USE OF THE NEW MEXICO MINES DATABASE IN RECLAMATION STUDIES[1]

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Abstract. The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has been collecting data on mining districts, mines, mills, and mineral deposits since it was created in 1927. The NMBGMR has been slowly converting years of historical data into an electronic relational database that eventually will be available on the Web or Internet, as funding becomes available. The database includes information on mining districts, mines, mills, chemistry, photographs (both recent and historic), and bibliography. The available data includes location, production, reserves, geologic, geochemical, resource potential, mining, ownership, and other data. The database is comprised of eight main tables that store data for mines, mining districts, samples, drillhole, waterwells, county, photographs, and projects, with more than 70 supporting tables. Each of these eight tables is linked to the others, where appropriate, and all the supporting tables are linked to one or more of these eight main tables. Once data are entered into appropriate tables and keyed to location, the data can be converted easily to GIS format for displaying on maps. The mine locations are keyed to specific points defined by latitude and longitude, whereas the districts are keyed to polygons. The purposes of this database are to provide computerized data that will aid in identifying and evaluating resource potential, resource development, management, and production, and possible environmental concerns. Environmental concerns include physical hazards (for example hazardous mine openings), indoor radon, regional exposure to radiation from the mines, and point sources of possible pollution in areas of known mineral deposits. These data will be useful to the State of New Mexico, as well as other government agencies to support informed land-use decisions.

ADDITIONAL KEY WORDS: GIS, database, economic geology, mining districts, Access 97

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[1]Paper was presented at the 2003 National Meeting of the American Society of Mining and Reclamation and the 9th Billings Land Reclamation Symposium, Billings MT, June 3-6, 2003. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2003 pp 795-808

DOI: 10.21000/JASMR03010795

https://doi.org/10.21000/JASMR03010795

Introduction

The NMBGMR has collected published and unpublished data on New Mexico's mines, mining districts, deposits, mineral occurrences, and mills since it was created in 1927 and is converting historical data into a relational database, the New Mexico Mines Database, using Microsoft Access 97. The purposes of this database are to provide computerized data to assist in:

- identifying and evaluating resource potential
- resource development, management, and production
- possible environmental concerns, such as physical hazards (e.g. hazardous mine openings), indoor radon, regional exposure to radiation from the mines, and point sources of possible contamination in areas of known mineral deposits.

These data will be useful to federal, state, and local government agencies, public organizations, private industry, and individual citizens in order to make better land-use decisions. These data are particularly useful in identifying mine sites in a given area and examining the potential for that mine site to contribute metals and/or other contaminants to the watershed.

The goal of the New Mexico Mines Database is to provide the best data available on mines and mining districts in New Mexico. Only public data is incorporated into the database, in order to protect some company data that is confidential. New information is continuously becoming available and will be incorporated into the database as funding permits. The New Mexico Mines Database includes updates of databases previously released by NMBGMR (McLemore et al., 2001, 2002).

The New Mexico Mines Database

Eight main tables comprise the New Mexico Mines Database (Appendix 1): Mines, Districts, Samples, Drillhole, Waterwells, County, Photographs, and Projects, with more than 70 supporting tables (available by request from the senior author). Each of these tables is linked to the others, where appropriate, and all the supporting tables are linked to one or more of these eight main tables. Additional tables of data can be added as long as the new table is linked to one of the eight main tables by the appropriate key attribute. Thus, the New Mexico Mines Database is constantly evolving to meet the needs of the users.

The Mines table and supporting tables provide information on the mines, quarries, mineral deposits, mineral occurrences, and mills located in New Mexico, and is defined by the mine id. The mine id is a unique number consisting of a prefix NM (for New Mexico), a two-letter abbreviation that represents the county followed by a unique number. Mine id is the key attribute used to link all appropriate supporting tables to the Mines table. The term *mine* is defined here as any prospect, mineralized outcrop, altered area, quarry, mine working, mill, smelter, or other mining-related facility, including geothermal wells and other mineral wells, but excluding petroleum wells. Altered and mineralized areas are included where known even if never mined or developed, because these areas have particular importance in terms of mineral resource development and/or environmental impacts.

A *mineral occurrence* is any locality where a useful mineral or material occurs. A *mineral prospect* is any occurrence that has been developed by underground or above ground techniques or by subsurface drilling to determine the extent of mineralization. The terms mineral occurrences and mineral prospects do not have any resource or economic implications. A mineral deposit is any occurrence of a valuable commodity or mineral that is of a sufficient size and grade (concentration) that might under past, present, or future favorable conditions has potential for economic development. An *ore deposit* is a well-defined mineral deposit that has been tested and found to be of sufficient size, grade, and accessibility to extract and process metals or other commodities at a profit at a specific time. Thus, the size and grade of an ore deposit changes as the economic conditions change. Mineral deposits and especially ore deposits are not found just anywhere in the world. Rather they are relatively rare and depend upon certain natural geologic conditions to form. The requirement that an ore deposit must be extracted at a profit makes them even more rare.

The District table provides information on mining districts, coal fields, or mineralized geographical areas as defined by File and Northrop (1966), North and McLemore (1986), McLemore and Chenoweth (1989), Hoffman (1996), and McLemore (2001) and is defined by the district id. The district id is a unique identification number with prefix of DIS. District id is the key attribute used to link all appropriate supporting tables to the District table. The term *mining district*, as used in this report, is a group of mines and/or mineral deposits that occur in a geographically defined area and locally are defined by geologic criteria (mineralogy, lithology, stratigraphic horizons, structural features, etc.). The names of mining districts as established by

File and Northrop (1966) are used wherever possible, but many districts have been combined and new districts have been added. There are 266 districts in the database. Not all mines are included in mining districts; many mines, especially industrial minerals deposits and aggregate deposits, are not recognized as separate districts. *Industrial minerals* are any rock, mineral, or other naturally occurring material of economic value, excluding metals and energy minerals. These include perlite, pumice, gypsum, salt, mica, aggregates (crushed stone, sand and gravel), zeolite, calcite, both silica and chemical limestone flux, mineral desiccants, feldspar, clay, humate, and semi-precious gemstones.

The Samples table provides information on samples and geochemical data collected at a mine or within a district. Sample and geochemical data are keyed to both a field id and a sample id. The field id is a unique field identification number. The sample id is a unique sample identification number, and in many cases may be identical to the field identification number. Sample id is the key attribute used to link all appropriate supporting tables to the chemistry tables. Some samples are split into two or more size fractions after collection, thus requiring a separate unique sample identification number, but the same field identification number. Other supporting tables include information on sample preparation, QA/QC, laboratory, method of analysis, upper and lower detection limits, chain of custody, and other data.

The Drillhole table provides information on the location, driller, and ownership of drill holes, including waterwells in a district or at a mine site. The Drillhole table is linked to the chemistry, stratigraphy, and other supporting tables by the Hole id (key attribute).

The Waterwells table provides information on ground water, including well construction, down hole geology, water level, and hydraulics data, and is linked to the Drillhole, stratigraphy, chemistry, and other supporting tables by the Hole id (key attribute).

The County table provides a list of counties in New Mexico, and is constructed as a drop down table (or lookup table) in the Districts, Mines, Samples, Drillhole, Waterwells, Projects, and Photographs tables. The county abbreviation is the key attribute that links the county table with all other appropriate tables. County production is linked to the county table. Please note that in 1983, Valencia County was split into two separate counties, Cibola County to the west and Valencia County to the east. The database reflects the current county, but earlier literature and file data refers to the original county designation.

The Photographs table provides data on the source, date, and captions for historic and recent photographs of mines and mining districts in New Mexico. Photographs of sample sites and samples also are included in some instances. The actual photographs are stored as jpeg files. The Photograph id is the key attribute that links the photographs to the other tables.

The Projects table provides information on NMBGMR projects. Project id is the key attribute that links the projects tables to the other tables.

Available Data

The available data for this database are from a variety of published and unpublished reports and miscellaneous files in the NMBGMR mining archives, and include information on location, production, reserves, resource potential, significant deposits, geology, geochemistry (rock, water, etc.), well data, historical and recent photographs, mining methods, maps, ownership, and other data. Since the database includes location information, the database can be added to GIS and incorporated with other GIS layers and databases, such as the New Mexico Geochronology database, the New Mexico Petroleum database, geologic maps, topography, igneous rocks database, geophysical data, and remote sensing.

Quality Control

The most difficult task is maintaining quality control of both the data being entered into the database and of the database itself. *Quality control* (QC) is a system of procedures, checks, audits, and corrective actions to ensure that data are collected, stored, and analyzed in an acceptable manner, and that technical aspects and reporting are adequate. The main objectives of a QC program are to:

- document the procedures for data collection, preparation, and analysis
- provide assurance as to precision and accuracy of chemical analyses using replicate samples, cross-laboratory checks, and certified reference materials
- provide information regarding data analysis and interpretation
- define an acceptable magnitude of error on chemical analyses
- determine completeness of the data set
- define the decision-making process to be used

- provide a chain of custody of samples when required.

All of these objectives can be met with relational databases such as the New Mexico Mines Database.

NMBGMR staff and students and will input data into the database (ACCESS 97), which can then be converted into GIS format. NMBGMR staff will check the database as it is being developed to ensure that data are being entered accurately. NMBGMR staff will check the accuracy of the locations of the mines using USGS topographic quadrangle maps and GIS.

Misuse Of Data

One of the concerns about releasing these data is that the general public will have ready access to locations of inactive mines. **Recreation in or around inactive mine sites is extremely dangerous, and can result in serious injury or death.** According to MSHA (Mine Safety and Health Administration) statistics, 106 fatalities involving non-employees have occurred since 1999 at inactive mines throughout the U.S., including 28 through September 2002. **Stay out and stay alive!**

Chemical data provided in the New Mexico Mines Database must be used with extreme caution. Although we strive to provide accurate and complete data, problems may still exist. Rarely do these data meet regulatory and statutory regulations and requirements that are required by government agencies at mine sites. This geochemical database can not be used in place of those regulations and statutory requirements. Many of the solid chemical data reported represent select, high-grade samples from the mine and are not always representative of the mineral deposit. The chemical data originate from a variety of sources, agencies, and individuals, as cited, and thus reflect variable unknown quality in many cases.

Production and reserve data also are provided in the database and must be used with caution. Mining production records and reserve data are generally of poor quality, particularly for the earliest times and many early records are conflicting. These production and reserve figures represent the best data available and were obtained from published and unpublished sources (NMBGMR file data). However, production figures and reserve data are subject to change as new data are obtained. Specific questions regarding chemical, production, and reserve data should be sent to the senior author.

Integration of the New Mexico Mines Database with the USGS Geoenvironmental Mineral Deposit Models

The geologic characteristics that geologists use to understand and classify mineral deposits also are important keys to understanding the effects of mineral deposits on the environment. These include mineralogy (most important is the amount and form of pyrite), host rock lithology, metal association, and geochemistry. The New Mexico Mines Database includes this information on a district and mine scale, wherever the data are available.

Numerous classifications have been applied to mineral deposits to aid in exploration and evaluation of metallic resources (Lindgren et al., 1910; Lindgren, 1933; Eckstrand, 1984; Guilbert and Park, 1986; Cox and Singer, 1986; Roberts and Sheahan, 1988; Sheahan and Cherry, 1993). Early classifications were based on the form of the deposit or a combination of form and perceived chemical conditions of formation, such as Lindgren's (1933) classification of mineral deposits associated with igneous rocks into epithermal, mesothermal, and hydrothermal. In the 1960s and 1970s, wide acceptance of plate tectonic theories led to the recognition that similar mineral deposits occur in areas of similar tectonic settings and resulted in classifications of mineral deposits according to tectonic settings (Sillitoe, 1972, 1981; Guilbert and Park, 1986). In the 1980s, mineral deposit models became popular, which incorporated tectonic setting and physical and chemical characteristics of the deposits (Cox and Singer, 1986; Roberts and Sheahan, 1988; Sheahan and Cherry, 1993). In New Mexico, North and McLemore (1986, 1988) and McLemore (2001) classified the silver and gold deposits of New Mexico according to age, mineral assemblages, form, alteration, tectonic setting, and perceived origin. This classification, with a few modifications and numerous additions, is retained in the New Mexico Mines Database (Table 1) and can be easily related to the USGS geoenvironmental mineral deposit models (du Bray, 1995), which provide geologic information that can be used to better understand, predict, minimize, and remediate potential environmental effects of mineral resources.

Table 1. Types of metallic mineral deposits in New Mexico (after North and McLemore, 1986, 1988; Cox and Singer, 1986; McLemore and Chenoweth, 1989; McLemore and Lueth, 1996; McLemore, 2001).

NMBMMR Classification	USGS Classification (USGS model number)	Commodities
Volcanogenic massive-sulfide (VMS)	Volcanogenic massive-sulfide (24a,b, 28a)	Au, Ag, Cu, Pb, Zn
Pegmatite (1.6-1.2 Ga)	Pegmatite (13a-h)	Be, Li, U, TH, REE, Nb, Ta, W, mica, feldspar (Sn)
Vein and replacement deposits in Precambrian rocks	Polymetallic veins, fluorite veins (22c, 26b)	Au, Ag, Cu, Pb, Zn, Mn, F, Ba
Syenite/gabbro-hosted Cu-Ag-PGE	None	Cu, Ag, PGE
Disseminated Y-Zr deposits in alkaline rocks	Alkaline complex associated zircon (11c)	Y, Zr, REE, U. Th
Carbonatite	Carbonatite (10)	REE, U, Th, Nb, Ta, Zr, Hf, Fe, Ti, V, Cu, apatite, vermiculite, barite
REE-Th-U veins in alkaline rocks	Th-REE veins (10b, 11d)	REE, U, Th, Nb, Ta
Sedimentary iron deposits	Oolitic iron (34f)	Fe
Sedimentary-copper deposits	Sediment-hosted copper (30b)	Cu, Ag, Pb, Zn, U, V
Limestone uranium deposits	none	U, V
Sandstone uranium deposits	Sandstone uranium (30c)	U, V, Se, Mo
Collapse-breccia pipe and clastic plug deposits	Solution collapse breccia pipe uranium (32e)	U, V, Se, Mo
Beach placer sandstone deposits (Th, REE, Zr, Ti, U, Fe, Nb, Ta)	Shoreline placer Ti (39c)	Th, REE, Zr, Ti, U, Fe, Nb, Ta
Sandstone hosted lead-zinc	Sandstone hosted lead-zinc (30a)	Pb, Zn
Replacement iron	Iron skarn (18d)	Fe
Porphyry Cu, Cu-Mo (±Au) (75-50 Ma)	Porphyry copper (17, 20c, 21a)	Cu, Mo, Au, Ag
Laramide Cu, Pb, Zn, Fe skarn (75-50 Ma)	Skarn (18a, 18c, 19a)	Au, Ag, Cu, Pb, Zn
Laramide vein (75-50 Ma)	Polymetallic veins (22c)	Au, Ag, Cu, Pb, Zn
Porphyry Mo (±W)	Porphyry Mo-W (16, 21b)	Mo, W, Au, Ag
Mo-W-Be contact-metasomatic deposits	W-Be skarns (14a)	Mo, W, Be, Pb, Zn, Cu
Carbonate-hosted Pb-Zn (Cu, Ag) replacement	Polymetallic replacement (19a)	Pb, Zn, Cu, Ag
Carbonate-hosted Ag-Mn (Pb) replacement	Polymetallic replacement, replacement manganese (19a, b)	Ag, Mn, Pb, Zn
Copper-lead-zinc skarns	Copper-lead-zinc skarns (18b, c)	Cu, Pb, Zn
Great Plains Margin (alkaline-related) (1) polymetallic, epithermal to mesothermal veins (2) gold-bearing breccia pipes and quartz veins (3) porphyry Cu-Mo-Au (4) Cu, Pb/Zn, and/or Au skarns or	Copper porphyry, polymetallic veins, copper skarns, iron skarns, placer gold (17, 22c, 18a,b, 18d, 39a)	Au, Ag, Cu, Pb, Zn, Mn, F, Ba, Te

carbonate-hosted replacement deposits (5) Fe skarns and replacement bodies (6) placer gold (7) Th-REE-fluorite and Nb epithermal veins, breccias, and carbonatites		
Volcanic-epithermal vein	Quartz-adularia, quartz-alunite, epithermal manganese (25b,c,d,e,g, 26b, 35a)	Au, Ag, Cu, Pb, Zn, Mn, F, Ba
Rhyolite-hosted tin	Rhyolite-hosted tin (25h)	Sn
Tin greisen	Tin greisen (15c)	Sn
Tin veins	Tin veins (15b)	Sn
Tin-polymetallic veins	Tin-polymetallic veins (20b)	Sn, Fe
Tungsten veins	Tungsten veins (15a)	W
Barite-fluorite veins	Barite-fluorite veins (27e)	Ba, F
Fluorite veins	Fluorite veins (IM26b)	F
Volcanogenic uranium	Volcanogenic uranium (25f)	U
Carbonate-hosted Mn replacement	Replacement Mn (19b)	Mn
Epithermal Mn	Epithermal Mn (25g)	Mn
Copper-silver (±U) vein deposits	Polymetallic veins (22c)	Cu, Ag, U
Mississippi Valley-type (MVT) (here restricted to Permian Basin)	Mississippi Valley-type (MVT) (32a-d)	Cu, Pb, Ag, Zn, Ba, F
Rio Grande Rift barite-fluorite-galena (formerly sedimentary-hydrothermal)	Fluorite and barite veins, polymetallic replacement (IM26b, c, 27e, 19a)	Ba, F, Pb, Ag, U
Surfical uranium deposits	None	U, V
Placer tungsten	None	W
Placer tin	Stream placer tin (39e)	Sn
Placer gold	Placer gold-PGE (39a)	Au, Ag

Geoenvironmental models provide one method of developing site conceptual models and identifying potential water quality impacts based on characteristics of the mineral deposit. A geoenvironmental model is a compilation of geologic, geochemical, geophysical, hydrologic, and engineering information pertaining to environmental behavior of geologically similar mineral deposits prior to mining, and resulting from mining, mineral processing, smelting, and refining (Plumlee and Nash, 1995; Plumlee et al., 1999). Geologic data are compiled, including deposit type, related deposit types, deposit size, host rocks, surrounding geologic terrane, wall rock alteration, nature of ore, mining and ore processing methods, deposit trace element geochemistry, primary mineralogy and zonation, secondary mineralogy, soil and sediment signatures, topography, hydrology, drainage signatures, climatic effects, and potential environmental concerns (Plumlee, 1999; Plumlee et al., 1999). The New Mexico Mines Database contains information, where available, on mine sites that can be used in conjunction with the geoenvironmental models to better understand, predict, minimize, and remediate possible environmental impacts at a mine site or within a mining district. Thus, sites can be initially assessed by determining site characteristics and comparing them with previously determined relationships between similar characteristics and their potential for adverse impacts on water quality. Ultimately each site needs to be characterized and evaluated separately to adequately determine if the mine site is affecting the environment, but the geoenvironmental mineral deposit models provide a first-cut understanding of the potential environmental effects.

Environmental Applications

The New Mexico Mines Database provides detailed information in specific fields on the mineralogy, host rock lithology, and metal association of each mine or mining district. The database also includes limited geochemical data of both solid (host rock, ore, mine wastes, tailings, stream sediments, etc.) and water (surface, ground, pit lakes, etc.) samples.

Goals of the database, with respect to environmental applications are:

- identify mine sites and types of deposits within a given area
- provide a history of previous study including the nature and extent of work conducted at a given mine site or facility in New Mexico
- quickly guide an investigator or an agency regulator to relevant information regarding a site
- provide the information necessary to focus a study on the most relevant issues to maximize time and expenditure
- provide a medium where accumulated data may be of use for numerous purposes not limited to permit applications, environmental assessments, human and ecological risk assessments, mine closure, mine plans of operation, academic research, and industrial evaluation.

The suitability of the data should be evaluated in the context of the purpose of the investigator. The NMBGMR has and is compiling data from the numerous sources at its disposal. The user is responsible for understanding the specific QA/QC and other documentation requirements of the investigation being conducted and the data should be used appropriately. Numerous references used in the development of the database are available in the New Mexico Bibliography kept by the NMBGMR. This provides an opportunity for the investigator to locate reports for further consulting, if desired.

Acknowledgements

Funding for this project was provided directly or indirectly by a variety of sources. Funding for inputting uranium data into a GIS compatible computerized database was provided in part by the U. S. Environmental Protection Agency (McLemore et al., 2002). The New Mexico State Land Office funded a minerals-resource assessment of Luna County (McLemore et al., 2001). The USGS funded a minerals deposit and mining district map of New Mexico. The Army Corps of Engineers funded the input of data into the database for Sierra and Otero Counties. This work is part of ongoing research on the mineral resources in New Mexico at NMBGMR, Peter Scholle, Director and State Geologist.

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APPENDIX 1: Simplified design of the New Mexico Mines Database, showing the relationship of the eight main tables (in bold type, Mines, District, Sample, Drillhole, Waterwells, Counties, Photographs, and Projects).