Red Lake | ? | — | W | W | — | <1,000 |

typically occur as lenses or blankets of disseminated and/or fracture coatings of copper minerals, predominantly chalcopyrite, chalcocite, malachite, and azurite with local uranium minerals, galena, sphalerite, and barite. Ore minerals in these sedimentary-copper deposits are typically associated with organic debris and other carbonaceous material. Locally sedimentary features such as bedding, crossbedding, paleochannels, and intraformational slumping also appear to control mineralization. Copper and other metals were probably transported in low-temperature solutions through permeable sediments, along bedding planes, and along faults. Replacement textures and diagenetic features of the organic material indicate that mineralization occurred shortly after burial. Oxidizing waters could have leached copper and other metals from (1) Proterozoic rocks enriched in these metals, (2) Proterozoic base-metal deposits, and (3) clay minerals and detrital grains within the red-bed sequences (LaPoint, 1976, 1979, 1989; Brown, 1984). Sources for chloride and carbonate needed to form soluble cuprous-chloride or cuprous-carbonate and other metal complexes (Rose, 1976) occur in older Paleozoic evaporite and carbonate sequences. Transport of metal-bearing waters occurred laterally through aquifers from Proterozoic highlands or, in some cases, by circulating, ascending fluids (Brown, 1984). Geologic, mineralogic, and isotopic studies of similar deposits elsewhere in the United States suggest that these waters are in approximate chemical equilibrium with quartz, feldspar, hematite, and mica at temperatures less than 75°C (Rose, 1976). Precipitation occurred at favorable oxidation-reduction interfaces in the presence of organic material or $H_2S$-rich waters. Subsequent processes, such as ground water, intrusions (such as at Sacramento), and/or structural events may have modified, altered, or even destroyed some deposits (LaPoint, 1979). Most sedimentary-copper deposits are low grade, low tonnage, and inaccessible to existing mills for current development for copper. They are generally low in silica and are not suitable as silica flux material.

## DESCRIPTION OF MINING DISTRICTS

Small mineral deposits are found in 4 districts in the Guadalupe Mountains (Fig. 1, Table 1, 2). The mountain range consists of a gently folded and tilted fault-block of predominantly Pennsylvanian and Permian sedimentary rocks that is bounded by north-trending range-forming faults of Tertiary age. Fractures and joints are associated with anticlines and synclines in the area, which increased permeability and allowed mineralizing and barren fluids to migrate through the host rocks. Many caves formed along these channels. Currently, there are no active mines or any production from these deposits.

### Calumet mining district

#### Location and mining history

The Calumet district in southeastern Eddy County and northern Culberson County, Texas is located in the western Guadalupe Mountains southwest of the Carlsbad Caverns National Park (Fig. 1). The district includes numerous small mines in oxidized MVT deposits that lie within Guadalupe Mountains National Park in Texas (Table 3). Minor prospecting has occurred in the district since the early 1900s (Thompson, 1983; Hayes et al., 1983). The only known production was from the Calumet mines in Texas where in 1914 and 1926-1927, approximately 66 short tons of ore containing 5,256 lbs of copper and 3 oz of silver were mined (Lasky and Wootton, 1933; Thompson, 1983).

#### Description of mineral deposits

The largest copper deposits in the district are at the Calumet mines in Texas, where copper and iron oxide minerals occur in dolomites of the Seven Rivers Formation along dissolution cavi-

TABLE 3. Mines and prospects in the New Mexico portion of the Calumet mining district (DIS037). Cu-copper, Pb-lead, Zn-zinc.

| Mine Id Number | Mine Name (Alias) | Location (section, township, range) | Latitude, Longitude (decimal degrees) | Commodities | Development | Host | References |
|---|---|---|---|---|---|---|---|
| NMED0003 | Cottonwood Cave | NE6 26S 22E | 32.0777 104.7365 | Cu, Pb, Zn, guano | cave | Permian Seven Rivers Formation | Hill (1996) |
| NMED0004 | Devil's Den (Broken Horseshoe) | NW21 26S 21E | 32.0325 104.8065 | Zn, Cu | 3 pits, 18 m adit | Permian Yates and Seben Rivers Formations | Hill (1996), Thompson (1983), Light et al. (1985), VTM unpublished field notes (3/6/97) |
| NMED0005 | Fir Canyon | NE36 25S 21E | 32.0895 104.7513 | Pb | 2m adit, pit | Permian Seven Rivers Formation | Thompson (1983), Hill (1996) |
| NMED0006 | Guadalupe Ridge | NE33 25S 22E | 32.0897 104.7034 | pyrite | pit | limestone | |
| NMED0007 | Lonesome Ridge | NE13 26S 21E | 32.0430 104.7560 | | outcrop | Permian Yates Formation | Hill (1996) |
| NMED0008 | Lucky 13 (MC-TH-PI) | NW15 26S 21E | 32.1904 104.7934 | Cu, Zn | 7 m shaft | Permian Seven Rivers Formation | Hill (1996), Thompson (1983), VTM unpublished field notes (3/6/97) |
| NMED0009 | Queen of Guadalupe (Guadalupe) | NE1 26S 21E | 32.0463 104.7934 | Cu, Pb, Zn | 70 m shaft-cave | Permian Seven Rivers Formation | Hill (1996), Thompson (1983), Light et al. (1985) |

ties, joints, fractures, and bedding planes. Thin, mineralized zones occur along a graben formed by the Dog Canyon fault (King, 1948). Samples assayed no gold or silver, 0.01-11.6% Cu, 0.001-0.004 % Mo, 0.01-4.8% Pb, and 0.5->5% Zn (Thompson, 1983). Similar deposits are found at the Copper Queen mine, Guadalupe Ridge area, Fir Canyon, Mc-Th-Pi prospect, and Devil's Den prospect in New Mexico (Thompson, 1983; Corbetta, 1987).

At the Queen of the Guadalupe mine, azurite, malachite, bornite, and abundant iron oxides occur in small, irregular cavity-filling deposits in sandstone and limestone of the Seven Rivers Formation. The shaft intersects a nearly vertical limestone cave. Samples assayed as much as 0.006 oz/short ton Au, 0.004-0.01% Cu, 0.001-0.02% Mo, 0.02-0.05% Pb, and 0.1% Zn (Thompson, 1983). A brecciated jasperoid sample from near the contact between the Seven Rivers and Yates Formations in the Lonesome Ridge area, south of the Queen of the Guadalupe mine, contained 0.06 ppm Ag, 5 ppb Au, 0.365 % Zn, and 170 ppm Pb (Corbetta, 1987). Silica and iron oxides have cemented the breccia fragments, indicating brecciation prior to mineralization.

Rock and stream-sediment samples from the Guadalupe Escarpment area are enriched in zinc, cadmium, arsenic, lead, and molybdenum (Light and Domenico, 1983; Light et al., 1985; Hayes et al., 1983; Corbetta, 1987). These geochemical anomalies are found near the limestone-dolomite interface in algal-reef deposits at or near the contact between the Seven Rivers and Yates Formations and are similar to geochemical associations found in some MVT deposits (Hayes et al., 1983). Two samples were collected from the district and assayed for this report (sample no. VTM97-9R, 11R). The samples contained no Ag or Ba, 80-84 ppm As, 10-1300 ppm Pb, and 100-4600 ppm Zn. One sample contained 9 ppb Au. These concentrations are uneconomic.

## GUADALUPE MOUNTAINS DISTRICT

### Location and mining history

Oxidized MVT deposits are found in the Guadalupe Mountains (Two Ladies) district in the eastern Guadalupe Mountains, southeastern Eddy County (Table 4, Fig. 1). Carlsbad Caverns National Park lies to the north and Guadalupe Mountains National Park lies to the southwest of the district. Minor prospecting has occurred in the district since the early 1930s. There is no known production from the district.

### Description of mineral deposits

Only three deposits are known; the Jurnigan gossan (Hill, 1996), Wallace Smith, and Two Ladies prospects (North and McLemore, 1986). The largest deposit is at the Two Ladies prospect, where a pod-shaped deposit approximately 30 m long replaces brecciated and vuggy limestone. The deposit consists of iron oxides, trace galena, trace smithsonite, trace hemimorphite, calcite, and quartz. Iron oxides, silica, and galena cement the breccia fragments, indicating brecciation prior to mineralization. Samples contained 0.32-2.34 oz/ton Ag and 27% Zn (Robert North, personal communication, 1993). Two samples were collected from the district and assayed for this report (sample no. VTM97-8R, 10R). The samples contained no silver, 62-80 ppm As, 10-3400 ppm Pb and 100-3100 ppm Zn. These concentrations are uneconomic. The other two deposits are smaller than the Two Ladies and consist of primarily iron oxides, calcite, and quartz.

## Lone Eagle mining district

### Location and mining history

The Lone Eagle mining district northwest of Carlsbad (Fig. 1, Table 5) is named after the Lone Eagle mine. It is also known as Lucky Strike, Golden Eagle and Ammon property. Numerous additional small brecciated zones contain iron oxides and may represent small, oxidized MVT deposits. Small uraniferous limestone and sandstone occurrences also are found throughout the district (Table 5).

### Description of mineral deposits

The Lone Eagle mine is the largest of the sedimentary-copper deposits in the district, and occurs in sandstones of the Yates Formation (Motts, 1962). Malachite, azurite, and chalcocite are disseminated throughout the sandstone as cements, replacements of grains, and coatings on fracture surfaces. The deposit is predominantly copper (as much as 2.51% Cu; Hill, 1996) with minor concentrations of lead (2590 ppm Pb; Hill, 1996) and uranium (0.004% $U_3O_8$; McLemore, 1983).

The Yates and Seven Rivers Formations contain small MVT deposits consisting of iron oxides, calcite, local marcasite, and smithsonite in brecciated and altered limestones and dolomites.

TABLE 4. Mines and prospects in Guadalupe Mountains mining district (DIS039). Cu-copper, Pb-lead, As-arsenic, Zn-zinc.

| Mine Id number | Mine Name (Alias) | Location (section, township, range) | Latitude, Longitude (decimal degrees) | Commodities | Development | Host | References |
|---|---|---|---|---|---|---|---|
| NMED0010 | Jurnigan gossan | SW8 24S 26E | 32.2288 104.3191 | Pb, Cu, As, Zn | pit | Permian Tansill Formation | Hill (1996) |
| NMED0011 | Two Ladies (Mosley Spring) | NE SE32 23S 25E | 32.2597 104.4138 | Cu, Pb, Zn | 4 shafts, 3-8.2 m deep, pits | Permian Yates Formation | North and McLemore (1986), Hill (1996), VTM unpublished field notes (3/7/97) |

TABLE 5. Mines and prospects in the Lone Eagle mining district (DIS040). Cu-copper, Pb-lead, Ag-silver, U-uranium, Fe-iron.

| Mine Id Number | Mine Name (Alias) | Location (section, township, range) | Latitude, Longitude (decimal degrees) | Commodities | Development | Host | Type Of Deposit | References |
|---|---|---|---|---|---|---|---|---|
| NMED0012 | Dark Canyon pyrite-macarsite | NE34 23S 25E | 32.2638 104.3785 | Fe | outcrop | Permian Seven Rivers Formation | Mississippi Valley type | Hill (1996) |
| NMED0014 | Little Watt | SW2 22S 24E | 32.4175 104.4709 | U, Cu | 8.2 m shaft | Permian Yates Formation | sedimentary copper (?) | McLemore (1983), Hill (1993, 1996) |
| NMED0013 | Golden Eagle (Lucky Strike, Lone Eagle, Ammon, Great Eagle) | SW14 21S 25E | 32.476 104.3713 | Cu, U, Pb, Ag | 6.2 m pit, 8.2 m decline caved | Permian Yates Formation | sedimentary copper | McLemore (1983), Hill (1993, 1996), Soule (1956), VTM unpublished field notes (11/18/81, 3/7/97) |
| NMED0017 | Middle Fork Waterhole marcasite | NE16 22S 25E | 32.3947 104.3956 | Fe | outcrop | Permian Yates, Tansill Formation | Mississippi Valley type | Hill (1996) |
| NMED0018 | Rocky Arroyo (Tepee, Pitts and Price, Jr.) | SE26 21S 24E | 32.4471 104.4728 | U, asphalt | 20 m adit | Permian Seven Rivers Formation | uraniferous limestone | McLemore (1983), Hill (1993, 1996), Motts (1962), VTM unpublished field notes (3/8/97) |
| NMED0019 | Unknown | NE24 21S 24E | 32.4674 104.4452 | U, asphalt | Outcrop at road cut | Permian Seven Rivers Formation | uraniferous limestone | McLemore (1983) |
| NMED0020 | W.R. Shaffer Ranch | 27 21S 24E | 32.4499 104.4849 | U(?) | 2 pits reported | Permian Queens Formation | sandstone uranium | McLemore (1983), VTM unpublished field notes (11/18/81) |
| NMED0016 | Living Desert | SE27 21S 26E | 32.4442 104.2774 | Fe | 7 m trench, 3.2 m adit, 3 m shaft | Permian Seven Rivers Formation | Mississippi Valley type | VTM unpublished field notes (3/7/97) |
| NMED0015 | Living Desert | NE34 21S 26E | 32.4406 104.2768 | Fe | 3.2 m adit | Permian Seven Rivers Formation | Mississippi Valley type | VTM unpublished field notes (3/7/97) |

Two samples were collected from the district and assayed for this report (sample no. VTM97-12R, 18R). The samples contained <0.5-1.4 ppm Ag, 6-10 ppm As, 19-45 ppm Pb, 31.5-13,300 ppm Cu, and 13-170 ppm Zn. These concentrations are uneconomic.

### Red Lake mining district

#### Location and mining history

The Red Lake (Caprock Escarpment) district, east of Artesia (Fig. 1) consists of oxidized MVT deposits. Several pits, an open cut, and two shafts (9 m and 10 m deep) have been developed on the property. Total production is unknown, but the district is reported to have produced copper, silver, and possibly lead and zinc (Anderson, 1957).

#### Description of mineral deposits

Mining activity in the Permian Rustler and Salado Formations has exposed small replacement pods and fracture fillings in breccias and cavity fillings. These deposits consist of chrysocolla, malachite, wulfenite, bornite, hemimorphite, anglesite, and descloizite in a gangue of quartz, calcite, dolomite, kaolinite, barite, goethite, and iron oxides (North and Tuff, 1986). Small pods of minor copper minerals occur disseminated throughout the adjacent sandstone. Most deposits are less than 1.2 m thick and less than 15 m long. Seven samples were collected and assayed for this report (sample no. VTM97-1R-7R). The samples contained <0.5-100 ppm Ag, 27-250 ppm As, 7-110 ppb Au, 140-64,000 ppm Pb, and 530->10,000 ppm Zn. These concentrations could indicate economic mineralization if the deposit was of significant size.

## INDUSTRIAL MINERALS

### Carlsbad potash district

The Carlsbad potash district in eastern Eddy and western Lea Counties (Fig. 1) is the largest potash producing area in the U. S. Potash occurs in Permian evaporite beds of the Salado Formation with approximately 600 m of evaporite deposits formed during the late stages of Permian basin sedimentary fill. Ore minerals include sylvite (KCl) and langbeinite ($K_2SO_4Ca_2MgSO_4$). Fluid inclusion data indicates deposition of langbeinite occurred at average temperatures of 71°C (Lowenstein and Spencer, 1990) and was syndepositional or early diagenetic (approximately 251 Ma) (Lowenstein and Spencer, 1990; Renne et al., 2001).

Intrepid Mining LLC and Mosaic Company currently operate potash mines in the district. Potash is used as fertilizer in agricultural markets and as a chemical in specialty and industrial markets. Mining is by underground methods. These deposits have been described in numerous reports, the most recent one by Barker and Austin (1996). The estimated potash reserves in the district amount to >553 million short tons. United Salt Corp. operates a solar evaporation salt production plant near Carlsbad (United Salt Corp., 2006). Salt is used in oil field drilling, animal feed, and to de-ice roads.

Mosaic Company, formed in 2004 from the combination of Gargill Crop Nutrition and IMC Global, is the world's largest potash and phosphate producer (Mosaic Company, 2005) with a capacity of 500,000 metric tons of red potash and 1,200,000 metric tons of K-Mag (langbeinite). In 2004, Mosaic produced 3,200,000 metric tons of muriate from ore containing 12.6% $K_2O$ of potash and 3,100,000 tons of ore containing 7.4% $K_2O$ of K-Mag (Mosaic Company, 2005). The reserves at Mosaic include an estimated total of 151.4 million short tons of potash ore in three mining beds with thickness ranging from 1 to >3 m. These ore reserves are estimated to yield 8.9 million tons of concentrate from sylvanite with an average grade of 60% $K_2O$ and 30.4 million tons of langbeinite concentrate with an average grade of approximately 22% $K_2O$. These reserves are expected to last 15-23 years (IMC Global Inc., 2003).

Intrepid Mining New Mexico LLC, aquired Mississippi Potash, Inc. and Eddy Potash, Inc., (which includes four potash properties in Carlsbad, New Mexico) for $27.4 million in 2004 and became the largest potash producer in the United States (Intrepid Mining, 2004). Intrepid employs approximately 650 people at 3 facilities in New Mexico. The West Facility, which consists of a potash mine and refinery, was originally built in 1929 by U.S. Potash and has an annual production capacity of approximately 538,000 short tons of red potash. The East Facility, which has an annual production capacity of approximately 560,000 short tons of white potash, consists of a potash mine, refinery, and compaction plant. The North facility consists of a granular compaction plant and storage facilities (Intrepid Mining, 2006). Two types of ore are processed. Flotation is used to produce red potash and hot leach crystallization is used to produce the higher purity white potash. Intrepid announced its intention to produce langbeinite by modifying the Carlsbad East potash plant to become the second langbeinite producer in the U. S. Intrepid also plans to convert the Eddy potash mine to solution mining by 2007. Sodium salt (NaCl) also is produced locally as a by-product. Intrepid is investigating in situ leaching technologies for potential use in the future.

### Other industrial minerals deposits

In 1903, Abijah Long filed a mining claim at Carlsbad Cavern and by 1904 began blasting shafts to mine bat guano (accumulations of bat excrement rich in phosphates and nitrates) by 1904. From 1904 – 1925, approximately 100,000 short tons of guano were mined from the main cave at Carlsbad Caverns National Park for use as fertilizer in the California orange groves and as nitrate for the manufacture of gunpowder (Bailey, 1925; National Park Service, 1997). Guano production also was reportedly produced from New Cave (now known as Slaughter Canyon Cave) (Hayes, 1965). It was during this early mining period that Jim White, working for the mining companies, realized the uniqueness of the caverns and initiated a series of events that ultimately led to the designation of the caverns as Carlsbad Cave National Monument in 1923. Mining of guano ceased soon thereafter.

Aggregate (sand, gravel, and crushed rock) is used for base course in highways, railroad abutments, and in cement, concrete, and blacktop. Aggregate pits are often found near highways or urban areas to minimize transportation costs. Sand and gravel deposits are typically formed by alluvial processes.

## RELATIONSHIP TO KARST PROCESSES

The MVT deposits in Eddy County typically are small, low grade, and related to cave formation in the Guadalupe Mountains. Mineralization and alteration in these deposits were strongly controlled by secondary porosity such as faults, fractures, brecciation, irregular cavities and dissolution features produced by dissolution of the host rock (karstification) that occurred prior to or during mineralization. Cementation of breccia fragments by quartz, iron oxides and other minerals indicates that brecciation formed prior to mineralization. Silicification of wall rocks is mostly absent in the MVT deposits of Eddy County, indicating the lack of high metal-bearing hydrothermal fluids (Lueth et al., 2005), which is consistent with their relatively simple mineralogy and chemistry (Tables 3, 4, 5). The similarity in mineralogy, chemistry, and deposition as cements and grain coatings, as well as the close proximity to MVT deposits, suggests that the sedimentary-copper deposits at Lone Eagle could be the equivalent of MVT deposits in the sandstone hosts and formed from similar basin fluids.

Stable isotopes indicate that the caves in the Guadalupe Mountains probably formed by the interaction of $H_2S$ with oxygenated ground water (Hill, 1995, 1996). $H_2S$ was likely derived from the biochemical reduction of sulfate from Permian evaporites, including the potash deposits (Hill, 1995, 1996; Lueth et al., 2005), which is consistent with some younger age determinations of langbeinite by Renne et al. (2001). Age determinations of alunite from Carlsbad Cavern and other caves in the Guadalupe Mountains indicate that hypogene cave formation occurred 11.6 to 3.9 Ma and was related to a change in position of the water table as the mountain range was tectonically uplifted (Polyak et al., 1998). Lueth et al. (2005) found a similar range in ages (10 to 0.4 Ma) for Rio Grande rift barite-fluorite deposits in central New Mexico and concluded that the coincidence between the ages in both types of deposits was a result of changes in elevation in the host rocks due to significant pulses of tectonic activity and uplift associated with Rio Grande rifting that affected southern New Mexico and adjacent areas.

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