STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of: **PROPOSED AMENDMENT TO 20.6.2 NMAC (Copper Rule)**	**No. WQCC 12-01(R)**

WRITTEN TESTIMONY OF LYNN LANDE

My name is Lynn Lande. I am the Chief Environmental Engineer at the Chino Mine. I am presenting this written testimony on behalf of Freeport-McMoRan Chino Mines Company, Freeport-McMoRan Tyrone Inc. and Freeport-McMoRan Cobre Mining Company (collectively, Freeport) regarding the Petition to Adopt 20.6.7 NMAC and Request for Hearing filed by the New Mexico Environment Department (NMED)on October 30, 2012, which includes the new rules for copper mines (Proposed Rule).

I. BACKGROUND AND EXPERIENCE

I have a BA degree from Kean University in Earth and Planetary Science and attended graduate school at Idaho State University in geology. I have over 26 years of mining experience dealing with mineral exploration and mine geology, as well as mine operation and reclamation activities.

Currently, I am employed by Freeport and serve as a Chief Environmental Engineer. My current responsibilities include the management of the Chino and Tyrone closure discharge permits, Chino Mine expansion projects, and the Cobre Environmental

Assessment under NEPA. I also participated as a Freeport representative on the Technical Committee for the development of the Proposed Rule and attended all of the Copper Rule Advisory Committee meetings. Prior to this position, I have served as a Senior Geologist at the Chino Mine where I held the positions of Ore Control Department Supervisor and Mine/Exploration Geologist. Prior to that I worked as a geologist at the Morenci Mine in Arizona, the largest copper producing mine in North American, and in Nevada I worked in two world class gold deposits as a geologist for Barrick Goldstrike and Newmont Mining Corporations.

A copy of my resume is provided as Exhibit Lande-1. It is accurate and up-to-date.

II. GEOLOGY OF COPPER DEPOSITS AND DEVELOPMENT OF OPEN PIT COPPER MINES

Before discussing the Proposed Rule, I will provide some background and technical information on the geology of copper deposits and the development of open pit copper mines. The most significant open pit copper mines around the world occur as copper porphyry deposits. There are eight copper porphyry deposits identified in New Mexico (Exhibit Lande-2, McLemore, 2008), although only the Chino, Tyrone and, just recently, Little Rock Mines are actively mining. Cobre and Copper Flat Mines are also copper porphyry deposits (Exhibit Lande-3, McLemore, 1996). With more exploration, the potential for additional deposits can be verified (McLemore, 2008). Research and exploration in New Mexico is dependent and the copper market (McLemore, 2008). The following geologic description of the genesis of a copper porphyry ore body is presented to better understand how an ore body forms and how ground water interacts with mineralized rock in an open pit mine.

Copper mineralization commonly occurs in association with the circulation of the hot waters generated in deep magma bodies and into the overlying geologic formations. Large bodies of solidified magma are called stocks, plutons or porphyries, which are relatively common, but those that contain economic metal concentrations are extremely rare. They are believed to be emplaced from one to nine kilometers below the earth's surface and tend to be elongated or circular in plan view (Exhibit Lande-4, Berger *et al.*, 2008). They are formed in a dynamic environment in which multiple intrusive episodes can occur over millions of years. During the cooling stages the rock continues to be under great pressure and high temperatures that range from 750 degrees Celsius (C) to 200 C degrees. These conditions can also create extensive fractures and faults in the cooling porphyry and surrounding rock. The enriched fluids and gasses precipitate minerals that contain much higher than average concentrations of metals like copper, gold and silver in various proportions that likely originated from the earth's mantle. The primary copper sulfide mineralization occurs along veins or as disseminated minerals in the host rock (Berger *et al.*, 2008) (*See* Exhibit Lande-5, See attached Fig. 1, Reynolds).

The copper bearing rock near the surface may undergo secondary enrichment also called supergene enrichment (*See* Exhibit Lande-6, See attached Fig. 2, Kelley, 2012). This is a weathering process where oxygen and rain water (meteoric water) infiltrates the fractured metal bearing rock causing the natural oxidation of iron sulfide (pyrite), which creates sulfuric acid that dissolves and mobilizes metals like copper. The top of the weathered zone is called a leach cap and can be identified by the rock that no longer has the capacity to generate acidity and are depleted of the more acid soluble metals. As the acid, metal rich fluid moves down into the underlying water table the low oxygen levels results in the reduction of the metals and sulfate to form sulfide mineral like chalcocite and pyrite. The enrichment zone can be tens to hundreds of feet thick. This process of forming the enrichment zone may take millions of years in response to changing tectonic and climatic conditions. Typically, the copper minerals found above this zone are called copper oxides and consist of malachite, azurite, cuprite and chrysocolla. The zone below the supergene enrichment is generally an assemblage of primary copper sulfide minerals like chalcopyrite and bornite, with pyrite and possibly molybdenite. Today, at the Chino Mine's open pit mine, ore is mined from both these zones, while the Tyrone Mine principally mines copper oxides and chalcocite. There is no supergene enrichment zone at the Copper Flat Mine (McLemore, 1996).

The Proposed Rule defines an "open pit" as an area where ore and waste rock is exposed and removed through surface mining. Open pit mines are typically developed based on the depth to ore from the surface (stripping ratio), ore distribution (vein or disseminated) and ore grade of the deposit. The ultimate dimensions of an open pit are determined by slope stability and economic considerations. Slope stability affects how steep the pit walls can be constructed. In general, geologic conditions that allow steeper slopes reduce the foot print of the open pit and the amount of overburden that must be removed, thereby allowing the economic removal of lower grade ore.

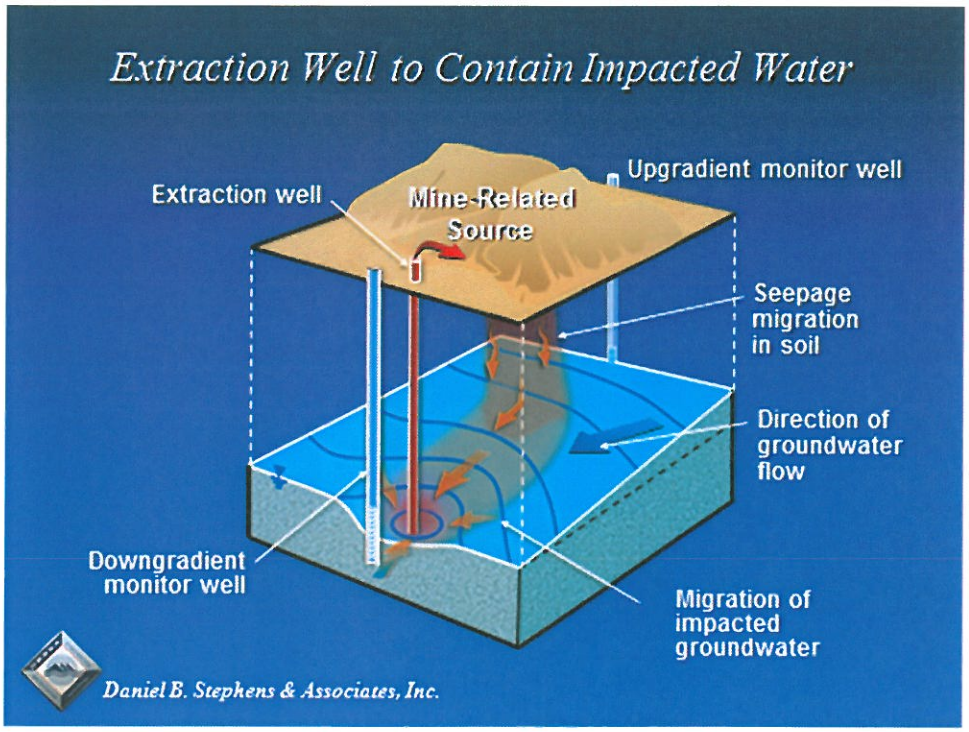
Many of the early underground mines in New Mexico were dug along high grade copper sulfide veins and stockworks near ground surface. Currently, there are no large copper underground mines operating in New Mexico. In New Mexico copper porphyry deposits were uplifted during regional tectonic/faulting events tens of millions of years ago. These regional geologic events can be seen in the systematic formation of mountain ranges and valleys throughout the Inter-Mountain West. Mountain building events are also a catalyst for rapid erosion, which may position copper porphyry deposits at or near the earth's surface (*See* attached Fig. 1, Reynolds,).

Both the Chino and Tyrone Mines are large open pit operations where low grade vein and disseminated copper ore located relatively near the surface can be economically extracted from the host or gangue rock. The current average mill or concentrate copper ore grade is 0.40 % with the remaining crushed material separated from the ore and stored in tailing dams. Leach ore in general has a lower copper grade and is transported to a leach stockpile, while uneconomic material is delivered to a waste stockpile. Overburden is stockpiled for future use as reclamation capping material.

Copper mines in general move more rock and develop larger open pits than other metal mining industries. The size of the mine will depend on the zone of enrichment and the cost for moving and extracting the ore. The Chino Mine is about 11,600 feet long, 8,500 feet wide and 2000 feet deep and basically consists of a single pit. The main Tyrone Mine is about 4,600 feet long, 4,300 feet wide and 1,300 feet deep, and has 8 satellite pits with the largest 3,700 feet long and the smallest 2,600 feet long. The trend in exploration projects is to drill longer more expensive boreholes around existing mines in the search for deeper ore deposits, therefore exploration and development costs are expected to increase. Processing, operating and reclamation costs also increase as a mine matures; however, both Chino and Tyrone reserves have increased and the Mines have the potential to expand, because of the sustained increase in copper value. Nevertheless, the copper market is often unpredictable and copper prices rise and fall for many economic and political reasons.

Chino Mine looking northeast (2012)

Why and when do open pit copper mines impact ground water? An open pit is a window into an ore deposit. The same geochemical processes that formed the supergene zone, through oxidation by air and rain in contact with sulfide minerals associated with a porphyritic host rock, also create low pH solution that flow along the highwalls to the pit bottom. Keep in mind, the following description does not account for ore deposits hosted in carbonate or calcite vein rich rock, which can act as a buffer neutralizing low pH water. The mineral enhanced low pH water may be a source to ground water depending on geologic and hydrologic conditions. The process has been studied extensively to find potential alternatives, but there are currently no prophylactic measures that can be employed to eliminate those impacts. However, the impact can be contained as shown in the illustration below. In most instances at mature mines like Chino and Tyrone Mines, the open pit has intersected the ground water table and ground water is captured in the bottom of the pit due to hydrologic conditions. The natural evaporation from the pit or pumping systems creates a hydrologic sink pulling and capturing ground water into the pit. This process has been proven using ground water level data collected by a series of monitor wells located around the pit over many years.



A newly established pit bottom may not initially intersect the ground water table, and if impacted water is capable of reaching the ground water table, there may be minor localized impacts to water quality, which can be addressed as necessary through water management practices. If the pit intersects the water table but evaporation of the water that enters the pit does not exceed the rate of ground water inflow, then the system is called a flow through pit. To minimize the impacts to ground water, the Proposed Rule requires a copper mine permit applicant to submit a mine operation water management plan with the permit application as well as divert surface water away from the pit where practical.

The world that is technologically dependent on copper for everything from electricity to renewable energy and the impacts associated with the process cannot be eliminated. Fortunately, these impacts can be safely managed and the Proposed Rule constitutes the codification of those safety measures. The open pit provisions in the Proposed Rule provide the clarity and expectations for ground water protection at an open pit that should accommodate both existing open pits, expansion of open pits and for the possibility of new open pit copper mines in New Mexico.

III. PROPOSED RULE REQUIREMENTS FOR OPEN PITS

The Proposed Rule addresses the operational requirements for open pits in section 20.6.7.24 NMAC, which provides as follows:

> **20.6.7.24 REQUIREMENTS FOR OPEN PITS**
>
> **A. Operational requirements.** A permittee operating an open pit shall operate the open pit pursuant to the following requirements, as applicable.
>
> (1) The open pit shall remain within the area identified in the discharge permit.
>
> (2) Stormwater shall be diverted outward and away from the perimeter of the open pit and, to the extent practicable, shall not be directed into the open pit.
>
> (3) Water generated from within the perimeter of the open pit and pit dewatering activities shall be managed according to a mine operation water management plan. The water management plan shall be submitted to the department for approval in a discharge permit application for a new copper mine facility or in an application for a discharge permit renewal.
>
> (4) During operation of an open pit, the standards of 20.6.2.3103 NMAC do not apply within the area of hydrologic containment.

An open pit is a collection area for precipitation that falls within its drainage area. An open pit that extends below the water table acts as a hydrologic sink collecting ground water, as described above. The Proposed Rule requires that, when practical, stormwater must be diverted away from the open pit. Water is diverted away from the open pit to reduce the volume of stormwater that becomes impacted water (water containing metals, low pH and high acidity). Once the impacted water reaches the bottom of the pit it must be managed to prevent migration away from the pit. Another reason water is diverted is to keep the roads and pit bottom as dry as possible reducing pumping and road maintenance.

The Proposed Rule requires an operational water management plan to describe to NMED how water will be handled during mine operations. Water collected in an open pit is an important source of water for the mining processes and is used for ongoing operations. A large percentage of mine water is recycled for ore processing at the concentrator and solvent extraction and electrowinning plants and sprayed on roads to minimize dust. The recycled process and storm water is collected and pumped from the open pit, detention ponds, reservoirs, tailing dams and interceptor wells. If sufficient water is not available, ground water is pumped to supplement the required volume. A detailed description of typical water management practices at copper mines that shows how water is recycled and conserved is illustrated by Exhibit Lande-7, Water in Mining Operations Video, produced by Freeport-McMoRan Corporation.

The slope direction of the highwalls in an open pit and surrounding stockpiles dictate where runoff will travel. Rainwater that falls within the perimeter of the pit will drain to the bottom of the pit. This drainage is inevitable and unavoidable, but safely manageable. Section 20.6.7.24.A(4) of the Proposed Rule provides that the ground water quality standards of 20.6.2.3103 NMAC to not apply inside the area of hydrologic containment during mining operations. If no area of hydrologic containment has been established because an open pit has not yet intersected the ground water table, then paragraph (4) would not apply, and ground water quality standards would apply. Consequently, a water management plan required under the Proposed Rule would need to describe how water would be managed in an open pit before hydrologic containment is established in order to protect the quality of ground water that is not contained.

Discharge permits issued under the Water Quality Act by NMED to date have not sought to apply or to enforce the standards of 20.6.2.3103 NMAC in open pits. As discussed above, there are no existing technologies to prevent sulfide oxidation from occurring and ground water quality standards from being exceeded in ground water that reports to an open pit during operations. Importantly, ground water within the area of the hydrologic sink is contained and isolated.

Mr. Neil Blandford's direct written testimony provides more technical details regarding the hydrologic aspects of open pits during the development, operation and closure of open pits. Also, Mr. Thomas Shelley's direct written testimony discusses how the Proposed Rule addresses open pits at closure. These testimonies should be consulted for additional details. This concludes my written direct testimony.

Lynn A. Lande

Lynn Lande

EXHIBITS

1. Curriculum Vitae of Lynn Lande. (Exhibit Land – 1).

2. McLemore V. T., 2008, Potential For Laramide Porphyry Copper Deposits, New Mexico Geological Society Guidebook, 59th Field Conference, Geology of the Gila Wilderness, 2008, pp. 141-150. (Exhibit Lande – 2).

3. McLemore V. T., 1996, Copper in New Mexico: New Mexico Geology Science and Service Volume 18, No. 2, pp. 25 – 36. (Exhibit Lande – 3).

4. Berger, B. R., Ayuso, R., Wynn, J. C., and Seal, R., 2008, Preliminary Model of Porphyry Copper Deposits: U.S. Department of the Interior and U.S. Geological Survey Open-File Report 2008-1321, pp.1 -55. (Exhibit Lande – 4).

5. Reynolds S. J., Formation of Porphyry Copper Deposit: Department of Geology, Arizona State University, ASU Department, Figure 1 http://reynolds.asu.edu/sierra_cobre/p_formation_color.htm). (Exhibit Lande – 5).

6. Kelley S. A., 2012, Tyrone Mine: NMBGMR Tour, pp. 1- 9 Figure 7. (Exhibit Lande – 6).

7. Freeport-McMoRan Copper & Gold, Water in Mining Operations Video. (Exhibit Lande – 7).

FIGURES

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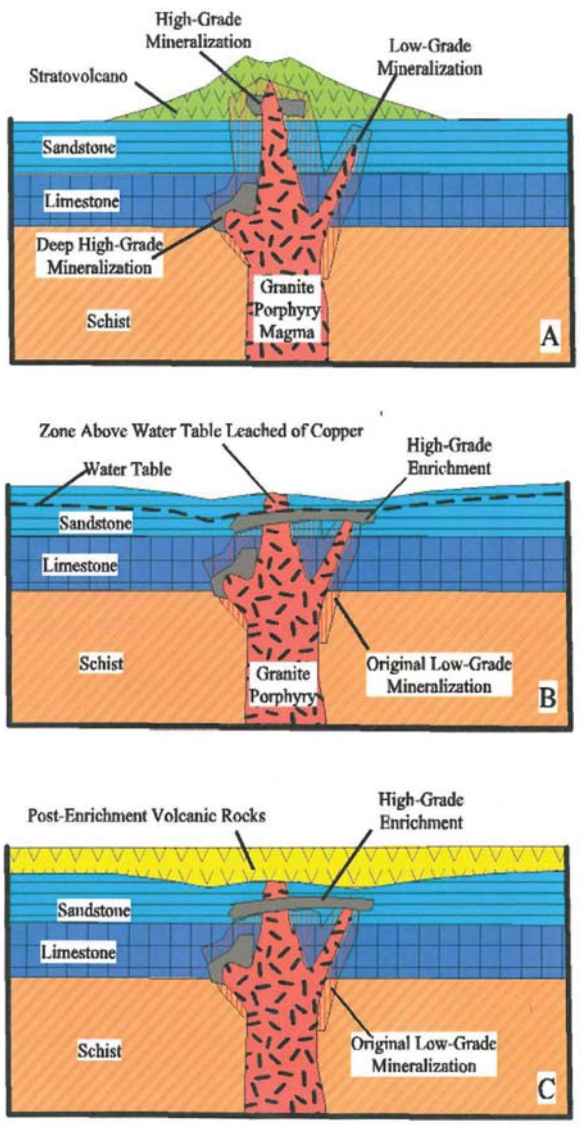
Figure 1. Formation of a Porphyry Copper Deposit



Initial formation of a porphyry copper deposit associated with a magma chamber beneath a stratovolcano. Hot water circulating near the magma forms low-grade copper mineralization next to the solidifying magma. High-grade mineralization forms over the top of the magma and in chemically reactive wall rocks, like limestone.

Erosion removes the stratovolcano and top of the original copper deposit. Rainwater and weathering cause copper to be leached from the top of the deposit and redeposited as the downward-moving groundwater reaches the water table. The resulting enriched zone is commonly high grade and fairly flat.

After erosion and enrichment, the deposit is covered by younger rocks, in this case volcanic rocks. The high-grade enriched zone is protected from further erosion, but now is buried and hidden. The volcanic landscape at the surface may contain few clues to the geological riches that lie at depth. Finding the deposit may require special methods (e.g., geochemical or electrical surveys), a number of risky drill holes, persistence, or luck.

Figure 1

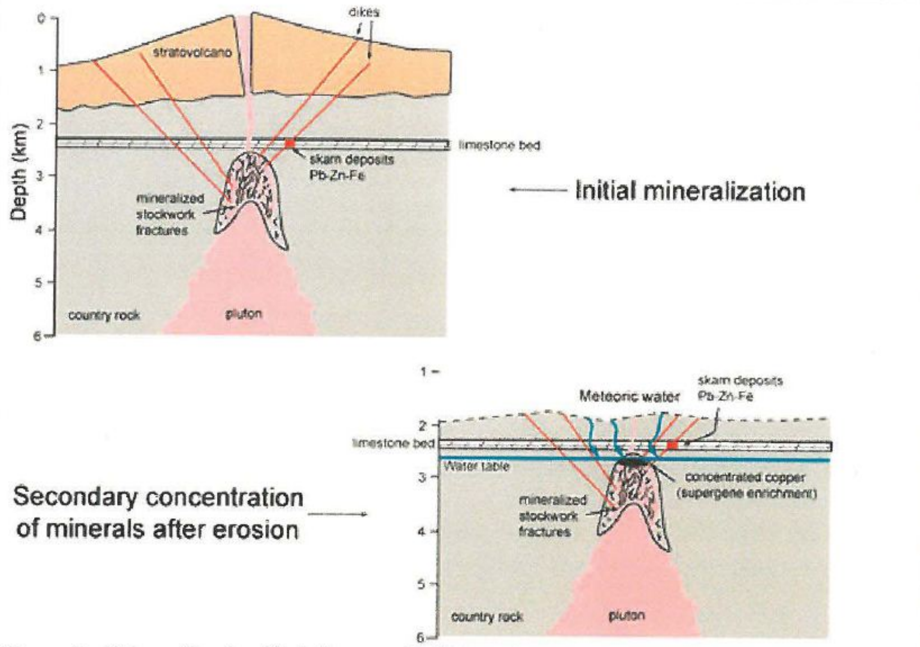


Figure 7 – Schematic, simplified diagram of initial porphyry copper mineralization and subsequent supergene concentration of copper minerals (incorporating images from Zientek and Orris, 2005, and Burnham, 1979).

Figure 2