BLM

FINAL

MINERAL ASSESSMENT REPORT

JANUARY 2012

Battle Mountain District Office - Nevada

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SUMMARY

The Bureau of Land Management (BLM) Battle Mountain District Office (BMDO) is in the process of revising the district's Resource Management Plan (RMP). As part of the RMP revision process, the BLM is required to prepare a Mineral Assessment Report providing information regarding mineral occurrences and potential within the BMDO Planning Area (planning area). This report provides an intermediate level of detail for mineral assessment as prescribed in BLM Manual 3060 (BLM 1994). Information presented in this report will be summarized and incorporated into an Environmental Impact Statement (EIS) for the proposed RMP and into the final RMP.

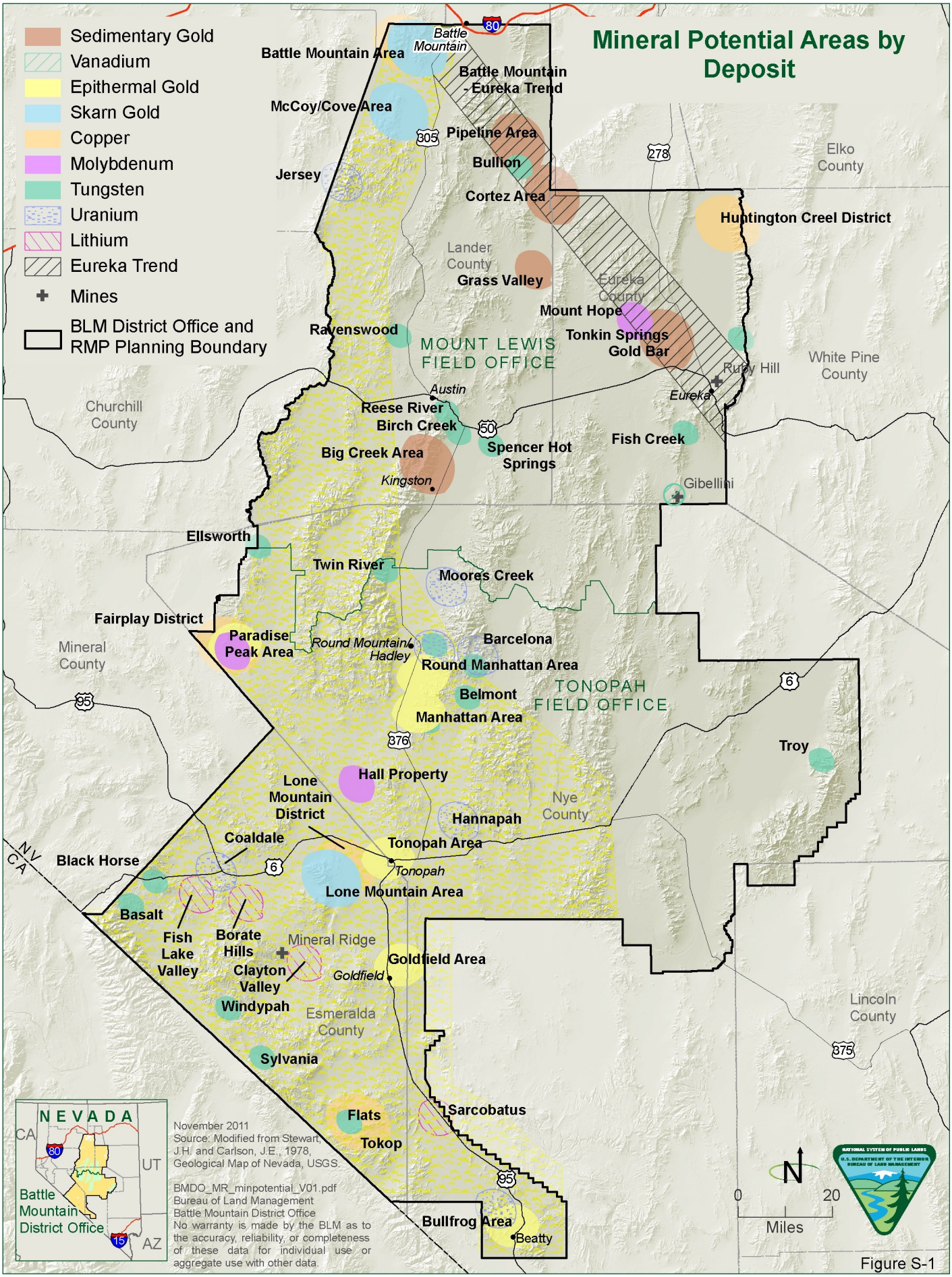
The geologic history of central and southern Nevada and the planning area is very complex and includes two major cycles of sedimentation (western and eastern facies sources), episodic thrust faulting, mountain building, and associated intrusive and igneous activity. More recent geologic history includes a period of crustal extension that was accompanied by bimodal (rhyolite-basalt) volcanism, large volume caldera volcanism, and basin and range block-faulting resulting in high-levels of shallow crustal heat flow. The regional and local geologic setting has been instrumental in the location of and potential for numerous economic metallic mineral deposits in the planning area, as well as development of economic geothermal resources.

MINING AND MINERAL ACTIVITY IN NEVADA

Mineral exploration, particularly for gold, is an ongoing enterprise in Nevada by both operators of existing mines and by other exploration companies. Exploration has been active recently (2010-2011) as gold prices have reached levels above US$1,800/ounce. Companies conducting exploration in Nevada in 2010 reported spending some US$153.6 million in 2009 (Dreisner and Coyner 2010). Exploration in large part takes place in areas near known mineral deposits and within historic districts; however, exploration is also conducted in other outlying areas that the mineral industry considers prospective for various reasons (Wallace *et al.*, 2004). **Figure S-1** shows the areas believed prospective for various metals in the planning area.

Nevada's total mineral industry production was valued at $5.8 billion in 2009 and precious metal production accounted for about $5 billion of this total (Driesner and Coyner 2010). Prospects for sustaining these production rates in the short run (1-5 years) are excellent and also quite likely in the long run (15-20 years).

Based on mining industry projections it appears that market conditions for gold will remain relatively consistent, with gold priced at sustainable levels in the $1,200+/ounce range. Within the next 10 years it is anticipated that 2-3 active mines will go into closure and be reclaimed in the planning area. These mine closures will likely be offset with both new projects being developed and placed into production, and the expansion of existing mines.


Mineral Potential Areas by Deposit
Sedimentary Gold
Vanadium
Epithermal Gold
Skarn Gold
Copper
Molybdenum
Tungsten
Uranium
Lithium
Eureka Trend
Mines
BLM District Office and RMP Planning Boundary
Battle Mountain Area
Battle Mountain
Battle Mountain - Eureka Trend
McCoy/Cove Area
Pipeline Area
Jersey
Bullion
Cortez Area
Huntington Creel District
Elko County
Lander County
Grass Valley
Eureka County
Mount Hope
Tonkin Springs
Gold Bar
Ruby Hill
White Pine County
Ravenswood
MOUNT LEWIS FIELD OFFICE
Eureka
Austin
Churchill County
Reese River
Birch Creek
Big Creek Area
Spencer Hot Springs
Fish Creek
Kingston
Gibellini
Ellsworth
Twin River
Moores Creek
Fairplay District
Paradise Peak Area
Round Mountain
Hadley
Barcelona
Round Manhattan Area
Mineral County
Belmont
TONOPAH FIELD OFFICE
Manhattan Area
Troy
Hall Property
Lone Mountain District
Hannapah
Nye County
Coaldale
Tonopah Area
Black Horse
Tonopah
Lone Mountain Area
Basalt
Fish Lake Valley
Borate Hills
Mineral Ridge
Clayton Valley
Goldfield Area
Goldfield
Windypah
Esmeralda County
Lincoln County
Sylvania
Flats
Sarcobatus
Tokop
Bullfrog Area
Beatty
NEVADA
CA
UT
AZ
Battle Mountain District Office
November 2011
Source: Modified from Stewart, J.H. and Carlson, J.E., 1978, Geological Map of Nevada, USGS.
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Bureau of Land Management
Battle Mountain District Office
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Figure S-1

A significant increase in exploration and mining activity has occurred with increasing metal commodity prices, placing additional demands on permitting and regulatory compliance agencies. This increased activity has also increased the potential for adverse effects on watershed and other resources in the planning area. Most of the effects are site specific and potential impacts are minimized by the requirement for environmental analysis during permitting of proposed exploration and mining activities. Other state and federal regulatory requirements include mitigation measures to reduce real or potential impacts, requirements for reclamation, and long term closure planning.

There are two commercial placer operations, Nevada Rae Gold, Inc.'s Black Rock Canyon Gold Mine and A.U. Mines, Inc.'s, Manhattan Gulch Mine, currently operating in the Battle Mountain District. It is likely that most major placer deposits have already been discovered and developed (Fitch 2003). Most modern placer mines operate under "Casual Use" criteria and involve individuals or clubs that mine using little or no equipment other than hand tools and sluice boxes.

Nevada has the largest amount of untapped geothermal resources in the U.S., with a potential of 2,500 to 3,700 megawatts of electricity annually (MWe) (USDOE 2004). In 2001, the Nevada legislature established a renewable energy portfolio standard that requires up to 25 percent of all electricity generated in Nevada be derived from renewable energy resources by 2025. Based on the energy portfolio, it is anticipated that renewable energy development would increase, which would likely include geothermal, wind, and solar resources. As many as eight new geothermal plants are expected to be in production by 2015 with a total capacity of about 300 megawatts. Exploration for new geothermal resources is expected to continue at the same rate as the current rate.

MINING AND MINERAL ACTIVITY IN THE PLANNING AREA

Locatable Minerals

The planning area has a long history of mineral development dating back to the 1860s and contains some famous gold and silver metal mining districts including: Battle Mountain, Eureka, Tonopah, Goldfield, Bullfrog, Northumberland, Paradise Peak, and Round Mountain. Significant production has been reported from all of those districts, indeed, at one time, the Eureka District was producing 20 percent of the world's lead production (Turner 2011). In all, there are more than 100 organized mining districts in the planning area (Tingley 1998).

Locatable minerals historically or currently mined within the planning area include metallic minerals (*i.e.*, gold, silver copper, mercury, zinc, molybdenum, manganese, uranium, and tungsten and industrial minerals (*i.e.,* limestone, barite, gypsum, diatomaceous earth, sulfur, and fluorspar). Currently, there are four open pit gold/silver mines (Ruby Hill, Cortez Hills/Pipeline, Phoenix, and Round Mountain). Industrial mineral mines operating in the planning area include two barite producers *(Argenta and Greystone Mines), lithium compounds (Silver Peak Operation), and* diatomite (Basalt Mine). Approximately 23 mining plans of operation are currently administered by the BMDO. A total of 2,507 mining notices (as of 1 January 2012) have been administered by the BMDO since 1990 and 18 are currently pending decisions. The US Geological Survey (USGS) has identified over 1400 mines and prospects in the state of Nevada (approximately 446 of which fall within the four counties in the planning area) (Sherlock *et al.* 1996).

Gems and semi-precious stones will likely continue to be mined on a small scale basis in the planning area. Deposits are small, usually hand-operated because great care must be taken when extracting the stones so as not to damage and devalue the pieces. Existing deposits will likely be extended and remain small with labor intensive mining methods.

While pluton-related and epithermal deposits hosting gold and silver are commonly associated with metals other than gold and silver, the potential for development of these metals, such as antimony, beryllium, iron, lead, manganese, mercury, uranium, and zinc is low to very low in the planning area. Potential for copper and molybdenum production in the planning area is high with active copper mining in the Battle Mountain District and development of the Mt. Hope molybdenum mine.

Moderate potential for development of tungsten deposits exists within the planning area. The price of tungsten has increased significantly in the last few years and has stimulated the production of tungsten elsewhere in the world where deposits are larger and higher grade than those found in Nevada. If prices were to remain high and demand increases somewhat, some companies might be encouraged in attempting to bring some of the larger, higher grade deposits of the planning area into production.

Locatable industrial mineral deposits of dolomite, gypsum, and perlite are not currently mined within the planning area. Diatomite is mined at the Basalt Mine in Esmeralda County. Low to moderate potential exists for production of most locatable industrial minerals, however, potential is good for production of additional barite from the planning area where deposits are located near transportation corridors and are mineable by inexpensive open-cut methods (currently there are two active barite mines in Mount Lewis Field Office (MLFO) and one active mine in which production is scheduled to resume). Lithium is being produced at the Silver Peak operation in Clayton Valley and exploration for additional lithium resources in that area is ongoing.

Saleable Minerals

Saleable mineral extraction and use will increase along with increasing mining activity, commercial development, recreation activities, and private property development, especially along the Interstate 80 corridor within the planning area. The minerals program administers 39 active sales and 175 free-use permits. Saleable mineral sites with a priority for use will likely include sand, gravel, and rock quarries located along State, County, and BLM managed roads.

Demand for continued development of aggregate deposits in the planning area remains high. Virtually all of the basins and valleys in the planning area have potential aggregate deposits but those deposits adjacent to their end uses or good transportation corridors will have the greatest development potential.

There is good potential for new development of clay deposits in the planning area. Clay mining for pharmaceutical uses is reported at the Vanderbilt Minerals Corp. Blanco Mine in Esmeralda County, but no Plan of Operation has been filed so this is a very small operation. Vanderbilt Minerals has a Plan of Operation for clay mill in Nye County. Clay deposits are sensitive to transportation and power costs so proximity to infrastructure is important and much of the planning area is remote to infrastructure; however, some clay minerals, high-quality bentonite and hectorite for example, are less sensitive to

infrastructure. Bentonite is used for sealants and drilling fluids. Markets for drilling fluids are expected to be strong for the foreseeable future and high-quality deposits are uncommon. Bentonite forms as an alteration product of felsic pyroclastic volcanic rocks which are common in the planning area; thus high-quality deposits are possible within the planning area although none are currently exploited. Hectorite is a lithium-bearing clay mineral and thus potential source of lithium; indeed, hectorite deposits are being actively explored in the McDermitt area of northwest Nevada. The southern part of the planning area has potential for hectorite deposits which may have formed near the lithium brine occurrences.

There is potential for development of pumice and cinder deposits although there are a number of occurrences and former mines within the planning area. Indeed, a new pumice mine is being authorized about 5 miles north of Beatty. The main reason for the low potential is the distance to significant markets. Pumice is primarily used as a low-density aggregate for concrete and is thus very sensitive to transportation costs. Primary markets in the region include Las Vegas, southern California, and possibly Phoenix. In all of those cases, there are sources for pumice closer to those markets. Cinder is used primarily for decorative purposes and low-density aggregate for concrete with a primary market in Las Vegas. There are sources closer to this market than the planning area that is currently in production. Development of pumice and cinder projects is possible in the planning area when deposits closer to the primary markets are depleted, but that is unlikely to happen in the foreseeable future.

There is little potential for significant development of building and ornamental stone deposits in the planning area, because of distance to adequate markets. Building stone is very sensitive to transportation costs and thus distance to markets is critical to development of these deposits. Las Vegas is the nearest market to the southern part of the planning area and one small operation north of Beatty produces decorative stone for that market. Reno is the closest market to the northern part of the planning area. There is a possibility that specialty building stone products can be developed. Those would include uniquely colored stone or unique dimension stone that, due to their unique qualities, are somewhat less sensitive to transportation costs. These would be niche markets and would involve small areas with limited overall production.

Leasable Minerals

Nine geothermal leases in the planning area are either in production (Beowawe and Jersey Valley), development (Buffalo Valley, Devils Canyon, McGinnis Hills, and Trail Canyon), or exploration (Alum, Silver Peak, and Reese River). The two active geothermal power plants (Beowawe and Jersey Valley) are located on the east and west borders of the planning area, respectively. Beowawe is producing about 17 megawatts and Jersey Valley is producing about 15 megawatts.

The planning area lies predominantly within the USGS Eastern Great Basin Oil and Gas Province. The most westerly portion of Lander and Nye County and all of Esmeralda County are in the Western Great Basin Oil and Gas Province. The oil field at Railroad Valley is in the planning area. Production at Railroad Valley, although modest at 46 million barrels, has been continuous since discovery in 1954. Oil fields in the planning area have produced about 51 million barrels. Recent assessments of potential in the region by the USGS suggest that two or three 40-80 million barrel oil fields are possible in the planning area. Modest exploration expenditures are expected to continue.

The outlook for production of petroleum products from oil shale within the planning area is poor in the short-term and probably poor in the long-term. Oil shale contains significant crude oil and may be used as a source of petroleum although the economics of the process is not very attractive at this time. Oil shale production will require a very large resource, access to energy, and access to large volumes of water. Significantly better deposits of oil shale occur in Colorado, Wyoming, and Utah which will limit the possibilities for the lesser quality material in Nevada. Those deposits would need to be exhausted before the Nevada deposits are very attractive which means that the outlook for short-term is quite poor. Long-term prospects are marginally better, but still not good.

Potential for development of leasable industrial rocks and mineral resources of the planning area also exists. Potential for development of salt deposits occurring in playas in the planning area is good, although, there is no current production of salt in the planning area. In the past, small producers have been active in several of the playas in the planning area.

Potential for significant potash production is low within the planning area. Potash is primarily used for fertilizer and is typically mined from large evaporite potash beds containing sylvite or carnallite which have not, as yet, been discovered in the planning area. Potash can also be produced by processing minerals such as alunite or kalinite which are also sources of aluminum. Papke and Castor (2003) and Price *et al*. (2009) report minor production of kalinite, but grades were too low to sustain production. Evaporation of brines used for lithium production produces small amounts of potash that are marketable, but the brines are not adequate grade to sustain potash production alone.

Potential for development of significant fumarole-related sulfur deposits in the planning area is low because fumarole environments have been thoroughly prospected for gold, silver, and mercury deposits. Small amounts of alum and sulfur are mined as a soil additive on a lease north of Silver Peak.

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ACRONYMS

BLM	United States Department of Interior, Bureau of Land Management
BMDO	Battle Mountain District Office
BOPD	barrels per day
BWPC	Bureau of Water Pollution Control
°C	degrees Celsius
CFR	Code of Federal Regulations
CNTB	central Nevada thrust belt
DOE	United States Department of Energy
DWR	Division of Water Resources
EA	environmental assessment
EGB Province	Eastern Great Basin Province
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EPCA	Energy Policy and Conservation Act
°F	degrees Fahrenheit
Ga	gigaannum
KGRA	Known Geothermal Resource Areas
km	kilometer
lb	pound
LUP	land use planning
m	meter
Ma	megaannum
MCF	million cubic feet
MLFO	Mount Lewis Field Office
MWe	megawatt of electricity
NAC	Nevada Administrative Code
NBMG	Nevada Bureau of Mines and Geology
NEPA	National Environment Policy Act
NDOT	Nevada Department of Transportation
NRC	Nuclear Regulatory Commission
NRS	Nevada Revised Statutes
PEIS	Programmatic Environmental Impact Statement
PFYC	Potential Fossil Yield Classification
ppm	parts per million
RFD	Reasonably Foreseeable Development
RMP	Resource Management Plan
ROD	Record of Decision

SERA RMP	Shoshone-Eureka Resource Management Plan
TFO	Tonopah Field Office
UCC	Union Carbide Corporation
US	United States
USBM	United States Bureau of Mines
USC	United States Code
USFS	United States Forest Service
USFWS	United States Wildlife Service
USGS	United States Geological Survey

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The U.S. Department of the Interior, Bureau of Land Management (BLM), Battle Mountain District Office (BMDO) is revising its current two Resource Management Plans [also known as land use plans, LUPs] and plan amendments. The two RMPs include the 1986 Shoshone-Eureka RMP and the 1997 Tonopah RMP. As part of the RMP revision process, BLM is required to prepare a mineral assessment report providing information regarding mineral occurrences and mineral potential within the BMDO RMP planning area. This report provides an intermediate level of detail for mineral assessment as prescribed in BLM Manual 3060 (BLM 1994). Information presented in this report will be summarized and incorporated into an Environmental Impact Statement (EIS) for the proposed RMP and into the final RMP.

The Mount Lewis planning area (under the guidance of the 1986 Shoshone-Eureka RMP [SERA RMP/Record of Decision {ROD}] and its amendments) administrative boundary encompasses approximately 4.4 million acres in Lander and portions of Eureka and Nye counties. Total land area encompassed within the Mt. Lewis planning area administrative boundary is without regard to land ownership.

The Tonopah planning area (under the guidance of the Tonopah RMP/ROD and three National Programmatic LUP Amendments) encompasses approximately 6.1 million acres in Nye and Esmerelda counties. Total land area encompassed within the Tonopah administrative boundary is without regard to land ownership.

The combined BMDO planning areas encompass about 10.48 million acres of public land. The planning areas include most of the resources or resource uses on public land for which BLM has authority as directed by Congress and Executive Orders; and on which the BMDO may make decisions as to resource use and allocations. BLM also administers the fluid mineral estate (oil and gas, geothermal) on National Forest System Lands within the planning area.

BLM's planning areas include minerals of split estate (areas such as private land where BLM administers federal subsurface minerals but the surface is owned by a nonfederal entity). The planning area does not include other private land, state-owned land, Indian reservations, or federal land not administered by the BLM; however, the analysis area includes certain resources in the context of large landscapes such as air quality, water resources, wide-ranging wildlife species, and socioeconomics. The analysis area may extend beyond the BMDO administrative boundaries.

This Mineral Assessment Report is intended to serve primarily as a planning tool providing land managers with additional information to develop management plans for land under their jurisdiction (DOI et al. 2003). The report describes areas of high mineral or oil and gas potential and evaluates the effectiveness of available permitting, regulatory requirements, NEPA evaluation procedures, and oil and gas stipulations while balancing the responsible development of those resources with the protection of other valuable resources in the planning area. The federal land inventory also allows resource managers

to identify areas of low mineral or oil and gas potential, but high potential for other resources or uses (e.g., wildlife or recreation).

This Mineral Assessment Report is organized into five sections: Section 1.0 is an introduction. Section 2.0 summarizes the geological setting as it relates to the development and use of leasable, locatable, and saleable minerals within the planning area. Subsections include physiography, geologic history, geologic units and stratigraphy, structural geology and tectonics, and paleontology. Section 3.0 describes existing mineral occurrences as locatable, leasable, and saleable mineral resources of the planning area. Section 4.0 discusses the mineral resource potential of the planning area. Section 5.0 includes references used in development of the report.

1.2 LAND INVOLVED AND RECORDS DATA

The BMDO RMP planning area (**Figure 1-1**) is located in central and southern Nevada and includes all of Esmeralda County and portions of Lander, Eureka, and Nye counties. BLM managed land within the overall planning area is considered the Decision Area. Within the planning area, land is also managed by the U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), Bureau of Reclamation, Bureau of Indian Affairs for Native American Indian Tribal Lands, State of Nevada, and private landowners.

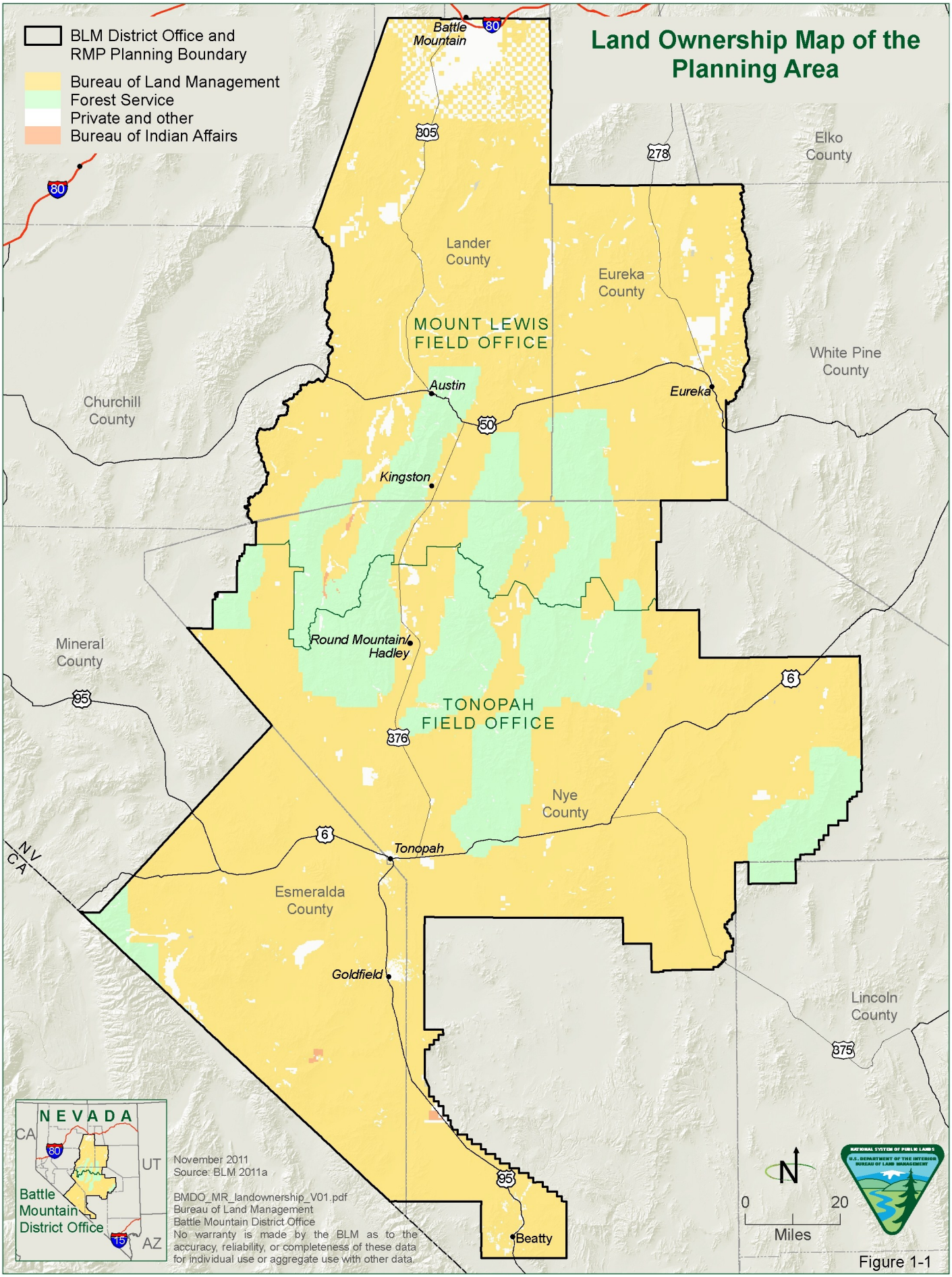
Information sources for this mineral assessment report were obtained from BLM, Nevada Bureau of Mines and Geology (NBMG), USGS, U.S. Bureau of Mines (USBM), Department of Interior Energy Policy and Conservation Act (EPCA) reports, industry reports, personal communication with BLM resource specialists, and other published and unpublished sources listed in the reference section.

1.3 LAND USE

Management issues and concerns in the Decision Area encompass nearly all resource programs and many different aspects of public land management. Resources and land uses under particular scrutiny at this time include: recreation, minerals, air, water, and cultural resources, range, wild horses and burros, threatened, endangered, and sensitive species, fire management, and land and realty programs.

The planning area has a history of mineral development dating back to the 1860s. Mining and exploration activities and development of geothermal resources are some of the important multiple uses undertaken in the planning area. Most metallic minerals are mined from open-pit operations; however, some underground mining occurs as well.

There are five major open pit gold/silver mines and four industrial mineral mines operating in the planning area. Approximately 23 mining plans of operation are currently administered by the BMDO. A total of 2,507 mining notices (as of 1 June 2012 have been administered by BLM since 1990 and 18 are currently pending decisions. The USGS identifies approximately 420 bedrock mines and prospects in the planning area (Sherlock *et al.* 1996). The minerals program administers 39 active sales and 175 free-use permits. Two geothermal power plants are located at Beowawe and Jersey Valley. Both are on the border of the planning area. Beowawe is producing about 17 megawatts and Jersey Valley about 15 megawatts. Since 1990, 176 geothermal leases have been issued.


Land Ownership Map of the Planning Area
BLM District Office and RMP Planning Boundary
Bureau of Land Management
Forest Service
Private and other
Bureau of Indian Affairs
Battle Mountain
80
305
278
Elko County
Lander County
Eureka County
MOUNT LEWIS FIELD OFFICE
White Pine County
Churchill County
Austin
Eureka
50
Kingston
Mineral County
Round Mountain
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BUREAU OF LAND MANAGEMENT

Figure 1-1

Fifteen oil fields have been located in the planning area, nine of which are currently producing. Total production from those fields is about 51 million barrels with 46 million barrels from fields in Railroad Valley. Since 1990, 1,565 oil and gas leases have been issued covering 2.6 million acres.

2. DESCRIPTION OF GEOLOGY

2.1 PHYSIOGRAPHY

2.1.1 Topography

The planning area lies in a north-south strip in the center of Nevada. The region is part of the Basin and Range Physiographic Region and is characterized by generally north-south mountain ranges separated by wide, flat basins (**Figure 2-1**). The maximum elevation in the planning area is 13,130 feet at Boundary Peak in western Esmeralda County. The lowest elevations are on the order of 3,000 feet in the basin bottoms. There are no major rivers within the planning area and drainage is typically into the basins which form playas (ephemeral lakes) at the lowest part of the basin.

2.1.2 Climate

The climate of the planning area is typically arid to semi-arid. Battle Mountain and Beatty represent the range of climate in the BMDO. Precipitation in Battle Mountain averages about 12.3 inches (31.2 cm) per year (Lander County 2005). March to May is the wettest period in Battle Mountain with one and one-half inches of precipitation per month. August and September are the driest months, averaging 0.47 inches per month. Temperatures, on the average, range between 18°F and 40°F in January and from 53°F to 87°F in July.

Beatty receives about 6 inches (15.2 cm) of precipitation a year (U.S. Climate Data 2011). July is the warmest month with an average high temperature of 97° F (36°C) and an average low temperature of 61°F (16°C). January and December are the coolest months with an average high of 54°F (12°C) and an average low of 27°F (-3°C) in December. The highest recorded temperature was 115°F (46°C) on June 11, 1961, and the lowest was 1°F (-17°C) on February 2, 1933.

The Basin and Range Province is the most arid area in the United States and the planning area includes some of the most arid lands in the Basin and Range Province. Potential annual water loss through evaporation exceeds the annual precipitation rate even at the higher elevations (BLM 2006). Most of the land in the planning area is desert shrubland, although, sufficient water is available to allow livestock to be grazed in some places. Development in the planning area has been limited by a paucity of recoverable freshwater. The individual basin-fill aquifers, which together compose the largest known ground-water reserves, receive little annual recharge and are easily depleted (BLM 2006). Precipitation in the mountain ranges may be 20 inches or more depending on the year.

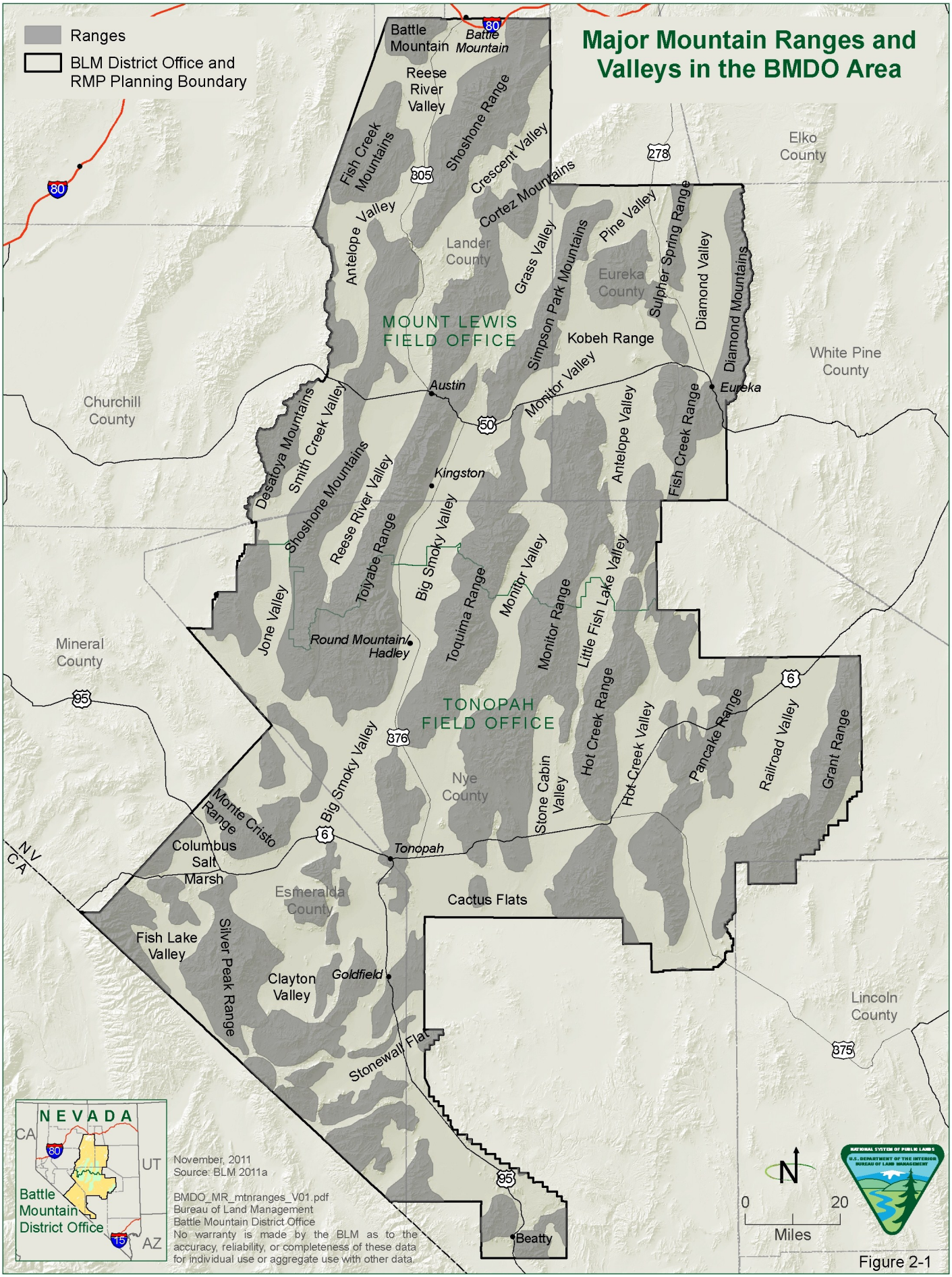
Major Mountain Ranges and Valleys in the BMDO Area
Ranges
BLM District Office and RMP Planning Boundary
Battle Mountain
Battle Mountain
Reese River Valley
Shoshone Range
Fish Creek Mountains
Crescent Valley
Cortez Mountains
Antelope Valley
Lander County
Grass Valley
Simpson Park Mountains
Pine Valley
Sulphur Spring Range
Diamond Valley
Diamond Mountains
Eureka County
Elko County
White Pine County
MOUNT LEWIS FIELD OFFICE
Kobeh Range
Monitor Valley
Austin
Eureka
Churchill County
Desatoya Mountains
Smith Creek Valley
Shoshone Mountains
Reese River Valley
Kingston
Antelope Valley
Fish Creek Range
Toiyabe Range
Big Smoky Valley
Toquima Range
Monitor Valley
Monitor Range
Little Fish Lake Valley
Jone Valley
Round Mountain/ Hadley
Mineral County
TONOPAH FIELD OFFICE
Hot Creek Range
Hot Creek Valley
Pancake Range
Railroad Valley
Grant Range
Big Smoky Valley
Nye County
Stone Cabin Valley
Monte Cristo Range
Columbus Salt Marsh
Tonopah
NV
CA
Esmeralda County
Cactus Flats
Fish Lake Valley
Silver Peak Range
Clayton Valley
Goldfield
Lincoln County
Stonewall Flat
Beatty
NEVADA
CA
UT
AZ
Battle Mountain District Office
November, 2011
Source: BLM 2011a
BMDO_MR_mtnranges_V01.pdf
Bureau of Land Management
Battle Mountain District Office
No warranty is made by the BLM as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data.
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Figure 2-1

2.2 GENERAL GEOLOGIC HISTORY AND SETTING

The geology of the planning area is complex. The oldest rocks in the planning area are Precambrian and the youngest are still forming. **Figure 2-2** summarizes the major geological events in northern Nevada and **Figure 2-3** shows the generalized geology of the planning area. **Table 2-1** summarizes the various lithologic units within the geologic units occurring in the planning area. For simplicity, faults have not been included on the map. Faults bound each of the mountain ranges and cut the mountain ranges as well as the basins. For this report, the geological history has been divided into the following general time-bounded sequences:

- Precambrian;
- Cambrian-Ordovician-Devonian-Silurian;
- Mississippian-Pennsylvanian-Permian;
- Triassic-Jurassic-Cretaceous;
- Tertiary; and
- Quaternary.

Each of these sequences is the result of specific tectonic events and is discussed individually in the following sections. In addition, plutonic igneous activity occurred during several distinct periods in the geological history and is discussed when appropriate.

During Precambrian time and the early Paleozoic Era, marine sediments and volcanics were deposited in an accretionary offshore basin setting within the Cordilleran (ancestral Rocky Mountain) geocline. This geocline was an elongated trough that extended north to south in western North America and included the area that is now eastern Nevada. Sedimentation was marked by two periods of alternating clastic and carbonate deposition (Price 2004). Outcrops of Precambrian rocks are restricted to small areas in the southern part of the planning area. These rocks consist predominantly of schists and gneisses. Uppermost Precambrian rocks include several quartzite and conglomerate units that are immediately overlain by lower Paleozoic rocks.

Lower Paleozoic rocks are widely distributed in the planning area. These rocks represent craton-margin materials deposited on the shelf, slope, and deep basins adjacent to the North American continent. During the Antler Orogeny, these rocks were extensively deformed during that orogeny when an island arc terrane collided with the west coast of North America. The Roberts Mountain thrust fault was formed at this time. The majority of mineralization in the northern Carlin trend is hosted in the Devonian carbonates and shales beneath the Roberts Mountain thrust (Micklethwaite 2011). The thrust forms such a significant feature that its hanging-wall and footwall rocks are referred to as "upper plate" and "lower plate" respectively (although confusing, upper plate rocks originate from lower in the sedimentary sequence). Throughout the northern Carlin trend, isoclinal, chevron, and open folds can be found in both upper plate and lower plate rocks, probably originating from emplacement of the Roberts Mountain allochthon.

This was followed by deposition of the Pennsylvanian-Permian craton-margin sediments that comprise sandstone, conglomerate, and shale with extensive carbonates. These rocks are sparsely represented in the planning area. By the end of the Paleozoic Era, active volcanoes existed in eastern California and western Nevada and volcanism continued throughout most of the Mesozoic Era. In addition, a number

of shallow marine invasions inundated parts of the region during the early Mesozoic Era and marine sedimentary formations alternated and inter-tongue with non-marine deposits derived from erosion of rocks further east in the continental interior.

At the end of the Permian, the Sonoma orogeny accreted a second island arc to the west coast of North America and intensely deformed the older rocks across most of Nevada. This orogeny is characterized by east-verging thrust faulting typified by the Golconda Thrust Fault. Late in the Mesozoic Era, the Pacific coastal region was again downwarped and the sea transgressed across the western portion of the Great Basin (Price 2004).

Triassic through Cretaceous time was characterized by shelf sedimentation and local felsic volcanism. These rocks are restricted to exposures in the extreme northern part of the planning area where sedimentary rocks are exposed in a small area southwest of Battle Mountain and a large area of felsic ignimbrites and flows are associated with volcaniclastic sedimentary rocks near Beowawe.

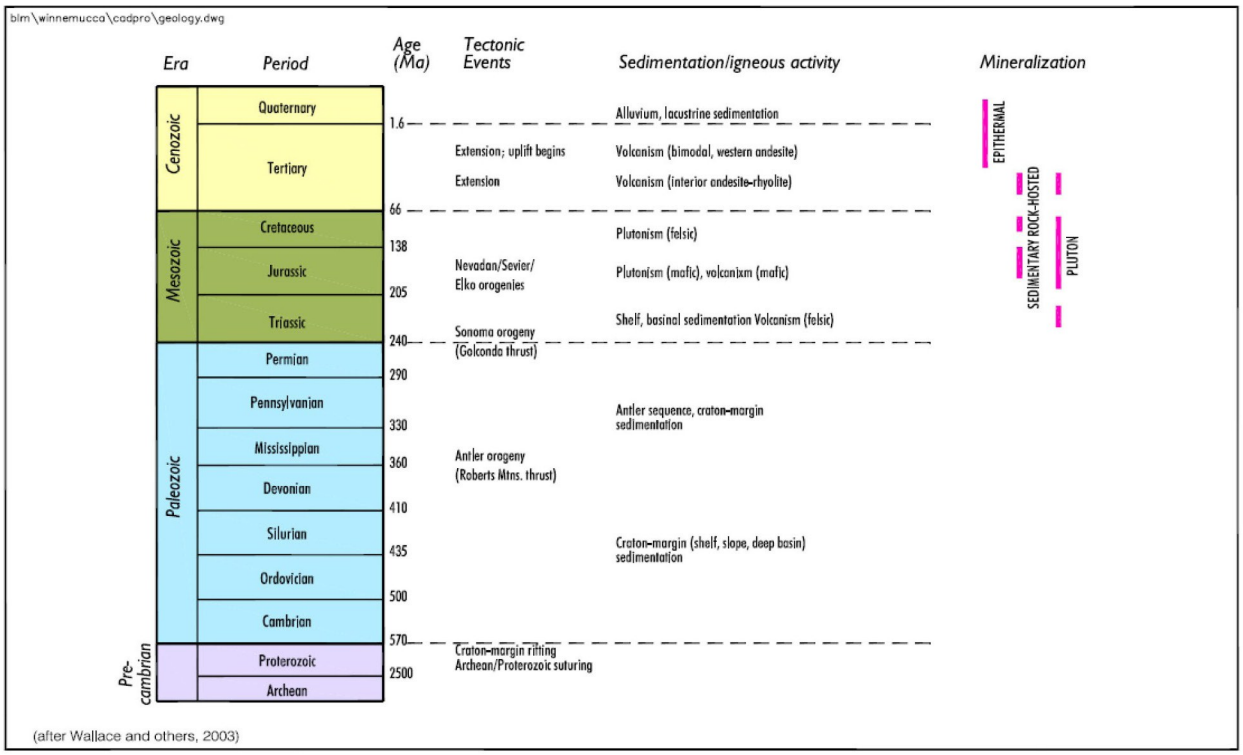
Jurassic and Cretaceous intrusive rocks are small, widely distributed granitoid plutonic rocks intruded into all earlier rocks and may have been associated with some of the volcanic rocks found during this time. At Yerrington, Nevada, west of the planning area, porphyry and skarn copper mineralization is associated with Jurassic intrusives. Mineral deposits in Nevada associated with Cretaceous intrusive rocks include the Robinson District near Ely, Nevada, east of the planning area.

The Tertiary was a time of extensive volcanism, much of it related to extensional tectonics that created the distinctive basin and range physiography which are, in fact, a series of alternating horsts and grabens. Tertiary volcanic rocks are extensively exposed throughout the planning area with the exception of the extreme northwest corner of the planning area where Eocene intrusives occur in the Battle Mountains. These rocks may host oil and gas plays in Railroad, Diamond, and Pine Valleys.

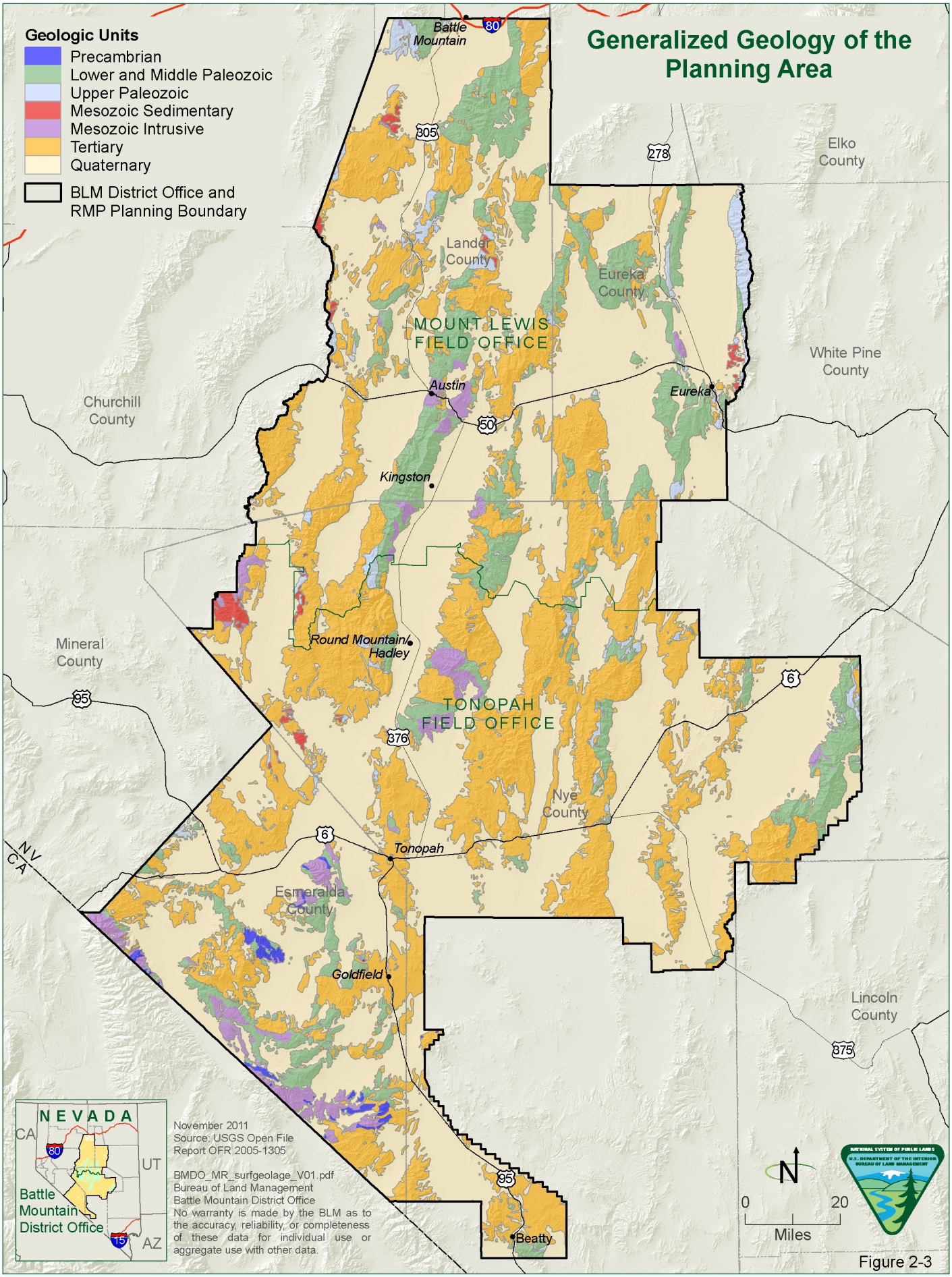
The Sierra Nevada Mountains of California rose during the Tertiary, creating a rain shadow and arid desert conditions to the east in Nevada (Eureka County 2007). During the Pleistocene, glaciers sculpted the highest peaks of the mountain ranges across Nevada, and tectonic processes continued the formation of Basin and Range physiography. Valleys continued to grow wider and fill with sediment. Volcanic eruptions continued throughout the state, depositing ash flows and lava. Quaternary deposits are present in many of the basin fill areas of Eureka County and consist predominantly of poorly consolidated to unconsolidated alluvial and lacustrine sediments.

Quaternary sedimentary materials fill all of the basins in the region and felsic to mafic volcanic rocks are exposed throughout the region. Substantial sand and gravel deposits occur throughout the Quaternary and local basaltic volcanism may have produced scoria deposits. Extensional tectonics continues today.

Figure 2-2: Geological Events in Northern Nevada



Source: BLM 2006.


Generalized Geology of the Planning Area
Geologic Units
Precambrian
Lower and Middle Paleozoic
Upper Paleozoic
Mesozoic Sedimentary
Mesozoic Intrusive
Tertiary
Quaternary
BLM District Office and RMP Planning Boundary
Battle Mountain
80
305
278
Elko County
Lander County
Eureka County
MOUNT LEWIS FIELD OFFICE
White Pine County
Churchill County
Austin
Eureka
50
Kingston
Round Mountain/ Hadley
Mineral County
95
6
TONOPAH FIELD OFFICE
376
Nye County
NV
CA
Tonopah
Esmeralda County
Goldfield
Lincoln County
375
95
Beatty
NEVADA
CA
UT
AZ
Battle Mountain District Office
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November 2011
Source: USGS Open File Report OFR 2005-1305
BMDO_MR_surfgeolage_V01.pdf
Bureau of Land Management
Battle Mountain District Office
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NATIONAL SYSTEM OF PUBLIC LANDS
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Figure 2-3

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
Qa	Quaternary	Alluvial deposits	Alluvial deposits - Locally includes beach and sand dune deposits	Lithology: alluvium; mass wasting; dune sand; lake or marine deposit (non-glacial)
Qls	Quaternary	Landslide deposits	Landslide deposits	Lithology: landslide; colluvium; sedimentary rock
Qm	Quaternary	Moraine deposits	Moraine deposits	Lithology: glacial drift
Qp	Quaternary	Playa, marsh, and alluvial-flat deposits, locally eroded	Playa, marsh, and alluvial flat deposits; locally eroded	Lithology: playa; alluvium
QTs	Pliocene to Quaternary	Sedimentary rocks	Sedimentary rocks - Mostly lake deposits	Lithology: lake or marine deposit (non-glacial); sedimentary rock
QTa	Miocene to Quaternary	Intrusive rocks of mafic and intermediate composition	Intrusive rocks of mafic and intermediate composition	Lithology: andesite; rhyodacite; basalt; sedimentary rock
QTb	Miocene to Quaternary	Basalt flows	Basalt flows - Locally includes maar deposits	Lithology: basalt; andesite; trachybasalt; latite; andesite
QToa	Miocene to Quaternary	Older alluvial deposits	Older alluvial deposits	Lithology: alluvium; lake or marine deposit (non-glacial)
Tb	Late Miocene to Middle Miocene	Basalt flows	Basalt flows	Lithology: basalt
Tba	Early Miocene to Early Pliocene	Andesite and basalt flows	Andesite and basalt flows - Mostly in about 17 to about 6 Ma. age range. In Humboldt County, locally includes rocks as old as 21 Ma May include rocks younger than 6 Ma in places	Lithology: basalt; andesite; shoshonite
Tr3	Middle Miocene to Late Miocene	Rhyolitic flows and shallow intrusive rocks	Rhyolitic flows and shallow intrusive rocks	Lithology: rhyolite; dacite; trachyte
Tr2	Early Oligocene to Early Miocene	Rhyolitic flows and shallow intrusive rocks	Rhyolitic flows and shallow intrusive rocks	Lithology: rhyolite; dacite; trachyte
Tr1	Late Eocene to Middle Eocene	Rhyolitic flows and shallow intrusive rocks	Rhyolitic flows and shallow intrusive rocks	Lithology: rhyolite; dacite; trachyte
Tri	Eocene to Miocene	Rhyolitic intrusive rocks	Rhyolitic intrusive rocks	Lithology: granitoid
Tmi	Eocene to Miocene	Intrusive rocks of mafic to intermediate composition	Intrusive rocks of mafic to intermediate composition	Lithology: diorite; monzodiorite; quartz diorite; quartz monzogabbro; tonalite; gabbro
Tts	Middle to Late Miocene	Ash-flow tuffs and tuffaceous sedimentary rocks	Ash-flow tuffs and tuffaceous sedimentary rocks	Lithology: ash-flow tuff; rhyolite; sandstone; dacite; trachyte

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
Ta3	Late Miocene to Middle Miocene	Andesite and related rocks of intermediate composition	Andesite and related rocks of intermediate composition - Flows and breccias	Lithology: andesite; latite; trachyte; dacite
Ts3	Late Eocene to Late Miocene	Tuffaceous sedimentary rocks	Tuffaceous sedimentary rocks - Locally includes minor amounts of tuff	Lithology: sandstone; limestone; siltstone; conglomerate; mudstone; dolostone (dolomite); felsic volcanic rock; intermediate volcanic rock; mafic volcanic rock; tuff
Tt3	Middle to Late Miocene	Welded and nonwelded silicic ash-flow tuffs	Welded and nonwelded silicic ash-flow tuffs - Locally includes thin units of air-fall tuff and sedimentary rock	Lithology: rhyolite
Ta2	Early Oligocene to Early Miocene	Andesite and related rocks of intermediate composition	Andesite and related rocks of intermediate composition - Flows and breccias	Lithology: andesite; trachyte; dacite
Tt2	Early Oligocene to Early Miocene	Welded and nonwelded silicic ash-flow tuffs	Welded and nonwelded silicic ash-flow tuffs - Locally includes thin units of ash-fall tuff and sedimentary rock	Lithology: rhyolite; dacite; trachyte
Ts2	Early Oligocene to Early Miocene	Tuffaceous sedimentary rocks	Tuffaceous sedimentary rocks - Locally includes minor amounts of tuff	Lithology: sandstone; siltstone; limestone; conglomerate; mudstone; debris flow; landslide; tuff
Tbr	Middle Eocene to Early Pliocene	Breccia	Breccia - Volcanic, thrust, and jasperoid breccia and landslide megabreccia	Lithology: volcanic breccia (agglomerate); tectonite; landslide
Ta1	Late Eocene to Middle Eocene	Andesite and related rocks of intermediate composition	Andesite and related rocks of intermediate composition - Flows and breccias	Lithology: andesite; latite
Tt1	Late Eocene to Middle Eocene	Welded and nonwelded silicic ash-flow tuffs	Welded and nonwelded silicic ash-flow tuffs - Locally includes thin units of air-fall tuff and sedimentary rock	Lithology: rhyolite; dacite; trachyte
Tgr	Paleocene to Late Miocene	Granitic rocks	Granitic Rocks - Mostly quartz monzonite and granodiorite	Lithology: granodiorite; quartz monzonite; granite; monzonite
Ts1	Late Cretaceous to Oligocene	Sedimentary rocks	Sedimentary rocks - Includes Sheep Pass Formation (Eocene) and related units and unnamed tuffaceous sedimentary rocks	Lithology: sandstone; conglomerate; limestone; siltstone; claystone; mudstone; shale; tuff; oil shale
TKs	Late Cretaceous to Eocene	Continental sedimentary rocks	Continental Sedimentary rocks - Includes units such as Pansy Lee Conglomerate in Humboldt County, part of Cretaceous(?) and Tertiary rocks of Kleinhampl and Ziony (1967) in northern Nye County	Lithology: conglomerate; sandstone; siltstone; mudstone; limestone
TJgr	Jurassic to Miocene	Granitic rocks, central and eastern Nevada	Granitic rocks, central and eastern Nevada - Mostly quartz monzonite and granodiorite. Inconclusively dated or not dated isotopically	Lithology: quartz monzonite; granodiorite; granite; peraluminous granite

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
Kgr	Cretaceous	Granitic rocks-Mostly quartz monzonite and granodiorite		Lithology: quartz monzonite; granodiorite; granite; monzonite; quartz diorite; peraluminous granite
Ks	Cretaceous	Continental deposits of siltstone, shale, conglomerate, and limestone	Continental deposits of siltstone, shale, conglomerate, and limestone - Includes units such as King Lear Formation in Humboldt County, Newark Canyon Formation in Eureka County, Willow Tank Formation and baseline Sandstone in Clark County	Lithology: conglomerate; sandstone; limestone; mudstone; siltstone
KJd	Jurassic to Cretaceous	Diorite		Lithology: diorite; quartz diorite; gabbro; granite; granodiorite; serpentinite
MZgr	Jurassic to Cretaceous	Granitic rocks, western Nevada	Granitic Rocks, Western Nevada (Mesozoic) - Mostly quartz monzonite and granodiorite. Inconclusively dated or not dated isotopically	Lithology: granodiorite; quartz monzonite; granite; quartz diorite; gabbro
JPu	Permian to Jurassic	Volcanogenic sedimentary rocks, tuff, andesite and felsitic flows, and carbonate rocks	Volcanogenic sedimentary rocks, tuff, andesite and felsic flows and carbonate rocks - Age uncertain. Mineral, Esmeralda, and Northwest Nye Counties	Lithology: greenstone ; sandstone; volcanic rock (aphanitic); limestone; siltstone; conglomerate
JTRs	Late Triassic to Early Jurassic	Shale, mudstone, siltstone, sandstone, and carbonate rock; sparse volcanic rock	Shale, mudstone, siltstone, sandstone, and carbonate rocks, sparse volcanic rocks - Includes Auld Lang Syne Group, Nightingale sequence of Bonham (1969), and Gabbs and Sunrise Formations	Lithology: claystone; shale; sandstone; siltstone; carbonate; volcanic rock (aphanitic); conglomerate
Jgr	Jurassic	Granitic rocks	Granitic rocks - Mostly quartz monzonite and granodiorite	Lithology: quartz monzonite; granodiorite; granite; monzonite; quartz diorite; peraluminous granite
TRc	Triassic	Limestone, minor amounts of dolomite, shale, and sandstone; locally thick conglomerate units	Limestone, minor amounts of dolomite, shale, and sandstone; locally thick conglomerate units - Includes Tobin, Dixie Valley, Favret, Augusta Mountain, and Cane Spring Formations and Star Peak Group in central Nevada and Grantsville and Luning Formations in west-central Nevada	Lithology: limestone; dolostone (dolomite); shale; sandstone; conglomerate; siltstone; andesite; chert
TRgr	Middle Triassic to Early Jurassic	Granitic rocks	Granitic rocks - Quartz monzonite in northern Esmeralda County	Lithology: granite; granodiorite; quartz monzodiorite
Jd	Early Jurassic to Middle Jurassic	Dunlap Formation	Dunlap Formation - Conglomerate, sandstone, greenstone, felsite, and tuff. Locally contemporaneous with folding and thrusting. Mineral County and adjacent parts of Esmeralda and Nye Counties	Lithology: sandstone; conglomerate; volcanic rock (aphanitic); limestone; siltstone; shale

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
Pc	Lower to Upper Permian	Cherty limestone and sparse dolomite, shale, and sandstone	Cherty limestone and sparse dolomite, shale, and sandstone - -Includes units such as Park City Group and equivalent rocks in northern Nevada and Toroweap Formation and Kaibab Limestone in southern Nevada	Lithology: limestone; shale; dolostone (dolomite); sandstone; siltstone; chert; conglomerate; phosphorite; evaporite
TRk	Permian to Early Triassic	Koipato Group and related rocks	Koipato Group and related rocks - Altered andesitic flows, rhyolitic tuffs and flows, and clastic rocks. Includes rocks mapped by Silberling (1959) as Pablo Formation and originally considered to be Permian in the Shoshone Mountains, Nye County. Includes Tallman Fanglomerate (Permian?) in Humboldt County	Lithology: rhyolite; andesite; clastic; basalt
TRPd	Early Permian to Early Triassic	Conglomerate, sandstone, shale, and dolomite	Conglomerate, sandstone, shale, and dolomite of Diablo Formation below and shale, sandstone, and conglomerate of Candelaria Formation above - Mineral, Esmeralda, and northwestern Nye Counties	Lithology: shale; siltstone; sandstone; dolostone (dolomite); limestone; conglomerate
PZsp	Late Devonian to Early Triassic	Serpentinite	Serpentinite - Mineral, northwestern Nye, and eastern Humboldt counties	Lithology: serpentinite
PPa	Pennsylvanian to Late Permian	Antler Sequence of Silberling and Roberts (1962)	Antler Sequence of Silberling and Roberts (1962) - Conglomerate, sandy to conglomeratic limestone, limestone, sandstone, and calcareous shale. Thin detrital and carbonate sequence within main part of Antler orogenic belt. Includes units such as Sunflower Formation of Bushnell (1967) in Elko County, Battle Formation, Antler Peak Limestone, and Edna Mountain Formation in Lander and western Eureka Counties, and Wildcat Peak Formation in northern Nye County	Lithology: conglomerate; limestone; sandstone; siltstone; shale
PPcd	Pennsylvanian to Late Permian	Sandy and silty limestone, conglomerate, and siltstone	Sandy and silty limestone, conglomerate, and siltstone - Includes units such as Strathearn Formation of Dott (1955) and Buckskin Mountain, Beacon Flat, and Carlin Canyon Formations of Dott (1955)	Lithology: limestone; conglomerate; siltstone; sandstone; chert

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
PMh	Mississippian to Permian	Havallah sequence of Silberling and Roberts (1962)	Havallah Sequence of Silberling and Roberts (1962) - Chert, argillite, shale, greenstone, and minor amounts of siltstone, sandstone, conglomerate, and limestone. Includes Schoonover Formation of Fagan (1962) and Reservation Hill Formation in Elko County, Farrel Canyon Formation in southwestern Humboldt County, Havallah and Pumpernickel Formations in Pershing, Lander, and parts of Humboldt Counties, and rocks originally considered a part of the Pablo and Excelsior Formations in northern Nye, northern Esmeralda, and southern Mineral Counties. Assignment of some rocks to the Havallah sequence in the East Range, Pershing County, is highly uncertain. Includes rocks ranging in age from Late Mississippian to Early Permian	Lithology: shale; metavolcanic rock; chert; siltstone; sandstone; conglomerate; limestone
Ml	Mississippian	Massive limestone	Massive limestone - In the San Antonio Mountains, western Nye County	Lithology: limestone; conglomerate; sandstone; argillite
MDs	Devonian to Mississippian	Shale, siltstone, sandstone, chert-pebble conglomerate, and limestone	Shale, siltstone, sandstone, chert-pebble conglomerate, and limestone - Includes units such as Pilot Shale, Joana Limestone, Chainman Shale, and Diamond Peak Formation in northern and eastern Nevada and Narrow Canyon Limestone, Mercury Limestone, and Eleana Formation in southern Nevada	Lithology: shale; limestone; siltstone; sandstone; conglomerate; dolostone (dolomite); chert; quartzite
Dc	Devonian	Dolomite, limestone, and minor amounts of sandstone and quartzite	Dolomite, limestone, and minor amounts of sandstone and quartzite - Includes units such as Sevy and Simonson Dolomites, Guilmette and Nevada Formations, and Devils Gate Limestone.	Lithology: dolostone (dolomite); limestone; sandstone; quartzite; conglomerate; shale; chert
Ds	Devonian	Shale, siliceous siltstone, chert, and minor amounts of limestone	Shale, siliceous siltstone, chert, and minor amounts of limestone - Includes Cockalorum Wash Formation of northern Nye County and Woodruff Formation and unnamed rocks in Elko County	Lithology: shale; chert; limestone; siltstone; dolostone (dolomite); sandstone
Dsl	Devonian	Slaven Chert	Slaven Chert - Chert and sparse limy sandstone, siltstone, and limestone. Lander County	Lithology: chert; shale; siltstone; sandstone; limestone
Sc	Silurian to Early Devonian	Dolomite	Dolomite - Includes units such as Laketown and Lone Mountain Dolomites. Locally includes rocks of Early Devonian age at top.	Lithology: dolostone (dolomite); limestone; chert; sedimentary breccia

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
St	Silurian to Early Devonian	Platy limestone and limy siltstone, chert at base	Platy limestone and calcareous siltstone, chert at base - Includes units such as Roberts Mountains Formation, and Storff Formation and Chellis Limestone of Decker (1962). Locally includes rocks of Early Devonian age at top.	Lithology: limestone; dolostone (dolomite); chert; siltstone; shale
Se	Silurian	Elder Sandstone	Elder Sandstone - Feldspathic sandstone, siltstone, shale, and chert. Lander County.	Lithology: arkose; siltstone; shale; chert
SOc	Silurian-Ordovician	Dolomite	Dolomite - Includes uppermost part of Ordovician System (Ely Springs Dolomite and Equivalent rocks) and all of Silurian System.	Lithology: dolomite
Osv	Ordovician to Devonian	Siliceous and volcanic rocks	Siliceous and volcanic rocks - Chert, shale, quartzite, greenstone, and minor amounts of limestone. Includes units such as Valmy Formation of north-central Nevada and some rocks mapped as Palmetto Formation in northern part of Esmeralda County and adjacent parts of Mineral and Nye Counties. Locally includes rocks of Silurian and Devonian age.	Lithology: chert; quartzite; shale; greenstone; limestone; conglomerate; siltstone; chemical
Oc	Ordovician	Limestone, dolomite, shale, and quartzite	Limestone, dolomite, shale, and quartzite - Includes units such as Pogonip Group, Eureka Quartzite, and Ely Springs Dolomite. Where Ely Springs Dolomite or equivalent rocks are included in SOc unit, this unit includes only the Pogonip Group and Eureka Quartzite or their equivalents.	Lithology: limestone; dolostone (dolomite); shale; quartzite; chert
Os	Ordovician	Shale, chert, and minor amounts of quartzite, greenstone, and limestone	Shale, chert, and minor amounts of quartzite, greenstone, and limestone - Includes units such as Vinini Formation of north-central Nevada, Palmetto Formation in southern and central parts of Esmeralda County, and Comus Formation in Humboldt County. Locally includes rocks of Silurian and Devonian age.	Lithology: chert; shale; limestone; quartzite; andesite; siltstone; sandstone; chemical; greenstone; dolostone (dolomite)
OCt	Middle Cambrian to Ordovician	Phyllite, shale, and limestone	Phyllite, shale, and limestone - Locally includes chert and quartzite. Includes Tennessee Mountain Formation of Bushnell (1967) in western Elko County, Broad Canyon sequence of Means (1962) in Lander County, and rocks originally mapped as Palmetto Formation in Toiyabe and Toquima Ranges, northern Nye County	Lithology: shale; limestone; sandstone; chert

TABLE 2-1
Lithologic Units in the Planning Area

Map Symbol	Age	Lithotypes	Formation Names	Lithology
OCc	Middle Cambrian to Ordovician	Dolomite and limestone	Dolomite and limestone - Undivided Cambrian and Ordovician rocks in part of Clark County; mostly Cambrian.	Lithology: dolostone (dolomite); limestone; shale
Cc	Late Cambrian to Middle Cambrian	Limestone and dolomite, locally thick sequences of shale and siltstone	Limestone and dolomite, locally thick sequences of shale and siltstone - Includes units such as Pioche Shale, Eldorado Dolomite, Geddes Limestone, Secret Canyon Shale, Hamburg Dolomite, Dunderberg Shale, and Windfall Formation of northern Nevada and Carrara, Bonanza King, and Nopah Formations of southern Nevada.	Lithology: limestone; dolostone (dolomite); shale; siltstone; sandstone; chert; conglomerate
Ch	Late Cambrian	Harmony Formation	Harmony Formation - Feldspathic and arkosic sandstone and minor amounts of shale, limestone, and chert.	Lithology: sandstone; shale; limestone; chert; conglomerate
Ct	Middle Cambrian to Late Cambrian	Shale and thin-bedded or laminated limestone; also thinly interbedded limestone and chert	Shale and thin-bedded or laminated limestone; also thinly interbedded limestone and chert - Includes units such as Preble and Emigrant Formations	Lithology: shale; limestone; chert; siltstone; quartzite; diorite; conglomerate
Csc	Early Cambrian to Middle Cambrian)	Scott Canyon Formation	Scott Canyon Formation - Chert, shale, greenstone, and sparse limestone and quartzite. Southeast Humboldt County and northwest Lander County.	Lithology: chert; shale; greenstone; limestone; quartzite; sandstone
CZq	Late Proterozoic to Early Cambrian	Quartzite and minor amounts of conglomerate, phyllitic siltstone, limestone, and dolomite	Quartzite and minor amounts of conglomerate, phyllitic siltstone, limestone, and dolomite - Includes Prospect Mountain Quartzite, Osgood Mountain Quartzite, and Gold Hill Formation in northern Nevada, and Stirling Quartzite, Wood Canyon Formation, and Zabriskie Quartzite in southern Nevada.	Lithology: quartzite; siltstone; dolostone (dolomite); limestone; phyllite; shale; conglomerate; sandstone
CZs	Late Proterozoic to Early Cambrian	Phyllitc siltstone, quartzite, and lesser amounts of limestone and dolomite	Phyllitic siltstone, quartzite, and lesser amounts of limestone and dolomite - Includes Reed Dolomite; Deep Spring, Campito, Poleta, Harkless, and Saline Valley Formations; and Mule Spring Limestone	Lithology: siltstone; limestone; dolostone (dolomite); quartzite; sandstone
Zw	Late Proterozoic	Wyman Formation	Wyman Formation - Phyllite and phyllitic siltstone and minor amounts of limestone, dolomite, and sandstone	Lithology: siltstone; limestone; sandstone; dolostone (dolomite)
Xm	Early Proterozoic	Metamorphic rocks	Metamorphic rocks - Gneiss and schist and lesser amounts of gneissic granite, pyroxenite, hornblendite, migmatite, pegmatite, and marble.	Lithology: gneiss; schist; marble; granite; pyroxenite; hornblendite; migmatite; pegmatite; amphibolite

2.3 GEOLOGIC UNITS BY ERA

2.3.1 Precambrian

Older Precambrian rocks are restricted to the southern part of the BMDO planning area (**Figure 2-3**). These rocks consist largely of gneiss and schist with minor granitoid intrusive rocks. Intensely folded granitic lenses in southern Nye County have been dated at 1.74 Ga (Stewart and Carlson 1978) leading to speculation that these rocks were metamorphosed in the Mesozoic.

During latest Precambrian time and the early Paleozoic Era, approximately 40,000 feet of marine sedimentary and basic volcanic rocks were deposited in an accretionary offshore basin setting. Late Precambrian quartzites and conglomerates with minor siltstones and carbonates record a transgressive event. These rocks include the Stella Lake Quartzite, Johnnie formation, Wyman Formation, Reed Dolomite, Deep Spring, Campito, Poleta, Harkless, Saline Valley Formations, and Mule Spring Limestone.

2.3.2 Lower Paleozoic Stratigraphy

Paleozoic formations are exposed primarily in structural windows (erosional breaks in an overlying thrust sheet that exposes underlying rocks) within the planning area and are in excess of 50,000 feet thick in Humboldt and Pershing Counties (**Figure 2-3**). Lower Paleozoic rocks are exposed throughout the BMDO planning area and comprise a complex mixture of marine clastic and chemical sedimentary rocks that are typically divided into three general groups:

- Western siliceous assemblage;
- Transitional assemblage; and
- Eastern carbonate assemblage.

The western siliceous assemblage represents deep-water sedimentation along the western margin of the North American craton and is locally intercalated with marine volcanic rocks. These rocks are typically exposed on the upper plate of the Roberts Mountain thrust (Stewart and Carlson 1978) and include chert, shale, argillite, and siltstone with minor quartzite and carbonates deposited as deep water marine deposits on the western flank of the North American continent. Rock formations include the Slaven Chert, Cockalorum Was Formation, Elder Sandstone, Fourmile Canyon Formation, Valmy Formation, Palmetto Formation, Vinini Formation, Harmony Formation, and Scott Canyon formation.

Rocks of the upper plate of the thrust fault (deeper water sediments) were displaced to the eastward along the Roberts Mountain thrust and now overlie shallower water sequences exposed in windows through the Roberts Mountain thrust plate. Movement along the Roberts Mountain thrust probably took place during the Antler orogeny as evidenced by a structural unconformity between late Silurian and early Mississippian depositional units throughout northern Nevada (Johnson 1977; Willden 1964; **Figure 2-2**). The structural relationship placing silicic and volcanic rocks over carbonate units along the Robert's Mountain Thrust is a major control for the localization of Carlin-type gold deposits in Nevada (Doebrich 1996).

Transitional assemblage rocks are time-equivalent to the western silicic assemblage and represent intermediate depth deposits consisting of limestone, chert, shale, calcareous siltstone, and phyllites. These rocks were deposited on the slope between the continental shelf and deep-water silicic deposits. Western siliceous assemblage rocks are typically exposed in the upper plate of the Roberts Mountain thrust above the transitional assemblage. These rocks include the following formations: Roberts Mountains, Storff, Chellis Limestone, Aura, Perkins Canyon, Preble, Emigrant, Reed Dolomite, Deep Spring, Campito, Poleta, Harkless, Saline Valley, and Mule Spring Limestone.

The eastern carbonate assemblage includes shallow marine, intertidal, and supratidal carbonate and associated rocks deposited on the continental shelf. These rocks occur in the lower plate of the Roberts Mountains Thrust and consist primarily of dolomite with minor limestone, shale, and quartzite including the Sevy Dolomite, Simonson Dolomite, Guilmette Formation, Nevada Formation, Devils Gate Formation, Laketown Dolomite, Lone Mountain Dolomite, Ely Springs Dolomite, Pogonip Group, Eureka Quartzite, and Ely Springs Dolomite. These rocks were deposited in shallow water as reefs and include fore reef and back reef deposits as well as limited amounts of clastic sedimentary materials deposited above sea level.

The majority of mineralization in the northern Carlin trend is hosted in the Devonian carbonate and shale units beneath the Roberts Mountain thrust (Micklethwaite 2011).

2.3.3 Upper Paleozoic Stratigraphy

The Mississippian through Permian periods formed small exposures throughout the northern two thirds of the planning area (**Figure 2-3**). The Upper Paleozoic is divided by some workers (Stewart and Carlson 1978) into a western siliceous and volcanic assemblage, a central belt, and an eastern clastic and carbonate assemblage.

The western assemblage comprises mafic to felsic volcanic rocks and clastic rocks believed to have been deposited on the western flank of the Antler orogenic belt. Most of these exposures are on the upper plate of the Golconda Thrust. These rocks include the Havallah Sequence which includes the Pumpernickel Formation and Excelsior Formation. Massive limestone, possibly related to this assemblage, occurs in western Nye County.

The central assemblage consists of conglomerate, siltstone, and limestone believed to have been deposited within the Antler orogenic belt. These rocks include the Diablo Formation, Candelaria Formation, Grossman Formation, Banner Formation, Nelson, and Mountain City Formation as well as the Antler Sequence which consists of conglomerate, limestone, sandstone, and calcareous shale. Individual formations within the Antler Sequence comprise the Battle Formation, Antler Peak Limestone, Edna Mountain Formation, and Wildcat Peak Formation.

The eastern assemblage was deposited in a foreland basin or continental shelf east of the Antler orogenic belt. These rocks consist of sandy and silty limestone, limestone, siltstone, sandstone, and conglomerate. Individual units include the Carbon Ridge Formation, Garden Valley Formation, Moleen Formation, Tomera Formation, Pilot Shale, Joana Limestone, Chainman Shale, Diamond Peak Formation, Narrow Canyon Limestone, Mercury Limestone, and Eleana Formation.

2.3.4 Mesozoic Sedimentary Rocks

Mesozoic (Triassic through Cretaceous) rocks within the planning area are exposed in a small area southwest of Battle Mountain (**Figure 2-3**). These rocks consist of shale, mudstone, siltstone, and carbonates with sparse volcanic rock of the Auld Lang Syne Group and limestone with minor dolomite, shale, and sandstone with local conglomerate of the Tobin Formation, Dixie Valley Formation, Favret Formation, Augusta Mountain Formation, Cane Springs Formation, Star Peak Group, Grantsville Formation, and Luning Formation.

2.3.5 Mesozoic Intrusive Rocks

The Sevier orogeny was accompanied by felsic igneous rocks intruded into the region during the Jurassic and, possibly, Cretaceous. These rocks range in composition from granodiorite to granite (**Figure 2-3**) and may be responsible for mineralization at McCoy/Cove and other skarn deposits in the region.

2.3.6 Tertiary Volcanic and Sedimentary Stratigraphy

Tertiary volcanic rocks are exposed in most of the mountain ranges in the planning area (**Figure 2-3**). These rocks formed in response to a regional extension that has been active in the Basin and Range since early Tertiary. Compositions range from basalt to rhyolite with volcanic types ranging from small basalt cinder cones or rhyolite domes to large caldera eruptions commonly known as "supervolcanoes" (Miller and Wark 2008). Numerous named ash-flow tuffs (ignimbrites) occur within the planning area. These rocks host numerous gold/silver deposits and host some oil in Railroad Valley.

Tertiary stratigraphy is complex largely because the volcanic rocks were erupted from what are, in essence, point sources and the erupted materials have somewhat limited aerial extents. Volcanic products from one eruptive center typically overlap products from other eruptive centers; complicating the stratigraphy. For that reason, details of the Tertiary volcanic stratigraphy throughout the planning area are not discussed here.

General stratigraphy of the supervolcanoes consists of a basal andesite layer with overlying rhyolitic volcanic rocks (Boden 1986; David *et al.* 2008). Centers of volcanism are generally younger to the southwest with the oldest volcanic rocks in the northeast part of Nevada and the youngest along the California border. Many of these volcanic centers are associated with base and/or precious metals mineralization (John 2008; McKee 1996).

2.3.7 Quaternary Rocks

Quaternary rocks in the planning area consist primarily of basin-fill material with minor amounts of alluvium, colluvium, and landslide deposits (**Figure 2-3**). Basin-fill deposits are several thousand feet thick depending on which basin is filled. Playa (ephemeral lake) deposits that form in most of the basins are also included in the Quaternary.

Most of the basin-fill materials are coarse to fine grained clastic sediments shed from adjacent mountain ranges. Alluvial fans from mouths of mountain canyons are an obvious geomorphic feature that attests to erosion of the mountains and deposition in the basins. Playas are predominantly fine grained clastic sediments with some salt deposits locally interfingered with sandstone and conglomerate. These deposits host lithium brines at Clayton Valley and may host lithium brines elsewhere.

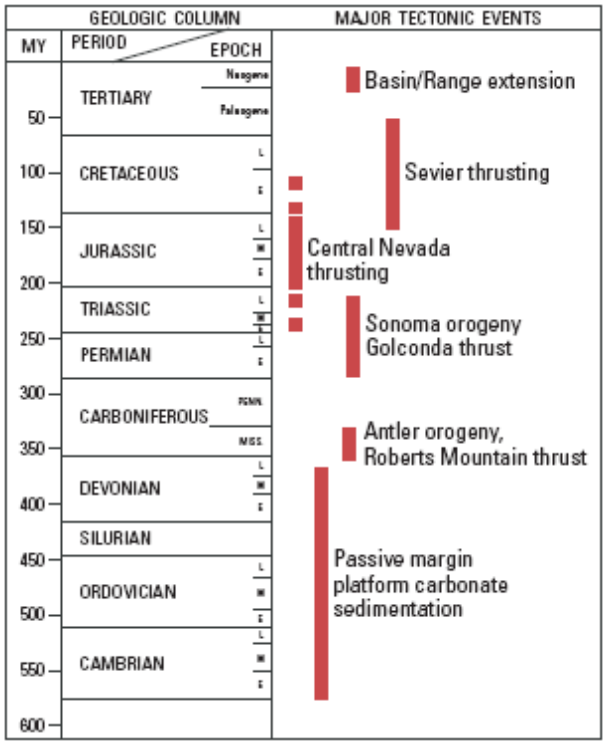
Numerous small basalt volcanoes occur within the planning area. These consist of flows, cinder cones, and small composite volcanoes. Maar volcanoes are included with these rocks. Quaternary rocks are the source for much of the sand and gravel in the planning area.

2.4 STRUCTURAL GEOLOGY AND TECTONICS SUMMARY

This summary of tectonics and structure is taken largely from Anna *et al.* (2007). References have been removed except where necessary for clarity.

Several major tectonic events combined to produce complex structural and stratigraphic patterns that characterize the geologic framework within the planning area (**Figure 2-4**; Anna *et al.* 2007). These events include the Antler orogeny, the Sonoma orogeny, late Paleozoic and Mesozoic thrusting, the Sevier thrust system, and Neogene extension (or Basin and Range extension).

Figure 2-4: Major Tectonic Events in the Planning Area



Source: Anna *et al.* 2007

2.4.1 Antler Orogeny and Roberts Mountain Thrust

The planning area was part of a passive carbonate platform margin environment throughout most of the early to middle Paleozoic (Anna *et al*. 2007). However, as the Late Devonian Antler orogeny began in the western Cordillera, the passive carbonate platform environment was replaced by clastic sedimentation in a thrust related foredeep basin. The Roberts Mountain allochthon formed a north-south-trending upland area in central Nevada in Early Mississippian time, with the Roberts Mountain thrust as the leading thrust. The allochthon consisted of an assemblage of lower Paleozoic, deep-basin graptolitic, cherty, and organic shales thrust over an autochthonous assemblage of fine grained clastics of Mississippian and Devonian carbonates. East-vergent thrusting created an eastward-migrating foredeep trough in front of the thrusting, followed by a forebulge or bathymetric high, and finally an easternmost back basin.

2.4.2 Sonoma Orogeny and Golconda Thrust

The Sonoma orogeny occurred in Permian and Triassic time, resulting in eastward transport of the Golconda allochthon consisting of deepwater clastic sediments of the Havallah sequence. The allochthon was thrust over the beveled Antler allochthon highland, although the east-verging Golconda thrust is west of and generally parallel to the Roberts Mountain thrust. Little deformation or metamorphism accompanied emplacement of the Golconda allochthon and only a modest amount of sediment was shed off of the uplifted fault sheet. As a result, the Sonoma orogeny, although having some effect on the burial history of Mississippian source rocks from Permian and Early Triassic deposition, did not play a major role in the petroleum potential of the EGB Province (Anna *et al.* 2007).

2.4.3 Central Nevada Thrust Belt

The central Nevada thrust belt (CNTB) is a narrow north-south-trending zone (at approximately 116.5° longitude) of compressional structures located in the hinterland of the Sevier orogenic belt (Anna *et al*. 2007). The thrust system was probably continuous for tens to hundreds of miles in the north-south direction but Neogene extension segregates the province into basins and ranges, and exposures of the CNTB are now observable only in the ranges. In addition, little evidence exists as to the thrust system's subsurface configuration, including how Neogene extension segmented the compressional structures. Although poorly constrained, evidence appears to support an Early Triassic to mid-Cretaceous age for the thrusting but the rates and timing of compression probably varied. Taylor (2001) mapped parts of the thrust belt as three stacked thrust sheets with the hanging walls consisting of Precambrian through Permian strata. Chamberlain and Gillespie (1993) mapped thrust sheets in southeastern Nevada, which they identified as part of the CNTB; in their opinion, structures within the thrust system may hold large accumulations of oil and gas and represent the best chance for a significant oil discovery in Nevada.

2.4.4 Sevier Thrust System

Willis (1999) defined the Cordilleran thrust system as an east-verging thrust system that extended from Alaska to Mexico and was tectonically active from Late Jurassic to early Tertiary time. It is part of the Cordilleran thrust system and the name Sevier is limited to the eastern Great Basin of Utah and adjacent

areas. The main or frontal part of thrusting is approximately 60 miles wide and extends from south-eastern Nevada to the Utah part of the Wyoming thrust belt.

Deformation in the eastern part of the thrust zone was thin skinned and susceptible to fault imbrication (thrust repetition of sedimentary sequences above the basement) and folding (Miller *et al.* 1992; Cowan and Bruhn 1992).

The Sevier system is distinguished from the Laramide system in both time and style. Although the systems overlap Cretaceous through the Eocene, a sequence of shorter duration than the Sevier system, and involve thick-skinned deformation characterized by uplift and thrusting of Precambrian basement. The effects of the Sevier emplacement of thrust sheets on autochthonous terrane are typical of thrust systems with a foredeep basin in front of the leading thrust and a forebulge high and a backbulge basin. The system prograded from west to east, depositing as much as several thousand feet of sediment, including potential source rocks of the Cretaceous, Mowry, and Hilliard Shales in the foredeep east of the province boundary. By the Late Cretaceous, most of the thrusting had ceased; then, either in the early Tertiary or as part of Neogene extension, compressional stresses relaxed enough to produce backsliding on thrust planes. As a result, the load of the hanging wall was removed from the footwall and may have promoted isostatic rebound in the footwall, which resulted in the formation of extensive fold belts, such as the Sevier Valley and Virgin River folds. However, these folds may be due to Sevier compression and not from isostatic rebound.

2.4.5 Neogene Extension and Related Structures

The EGB Province underwent extensional deformation in the Neogene, resulting in the formation of the present-day Basin and Range Province. Basin and Range extension began about 25 Ma when the west-moving North American plate started to override the Pacific plate (before overriding the Farallon plate (Wernicke 1992). As the North American plate continued migrating westward, a deep seated, relatively stationary, north trending upwelling of the mantle caused extension in the east-northeast direction. Thin and structurally weak Phanerozoic rocks broke into horst and graben (basin and range) blocks. As in many extensional terranes, individual basins differ in their structural configurations - some basins are bound by steep to vertical normal faults, some by gently dipping normal faults, and some by steep faults at the surface that become listric at depth – a characteristic that complicates exploration strategies.

Magmatism and metamorphic core complexes are associated with basin and range extensional tectonics (Miller *et al.* 1998). The Columbia Plateau basalts flooded southern Idaho and adjacent areas, and there was uplift of metamorphic core complexes in northeastern Nevada. Emplacement of core complexes enhanced the effects of extension by pushing strata away from the uplift.

2.4.6 Basin Development

Railroad Valley

Railroad Valley has produced most of the oil in the planning area and has been extensively studied to determine relations between structure and oil production. Several interpretations of basin configuration

have evolved, based on improved seismic acquisition and processing and, better understanding of deformation styles and kinetics. Lund *et al.* (1993) and Potter *et al.* (1992) for example, reported that a low-angle attenuation fault that underlies Railroad Valley, exposed in the adjacent range, was a result of asymmetric arching rather than a series of down-to-the-west high-angle normal faults. According to them (Lund *et al.* 1993; Potter *et al.* 1992), 1) some high-angle normal faults exist as part of the deformation process, but they are not the dominant style, and 2) a transfer of heat from the lower plate of the low-angle fault to the otherwise cool upper plate could occur by either convection or discrete pathways through the high-angle normal faults or fracture zones, possibly allowing source rocks in the upper plate to reach oil generating temperature.

Pine Valley

Pine Valley has four field discoveries, but only the Blackburn field has commercial production. Distribution of fields and seeps indicates that oil could have multiple migration routes throughout the valley, but the lack of traps or seals may limit the volumes of accumulation.

Pine Valley has had two major periods of deformation: emplacement of the Mississippian Roberts Mountain allochthon and Neogene extension. The Roberts Mountain allochthon was emplaced between mid-Osagean and Meramecian time that encompassed the Diamond Peak and Chainman Formations. The allochthon moved deep-basin cherty, graptolitic, organic shales (termed the Western Assemblage - WA) about 65 miles eastward, overriding parts of the Chainman Formation. According to Carpenter *et al.* (1993), emplacement of the allochthon was relatively passive; however, post-allochthon Mesozoic deformation faulted and folded sections above and below the Roberts Mountain thrust. Although the organic material in the WA has not been typed to oil produced in the valley, the combination of the WA and the Chainman Formation could represent substantial source rock potential for the area.

Pine Valley was formed by Neogene extension starting in late Oligocene time and by fault offsets in Holocene alluvium, which indicates extension is ongoing (Carpenter *et al.* 1993). The basin floor dips east into the high-angle Pine Valley fault, which defines the east edge of the basin. Folds and faults in the area formed during both pre-extensional and extensional deformation. Force folds, normal faults, and reverse faults are typical features creating multiple structural configurations and potential traps in the basin.

Paleontology

No systematic field survey has been conducted for paleontological resources in the planning area, but the paleontological resource potential is in the process of being classified according to the Potential Fossil Yield Classification (PFYC) system. Using the PFYC system, geologic units are classified based on relative abundance of vertebrate fossils or scientifically significant invertebrate or plant fossils and their sensitivity to adverse impacts, with a higher class number indicating a higher potential. This classification is applied to the geologic formation, member, or other distinguishable unit, preferably at the most detailed mappable level. The PFYC system is meant to provide baseline guidance for predicting, assessing, and mitigating impacts to paleontological resources.

While no systematic field surveys have been conducted, numerous paleontological localities have been identified by independent researchers. Some of the most important paleontological resources found in

or around the planning area include Mesozoic icthyosaurian fossils, Triassic hybodont shark remains, a geologic exposure exhibiting remains of a fossilized forest, and various localities that contain assemblages of fossils unknown to science prior to discovery of the sites.

Few Early Precambrian rocks are preserved in Nevada. Fossils of blue-green bacteria in some Late Precambrian rocks in the southern and eastern part of the state indicate shallow seas began to flood the edge of a quiet continental margin (Paleoportal 2011a).

Paleozoic rocks are well represented in Nevada. Warm, shallow seas gradually flooded the state during the early part of this time interval and continued to cover the southern and eastern part of the state through the Devonian; the water deepened into an ocean basin to the northwest. Reef communities flourished in shallower parts of the sea, while fossils of graptolites and other floating organisms are preserved in some deep-water deposits. An episode of mountain building (the Antler Orogeny) occurred toward the end of the Devonian and continued into the early part of the Carboniferous. By the Permian, sea level had dropped and parts of Nevada were dry land. Plant fossils can be found in rocks formed in shallow lagoons and beaches in the eastern part of the state, while scattered reefs still existed in the north and northeast. Deep oceans persisted in the northwest, and chert and shale deposits from this time are rich in the fossils of plankton.

The Roberts Mountain, Monitor Range, and Lone Mountain in Eureka County have been an important resource in the study of Late Ordovician period mass extinction according to Finney *et al.* (1999). The Late Ordovician mass extinction was the second greatest of five large prehistoric mass extinctions. Eureka County contains an exceptional record of the Late Ordovician mass extinction in three sedimentary successions. These Eureka County records are uniquely complete compared to other locations in the world and include distinct sedimentological signals of sea-level changes, abundant fossils, and well preserved carbon profiles. This allows unparalleled opportunity for scientists to assess associations between glaciation, extinction, and disruption of the carbon cycles.

The Simpson Park Range (Red Hill area) and Roberts Mountains have produced a number of Devonian period vertebrate fish fossils along with marine invertebrates. Turner (1988) states the fossil specimens discovered include dipnoans, acanthodians, arthrodires, antiarchs, and crossopterygians. Burrow (2003) describes several upper Silurian vertebrates from the same area. These are important occurrences because they are some of the earliest vertebrates in the geological record.

The Permian Period marks the end of the Paleozoic Era and the time of the largest mass extinction in Earth's history. This extinction event affected many different environments, but it affected marine communities the most by far. An estimated 90 percent of all species became extinct at the end of the Permian. Gone were the trilobites, rugose and tabulate corals, and many species of brachiopods,mollusks, and echinoderms (Paleoportal 2011b). As the climate became drier, vast swamps of the Carboniferous disappeared and were replaced by forests more tolerant of dry conditions. Modern conifers first appeared in the fossil record of the Permian.

The Mesozoic was a time of changing sea level and intense tectonic activity. In the Triassic, the ocean continued to recede; however, deeper water persisted in the central and western parts of the state, and fossils of ichthyosaurs and ammonites are abundant (Paleoportal 2011c). The Berlin-Ichthyosaur State Park is located near the mouth of West Union Canyon in the Shoshone Mountains of central Nevada.

At the ichthyosaur site, a building protects an exposed bedrock surface that contains the bones of several giant ichthyosaurs. These marine reptiles died and were buried in sediments about 217 Ma during the Triassic period (upper Carnian) (UCMP 2011). At that time, an arm of what is now the Pacific Ocean covered portions of the west, including present-day Nevada. The ichthyosaur-bearing rocks, which also contain ammonites, are part of the Luning Formation. Ammonites and marine bivalves were the first fossils to be found here, but it is believed that early miners were the first to notice the ichthyosaur bones.

Rocks from the Jurassic indicate a deep-water environment limited to the northwest, a shallow marine environment in the central area, and non-marine environments to the south and east. Cretaceous rocks are rare in Nevada, but they indicate that a volcanic island arc formed along the western edge of the state. Scattered twigs believed to be from Sequoia trees are reported from Eureka County are the only known Cretaceous fossils from the state.

During the Early Cenozoic (Tertiary), tectonic activity was intense and blocks of crust rose to form mountains, while others dropped to form basins, initiating the Basin and Range Province we see today. Bears, camels, horses, rhinoceros, chalicotheres (a relative of horses, rhinos, and tapirs), musk deer, and early elephants roamed through woodlands populated with oak, redwood, and willow. Volcanic eruptions were frequent. During the Late Cenozoic (Quaternary), the Sierra Nevada Mountains were uplifted, and glaciers sculpted the highest peaks. Mammoths, horses, camels, and giant ground sloths roamed freely. Volcanic eruptions continued throughout the state, depositing ash flows and lava. Conodonts and fish are found in marine or lacustrine environments.

The planning area also includes a wealth of invertebrate paleontological resources, including crustaceans, mollusks, trilobites, and brachiopods. Flora fossil types include rushes, willows, an abundance of fossilized wood of early conifers, and a variety of grasses, ferns, and other plant types.

3. MINERAL RESOURCE OCCURRENCES

3.1 LOCATABLE MINERAL RESOURCES

3.1.1 Introduction

Locatable minerals are minerals for which the right to explore, develop and extract mineral resources on federal land open to mineral entry is established by the location (or staking) of lode or placer mining claims as authorized under the General Mining Law (May of 1872) as amended. Mining is also regulated under the Wilderness Act, the Wilderness Study Area Act and other applicable federal regulations. Some of these Federal regulations include: 43 CFR 3809, Surface Management Regulations; 6300 Wilderness Regulations; 5860 Wilderness Management Handbook; 43 CFR 3802, Exploration and Mining, Wilderness Review Program and 43 CFR 3715, Use and Occupancy.

Examples of locatable minerals historically or currently mined within the planning area include metallic minerals (*i.e.* gold, silver, copper, mercury, zinc, molybdenum, uranium, tungsten, etc.) and industrial minerals (*i.e.* limestone, barite, gypsum, diatomaceous earth, fluorspar, and opal).

Nevada has produced more gold, barite and gypsum than any other state in the nation and is the world's sixth largest gold producer. Mining in Nevada also produces a variety of other mineral commodities including aggregates, copper, diatomite, dolomite, gemstone, limestone, lithium and magnesium compounds, perlite, potassium sulfate, salt, silica sand, specialty aggregates and clays. In all, Nevada mineral production was $5.8 billion in 2009 (excluding oil and geothermal energy) and precious metals accounted for about $5.0 billion of that total.

3.1.2 BLM Locatable Minerals Program

BLM'S locatable mineral program is reactive to proposals to explore and/or plans to mine an area as submitted by individuals or mining companies. Surface disturbing activities under the jurisdiction of 43 CFR 3809 regulations (43 CFR 3802 if within a wilderness study area) are reviewed on a case-by-case basis. BLM's decision to authorize surface disturbance activities requires compliance with the National Environmental Policy Act (NEPA). Occupancy related to mining is regulated under 43 CFR 3715. The intent of these regulations is to prevent unnecessary or undue degradation of surface resources or the environment, to ensure reasonable reclamation of disturbed sites on public land, and to prevent surface occupancy on unpatented mining claims for non-mining purposes.

The regulatory framework necessary for oversight and permitting of mineral exploration and mining operations is in place. Exploration or production activities disturbing more than five acres (two hectares) require a Plan of Operation, Reclamation Plan, and NEPA environmental analysis and compliance. Notices (required for exploration surface disturbances of less than 5 acres using both mechanized and non-mechanized equipment and no explosives) and Plans of Operation both require reclamation bonding. Notices and "casual use" are not designated federal actions and thus do not require environmental analysis. Casual use areas do not require approval by the BLM. Notices are reviewed and approved by an authorized officer and measures applied to prevent unnecessary or undue surface degradation.

The planning area has a long history of mineral development dating back to the 1860s. Currently there are four large open pit / underground gold / silver mines (**Table 3-1**), and three industrial mineral mines in operation (**Table 3-2**). There are a number of small mines in the planning area and several projects are in the permit process. From the record, 2,507 mining notices have been submitted since 1990. Note that **Table 3-3** includes active small mines and exploration programs, but excludes permitted sand and gravel operations. The minerals program administers 39 active sales and 175 free-use permits.

TABLE 3-1
2009 Production for Metal Mines in the Planning Area

Mine - Metals	County	Operator	Au (oz)	Ag (oz)	Cu (lbs)
Ruby Hill Mine	Eureka	Barrick Gold Corporation	103,523	39,110	
Cortez Hills/Pipeline Mines	Lander	Barrick Cortez, Inc.	517,512	74,080	
Phoenix Project	Lander	Newmont Mining Corp.	218,732	1,212,153	23,733,389
Smoky Valley Common Operation	Nye	Round Mountain Gold Corp.	414,941	850,878	
Mineral Ridge	Nye	Golden Phoenix	*	-	-
Manhattan Gulch	Nye	A.U. Mines Inc.	**	-	-

Au = gold; Ag = silver; Cu = copper; * Began production in early 2011; ** Under Development

TABLE 3-2
Industrial Minerals in the Planning Area – 2009 Production

Mine - Industrial Minerals	County	Operator	Barite (tons)
Argenta Mine and Mill	Lander	Baker Hughes Drilling Fluids	Barite - 84,470 tons
Battle Mountain Grinding Plant (Greystone Mine)	Lander	M-I Swaco	Barite - 220,650 tons
Silver Peak Operations	Esmeralda	Chemetall Foote Corp.	Lithium compounds
Basalt Mine	Esmeralda	Grefco Minerals, Inc	Diatomite

TABLE 3-3
Plans of Operation in the Planning Area

Project/Permit	County	Operator	Commodity
Rulco	Esmeralda	Rulco LLC	Sulfur
Nivloc Prospect	Esmeralda	Silver Reserve Corp	Silver
North Goldfield	Esmeralda	Earl W Smith	Gold
Monte Cristo Project	Esmeralda		Gold
Mineral Ridge Mine	Esmeralda		Gold
Lone Mountain Turquoise	Esmeralda	Lone Star Mining LLC	Turquoise
Inland Navigator Project	Esmeralda		Gold, Silver
Global Silica Mine	Esmeralda	Global Silica	Silica

TABLE 3-3
Plans of Operation in the Planning Area

Project/Permit	County	Operator	Commodity
February Premier Mine	Esmeralda	Lodestar Gold Inc	Gold
Drink Water Pit	Esmeralda	Golden Phoenix Minerals Inc	Gold
Crescent Mine Project	Esmeralda	B.P. Partners Inc	Gold
Columbia Gold Mines Ltd	Esmeralda	Columbia Gold Mines Ltd	Gold
Alum Mine	Esmeralda	D.C. Minerals Inc	Sulfur
Dunphy	Eureka	Pediment Gold LLC	Gold
Lookout Mountain Project	Eureka	BH Minerals	Gold
Mount Hope	Eureka	Eureka Moly LLC	Molybdenum
Nevada Barth Iron Mine & Mill	Eureka	Saga Exploration Co	Magnetite
Red Canyon Project	Eureka	Montezuma Mines	Gold
Buffalo Valley - Newmont	Lander	Newmont Mining Corp	Gold
Cedars - Newcrest	Lander	Newcrest Resources Inc	Gold
Cove-Helen Underground Project	Lander	Victoria Resources	Gold
McCoy Cove	Lander	Newmont Mining Corp	Gold; Silver
Elder Creek Project	Lander		Gold, Silver
Firecreek	Lander	Klondex Mine Ltd	Gold
Galena Canyon	Lander	Madison Minerals	Gold
Goat	Lander	Barrick	Gold
Gold Acres	Lander	Barrick	Gold
Grass Valley Ranch	Lander	Newmont Mining Corp	Gold
Greystone Mine & Mill	Lander	M-I Drilling Fluids Co	Barite
Hilltop Project	Lander	Cortez Joint Venture	Gold
HM Project	Lander	Barrick	Gold
Horse Mountain	Lander	Newcrest Resources Inc	Gold
Irish Rose	Lander	Newmont Mining Corp	Gold
Jack Creek	Lander	Placer Dome	Gold
Keystone	Lander	Placer Dome	Gold
Fire Creek	Lander	Klondex Gold & Silver	Gold
Luna-Redrock	Lander	Centerra (U.S.) Inc	
McGinness Hills Project	Lander	Newcrest Resources Inc	Gold
Modoc	Lander	Golden Predator Mines	Gold
Mule Canyon Mine	Lander	Newmont USA Limited	Gold
North Kingston	Lander		Gold, Silver
Robertson Project	Lander	Coral Resources Inc.	Gold
Rock Island	Lander	Newcrest Resources Inc	Gold
Slaven Canyon Exploration	Lander	White Knight Gold (US) Inc	Gold

TABLE 3-3
Plans of Operation in the Planning Area

Project/Permit	County	Operator	Commodity
Squaw Butte	Lander	Newmont Mining Corp	Gold
Timber Canon	Lander	Nevada Pacific Gold (US) Inc	Gold
True Grit	Lander	Placer Dome	Gold
Ash Meadows Plant and Mine	Nye	ZEOX Mineral Materials Corp	Zeolite
Corcoran Canyon Project	Nye	Bullion River Gold Corp	Silver
Gold Hill Project	Nye	Round Mountain Gold Corp	Gold
Golden Arrow	Nye	Pacific Ridge Exploration	Gold
Hasbrouck Mountain	Nye	Centerrra	Gold
Manhattan Gulch Operation	Nye	Bob Bottom	Gold
Manhattan Mill	Nye	Tin Cup Mining Corp	Gold
Midway Property	Nye	MGC Resources Inc	Gold
North Bullfrog	Nye	Mayflower	Gold
Northumberland Project	Nye	Newcrest Resources Inc	Gold
Royston Claims	Nye	Dean Otteson	Turquoise
Silverbow	Nye	Golden Predator Mines	Gold
Silverton Project	Nye	Newcrest Resources Inc	Gold
South Monitor	Nye	Golconda Gold Inc	Gold
Sterling Mine	Nye	Sterling Gold Mining Corp	Gold
Stonewall Springs	Nye		Gold
Sullivan	Nye		Gold
Summit Project	Nye		Gold
Thunder Mountain Exploration Project	Nye	Alaska Gold Company	Gold
White Buffalo	Nye	Dean Otteson	Turquoise
White Caps Mill	Nye	Vanderbilt Minerals Corp	Smectite Clay

3.1.3 Geological History of Mineral Resources

The structural and geologic history of Nevada, in particular the Paleozoic and early Mesozoic compressional mountain building events with associated thrusting and plutonism, and the later Tertiary crustal extension events with high heat flow into the earth's crust and associated volcanism, has created a variety of mineral deposits in numerous mining districts throughout the state of Nevada and particularly within the planning area. Metallic mineral deposits of central Nevada are spatially, temporally, and genetically related to the emplacement of a large number of small stocks and a few larger intrusive bodies (batholiths) associated with these mountain building and crustal extension events. Development of extensive fracture and fault systems associated with mountain building is also spatially related to formation of various vein type and replacement mineral deposits (as well as with geothermal resources). Intrusive stocks created hydrothermal systems necessary for mobilization and deposition of

metallic minerals, and fracture and fault systems provided conduits along which hydrothermal solutions were mobilized. In and near these pathways, valuable ores of native metals (gold and silver) or sulfide minerals containing copper, lead, zinc, and molybdenum were deposited. In many deposits, several different valuable metallic mineral assemblages may be present at the same location.

The US Geological Survey (USGS) has identified over 1400 mines and prospects in the state of Nevada (approximately 446 of which fall within the four counties in the planning area) (Sherlock *et al.* 1996).Erosion of mineralized bedrock has locally concentrated gold into economic placer deposits. Approximately 78 percent of all deposits occur within existing established historical mining districts (Sherlock *et al.* 1996).

The planning area contains some of the most famous gold and silver metal mining districts in the US, including: Battle Mountain, Cortez, Round Mountain, Tonopah, Goldfield, and Eureka (Davis and Hess 2009). Those districts have also produced significant copper, lead, zinc, and tungsten. In all, approximately 100 organized mining districts are located within the planning area (Tingley 1998). Economic deposits of lithium, barite, diatomite, silica, and sand and gravel are being mined or have been mined in the past. Locatable mineral deposits are discussed in greater detail by commodity below.

3.1.4 Mining History

Mining within the planning area began in earnest in the 1860s and continues today. Mines within the planning area produced approximately one-half of the gold, 12 percent of the silver, and 10 percent of the copper produced in Nevada in 2008. Total production of gold, silver, and copper from Nevada is largely a matter of conjecture because much of the early production was not reported, but the mines at Tonopah, Goldfield, Beatty, Eureka, Battle Mountain, and elsewhere were significant producers of precious and base metals.

3.1.5 Active Mines

Figure 3-1 shows the location of active mines and energy producers in Nevada in 2009. Mines located in the planning area are briefly described below. Several smaller mines are located within the planning area but are not described.

Phoenix Mine

The Phoenix Mine is located in Copper Canyon approximately 11 miles south of Battle Mountain in Lander County, Nevada. Exploitation of gold, copper, and silver ores from the Battle Mountain mining district, best known for the Fortitude gold skarn deposit, dates back to the mid-1860s (Roberts and Arnold 1965). Following its acquisition of Battle Mountain Gold Corporation Newmont Mining Corporation has been developing the district, concentrating on drilling Antler Sequence rocks untested by Battle Mountain Gold (Breit *et al.* 2011). Production from the district from initiation of mining through 2009 is presented in **Table 3-4**. As of January 2010 reserves at the Phoenix Mine stood at 287,536,000 tons at an average gold grade of 0.62 g/ton (0.020 opt) for 178,537 kg (5,739,972 oz) Au and an overage copper grade of 0.156 wt. percent for 408,182 tons (898,000,000 lbs) Cu.

TABLE 3-4
Production of Gold-Silver-Copper From the Phoenix Mine Area

Year	Process	Au (kg)	Ag (kg)	Cu (tons)
Pre-2001		95,943	495,707	102,002
2001	Reona HL	226		
2002	Reona HL	188		
2003	Reona HL	114		
2004	Reona HL	239		
2005	Reona HL	238		
2006	Phoenix Mill	4,292	14,034	3,492
2007	Phoenix Mill	6,242	25,088	6,292
2008	Phoenix Mill	6,824	41,325	9,553
2009	Phoenix Mill	6,128	39,474	10,525
Totals		**120,434**	**615,628**	**131,864**

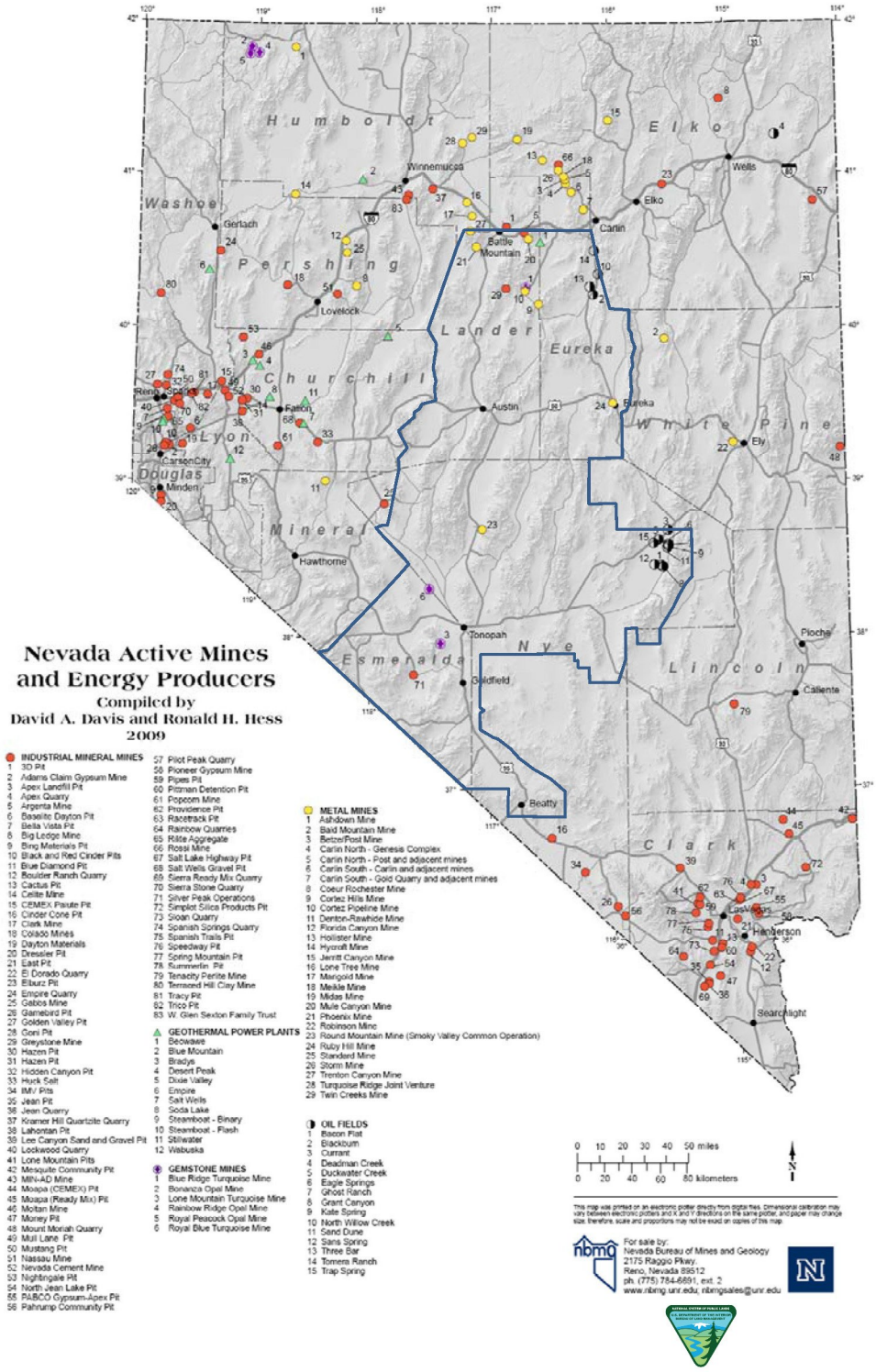
Au = gold; Ag = silver; Cu = copper; kg = kilogram;

The Phoenix deposit lies on the northwest end of the Battle Mountain-Eureka trend, a northwest-trending mineral belt, west and sub-parallel to the Carlin trend. While Phoenix and the Battle Mountain district are commonly recognized as part of the Battle Mountain-Eureka trend, it should be noted that north-south structural control, addressed in more detail below regarding Phoenix, is important in individual deposits from Phoenix north through Trenton and North Peak, Lone Tree, and Twin Creeks. The Phoenix deposit could be interpreted to be at the south end of the "Rabbit Suture" proposed by Bloomstein *et al.* (1991).

The regional geologic setting of the Battle Mountain mining district has been well documented by Roberts (1964), Doebrich (1995), and Doebrich and Theodore (1996). Rocks that were part of the Antler and Sonoma orogenic events that affected the western margin of North America are found at Phoenix. The Cambrian Harmony Formation, emplaced above the Devonian Scott Canyon Formation along the Dewitt thrust (Roberts 1964), is part of the Roberts Mountains allochthon (Roberts *et al.* 1958). Deposited in angular unconformity on the Cambrian rocks are the Pennsylvanian-Permian Antler sequence rocks (Roberts 1964), which are the principal host rocks for Au-Ag-Cu-Pb-Zn mineralization at Phoenix. The Havallah sequence (Silberling and Roberts 1962) was emplaced above the Antler sequence rocks by the Golconda thrust. At Phoenix, these Paleozoic rocks have been intruded by the Eocene age (Theodore *et al.* 1973) granodioritic Copper Canyon stock (Roberts 1964) and are locally overlain by the Eocene tuff of Cove Mine (John *et al.* 2008), a Pliocene olivine basalt (McKee 1992), and alluvium that occurs both above and below the basalt.

Au-Cu-Ag-Pb-Zn skarn mineralization at Phoenix is centered about the Eocene Copper Canyon granodiorite porphyry stock. Paleozoic sedimentary rocks within two miles of the stock have undergone strong thermal metamorphism (hornfels) and metasomatism (skarn). Metal zonation is manifest by a Cu-Mo core close to the stock grading outward into proximal Cu-Au-Ag, Au-Ag and distal Pb-Zn-Ag mineralization.

Figure 3-1: Active Mines and Energy Producers in Nevada in 2009



Source: Davis and Hess 2009.

Mineralization occurs within the three mile long, north-south Copper Canyon structural corridor. This 800–1,700 foot wide corridor is bounded on the west by the Canyon fault zone, which has 1,800 feet of apparent normal offset, and on the east by the ore-controlling Virgin fault zone, which displays 300–800 feet of apparent normal offset. Stratiform skarn mineralization is cut by high-angle west-dipping faults. Current Au and Cu reserves at Phoenix are hosted largely in the Pennsylvanian-Permian Antler overlap sequence, which consists of a generally fining upward sequence of ferruginous conglomerate of the Battle Formation, limestone of the Antler Peak Formation, and calcareous sandstone of the Edna Mountain Formation. The Cambrian Harmony Formation, upon which the Antler sequence was deposited, is only weakly mineralized. Allochthonous argillite and chert of the Permian Havallah sequence overlie the Antler sequence rocks in the upper plate of the Golconda thrust. Hypogene mineralization in both the Harmony Formation and the Havallah sequence is generally structurally controlled.

Gold-copper reserves at Copper Canyon are roughly separated by the Copper Canyon stock. Pyrrhotite-pyrite skarn of the Antler Peak Limestone hosts high-grade gold ore in the Fortitude ore body north of the stock, whereas lower gold grades are present in the underlying Battle Formation. In contrast, Au-Cu-Ag mineralization in the Bonanza area, south of the stock, is hosted mainly in skarn of the Battle Formation; particularly in its lowermost conglomerate unit. Only a small amount of Antler Peak Limestone and no Edna Mountain Formation are recognized south of the stock, which can be a function of either non-deposition in this area or those units might have been faulted out by the Golconda thrust. Fracture-controlled Au-Cu mineralization occurs along the north, south and west margins of the Copper Canyon stock in hornfelsed Havallah sequence in the West Bonanza, Reona, and Sunshine deposits, respectively.

Cortez Hills/Pipeline Mines

Prospecting and mining within the Cortez District dates back to 1862 when silver was discovered in the Cortez and Mill Canyon areas. The Cortez Hills Complex is a cluster of Carlin-type deposits within the Cortez District comprising two in-situ and connected Carlin-type ore bodies with differing geometries and an exotic satellite deposit (Pediment deposit) which is eroded and re-deposited adjacent to the sub-cropping Cortez Hills ore body. The upper portions of Cortez Hills consist of a conical-shaped breccia body generally localized between Tertiary quartz porphyry sills cutting Devonian Wenban Limestone and locally recognized Horse Canyon Formation (Rodeo Creek Formation equivalent) (Arbonies *et al.* 2011).

Cortez Hills is one of the premier gold deposits in North Central Nevada. The Cortez district has produced more than 11 million ounces of gold over more than a century of mining, with the bulk of production occurring from 1995 to the present. The district is controlled 100 percent by Barrick Cortez Mines. The Cortez Hills Complex is being developed by both open pit and underground mining methods, with underground production commencing in late 2008 and open pit production commencing in 2009. During the first five years of full production, an estimated 1 million ounces of gold will be produced annually from combined operations at Cortez Hills and Pipeline (Barrick 2008). At the end of 2008, the published resource base for the Barrick Cortez Mines was 13,384,000 ounces of gold contained within proven and probable reserves; 3,743,000 ounces of gold contained within measured and indicated mineral resources; and an additional 3,848,000 ounces of gold within inferred mineral resources (Barrick 2008).

Paleozoic sedimentary rocks form the regional basement throughout the Cortez District and have undergone a complex history of sedimentation and deformation. These rocks are divided into two different stratigraphic packages deposited in different environments and juxtaposed by the Roberts Mountains thrust complex. Marine clastic rocks or western assemblage rocks (upper plate), were deposited in deep water to the west while carbonate rocks, or eastern assemblage rocks (lower plate), were deposited within shallow water along a passive continental margin to the east (Stewart 1980).

The formations associated with the Western Assemblage are primarily deep water siliceous sedimentary rocks with little or no carbonate. These formations include the Ordovician Valmy and Vinini Formations, Silurian Elder Sandstone, and Devonian Slaven Chert (Gilluly and Masursky 1965). Formations associated with the Eastern Assemblage are predominately carbonate-rich reef, shelf, slope and basin facies and include the Cambrian Hamburg Formation, Ordovician Eureka Quartzite and Hanson Creek Dolomite, Silurian to Devonian Roberts Mountains Formation and Devonian Wenban Limestone and Horse Canyon Formation. The Hanson Creek Dolomite, Roberts Mountains Formation, Wenban Limestone, and Horse Canyon Formation are primary host rocks for Carlin-type gold mineralization within the district.

Smoky Valley Common Operation

The Smoky Valley Common Operation consists of the Round Mountain and nearby deposits operated as open pit mines. Reserves at Round Mountain were 73.0 Mt grading 0.018 oz/t or 1.319 million oz Au (Barrick 2010).

The Round Mountain deposit is located on the western edge of the Toquima Range between the Toquima caldera complex to the north and the Manhattan caldera to the south. Mineralization is hosted by variably welded, 26.7 Ma, rhyolitic tuff of Round Mountain that may be outflow from the Mount Jefferson Caldera. Pre-Tertiary basement rocks in the planning area consist of lower Paleozoic sedimentary and metasedimentary rocks and Cretaceous granitic rocks. The deposit is located immediately east of the range bounding fault system (Fifarek and Gerike 1991).

The current operation began in 1977 and has been developed along the fracture controlled mineralization in the middle, densely welded portion of the tuff of Round Mountain. Most of the open pit production came from zones of early, northwest-striking veinlets characterized by overgrowths of quartz and adularia on quartz and sanidine phenocrysts, respectively in wallrock. These veinlets include isolate limonite casts after pyrite and contain gold. Coextensive veinlets of chlorite-pyrite contain no gold. Tuff hosting the mineralization has been intensely altered to a propylitic assemblage consisting of adularia, albite, chlorite, and pyrite (Fifarek and Gerike 1991).

Densely welded tuff of Round Mountain has potassically altered to quartz-adularia-white mica and prior to oxidation, calcite and pyrite. At high levels in the deposit, the tuff was subsequently silicified or argillized where alteration was incomplete.

Ruby Hill Mine

The Ruby Hill mine is located on the Battle Mountain/Eureka gold trend, less than one-half mile from the town of Eureka. Ruby Hill is an open-pit, heap leach operation. In 2010, Ruby Hill produced 81,000 ounces of gold at total cash costs of $702 per ounce. Proven and probable mineral reserves as of December 31, 2010 were 17.2 Mt grading 0.065 oz/t or 1.122 million ounces of gold (Barrick 2010).

Homestake discovered the West Archimedes deposit in 1992 by drilling under alluvial cover east of a small mineralized prospect pit on Mineral Point, near the northern limit of bedrock exposure. Definition drilling in 1993 defined the footprint of West Archimedes, and discovered the East Archimedes deposit under approximately 600 feet of alluvial cover and east of a small barren zone (Cope *et al.* 2011).

Silver Peak Operations

Silver Peak is a brine operation that has been in continuous production since 1967. Lithium carbonate and lithium hydroxide are the primary products. The operation is located in Clayton Valley, Esmeralda County, approximately 35 mi southwest of Tonopah. Reserve and production information are not generally available, but historical data suggest that about 1,000 tons of Li are produced annually (Keast 2011). Price *et al.* (2000) estimated 2 to 22 million tons of Li were released into the Clayton Valley water system and may be available for extraction; however, this number does not represent a reserve at Silver Peak.

The lithium recovery operation pumps brines from 100 to 250 m depth. Brines used for production in 1970 were reported (Garrett 2004) to contain 300 ppm Li, and are concentrated to approximately 6,000 ppm Li by solar evaporation. Processing of the concentrated brine is completed 3 miles away at a plant in the town of Silver Peak.

Pre-Tertiary rocks outcrop in the ridges surrounding Clayton Valley and include Precambrian metamorphic and sedimentary rocks, Paleozoic marine sediments, and Mesozoic intrusions. The oldest rocks include the upper Precambrian Wyman Formation, Reed Dolomite, and the Deep Spring Formation. The Precambrian and Lower Cambrian Andrews Mountain member of the Campito Formation is also present. Conformably overlying these rocks are approximately 2,400 meters of Cambrian and Ordovician strata consisting of siltstone, black shale, chert, limestone and dolomite that represents deep water facies equivalents of the Paleozoic shelf carbonates of central and eastern Nevada. The units include the Lower Cambrian Montenegro member of the Campito Formation; Poleta Formation; Harkless Formation and Mule Springs Limestone; Middle and Upper Cambrian Emigrant Formation; and, Ordovician Palmetto Formation.

Plutonic rocks intrude the Precambrian and Paleozoic strata at Lone Mountain, Weepah Hills, Palmetto Mountains, and Mineral Ridge. These rocks are generally grey, coarse to medium grained, quartz monzonites with ages ranging from Jurassic to Tertiary. There is no evidence that pre-Tertiary rocks have contributed to the lithium collected in the playa and brine at Clayton Valley.

Resting unconformably on these older rocks are younger, Tertiary and Quaternary sediments and volcanics, which provide the aquifers for the lithium-bearing brines. Some of the volcanics to the east of Clayton Valley contain higher levels of lithium than normal. It is believed that, as they weathered, they provided the lithium in groundwater which moved down to the low point in the drainage system which is Clayton Valley. Other lithium sources, such as local hot springs and other volcanics, may have contributed to the lithium accumulated in Clayton Valley.

Steeply dipping normal faults to the west have resulted in bedrock depressions into which brines have accumulated. Fault scarps form the east side of the valley and sediments dip gently toward this side (Davis *et al.* 1986). Brines are encountered at multiple levels, which vary across the basin and are controlled by the position of the more porous beds.

Argenta Mine

The Argenta district is located in the northern Shoshone Range, approximately 14 miles east of Battle Mountain. Silver was discovered in the planning area about 1867, with a small town developed by 1868 (Carpenter 1994). Argenta continues to be a siding on the Southern Pacific Railroad and a loading point for much of the barite now mined in the district.

Three major barite mines, several smaller mines, and numerous prospects were developed and explored in the district. At Argenta, thin to thick beds of massive barite occur interbedded with chert beds of the Slaven Chert. The largest mine in the district, the Argenta, also known in the past as the Barium King or Nevada Barite, has produced more than 100,000 tons of barite from several large open pits totaling more than $1 million (Stager 1977). The nearby Shelton mine, or Barite (Baryte) No. 1 and No. 3 mine, has not been worked since the mid-1960s. This deposit yielded in excess of 50,000 tons of barite totaling more than $100,000 according to past production figures (Stager 1977). These production figures represent mining through 1969, based on barite values for this time. Most of the barite mined is used for high-density drilling muds in California and in the Gulf Coast area.

Greystone Mine

The Greystone Mine is located in the Shoshone Range. Bedded barite occurs in the Devonian Slaven Chert and Ordovician Valmy formation at the Greystone Mine (Castor and Ferdock 2003). Chert and very fine-grained quartz are interlayered with the barite (Zimmermann 1969). The thickest barite beds lie where the chert and shaly layers are thinnest. These are features one would normally find in sediment. These and other observations suggest a formation by syn-diagenetic processes.

Existing Claims

As of 2008, 65,000 mining claims were active in the planning area.. The total number of claims varies almost daily as the region is an active exploration area with numerous exploration companies and individuals actively exploring.

3.1.6 Mineral Exploration

Mineral exploration, particularly for gold, is an ongoing enterprise in Nevada by both operators of existing mines and by outside exploration companies. Exploration has been active recently (2009-2010) as gold prices have sustained levels above $1,000/ounce and are currently on the order of US$1,800/ounce. The Nevada Commission on Mineral Resources produces an annual exploration summary for the State of Nevada. The latest was for 2009 (Dreisner and Coyner 2010). The basis for the report is a survey sent to all of the known exploration groups in the area. For this survey, 22 companies responded and reported spending $153.6 million in 2009. Over $92 million was spent on expansions and $18.7 million on grass-roots exploration. Worldwide exploration expenditures in 2009 were estimated at $427.7 million (**Table 3-5**). The respondents reported holding 61,773 claims in Nevada and 81,984 in the US as a whole.

TABLE 3-5 Exploration Expenditures in Millions of US Dollars							
All Respondents	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Nevada	69.2	79.7	121.3	164.9	167.9	158.1	110.9
Rest of U.S.	2.2	9.5	16.7	35.6	30.7	39.5	7.5
Outside U.S.	326.2	348.7	418.5	414.7	558.1	496.7	309.3
Total World	397.6	437.9	556.5	615.2	756.7	694.3	427.7

Source: Dreisner and Coyner 2010.

Exploration in large part takes place in areas near known mineral deposits and within historic districts; however, exploration is also conducted in other outlying areas that the mineral industry considers prospective for various reasons (grass-roots exploration). Large portions of the planning area are difficult to explore as geographic areas prospective for gold deposits are covered by Late Cenozoic volcanic rocks and sedimentary basin fill sediments. **Table 3-6** summarizes the exploration plans from 2007 to 2010. Gold is the most common commodity sought in central Nevada.

TABLE 3-6 Exploration Plans in the Planning Area Since 1990			
Operator	**Project Name**	**Authorized Disturbance on BLM Administered Land**	**Commodity**
Tonkin Springs LLC	Tonkin springs Explo.	21.2	Gold
MI Drilling Fluids	Greystone	131	Barite
Fairmile Gold	Buffalo Valley	137	Gold
Barrick	Toiyabe JV	60	Gold
Barrick	Cortez	50	Gold
Newmont	5 Exploration Areas	122.6	Gold
Newmont	Argenta Exploration	65.3	Gold
MI Drilling Fluids	Mountain Springs	74	Barite
Millard Shirrill	Little Guys Claim	3	Gold
Coral Resources	Robertson	21.4	Gold
Newmont	Claim Block Exploration	299.4	Gold
Barrick	Ruby Hill	745.3	Gold
Barrick	Hilltop	92	Gold
Barrick	Patty	24	Gold
Klondex Gold & Silver	Fire Creek	49	Gold
*X-Cal (now Paramount)	Mill Creek	20	Gold
*Independence	Wilson	50	Gold
Newmont	Buffalo Valley	96	Gold
BH Minerals USA	Lookout Mtn Exploration	56.12	Gold

TABLE 3-6
Exploration Plans in the Planning Area Since 1990

Operator	Project Name	Authorized Disturbance on BLM Administered Land	Commodity
Montezuma Mines	Red Canyon	125	Gold
*Victoria Resources	Cove Helen	419.3	Gold
*Joseph Carruthers	Morning Star	0.67	Gold
*US Gold Corp	Gold Pick Exploration	91.6	Gold

* there are proposed exploration plans that have not been approved as of 1/12

Gold and Silver

Exploration for all types of gold and silver deposits in the planning area continues at a significant pace. Gold production in the planning area during 2008 was on the order of 3.4 million ounces which is about 57 percent of Nevada's production and 41 percent of US production. Most of the precious metals and many of the other metals are currently being produced from recently developed (since 1982) open-pit mines of varying sizes (some open pits are more than a mile across) with heap leach technologies being used to recover much of the precious metal. In recent years, conventional oxide and sulfide milling, in addition to heap leach technologies, have been used to recover precious metals and copper and other metals. Use of underground mining methods has increased in recent years in some districts in Nevada.

Most of the mining companies are actively exploring to replace reserves consumed in mining. Numerous (15 or so in 2009) junior exploration companies are doing grass-roots exploration in both existing districts and in areas previously unexplored (Driesner and Coyner 2010). More or less all of the exploration is for bedrock deposits; however, there are occurrences of placer gold that are economic such as the Black Rock Canyon Mine that are attractive exploration properties (Pacific Gold Corp. 2011).

With the current economic uncertainty which has resulted in record high prices for gold ($1,792/oz; 17 Aug 2011) and silver ($40.50; 17 Aug 2011), exploration expenditures are expected to continue and possibly increase.

It is impossible to identify specific areas within the planning area that are more prospective for precious metals deposits than others. Most of the exposed Paleozoic and Cenozoic rocks in the planning area are prospective for either Carlin-type or epithermal gold deposits. Skarn gold deposits may occur on the peripheries of any of the Mesozoic or Cenozoic intrusives in the planning area. Some areas, such as the Cortez Hills, Battle Mountain, and Round Mountain will have disproportionate expenditures because they are known to host large deposits, but old districts such as Tonopah, Goldfield, and Eureka should see significant expenditures because of high gold prices. Known, low-grade deposits will receive additional exploration.

Copper

Copper exploration has been a minor component to the overall exploration effort. It is not possible to segregate the expenditures for copper exploration from the overall expenditure, but some areas have

attracted some exploration. With copper trading at about $4.00/lb (London Metal Exchange [LME] 17 Aug 2011), expenditures are expected to increase and old copper districts will see significant expenditures. Tingley (1998) identified a number of districts such as Battle Mountain, Fish Creek, and Fairplay that may include porphyry copper deposits. Skarn type deposits related to intrusives are found in the Battle Mountain/ Phoenix Mine (Breit *et al.* 2011); Lone Mountain (Tingley 1998), and Tokop (Tingley 1998) districts. All of these areas are attractive for copper exploration. More or less all of the Jurassic, Cretaceous, and Tertiary intrusive areas are at least prospective for copper deposits.

Molybdenum

Molybdenum exploration is expected to increase because of the current high price ($34.50/lb). General Moly is attempting to get the Mt. Hope project in Eureka County into production (General Moly 2011). Other molybdenum projects such as the Hall (Nevada Moly) deposit in Nye County will garner interest and additional exploration (Shaver 1991). Other prospects in the Battle Mountain, Oak Spring, Fairplay, and Sylvania districts (Tingley 1998) should receive additional exploration. At the current price, most of the Cretaceous and Tertiary felsic intrusive areas will receive additional exploration.

Tungsten

Nevada has had significant tungsten production from skarn and vein deposits in the past (**Table 3-7**; Tingley 1998), but little, if any, is currently produced. China has dominated the tungsten market for several decades which has tended to depress the price and limit exploration. Current prices ($17.50/lb; 17 Aug 2011) should spur exploration in several of the districts in the planning area. Each of those areas should see exploration expenditures.

TABLE 3-7
Districts in the Planning Area with Historical Tungsten Production

District	County	Deposit Type
Basalt	Esmeralda	Tungsten skarn deposits
Black Horse	Esmeralda	Tungsten skarn deposits
Sylvania	Esmeralda	Tungsten skarn deposits
Tokop	Esmeralda	Tungsten skarn deposits
Windypah	Esmeralda	Tungsten skarn deposits
Diamond	Eureka	Tungsten skarn deposits
Fish Creek	Eureka	Tungsten skarn deposits
Birch Creek	Lander	Tungsten skarn deposits
Bullion	Lander	Tungsten skarn deposits
Ravenswood	Lander	Tungsten vein deposits
Reese River	Lander	Tungsten skarn deposits
Spencer Hot Springs	Lander	Tungsten skarn deposits
Barcelona	Nye	Tungsten skarn deposits
Belmont	Nye	Tungsten vein deposits
Currant	Nye	Tungsten skarn deposits

TABLE 3-7 Districts in the Planning Area with Historical Tungsten Production		
District	**County**	**Deposit Type**
Ellsworth	Nye	Tungsten vein deposits
Manhattan	Nye	Tungsten vein deposits
Oak Spring	Nye	Tungsten skarn deposits
Round Mountain	Nye	Tungsten vein deposits
Troy	Nye	Tungsten skarn deposits
Twin River	Nye	Tungsten skarn deposits

Lead-Zinc

Significant lead and zinc production has not occurred in recent years within the planning area, but historical production has occurred in several districts (**Table 3-8**). Current lead and zinc prices are $1.00/lb and $0.95/lb (17 Aug 2011). Most of the districts in **Table 3-8** are prospective for lead and zinc, but the prices are unlikely to spur significant activity unless the base metals are accompanied by significant precious metals, which is typical.

TABLE 3-8 Districts with Reported Lead-Zinc Production		
District	**County**	**Type**
Buena Vista	Esmeralda	Polymetallic vein deposits
Dyer	Esmeralda	Polymetallic vein deposits
Hornsilver	Esmeralda	Polymetallic vein deposits
Lida	Esmeralda	Polymetallic vein deposits
Lone Mountain	Esmeralda	Polymetallic vein/replacement deposits; Copper Skarn
Montezuma	Esmeralda	Polymetallic replacement deposits
Tokop	Esmeralda	Polymetallic vein deposits; Copper Skarn
Tule Canyon	Esmeralda	Polymetallic vein deposits
Alpha	Eureka	Polymetallic replacement deposits
Cortez	Eureka	Polymetallic vein/replacement deposits
Diamond	Eureka	Polymetallic vein deposits
Eureka	Eureka	Polymetallic replacement deposits
Huntington Creek	Eureka	Copper skarn Deposits
Lone Mountain	Eureka	Polymetallic replacement deposits
Battle Mountain	Lander	Polymetallic vein/replacement deposits; Copper Skarn; Porphyry Cu
Birch Creek	Lander	Polymetallic vein deposits
Bullion	Lander	Polymetallic vein deposits
Fish Creek	Lander	Porphyry copper, skarn related deposits

TABLE 3-8 Districts with Reported Lead-Zinc Production		
District	**County**	**Type**
Hilltop	Lander	Polymetallic vein deposits
Kingston	Lander	Polymetallic vein deposits
Lewis	Lander	Polymetallic vein deposits
Ravenswood	Lander	Polymetallic vein deposits
Reese River	Lander	Polymetallic vein deposits
Barcelona	Nye	Polymetallic vein deposits
Belmont	Nye	Polymetallic vein deposits
Ellsworth	Nye	Polymetallic vein deposits
Fairplay	Nye	Porphyry copper deposits
Gabbs	Nye	Polymetallic replacement deposits
Jefferson Canyon	Nye	Polymetallic vein deposits
Jett	Nye	Polymetallic vein deposits
Morey	Nye	Polymetallic replacement deposits
Northumberland	Nye	Polymetallic vein deposits
Republic	Nye	Polymetallic vein deposits
Reveille	Nye	Polymetallic replacement deposits
Troy	Nye	Polymetallic vein deposits
Twin River	Nye	Polymetallic vein deposits
Tybo	Nye	Polymetallic vein/replacement deposits
Washington	Nye	Polymetallic vein deposits
Willow Creek	Nye	Polymetallic vein/replacement deposits

Source: Tingley 1998.

Vanadium

American Vanadium is actively exploring the Gibellini deposit in Eureka County, Nevada, about 27.5 miles south of the town of Eureka. The project's resource includes 122 million pounds of indicated vanadium (*i.e.*, vanadium pentoxide or V_2O_5) grading 0.339 percent, and an additional 16 million pounds of inferred vanadium grading 0.282 percent. The current LME price is $7.75/lb. Vanadium is traditionally a by-product of mining base metals and/or uranium and it typically not explored for or produced as a primary commodity.

Vanadium deposits occur in organic-rich siliceous mudstone, siltstone, and chert of the Devonian Woodruff Formation that ranges from 175 to over 300 feet thick. The shale has been oxidized to various hues of yellow and orange to a depth of 100 feet. Vanadium mineralization is tabular, conformable with bedding, and remarkably continuous in grade and thickness between drill holes. Higher vanadium grades are associated with a mixed oxide and sulfide zone that is sub-parallel to the topographic surface. Vanadium reportedly occurs in manganese nodules and organic matter. Vanadium

mineralization is thought to be the result of syngenetic and early diagenetic metal concentration in the marine shale rocks.

The Carlin Vanadium Project consists of 72 unpatented mineral claims covering ~1,270 acres (578 ha) and is located along the Carlin gold trend about six miles southwest of Newmont's Carlin Operations and six miles west of Newmont's Rain Deposit. EMC Metals owns a 100 percent interest in the Carlin Vanadium Project. An Inferred resource of 28 Mt at 0.515 percent V2O5 has been estimated assuming a cut-off grade of 0.3 percent V2O5. Although this project is not within the planning area, it is very near the Planning area boundary and believed to be pertinent to this discussion.

The deposit was originally discovered in the 1960s by Union Carbide Corporation (UCC) that outlined a significant 1,000 by 3,000 by 50 feet thick zone of vanadium mineralization in black shales within the Devonian Woodruff Formation which consists of dark grey to black siliceous mudstones, and chert with lesser amounts of shale, siltstone, dolomitic siltstone, and calcareous sandstone. The Woodruff formation is unconformably overlain by shallow dipping Permian-Pennsylvanian siltstones, shales, conglomerates, and carbonates of the Chainman and Diamond Peak Formations.

Uranium

Uranium exploration is active throughout the world. Current prices are on the order of $50/lb (www.metalprices.com 17 August 2011). Uranium has been reported from several districts in the planning area (**Table 3-9**), but little has been mined. The Apex mine in Lander County, three miles south of Austin, Nevada, was explored in 1953 (Great Western Mining 2011). The mine reportedly produced 45 tons of uranium from 1954 until 1966. Uranium occurs as autunite and meta-autunite in fractured Cambrian quartzite and argillite, adjacent to Jurassic quartz monzonite. The McDermitt Caldera, in Humboldt County, was an area of intensive uranium exploration and mining during the late 1970s. High-grade uranium deposits have recently been discovered near the ghost town of Marietta, in Mineral County, Nevada, which may lead to additional exploration in other parts of Nevada. Some new properties have been staked or reactivated (Prospect Uranium news release, 21 Aug 2007). On Sep. 27, 2008, Uranium King Corporation and Uranium Company of Nevada, LLC (both 100 percent owned subsidiaries of Uranium King Ltd) provided notice to the Nuclear Regulatory Commission (NRC) that they intended to submit an application to construct and operate a uranium recovery facility in Lander County, Nevada at the site of the former Apex Uranium Mine (now owned by AusAmerican Mining. The Apex-Lowboy deposit is believed to contain 615,000 metric tons at a grade of 0.07 percent U_3O_8 (Randabel and Vukovic 2009).

TABLE 3-9
Districts with Reported Uranium Occurrences

District	County	Type	Commodity
Coaldale	Esmeralda	Volcanogenic uranium deposits	coal, U, turquoise, variscite, Pb, Ag, Mo
Crow Springs	Esmeralda	Simple antimony deposits	turquoise, Ag, Pb, Cu, Au, Sb, U, perlite
Tokop	Esmeralda	Tungsten skarn deposits	Au, Ag, Pb, W, Cu, U
Tule Canyon	Esmeralda	Polymetallic vein deposits	Au, Ag, Mo, U
Eureka	Eureka	Polymetallic replacement deposits	Ag, Pb, Au, Cu, Zn, Mo, Fe, As, Sb, U,

TABLE 3-9
Districts with Reported Uranium Occurrences

District	County	Type	Commodity
			Be, Ti
Birch Creek	Lander	Tungsten skarn deposits	Au, W, U, Ag, Pb, Cu, Mo, Be, As
Barcelona	Nye	Volcanogenic uranium deposits	Ag, Hg, Au, Pb, Sb, W, Mo, Cu, Zn, U
Bullfrog	Nye	Volcanogenic uranium deposits	Au, Ag, Cu, Pb, montmorillonite, U
Morey	Nye	Polymetallic vein/replacement deposits	Ag, Au, Pb, Sb, tin, U
Northumberland	Nye	Polymetallic vein deposits	Au, barite, Ag, Zn, U
Northumberland	Nye	Sediment-hosted gold deposits	Au, barite, Ag, Zn, U
Round Mountain	Nye	Volcanogenic uranium deposits	Au, Ag, W, Pb, Hg, U, As, Ti
Tonopah	Nye	Comstock epithermal vein deposits	Ag, Au, Pb, Cu, W, Zn, Hg, U, As
Troy	Nye	Polymetallic vein deposits	W, Au, Pb, Zn, Ag, Cu, Be, U

Pb = lead; Ag = silver; Mo = molybdenum; Cu = copper; Au = gold; Sb = antimony; U = uranium; W = wollastonite; Zn = zinc; Fe = iron; As = arsenic; Be = beryllium; Ti = titanium; Hg = mercury;

Source: Tingley 1998.

Other Metals

Metals such as beryllium, antimony, arsenic, iron, and manganese, are known to occur within the planning area (Tingley 1998). These metals are not actively explored; antimony, arsenic, and mercury occur with many of the precious metals mines and are considered to be deleterious elements and because of the limited market, they must be disposed of or specifically managed rather than produced for market. The proposed Round Mountain Mine expansion will result in marketable amounts of mercury. Iron occurs as magnetite in skarn deposits and pyrite in many of the base and precious metals deposits. The extent of those deposits is not known. Exploration for magnetite and pyrite as sources of iron is virtually nil because of the extensive iron ore deposits elsewhere in the world. Similarly, manganese mines elsewhere in the world are well established and typically have very high grades and tonnages, limiting exploration for additional deposits.

3.1.8 Industrial Minerals

Lithium

Lithium is a mining industry buzz-word at this time. It is used extensively in batteries that may provide electrical storage for cars and other large machines. Lithium is typically marketed as lithium carbonate (Li_2CO_3) which is currently selling for about $6,600/ton. The Silver Peak operation in Esmeralda County is currently the only lithium producer in the US and produces lithium from brine deposits in the playa in Clayton Valley. Significant exploration around Silver Peak's claims is occurring (Keast 2011). Lithium Corporation is exploring for similar brine deposits in Fish Lake Valley and Grass Valley (Lithium Corp. 2011). American Lithium is exploring Sarcobatus Flats, Teels Marsh, and Fish Lake Valley for brines

(American Lithium 2011). TNR Gold recently acquired property in Fish Lake Valley (TNR Gold 2009), and Tonogold Resources recently acquired claims in Sarcobatus Flats (Tonogold Resources Inc. 2009).

In addition to the brine prospects, lithium has been found with boron in the Boron Hills where boron and lithium mineralization is contained in a Quaternary/Tertiary age, stratabound claystone and tuff (American Lithium 2011). These deposits were explored in the 1980s by US Borax.

Barite

Barite is used primarily as a drilling mud for oil and gas drilling. Current prices are approximately $120/metric ton (Elliot 2011). Barite is currently mined at the Greystone and Argenta mines in the Shoshone Range. The Argenta Mine shipped about 85k tons of barite in 2009 and the Greystone mine shipped about 221k tons of barite in 2009 (Driesner and Coyner 2010). Little information is publically available regarding reserves at those mines.

Barite is known to occur in the Toquima Range (Shawe *et al.* 1967). Numerous other occurrences in the planning area are documented by Horton (1963) and Papke and Castor (2003) (**Table 3-10**). Most of those occurrences are in the Shoshone Range in Lander County, but barite occurs locally in Eureka, Nye, and Esmeralda counties. Exploration levels are believed to be quite low because of the known resources.

TABLE 3-10
Known Barite Occurrences in the Planning Area

County/Name	Type	Production
Esmeralda		
Candelaria	Vein	Past Production
Maxfield	Vein	Past Production
American Barium	Vein	Past Production
Put	Vein	Past Production
Eureka		
Boulder Ridge	Vein	Past Production
Queen Anne	Bedded	Past Production
Maggie Creek	Vein	Past Production
Sansinena	Bedded	Past Production
Bear	Vein	Past Production
Big Joker	Bedded	Past Production
Bat	Bedded	Past Production
Elizondo	Bedded	Past Production
Hawkeye	Vein	Past Production
Lander		
Cutler-Rimrock	Bedded	Past Production
Argenta area	Bedded	Active

TABLE 3-10 Known Barite Occurrences in the Planning Area		
County/Name	**Type**	**Production**
Beacon	Bedded	Past Production
Miller	Bedded	Past Production
Pleasant View - Slaven Canyon	Bedded	Past Production
Darling Darlene	Bedded	Past Production
Dutch Boy - Bateman Canyon	Bedded	Past Production
Bradshaw - White Rock - MS	Bedded	Past Production
Ferris Creek	Bedded	Past Production
Mountain Springs	Bedded	Past Production
Cammy - Mustang Lode	Bedded	Past Production
Greystone	Bedded	Active
Clipper	Bedded	Past Production
Bald Mountain	Bedded	Past Production
Palo Alto	Vein	Past Production
Bird	Bedded	Past Production
Allen	Bedded	Past Production
Reeds Canyon	Bedded	
Nye		
Summit Creek	Bedded	Past Production
P and S	Bedded	Active
Monitor	Bedded	Past Production
Ann	Bedded	
East Northumberland Canyon	Bedded	Past Production
Sky	Vein	Past Production
Warm Springs	Bedded	Past Production
Jumbo	Bedded	Past Production

Source: Papke and Castor 2003.

Diatomite

Production of diatomite in Nevada accounts for more than 30 percent of domestic production. About 60 percent of the diatomite produced is used in filtration processes and the remainder is used in absorbents, fillers, and cement. Emerging uses include pharmaceutical processing and nontoxic insecticides (NBMG 2003).

Diatomite is reportedly produced from the Basalt mine in Esmeralda County (Papke and Castor 2003; Tingley 1998), and a new mine northeast of Columbus Salt Marsh is in the process of being permitted, but no other production is known. Diatomite occurs at the Crow Springs and Shu Fly prospects in Esmeralda County and the Cedar Mountains prospect in Nye County (Papke and Castor 2003).

Mineable deposits generally must have less than 50 meters of cover and be capable of being mined using inexpensive open-cut methods. Deposits must also be close to transportation corridors as crude diatomite can only be economically be trucked from 50 to 100 km to mills (Nash 1996). Exploration is thus restricted to proximity to infrastructure.

Carbonate Minerals

Carbonate minerals comprise lime, limestone, and dolomite. Carbonate rocks produced in Nevada are used in gold mining operations, cement making, nutrition, agricultural, and other industrial applications (USGS 2003).

Economic factors include; low magnesium and iron content, transportation accessibility, and in some cases, a natural gas line for kiln operation. Regional gold mining operations have increased the demand for limestone products, which are used to control pH of milling operations.

There are no permitted carbonate mineral operations in the planning area, but Papke and Castor (2003) report that calcium carbonate was historically produced from the Columbus Mine in Esmeralda County. Exploration for carbonate minerals is not expected to be significant in the planning area because of distance to significant markets for products like cement.

Fluorspar

Fluorspar or fluorite is produced primarily for use as a flux in metallurgical operations and, less so, for optical purposes. Fluorite occurs primarily as a vein and accessory mineral, such as with lead and silver ores. It can also be found in cavities of limestone and dolomite in hydrothermal settings (Mason and Berry 1968). Fluorite occurrences in the planning area are primarily vein type, favored in limestone, and in or near intrusive rocks of Cretaceous to Miocene age that provided fluorine.

Fluorspar has been reported from several districts in the planning area. These locations are summarized in **Table 3-11**. No production occurs in Nevada at this time and little exploration is anticipated.

TABLE 3-11
Fluorspar Occurrences in the Planning Area

District	County	Type
Buena Vista	Esmeralda	Polymetallic vein deposits
Sylvania	Esmeralda	Tungsten skarn deposits
Fish Creek	Eureka	Tungsten vein deposits
Bare Mountain	Nye	Hot spring gold deposits
Cloverdale	Nye	Comstock epithermal vein deposits
Currant	Nye	Tungsten skarn deposits
Manhattan	Nye	Tungsten vein deposits

Source: Tingley 1998.

Gypsum

Nevada accounts for approximately 10 percent of the domestic gypsum production estimated at 1.85 million tons in 2002 and 2003 and 2.31 million tons in 2004. Gypsum is used in the production of wallboard, plaster products, cement, fertilizer, and industrial filler. Gypsum is an evaporate deposit and is the first salt deposited in the evaporation of sea water (Mason and Berry 1968). Known deposits in northwestern Nevada are of marine origin and formed in marginal marine basins where periodic influx of sea water provided precipitated salts during periods of evaporation. Gypsum beds can be extensive and exceed 300 feet in thickness. Limestone, dolomite, salts, and clastic rocks can be interbedded with the gypsum beds. The age of most of the gypsum beds within the planning area are Triassic and Jurassic (Nash 1996). Gypsum is produced from three mines in Nevada (Castor 2004); however, none are within the planning area and exploration for gypsum is not expected in the planning area.

Silica

Silica minerals have been reported from the Cuprite and Bare Mountain mining districts. Cuprite had past production of silica according to Papke and Castor (2003) but the total production is unknown. No exploration for silica is anticipated except for possible flux for mineral processing and only then if precious metals content is somewhat high.

Talcose Minerals

Papke and Castor (2003) identified nine properties within the planning area with past production of talcose minerals (**Table 3-12**). Total production is not recorded and no exploration is expected.

TABLE 3-12
Known Talcose Mineral Deposits in the Planning Area

County	Mine, Prospect, or Area name	Deposit Type
Esmeralda	Silver Peak Range	Chlorite
Esmeralda	Palmetto district	Talc
Esmeralda	Lida	Chlorite
Esmeralda	Oasis Mine area	Talc, Chlorite
Esmeralda	Central Sylvania district	Chlorite, Talc
Esmeralda	Log Spring	Talc
Esmeralda	White Top	Sericite, Chlorite
Esmeralda	Nevada	Chlorite, Sericite
Nye	Lodi Hills	Talc, Chlorite

Source: Papke and Castor 2003.

Wollastonite

Mining of wollastonite occurred at the Gilbert Mine in Esmeralda County (Papke and Castor 2003). Total production is not recorded and no operations are currently permitted.

Zeolites

Several large zeolite deposits exist in Nevada and historic production was significant in Pershing and Churchill Counties; however, no production has been reported from the planning area. **Table 3-13** summarizes the known zeolite deposits (Papke and Castor 2003). Zeolites are used in various ion exchange and absorbent applications (Nash 1996). Zeolites form during diagenetic alteration of silicic glass in tuffs and volcaniclastic rocks.

Deposits of zeolites form in tuffaceous rocks deposited in subaerial, submarine, and lacustrine environments and subjected to alkaline conditions. The largest deposits are in alkaline lake-type settings frequently located along rifts and block-faulted basins. Deposits range in age from Paleozoic to Recent, although most are of Tertiary age (Nash 1996).

TABLE 3-13
Occurrences of Zeolites in the Planning Area

County	Mine, Prospect, or Area Name	Deposit Type
Esmeralda	Tonopah	Mordenite
Esmeralda	Silver Peak	Clinoptilolite, Mordenite
Esmeralda	Montezuma	Clinoptilolite, Mordenite
Eureka	Pine Valley	Erionite
Lander	Fish Creek	Clinoptilolite
Lander	Reese River	Erionite, Chabazite
Nye	Currant	Analcime
Nye	San Antonio	Analcime
Nye	McKinney Tanks	Clinoptilolite
Nye	Nevada Test Site	Clinoptilolite, Mordenite, Analcime
Nye	Beatty Wash	Clinoptilolite
Nye	Beatty Mountain	Clinoptilolite, Mordenite

Source: Papke and Castor 2003.

3.1.9 Gems and Semi-Precious Stones

Permitted Turquoise mining occurs at the Blue Ridge and Carico Lake mines in Lander County and the Lone Mountain and Royal Blue mines in Esmeralda County. Little information is publicly available on the operations or resources.

The Blue Ridge mine, in Lander County, Nevada, is in the Bullion Mining district and consists of nine mining claims. Colors range from green to yellow with the brightest yellow. These colors are caused by the high zinc content of the material, which replaces other minerals (Nevada Gem 2011).

The Carico Lake mine is in Lander County, Nevada. The name comes from its location a few miles west of the Carico Lake bed. Turquoise coming from the mine ranges from light green to a medium blue with a matrix of mostly limonite (Nevada Gem 2011).

The Lone Mountain turquoise mine is located in Esmeralda County, Nevada. The turquoise is noted for its ability to hold its color and not fade. Usually found in nodules, Lone Mountain turquoise ranges in color from clear blue to spider-web (Indian Village 2011).

The Royal Blue Turquoise Mine is in the Royston District on the Nye-Esmeralda County border. This turquoise comes in a wide range of colors.

Exploration for turquoise is largely a "rock-hound" venture and is unlikely to attract significant expenditures. There is currently no system in place to monitor the value of gems and semi-precious stones taken from deposits. Several websites, including www.turquoisefacts.com/turquoise-mines list numerous localities and mines that produce turquoise in Nevada.

3.2 SALEABLE MINERALS

Mineral materials (a.k.a. saleable minerals) include sand, gravel, stone, pumice, clay, and petrified wood that are sold at fair market value under the 43 CFR 3600 regulations.

3.2.1 Aggregate, Sand, and Gravel

Sand and gravel are the most common mineral materials consumed in the Battle Mountain District. The commodity is sold to individuals and corporate entities through negotiated sales. Federal, State, local government and non-profit organizations are permitted free use of these materials for qualified purposes.

Typically, BLM provides for common use areas which are broad geographic areas from which BLM can make disposals of mineral materials to many persons, with only negligible surface disturbance. In some cases, BLM provides for a Community Pit; a small defined area from which the BLM can make disposals of mineral materials to many persons. **Table 3-14** is an inventory of the current number of sites provided by BLM for mineral material consumption.

In addition, there are about 170 material site rights-of-way issued to the Nevada Department of Transportation (NDOT) for sand and gravel.

TABLE 3-14
Battle Mountain District Mineral Materials Case File

Active or pending gravel pits	248
Community Pits	21
Common Use Area	1
Negotiated Sales	39
Free Use Permits	175
Lander County Pits	92
Eureka County Pits	41
Nye County Pits	22
Esmeralda County pits	6

3.2.2 Clay

One permitted clay operation is located within the planning area (Blanco Mine [bentonite] in Esmeralda County). Papke and Castor (2003) reported that the New Discovery and Amargosa Mines were also active just outside the Planning Area boundary in Nye County.

3.2.3 Pumice and Cinder

No permitted pumice or cinder operations are located within the planning area; however, a new pumice mine is being permitted north of Beatty. Papke and Castor (2003) report past production of cinder at Silver Peak in Esmeralda County and from the Cin-R-Lite deposit in Nye County. They also report a cinder occurrence at Lunar Crater in Nye County.

3.2.4 Building, Ornamental, and Specialty Stone

D&H Mining produces decorative stone for the Las Vegas market. The mine pits are located 6-8 miles North of Beatty. No other building, ornamental, or specialty stone operations have been permitted within the planning area.

3.2.5 Petrified Wood

Castor and LaPointe (2001) report petrified wood, agate, obsidian, and chalcedony occurrences in the Daisy Creek area of Lander County and Coaldale, Tonopah, Montezuma Range, and Stonewall Pass areas of Esmeralda County. These are considered to be "Rockhound" areas and appear to have no special status or claims.

3.2.6 Building Stone

No permitted building stone operations are located within the planning area, but Papke and Castor (2003) indicate that three mines have past production of building stone (**Table 3-15**). Significant exploration is not anticipated.

TABLE 3-15
Building Stone Occurrences in the Planning Area

County	Mine, Prospect, or Area Name	Deposit Type
Nye	Cedar Mountains "aragonite"	Calcite Vein
Nye	Nevada Neanderthal	Tuff
Nye	Carrara	Marble

Source: Papke and Castor 2003.

3.3 LEASABLE MINERALS

Leasable minerals, as defined by the Mineral Leasing Act (February 1920; and 43 CFR 3000-3599, 1990), include the subsets leasable solid and leasable fluid minerals. Leasable solid minerals include: coal, oil

shale, native asphalt, phosphate, sodium, potash, potassium, and sulfur. Leasable fluid minerals include oil, gas, and geothermal resources. Rights to explore for and produce these minerals on public land may only be acquired by competitive leasing. Past exploration activities and current research indicate that occurrences of oil, oil shale, phosphate, and potash have been identified in the planning area (Papke 2003). Deposits of sodium minerals and sulfur have been mined in the past within the planning area. Low grade coal deposits have also been identified.

BLM has developed more rigorous guidelines to be used in the development of fluid minerals that are described in BLM Handbook H-1624-1, Planning for Fluid Mineral Resources (BLM 1990). This handbook is supplemented by Information Memorandum No. 2004-089 (BLM 2004) that presents BLM's Policy for Reasonably Foreseeable Development (RFD) Scenario for Oil and Gas. The occurrences of leasable minerals within the planning area are discussed by commodity below.

3.3.1 Geothermal Resources

Introduction

Activity on geothermal resource exploration and development operations is increasing and is expected to continue to increase in the future. Department of Energy and State of Nevada grants and tax incentives are encouraging companies to develop geothermal and other renewable energy resources. Geothermal use is broken into two main uses; electrical generation and direct uses. In the planning area, electrical generation is the primary geothermal resource use.

Geothermal resources occur most often in areas where there is anomalously high heat flow caused by volcanism, near-surface magma, or some other exceptionally hot subsurface body (Coolbaugh et al. 2002). The resource often occurs along fault or fracture zones where conduits in the bedrock allow groundwater to circulate to depths for warming prior to being circulated back toward the surface. The planning area has abundant geothermal resources including thermal springs, where warm or hot water comes to surface naturally, and thermal wells, which must be drilled, developed, and sometimes pumped. Generating electricity with geothermal energy requires very hot water generally found at great depths below the surface. The technology used to generate electricity from hydrothermal fluids depends on the state of the fluid (whether steam or water) and its temperature. Three types of geothermal-powered electrical generation plants are operating today, each of which ultimately employs steam to drive a turbine:

- Dry steam power plants are the simplest and oldest design and directly use geothermal steam of 150°C (300°F) or more to turn turbines.
- Flash steam power plants pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines. These plants require fluid temperatures of at least 180°C (355°F).
- Binary systems require the water from the geothermal reservoir to be used to heat another "working fluid" which is vaporized and used to turn the turbine/generator units. The geothermal water and the "working fluid" are each confined in separate circulating systems or "closed loops" and never come in contact with each other. The advantage of the Binary Cycle plant is that they can operate with water temperatures as low as 57°C (135°F), by using working fluids that have an even lower boiling point than water. This plant design also produces no air emissions. Geothermal water that is not hot enough for electrical generation may be used for general building heating or for other

purposes such as growing crops, dehydrating vegetables, fish farming, spas, recreational hot springs, and swimming pools.

The current production of geothermal energy places it third among renewable energy sources, following hydroelectricity and biomass, and ahead of solar and wind energy (REN21 2011).

Nevada has the largest amount of untapped geothermal resources in the U.S. with a potential of 2,500 to 3,700 megawatts of electricity annually (MWe). One MWe powers approximately 1,000 homes per year (USDOE 2004). Geothermal energy provides about 9 percent of northern Nevada's electricity, and statewide there are 14 power plants operating at 10 geothermal sites (USDOE 2004).

All land within the planning area is open to geothermal leasing and development with exception of Wilderness Areas, Wilderness Study Areas, community watersheds, critical wildlife habitat areas, and military reservations. Geothermal energy resource exploration and development has increased dramatically in the past four years. The planning area currently has 86 authorized geothermal leases, covering 97,005 acres, and 2 pending geothermal applications, covering 12,137 acres. The MLFO prepared a "Programmatic Environmental Assessment Geothermal Leasing and Exploration - Shoshone-Eureka Planning Area" in 2002. The Tonopah Field Office (TFO) implemented the "Proposed Tonopah RMP and Final Environmental Impact Statement" (1994) and a programmatic Environmental Assessment for geothermal leasing to expedite processing geothermal lease applications. In addition, The Geothermal Programmatic Environmental Impact Statement (PEIS) for Geothermal Leasing in the Western US was approved on December 17, 2008 to expedite processing geothermal lease applications. About 20 percent of the land within the Battle Mountain District is potentially valuable for geothermal resources, located mainly in Esmeralda and Lander counties. Pending lease applications cover less than one percent and are near the town of Carvers in Nye County and in Crescent Valley in Lander County. **Figure 3-2** shows the location of geothermal leases within the planning area. The current geothermal program includes six exploration projects and one production/utilization project in the Mt Lewis Field Office and three exploration projects in the Tonopah Field Office planning areas.

Leasing Regulations

Geothermal energy resources are considered a leasable fluid mineral commodity. Administration of competitive and non-competitive leases for geothermal exploration and production is granted under the authority of the Geothermal Steam Act of 1970 as amended (30 U.S.C. 1001, et. seq.) and the implementing regulations found at 43 CFR 3200, et seq. BLM is the designated federal administrator of geothermal leases on land under the jurisdiction of the U.S. Department of the Interior, U.S. Department of Agriculture (with their concurrence), land conveyed to the U.S. where geothermal resources were reserved to the U.S., and land subject to section 24 of the Federal Power Act (16 U.S.C. 818). Leases may be awarded for a primary term of 10 years. If the lease results in a producing resource, the lease term may be extended by an additional 40 years with subsequent renewals granted in the event of continued resource production. Leasing and development is a discretionary action subject to NEPA review. The BMDO planning area administers geothermal resources under the Geothermal Resources Leasing Programmatic Environmental Assessment of 2002 (BLM 2002).

Other Applicable Regulations

Once a lease has been secured on public land administered by BLM, other state regulations apply to the development of geothermal resources. The Nevada Revised Statutes (NRS) Chapter 534A (Geothermal Resources) describes Nevada State laws pertaining to geothermal resources. Implementing regulations concerning drilling permits and fees, production requirements, rules for well abandonment and plugging, and record keeping and reporting are found in the Nevada Administrative Code (NAC) Chapter 534A.

The lead state agency tasked with implementation of the state's geothermal regulations is the Nevada Commission on Mineral Resources – Division of Minerals. The Nevada Department of Conservation and Natural Resources – Division of Water Resources (DWR) is responsible for issuing water rights that may be associated with development of geothermal resources and they and the Division of Water Planning have divided up the planning area into Hydrographic Basins the character of which are described below.

The Bureau of Water Pollution Control (BWPC) is the body that regulates underground fluid injection, a common practice for managing extracted geothermal water, and surface disposal of waste water (including geothermal fluids). Aquaculture projects using geothermal resources have additional permitting requirements administered by the Nevada Department of Wildlife.

General Geological Setting

Nevada lies within the Basin and Range physiographic province, an area of crustal extension that has remained active since the mid-Miocene. The Basin and Range is characterized by Cenozoic (0 to 65 Ma) tilted fault blocks forming northeast-trending longitudinal mountain ranges separated by broad valleys. Nevada occupies the area of highest crustal heat flow in North America (BLM 2006) and consequently within the planning area there are abundant geothermal resources. Nearly all of Nevada's resources are related to deep fluid circulation associated with crustal extension and high heat flow. The highest temperatures are located in the northwestern part of the state. This area of high heat flow parallels the northeast-trending Humboldt structural zone in northern Nevada (Faulds *et al.* 2002). Major faults in this region include the Olinghouse fault, faults bounding the Smoke Creek and Black Rock Deserts, faults along the northwestern margin of the Carson Sink, Stillwater fault in Dixie Valley, Midas fault, and Malpais fault near Beowawe (Faulds *et al.* 2002).

Geothermal fields in Nye and parts of Esmeralda and Eureka counties do not fall into any recognized regional trends (Faulds *et al.* 2011). These occur along range-bounding faults that may be part unrecognized regional fault zones or they may be isolated areas. Additional research is required.

The lithology and structural features of the mountain blocks and hydrologic basins throughout the planning area are critical with regard to the occurrence of water, geothermal, and mineral resources. Most of the bedrock formations lack permeability except where fault zones or fractures have been created by deformation. Thus, where there are no or few fractures or faults, precipitation tends to run off to the adjacent valleys. Where fractures and faults are present, a portion of the precipitation may infiltrate into deep circulation patterns, which may be sufficiently deep to generate a geothermal resource.

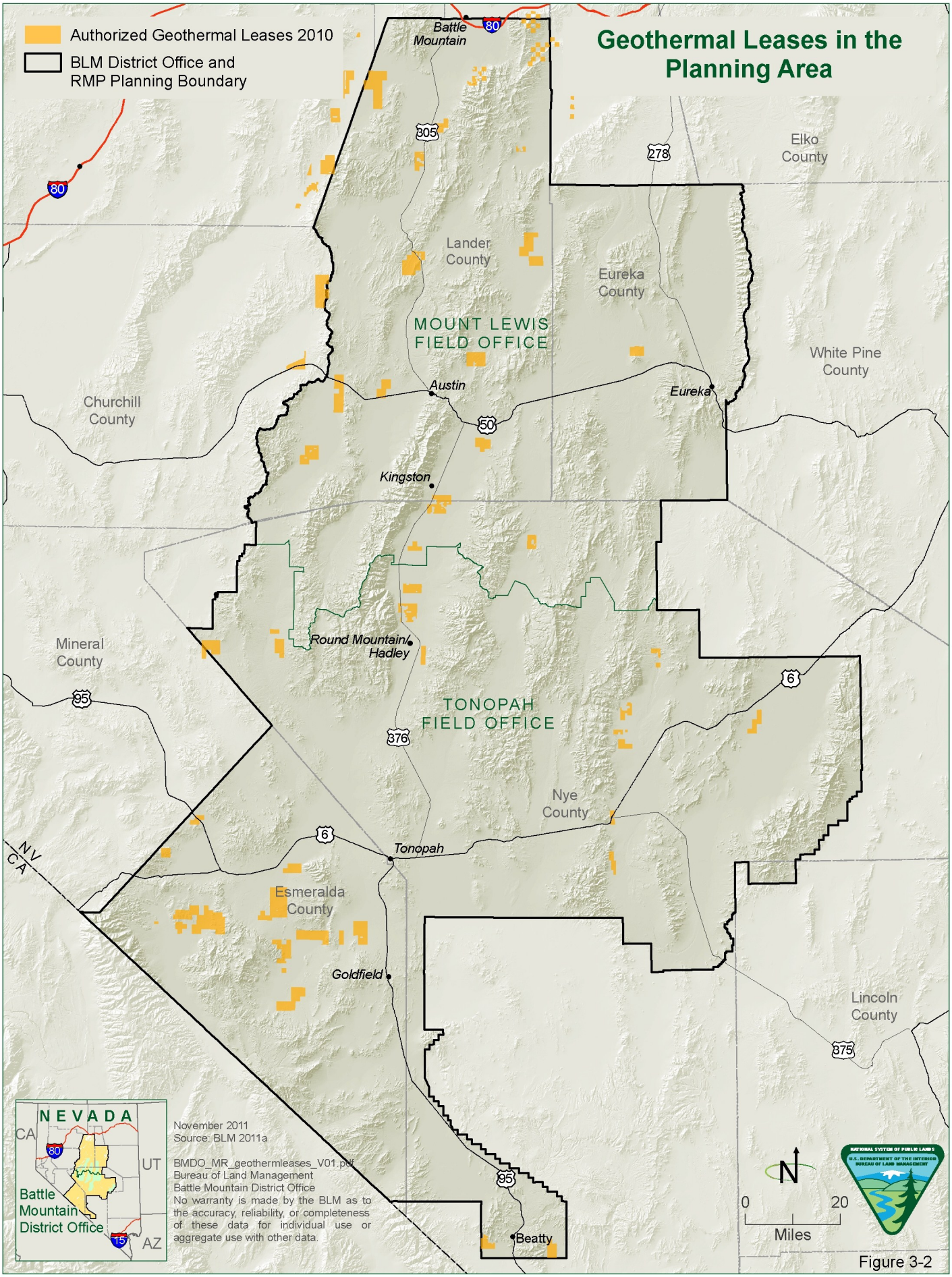

Geothermal Leases in the Planning Area
Authorized Geothermal Leases 2010
BLM District Office and RMP Planning Boundary
Battle Mountain
80
305
278
Elko County
Lander County
Eureka County
MOUNT LEWIS FIELD OFFICE
White Pine County
Churchill County
Austin
Eureka
50
Kingston
Mineral County
Round Mountain/ Hadley
95
6
TONOPAH FIELD OFFICE
376
Nye County
Tonopah
NV
CA
Esmeralda County
Goldfield
Lincoln County
375
Beatty
NEVADA
CA
UT
AZ
Battle Mountain District Office
15
November 2011
Source: BLM 2011a
BMDO_MR_geothermleases_V01.pdf
Bureau of Land Management
Battle Mountain District Office
No warranty is made by the BLM as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data.
N
0
20
Miles

Figure 3-2

Historic Exploration

Exploration and development of geothermal resources in the planning area began at least as early as the 1950s in areas known as Known Geothermal Resource Areas (KGRAs). As described in the Geothermal Resources Listing Programmatic EA (BLM 2002), geothermal leasing activity within the planning area peaked in the early to mid-1980s. Since then, leasing activity for geothermal resources has been relatively slow until the California energy crisis surfaced in 2000. Approximately 111 geothermal lease applications have been received since 2002. **Figure 3-2** shows existing authorized leases (as of May of 2010).

Existing Fields and Development of Resources

Beowawe

The Beowawe geothermal field is on the border of Eureka and Lander counties, on the border of the planning area. The project currently generates 17.7 megawatts. The Beowawe geothermal power station is owned by Terra-Gen Power and started producing energy in 1985.

Jersey Valley Geothermal Project

Jersey Valley Geothermal Project has an approved Power Purchase Agreement and is now online producing 15 megawatts. The Jersey Valley geothermal project is owned by Ormat Technologies Co. and is located in a remote area in both the Lander and Pershing Counties of Nevada.

Clayton Valley 1 Project

The Clayton Valley 1 Project is located in Esmeralda County southwest of Tonopah, NV and is expected to generate 53.5 megawatts when it comes on line in 2014. This project is being developed by Ram Power Corp. Through earlier exploration, 31 gradient holes have been drilled with a high probability of a 300°F resource shallower than 2500 feet.

McGinnis Hills Geothermal Project

The McGinnis Hills Geothermal Project is located in a remote area in both the Lander and Pershing Counties and is expected to generate 51 megawatts. The project is owned by Ormat Technologies Co. The project has an approved Power Purchase Agreement and is scheduled to be operational by 2014.

Other Projects

Leases issued since 1990 are shown in **Table 3-16**. A total of 176 leases were issued: 61 were competitive, and one is based on a mining claim. Other fields in various stages of development (**Table 3-17**) occur throughout the planning area.

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 052845	Lander	1,803.72	Closed	Noncompetitive	30-Jul-91	CALIFORNIA ENERGY CO
NVN 052846	Lander	1,117.44	Closed	Noncompetitive	30-Jul-91	CALIFORNIA ENERGY CO
NVN 052847	Lander	640.00	Closed	Noncompetitive	30-Jul-91	CALIFORNIA ENERGY CO
NVN 054829	Esmeralda	2,555.00	Closed	Noncompetitive	8-May-92	FISH LAKE POWER CO
NVN 054830	Esmeralda	1,928.24	Closed	Noncompetitive	8-May-92	EARTH POWER ENERGY
NVN 055115	Esmeralda	2,556.24	Closed	Noncompetitive	8-May-92	FISH LAKE POWER CO
NVN 055642	Lander	1,547.25	Closed	Noncompetitive	7-Dec-92	CORTEZ JOINT VENTURE
NVN 055643	Lander	1,502.00	Closed	Noncompetitive	12-Nov-92	CORTEZ JOINT VENTURE
NVN 055645	Esmeralda	640.00	Closed	Noncompetitive	12-Nov-92	VARNER CARL W
NVN 055734	Esmeralda	640.00	Closed	Noncompetitive	12-Nov-92	FISH LAKE POWER CO
NVN 055735	Esmeralda	640.00	Closed	Noncompetitive	13-Nov-92	FISH LAKE POWER CO
NVN 055736	Esmeralda	640.00	Closed	Noncompetitive	13-Nov-92	FISH LAKE POWER CO
NVN 055824	Esmeralda	2,550.00	Closed	Noncompetitive	12-Nov-92	WRIGHT ROBERT L
NVN 055825	Esmeralda	1,300.60	Closed	Noncompetitive	12-Nov-92	WRIGHT ROBERT L
NVN 056087	Esmeralda	640.00	Closed	Noncompetitive	12-Nov-92	FISH LAKE POWER CO
NVN 056338	Esmeralda	640.00	Closed	Noncompetitive	2-Feb-93	GEO-ENE PTNR-1983LTD
NVN 056339	Esmeralda	640.00	Closed	Noncompetitive	2-Feb-93	GEO-ENERGY PARTNERS
NVN 056827	Lander	639.11	Closed	Noncompetitive	10-Jun-93	CALIFORNIA ENERGY CO
NVN 057530	Nye	596.00	Closed	Noncompetitive	2-Sep-93	MCGEE CHARLES M
NVN 058352	Esmeralda	946.32	Expired	Noncompetitive	23-May-94	MAGMA GEO-83 JV
NVN 060860	Esmeralda	1,928.24	Closed	Noncompetitive	29-Sep-97	GEO-ENE PTNR-1983LTD
NVN 061283	Lander	1,547.25	Closed	Noncompetitive	19-Nov-97	PLACER DOME US INC
NVN 073967	Nye	240.00	Authorized	Noncompetitive	29-Jan-01	SILVER STATE GEOTHERMAL LLC
NVN 073991	Lander	1,432.38	Authorized	Noncompetitive	27-Aug-02	CORTEZ JOINT VENTURE
NVN 074097	Esmeralda	2,200.00	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD
NVN 074098	Esmeralda	2,555.80	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 074099	Esmeralda	2,482.00	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD
NVN 074100	Esmeralda	2,560.00	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD
NVN 074237	Nye	1,080.00	Closed	Noncompetitive	18-Jul-01	GOODSPRINGS DEV CORP
NVN 074360	Nye	635.00	Closed	Noncompetitive	26-Sep-02	MCGEE CHARLES M
NVN 074695	Nye	1,280.00	Closed	Noncompetitive	10-Dec-01	GOODSPRINGS DEV CORP
NVN 074724	Nye	1,270.88	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074725	Nye	1,269.66	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074728	Nye	1,261.50	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074729	Nye	2,560.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074730	Nye	1,236.38	Closed	Noncompetitive	4-Jun-02	AMP RESOURCES LLC
NVN 074731	Nye	1,379.00	Closed	Noncompetitive	4-Jun-02	AMP RESOURCES LLC
NVN 074733	Nye	2,443.52	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074734	Nye	2,560.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074735	Nye	2,541.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074736	Nye	632.16	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074737	Nye	634.10	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 074847	Lander	1,920.00	Closed	Noncompetitive	18-Sep-02	ART LLC
NVN 074851	Lander	1,200.00	Authorized	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074852	Lander	520.00	Authorized	Noncompetitive	17-Dec-02	ORMAT NEVADA INC
NVN 074856	Lander	1,275.60	Authorized	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074865	Lander	2,560.00	Closed	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074866	Lander	1,921.64	Authorized	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074867	Lander	555.07	Authorized	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074868	Lander	2,560.00	Closed	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074869	Lander	1,280.00	Closed	Noncompetitive	18-Sep-02	ORMAT NEVADA INC
NVN 074880	Eureka	1,200.00	Closed	Noncompetitive	18-Sep-02	ORMAT NEVADA INC

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 074932	Esmeralda	2,541.00	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD
NVN 074933	Esmeralda	2,549.00	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD
NVN 075008	Nye	2,560.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 075009	Nye	2,440.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 075010	Nye	1,903.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 075011	Nye	1,830.59	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 075012	Nye	2,560.00	Closed	Noncompetitive	21-May-02	AMP RESOURCES LLC
NVN 075549	Esmeralda	1,940.60	Authorized	Noncompetitive	21-May-02	ORMAT NEVADA INC
NVN 075550	Esmeralda	1,910.00	Authorized	Noncompetitive	21-May-02	ORMAT NEVADA INC
NVN 075560	Esmeralda	640.00	Authorized	Noncompetitive	21-May-02	ORMAT NEVADA INC
NVN 075561	Esmeralda	640.00	Authorized	Noncompetitive	21-May-02	ORMAT NEVADA INC
NVN 075656	Esmeralda	1,912.04	Authorized	Noncompetitive	21-May-02	GEO-ENERGY PARTNERS-1983 LTD
NVN 075970	Nye	631.77	Closed	Noncompetitive	17-Sep-02	AMP RESOURCES LLC
NVN 076208	Esmeralda	640.00	Authorized	Noncompetitive	22-Jul-04	GEO-ENERGY PARTNERS-1983 LTD
NVN 076209	Lander	2,560.00	Authorized	Noncompetitive	26-Aug-03	ORNI 20
NVN 076210	Lander	2,563.00	Authorized	Noncompetitive	26-Aug-03	ORNI 15
NVN 076211	Lander	2,560.00	Authorized	Noncompetitive	26-Aug-03	ORNI 20
NVN 076279	Esmeralda	2,555.00	Authorized	Noncompetitive	26-Feb-03	GEO-ENERGY PARTNERS-1983 LTD
NVN 076332	Esmeralda	2,279.00	Authorized	Noncompetitive	26-Feb-03	ALUM GEOTHERMAL POWER LLC
NVN 076333	Esmeralda	2,359.00	Authorized	Noncompetitive	26-Feb-03	ALUM GEOTHERMAL POWER LLC
NVN 076334	Esmeralda	2,560.00	Authorized	Noncompetitive	26-Feb-03	ALUM GEOTHERMAL POWER LLC
NVN 076348	Esmeralda	2,480.00	Closed	Noncompetitive	26-Feb-03	GOODSPRINGS DEV CORP
NVN 076526	Esmeralda	2,560.00	Closed	Noncompetitive	29-May-03	GOODSPRINGS DEV CORP
NVN 076676	Lander	1,420.00	Authorized	Noncompetitive	31-Oct-03	REESE RIVER GEO POWER LLC
NVN 077110	Esmeralda	640.00	Authorized	Noncompetitive	27-Aug-03	SILVER PEAK GEO POWER LLC
NVN 077111	Esmeralda	640.00	Authorized	Noncompetitive	27-Aug-03	SILVER PEAK GEO POWER LLC

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 077112	Esmeralda	628.30	Authorized	Noncompetitive	31-Jul-03	SILVER PEAK GEO POWER LLC
NVN 077113	Esmeralda	640.00	Authorized	Noncompetitive	31-Jul-03	SILVER PEAK GEO POWER LLC
NVN 077247	Lander	1,020.00	Authorized	Noncompetitive	31-Oct-03	REESE RIVER GEO POWER LLC
NVN 077482	Lander	1,510.00	Authorized	Noncompetitive	28-Jul-05	ORNI 15
NVN 077483	Lander	2,520.00	Authorized	Noncompetitive	28-Jul-05	ORNI 15
NVN 077627	Esmeralda	2,560.00	Authorized	Noncompetitive	22-Jul-04	GEO-ENERGY PARTNERS-1983 LTD
NVN 077628	Esmeralda	2,556.24	Authorized	Noncompetitive	22-Jul-04	GEO-ENERGY PARTNERS-1983 LTD
NVN 077778	Lander	1,641.00	Authorized	Noncompetitive	19-Jun-06	WESTERN GEO PRTNRS LLC
NVN 077779	Lander	1,920.00	Authorized	Noncompetitive	19-Jun-06	WESTERN GEO PRTNRS LLC
NVN 077780	Lander	1,280.00	Authorized	Noncompetitive	19-Jun-06	WESTERN GEO PRTNRS LLC
NVN 077801	Nye	635.00	Authorized	Noncompetitive	3-Nov-04	RASER POWER SYSTEMS LLC
NVN 078144	Esmeralda	160.00	Authorized	Noncompetitive	22-Jul-04	SILVER PEAK GEO POWER LLC
NVN 078572	Lander	1,920.00	Authorized	Noncompetitive	28-Oct-04	ORMAT NEVADA INC
NVN 078687	Lander	1,180.00	Authorized	Noncompetitive	30-Sep-04	REESE RIVER GEO POWER LLC
NVN 078688	Lander	2,525.00	Authorized	Noncompetitive	30-Sep-04	REESE RIVER GEO POWER LLC
NVN 078780	Esmeralda	1,918.36	Authorized	Noncompetitive	30-Sep-04	SILVER PEAK GEO POWER LLC
NVN 080603	Esmeralda	640.00	Authorized	Noncompetitive	21-Dec-05	SILVER PEAK GEO POWER LLC
NVN 080604	Esmeralda	487.38	Authorized	Noncompetitive	21-Dec-05	SILVER PEAK GEO POWER LLC
NVN 080605	Esmeralda	619.34	Authorized	Noncompetitive	21-Dec-05	SILVER PEAK GEO POWER LLC
NVN 083959	Nye	3,751.95	Authorized	Competitive	10-Sep-07	SILVER STATE GEOTHERMAL, LLC
NVN 083960	Nye	2,445.10	Authorized	Competitive	10-Sep-07	SILVER STATE GEOTHERMAL, LLC
NVN 083961	Nye	5,000.00	Authorized	Competitive	29-Aug-07	RASER POWER SYSTEMS LLC
NVN 083962	Nye	1,891.48	Authorized	Competitive	29-Aug-07	RASER POWER SYSTEMS LLC
NVN 083964	Lander	4,160.00	Authorized	Competitive	29-Aug-07	RASER POWER SYSTEMS LLC
NVN 083965	Nye	4,273.76	Authorized	Competitive	29-Aug-07	RASER POWER SYSTEMS LLC
NVN 083966	Lander	5,120.00	Authorized	Competitive	10-Sep-07	ORNI 39 LLC

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 083967	Lander	2,340.00	Authorized	Competitive	10-Sep-07	ORNI 39 LLC
NVN 083968	Lander	2,462.64	Authorized	Competitive	10-Sep-07	ORMAT NEVADA INC
NVN 085713	Esmeralda	2,560.00	Authorized	Competitive	26-Aug-08	MAGMA ENERGY US CORP
NVN 085718	Esmeralda	5,078.00	Authorized	Competitive	26-Aug-08	RAM POWER INC
NVN 085719	Esmeralda	2,548.00	Authorized	Competitive	26-Aug-08	RAM POWER INC
NVN 085725	Lander	3,821.46	Authorized	Competitive	26-Aug-08	MAGMA ENERGY US CORP
NVN 085726	Lander	4,435.60	Authorized	Competitive	26-Aug-08	MAGMA ENERGY US CORP
NVN 085728	Lander	1,735.02	Authorized	Competitive	26-Aug-08	MAGMA ENERGY US CORP
NVN 085735	Esmeralda	640.00	Authorized	Competitive	20-Aug-08	SILVER PEAK GEO POWER LLC
NVN 085736	Esmeralda	3,098.18	Authorized	Competitive	26-Aug-08	RAM POWER INC
NVN 085737	Esmeralda	1,500.00	Authorized	Competitive	26-Aug-08	RAM POWER INC
NVN 085738	Esmeralda	1,920.00	Authorized	Competitive	26-Aug-08	RAM POWER INC
NVN 085739	Esmeralda	3,097.23	Authorized	Competitive	20-Aug-08	SIERRA GEOTHERMAL POWER LLC
NVN 086900	Esmeralda	4,473.00	Authorized	Competitive	7-Aug-09	RAM POWER INC
NVN 086901	Esmeralda	5,108.00	Authorized	Competitive	7-Aug-09	RAM POWER INC
NVN 086903	Lander	5,117.34	Closed	Competitive	7-Aug-09	HALLADOR PETROLEUM CO
NVN 086904	Lander	4,478.76	Closed	Competitive	7-Aug-09	HALLADOR PETROLEUM CO
NVN 086905	Lander	1,880.48	Authorized	Competitive	7-Aug-09	MAGMA ENERGY US CORP
NVN 086910	Lander	4,972.09	Closed	Competitive	7-Aug-09	HALLADOR PETROLEUM CO
NVN 086911	Lander	4,997.52	Closed	Competitive	7-Aug-09	HALLADOR PETROLEUM CO
NVN 086913	Lander	3,867.00	Authorized	Competitive	7-Aug-09	ALLIED NEVADA GOLD CORP
NVN 086914	Eureka	2,568.20	Authorized	Competitive	7-Aug-09	ALLIED NEVADA GOLD CORP
NVN 086936	Esmeralda	5,086.16	Authorized	Competitive	7-Aug-09	RAM POWER INC
NVN 086937	Esmeralda	5,115.24	Authorized	Competitive	7-Aug-09	RAM POWER INC
NVN 086938	Esmeralda	5,120.00	Authorized	Competitive	7-Aug-09	RAM POWER INC
NVN 086939	Esmeralda	4,997.96	Authorized	Competitive	7-Aug-09	RAM POWER INC

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 086948	Lander	5,093.00	Authorized	Noncompetitive	5-Aug-09	EARTH POWER RESOURCES INC
NVN 086951	Lander	3,839.18	Closed	Noncompetitive	5-Aug-09	GEOTHERMAL TECHNICAL PARTNERS
NVN 087003	Esmeralda	860.00	Authorized	Noncompetitive	22-Jul-04	SILVER PEAK GEO POWER LLC
NVN 087008	Esmeralda	900.00	Authorized	Mining claim	27-Oct-10	CHEMETALL FOOTE CORP
NVN 087225	Nye	400.00	Authorized	Noncompetitive	18-Nov-10	RODRIGUES DALE RAE
NVN 087236	Lander	4,915.60	Authorized	Noncompetitive	28-May-10	EARTH POWER RESOURCES INC
NVN 088413	Esmeralda	2,560.00	Authorized	Competitive	10-Jun-10	VENTURE PROSPECTS LLC
NVN 088424	Esmeralda	2,560.00	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088425	Esmeralda	1,920.00	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088426	Esmeralda	2,811.00	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088427	Esmeralda	2,877.45	Authorized	Competitive	24-May-10	SIERRA GEOTHERMAL POWER LLC
NVN 088431	Esmeralda	632.00	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088438	Lander	4,541.00	Authorized	Competitive	24-May-10	SIERRA GEOTHERMAL POWER LLC
NVN 088439	Lander	3,849.24	Authorized	Competitive	24-May-10	BARRICK CORTEZ INC
NVN 088440	Nye	3,440.00	Authorized	Competitive	10-Jun-10	0718033 NEVADA LTD
NVN 088441	Nye	2,080.00	Authorized	Competitive	10-Jun-10	0718033 NEVADA LTD
NVN 088442	Nye	4,389.57	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088443	Nye	2,200.00	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088444	Nye	4,484.00	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088458	Esmeralda	3,902.48	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088459	Esmeralda	3,842.00	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088460	Esmeralda	3,360.00	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088461	Esmeralda	2,303.16	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088462	Esmeralda	4,462.36	Authorized	Competitive	10-Jun-10	VENTURE PROSPECTS LLC
NVN 088463	Esmeralda	2,604.04	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088464	Esmeralda	2,560.00	Authorized	Competitive	10-Jun-10	RAM POWER INC

TABLE 3-16
Geothermal Leases in the Planning Area Since 1990

Serial Nr	County	Acres	Status	Lease Type	Date	Operator
NVN 088465	Esmeralda	4,478.80	Authorized	Competitive	10-Jun-10	RAM POWER INC
NVN 088466	Esmeralda	5,111.44	Authorized	Competitive	10-Jun-10	VENTURE PROSPECTS LLC
NVN 088470	Nye	4,160.22	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088471	Nye	3,190.65	Authorized	Competitive	10-Jun-10	HOV ENERGY
NVN 088490	Lander	3,660.12	Authorized	Noncompetitive	21-Jun-10	MUSTANG GEOTHERMAL CORP
NVN 088491	Lander	2,905.60	Authorized	Noncompetitive	28-May-10	HOV ENERGY
NVN 088492	Lander	2,560.00	Authorized	Noncompetitive	28-May-10	HOV ENERGY
NVN 088493	Nye	2,859.78	Authorized	Noncompetitive	28-May-10	HOV ENERGY
NVN 088494	Nye	1,720.00	Authorized	Noncompetitive	28-May-10	MUSTANG GEOTHERMAL CORP
NVN 088495	Nye	3,715.47	Authorized	Noncompetitive	28-May-10	HOV ENERGY
NVN 088496	Nye	4,480.00	Authorized	Noncompetitive	28-May-10	HOV ENERGY
NVN 089607	Esmeralda	2,475.00	Authorized	Competitive	15-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089608	Esmeralda	4,137.92	Authorized	Competitive	15-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089609	Esmeralda	3,021.78	Authorized	Competitive	15-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089610	Lander	2,210.00	Authorized	Competitive	15-Apr-11	ORMAT NEVADA INC
NVN 089619	Esmeralda	3,864.00	Authorized	Noncompetitive	19-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089620	Esmeralda	5,120.00	Authorized	Noncompetitive	19-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089621	Esmeralda	1,949.00	Authorized	Noncompetitive	19-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089622	Esmeralda	3,866.00	Authorized	Noncompetitive	19-Apr-11	TGP DEVELOPMENT COMPANY LLC
NVN 089626	Esmeralda	4,345.00	Authorized	Noncompetitive	19-Apr-11	TGP DEVELOPMENT COMPANY LLC

TABLE 3-17
Geothermal Projects in the Planning Area

Project Name	County	MW	Developer	Land Type	Online Date	Status
Beowawe	Land/Eureka	17	Terra-Gen Power	BLM	Now	In Service
Buffalo Valley	Lander	30	Ormat Technologies	BLM	TBD	PPA, Final Permits
Devil's Canyon	Nye	10	Raser Technologies	BLM/Private	TBD	PPA, Final Permits
McGinnis Hills	Lander	30	Ormat Technologies	BLM	2014	PPA, Final Permits
Trail Canyon	Nye	10	Raser Technologies	BLM	TBD	PPA, Final Permits
Clayton Valley	Esmeralda	160	Ram Power	BLM	2014	Regulatory Approval
Alum	Esmeralda	33	Sierra Geothermal Power	BLM	2013/2014	Exploration
Silver Peak	Esmeralda	15	Sierra Geothermal Power	BLM	2012	Exploration
Reese River	Lander	26	Sierra Geothermal Power	BLM	2012	Exploration

BLM = Bureau of Land Management; TBD = To Be Determined; PPA = Power Purchase Agreement

3.3.2 Oil and Gas

Introduction

Federal oil and gas leasing authority stems from the 1920 Mineral Leasing Act, as amended, for public land, and the 1947 Acquired Lands Leasing Act, as amended, for acquired land. Leasing of federal oil and gas is affected by other acts and regulations contained in 43 CFR 3100 with additional requirements and clarification found in Onshore Operating Orders and Washington Office manuals and instruction memorandums. Oil and gas leasing on Federal public land is administered by BLM through a competitive and noncompetitive leasing system.

An oil and gas lease grants the right to explore, extract, remove, and dispose of oil and gas resources that may be found in the leased land. Lease rights are controlled by standard lease terms and may be subject to particular lease stipulations (restrictions to further protect other resources) and other permit approval requirements based on a NEPA analysis of proposed disturbances and cumulative impacts. Stipulations and permit requirements describe how lease rights are modified. Lease stipulations and permit conditions of approval allow for management of federal oil and gas resources while giving due consideration to other resources and land uses.

Leasing Process and Oil and Gas Program Decision Points

Knowledge of existing geology of the planning area, as it relates to oil and gas occurrences, is based on bedrock geologic mapping (**Figure 2-3**), detailed basin analysis (Anna *et al.* 2007), and oil and gas test

wells drilled in the planning area. Detailed bedrock geologic maps of 1:250,000 quadrangles were compiled by the USGS by county (Albers and Stewart 1972; Cornwall 1972; Kleinhampl and Ziony 1984; Kleinhampl and Ziony 1985; Roberts *et al.* 1967; Stewart and McKee 1977) and are available as electronic files from the Nevada Bureau of Mines and Geology.

Oil and gas fields in the planning area occur in Railroad Valley and Pine Valley located in central Nevada (**Figure 3-3, Table 3-18**; LaPointe *et al.* 2007). Oil and gas in Railroad Valley occurs mainly in Miocene and younger age basins formed during the Basin and Range Orogeny. Hydrocarbon traps are stratigraphic and structural in nature. The majority of oil and gas are trapped in the fractured, Oligocene age volcanic rocks and are believed to be sourced from deeper Cretaceous and early Tertiary marine sediments. Most of the oil produced in the planning area is low in gravity. Gas production in the planning area is negligible and constitutes only about 0.05 percent of all produced hydrocarbons.

Pine Valley oil production comes primarily from Oligocene and Miocene sedimentary and volcano-sedimentary rocks, but rocks as old as the Devonian Telegraph Canyon Formation host oil in the planning area.

The oil and gas program currently consist of drilling exploratory based production wells on existing oil fields in the Railroad Valley (**Figure 3-3**). Currently, 674 authorized oil and gas leases and 2 pending leases covering more than 1,210,805 acres are located in the Battle Mountain district. A total of 1,565 leases have been authorized since 1980. Since 1954, 771 oil and gas wells have been drilled in the planning area. Total hydrocarbon production since 1950 is 50.1 million barrels of oil (**Table 3-19**) and 347,734 million cubic feet (MCF) of gas. Oil production in 2010 amounted to 425,705 barrels of oil. **Figure 3-4** shows the location of the current authorized leases in the planning area.

Leasing Regulations

Oil and gas leases are issued for public domain land under authority of the Mineral Leasing Act of February 25, 1920 (41 Stat. 437; 30 U.S.C. 181 *et.seq.*) as amended and supplemented; the Act of August 8, 1946 (60 Stat. 950); and the Act of September 2, 1960. Authority for leasing on acquired land comes from the Leasing Act for Acquired Lands enacted on August 7, 1947 (61 Stat. 913). Upon passage of the Federal Onshore Oil and Gas Leasing Reform Act of 1987 (Pub. L 100-203), BLM made a major revision to the Federal Oil and Gas regulations in 43 CFR 3100. Effective on June 17, 1988, the new regulations cover competitive and noncompetitive onshore oil and gas leasing.

Within the planning area, oil and gas management is further defined by the Regional Geothermal/Oil and Gas Leasing Environmental Assessment of June 1982 (EA-NV-020-2-38, N-11821) as amended. This document defines stipulations for the exploration, development, and production of oil and gas resources. These stipulations are imposed in addition to the Uniform Standard Lease Stipulations (contained 43 CFR 3100) and site specific Best Management Practices incorporated into Applications for Permit to Drill. These stipulations outline surface occupancy, timing limitation, and controlled surface use restrictions.

Figure 3-3 Location and Relative Sizes of Oil Fields from Which Production has been Recorded in Nevada (Area 3 - Railroad Valley is within the Planning Area; From LaPointe et al. 2007)

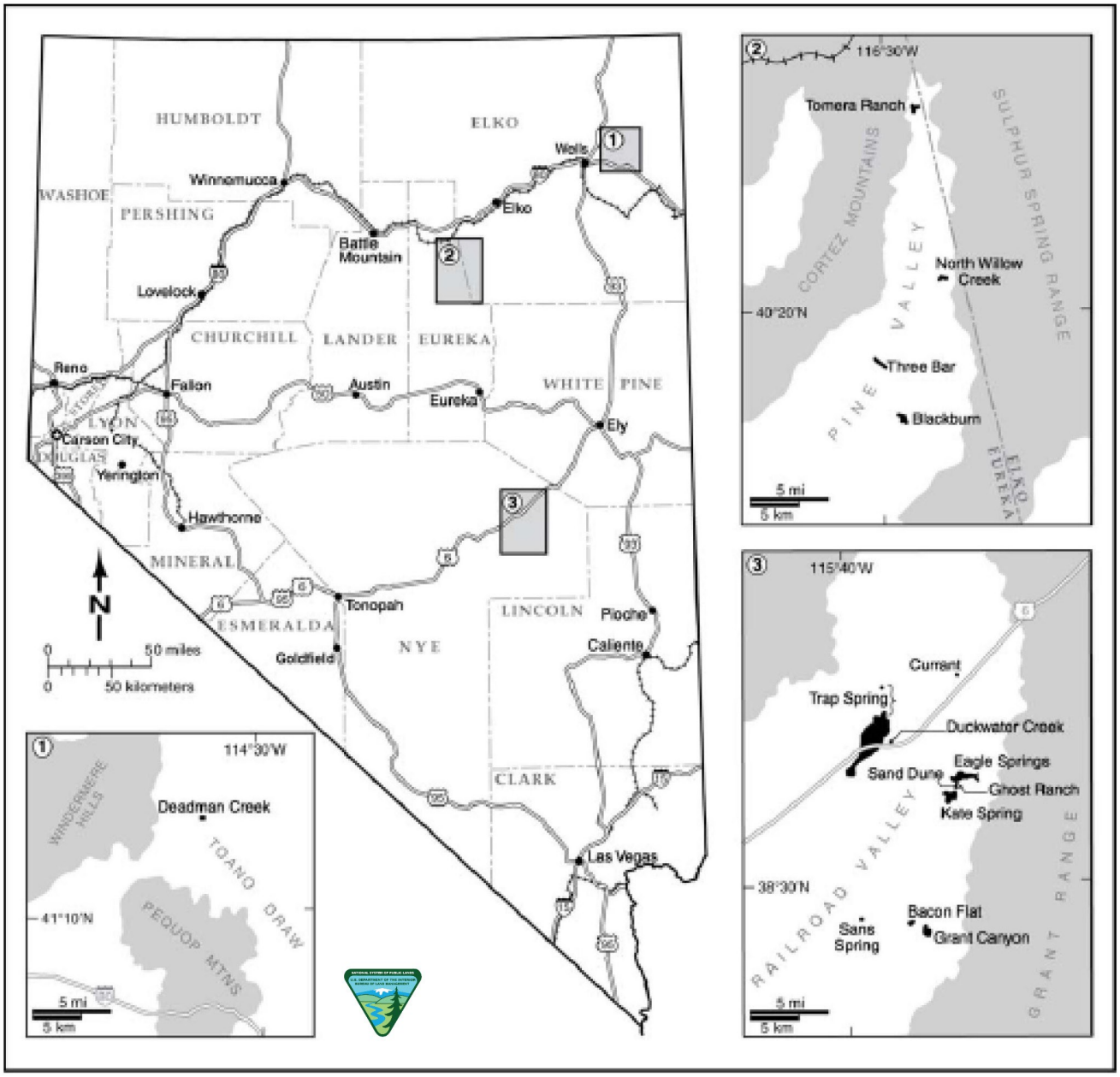


TABLE 3-18
Location of Oil Fields in the Planning Area

Oil Field Name	Location	County	UTM East	UTM North	Township	Range	Section	Quarter Section
Eagle Springs	Railroad Valley	Nye	627676	4273342	9N	57E	35	SE/4 NE/4 NW/4
Kate Spring	Railroad Valley	Nye	627193	4270858	8N	57E	2	NW/SW
Trap Spring	Railroad Valley	Nye	617249	4273931	9N	56E	27	SE/SE
Currant	Railroad Valley	Nye	627560	4283509	10N	57E	26	SW/SE
Bacon Flat	Railroad Valley	Nye	622670	4257863	7N	57E	17	C/SW
Blackburn	Pine Valley	Eureka	573279	4453568	27N	52E	8	C NE/4 SW/4 SW4
Grant Canyon	Railroad Valley	Nye	624173	4256785	7N	57E	21	C E/2 SW/4 NW/4 Sec. 21, T 7N, R 57E
Tomera Ranch	Pine Valley	Eureka	574050	4485300	30N 31N	52E 53E	5 33	SE/NE/NE
North Willow Creek	Pine Valley	Eureka	576920	4468420	29N	52E	27	NW/SE
Three Bar	Pine Valley	Eureka	571050	4459310	28N	51E	25	C NE/4
Duckwater Creek	Railroad Valley	Nye	620800	4276600	9N	57E	19	NW/NW
Sans Spring	Railroad Valley	Nye	617700	4258450	7N	56E	14	SW/NW
Ghost Ranch	Railroad Valley	Nye	627980	4272120	8N 9N	57E	2 34 35	NE/NW 02; SE/SW 35
Sand Dune	Railroad Valley	Nye	627800	4272050	9N	57E	35	SE/SE/SE

Source: LaPointe *et al.* 2007

TABLE 3-19
Oil Production (in Barrels) in the Planning Area 1954 to February 2011

Year	Eagle Springs	Bacon Flat	Currant	Duckwater	Ghost Ranch	Grant Canyon	Kate Spring	Sand Dune	Sans Springs	Trap Spring	Blackburn	N. Willow Creek	Three Bar	Tomera Ranch	Total Production
	Railroad Valley										Pine Valley				
1954 - 1989	3,945,917	314,660	641	-	-	11,838,587	271,148	-	-	7,901,672	1,905,504	13,493	-	6,478	26,198,100
1990	41,609	-	-	3,095	-	2,345,858	434,349	-	-	939,910	238,240	3,169	3,601	2,605	4,012,436
1991	42,043	-	-	4,190	-	2,124,021	324,207	-	-	690,697	203,023	2,365	17,684	3,067	3,411,297
1992	43,691	178,845	-	2,764	-	2,499,831	203,274	-	-	554,410	231,719	4,491	362	2,295	3,721,682
1993	7,075	102,030	-	2,256	-	495,934	150,309	-	69,478	427,150	599,857	3,928	1,961	2,140	1,862,118
1994	66,565	192,601	-	1,269	-	308,709	122,544	-	44,279	378,829	576,853	3,737	229	1,970	1,697,585
1995	162,296	43,057	278	655	-	202,129	104,574	-	22,174	362,985	435,975	6,419	-	1,405	1,341,947
1996	171,638	28,891	-	433	34,166	168,163	87,789	-	17,228	306,858	239,934	3,619	-	387	1,059,106
1997	137,278	22,465	202	168	113,016	143,707	76,280	-	45,001	288,686	151,151	1,478	-	659	980,200
1998	111,562	18,757	230	491	65,370	126,128	69,768	12,465	21,759	257,921	112,008	1,502	-	574	798,793
1999	82,067	16,849	28	93	49,348	112,715	65,315	15,122	11,127	263,566	89,400	123	-	398	706,151
2000	59,394	14,766	55	116	41,454	102,113	57,644	12,624	6,990	246,725	78,136	146	-	488	620,651
2001	67.024	13,898	33	968	36,173	92,899	55,198	13,461	6,356	218,198	66,899	144	-	-	571,251
2002	67,908	12,647	21	869	31,814	85,722	53,408	14,211	5,532	206,424	62,412	573	-	11,901	553,442
2003	57,946	11,763	23	436	26,129	79,293	49,698	13,123	4,775	193,191	54,623	349	-	1,981	493,330
2004	45,176	10,612	9	200	36,423	73,879	45,656	13,124	4,169	181,937	51,372	377	-	124	463,058
2005	54,362	7,556	3	185	37,874	68,944	44,288	11,878	3,324	170,896	45,369	2,064	-	-	446,743
2006	54,708	8,112	-	122	30,255	70,158	41,124	10,618	3,265	163,299	41,491	2,552	-	-	425,704
2007	56,992	8,301	81	150	26,070	62,236	38,411	10,562	2,971	159,821	39,477	1,256	-	-	408,244
2008	58,683	7,968	108	120	23,615	56,247	36,863	10,467	2,407	196,089	43,600	56	-	-	436,271
2009	53,851	7,764	111	120	24,011	60,036	38,347	9,883	1,419	181,320	77,730	-	-	-	454,592
2010	57,395	6,169	109	118	21,630	68,927	33,824	3,687	1,233	175,353	57,260	-	-	-	425,705
2011	9,279	1,182	-	20	3,424	10,782	5,077	406	213	27,558	6,655	-	-	-	64,596
TOTAL	**5,454,459**	**1,028,893**	**1,932**	**18,838**	**600,772**	**21,197,018**	**2,409,095**	**151,631**	**273,700**	**14,493,495**	**5,408,688**	**51,841**	**23,837**	**36,472**	**51,150,671**

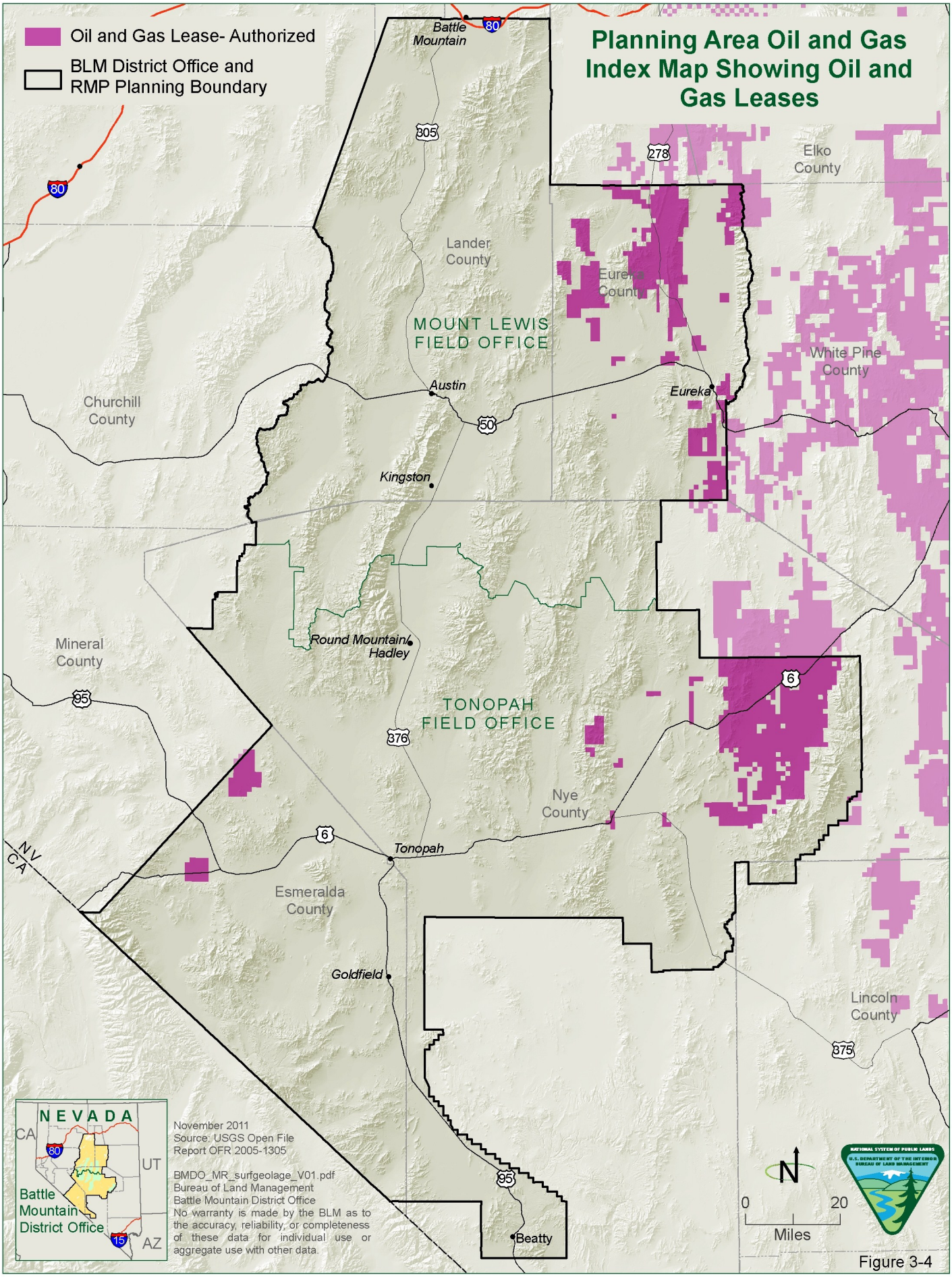

Planning Area Oil and Gas Index Map Showing Oil and Gas Leases
Oil and Gas Lease- Authorized
BLM District Office and RMP Planning Boundary
Battle Mountain
80
305
278
Elko County
Lander County
Eureka County
MOUNT LEWIS FIELD OFFICE
White Pine County
Churchill County
Austin
Eureka
50
Kingston
Round Mountain
Hadley
Mineral County
95
6
TONOPAH FIELD OFFICE
376
Nye County
NV
CA
Tonopah
Esmeralda County
Goldfield
Lincoln County
375
Beatty
NEVADA
CA
UT
AZ
Battle Mountain District Office
15
November 2011
Source: USGS Open File Report OFR 2005-1305
BMDO_MR_surfgeolage_V01.pdf
Bureau of Land Management
Battle Mountain District Office
No warranty is made by the BLM as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data.
N
0
20
Miles
NATIONAL SYSTEM OF PUBLIC LANDS
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Figure 3-4

Other guiding Federal actions include the Wilderness Act, the Wilderness Study Area Act, and other applicable federal regulations. Federal regulations common to all leasable minerals include: 6300 Wilderness Regulations and 5860 Wilderness Management Handbook. Another set of regulations that are administered by BLM and contained in 30 CFR 270 regulate exploration, development, and production operations under federal leases.

Historic Production

The first well drilled for oil in Nevada was a 1,890-foot-deep dry hole drilled in Washoe County just southwest of Reno in 1907. Few wells were drilled in the State from 1907 to the early 1950s; these dry holes are all poorly known because no permits or other records were required until 1953.

In 1954, Shell Oil Co. drilled and completed the Eagle Springs No. 1-35 well in Railroad Valley, Nye County. This well became the first commercial oil producer in Nevada. The Eagle Springs Field included 14 wells with average production of nearly 20,000 barrels of oil per well per year by 1968. In 1985, ten wells still produced in the field; two wells made 18,000 barrels of oil and the rest averaged 2,800 barrels for the year. Most Eagle Springs Field wells were shut-in (not produced) for most of 1986 because of low crude oil prices. Initial estimates of recoverable reserves for the field were 4 million barrels of oil. By the end of 1986, 3.8 million barrels had been produced.

The second discovery that resulted in commercial oil production in Nevada came in 1976, when Northwest Exploration Co. drilled and completed the Trap Spring No. 1 well in Railroad Valley, five miles west of the Eagle Springs Field. One hundred and forty-five dry holes had been drilled in Nevada after the Eagle Springs discovery and before the Trap Spring discovery. By 1980, 15 wells were completed in the Trap Spring Field, with an average production of 76,700 barrels of oil per well per year. In 1985, 27 wells were located in the field, with an average production for the year of 18,600 barrels of oil per well. Recoverable reserves were initially estimated to be 10 million barrels of oil. By the end of 1986, 6.8 million barrels had been produced.

Nevada's third discovery well, the Northwest Exploration Co. Currant No. 1, was drilled in 1978, in Railroad Valley, 6 miles north of the Eagle Springs Field. This well produced only 646 barrels of oil before it was plugged and abandoned (This well was producing a couple of hundred barrels of oil per year in the late 1990s.) No other wells were drilled in the Currant Field.

Northwest Exploration Co. Bacon Flat No. 1, drilled in 1981, was Nevada's fourth discovery well. The Bacon Flat Field is in Railroad Valley, 9 miles south of the Eagle Springs Field. The field consists entirely of the discovery well, but this well produced 210,000 barrels of oil and was still flowing at an average of 200 barrels of oil per day by the end of 1986. Reserve estimates are unavailable.

The only oil production outside of Railroad Valley was discovered in 1982 by Amoco Production Co. The Amoco Blackburn No. 3 was drilled and completed in Pine Valley, Eureka County, about 120 miles north of the nearest production in Railroad Valley. By the end of 1986, the Blackburn Field included four wells and had produced nearly a million barrels of oil; the two best wells were still averaging 300 to 450 barrels of oil per day. Reserve estimates are unavailable. (367 barrels of oil were produced from the Deadman Creek Field in Elko County in 1997-1998 before it was shut-in).

The discovery of Nevada oil outside of Railroad Valley renewed the interest of many exploration companies. By the late 1970s, oil and gas leasing in Railroad Valley was essentially closed, that is, nearly

all leases were taken, making it difficult or expensive for new companies to explore in the valley. Nearly two-thirds of all wells drilled by 1982 had been drilled in Railroad Valley. In other valleys, there had been little drilling and leases were still available and cheap. Since the Blackburn Field discovery, exploration has expanded throughout Nevada, and by the end of 1986, less than half of all wells ever drilled in Nevada were in Railroad Valley.

The most prolific oil field in Nevada was discovered in 1983, when Northwest Exploration Grant Canyon No. 1 was drilled and completed. The Grant Canyon Field is in Railroad Valley, less than a mile east of the Bacon Flat Field. The discovery well watered out and was shut in by early 1986; at year-end the remaining two field wells continued to produce at average rates of 2,200 and 4,100 barrels of oil per day. For a time, Grant Canyon No. 3 was the most prolific onshore oil well in the continental United States, flowing up to 4,300 barrels of oil per day. Recoverable reserve estimates are 13 million barrels of oil; 5.3 million barrels had been produced by the end of 1986.

The most recent oil discovery in Nevada was drilled in 1986: the Marathon Oil Co. Kate Spring No. 1, in Railroad Valley less than a mile south of the Eagle Springs Field. This discovery well had an initial flowing potential of 345 barrels of oil and 1,371 barrels of water per day. The well produced 1,500 barrels of oil before it was shut in because of engineering problems and low prices for crude oil.

Drilling activity in 1986 was limited because of unstable and low oil prices, but operators continue to permit wells in Nevada. Future increases in drilling activity will be related to increased prices for crude oil. Federal oil and gas leasing policies, favorable State oil and gas regulations, and recently published articles in petroleum industry journals should all continue to encourage petroleum exploration and production activity in Nevada. (A good summary of the oil fields of Nevada is the Nevada Petroleum Society's 1994 publication NPS1, Oil Fields of the Great Basin.

The activity of the oil and gas industry in Nevada has been summarized in the NBMG annual report The Nevada Mineral Industry since 1979. These are available through the NBMG Publication Sales Office and the 1994 through 1999 issues are free on the NBMG website. Nevada's oil production peaked at about 4,000,000 barrels in 1990 and slipped to about 700,000 barrels in 1999. Between 1953 and 1999, Nevada has produced over 46,000,000 barrels of oil of which over 20 million barrels has been produced from the Grant Canyon Field and almost 13 million barrels has been produced from the Trap Springs Field.

Nevada continues to be considered a frontier state for oil exploration with 15 small oil fields in three areas of the state (Pine Valley in northern Eureka County, Railroad Valley in northeastern Nye County, and Deadman Creek in Elko County). Since 1907, about 750 wells have been drilled including about 270 wells drilled since 1986 of which about 50 were producers. As of 1999, 99 wells were listed as producers of which 26 had been shut in for one year or more.

Basin Geology

Railroad Valley (**Figure 3-3**) has produced most of the oil in the EGB Province and has been extensively studied to determine relations between structure and oil production. Several interpretations of basin configuration have evolved, based on improved seismic acquisition and processing and better understanding of deformation styles and kinetics. Lund *et al.* (1993) and Potter *et al.* (1992) for example, reported that a low-angle attenuation fault that underlies Railroad Valley, exposed in the adjacent range, was a result of asymmetric arching rather than a series of down-to-the-west high-angle normal faults.

According to them (Lund *et al.* 1993; Potter *et al.* 1992), 1) some high-angle normal faults exist as part of the deformation process, but they are not the dominant style, and 2) a transfer of heat from the lower plate of the low-angle fault to the otherwise cool upper plate could occur by either convection or discrete pathways through the high-angle normal faults or fracture zones, possibly allowing source rocks in the upper plate to reach oil generating temperature.

Individual Field Characteristics

The general geological characteristics of each producing field are summarized in **Table 3-20**. The Grant Canyon and Eagle Springs fields are discussed in more detail below.

The Grant Canyon field is located on the east side of Railroad Valley, 8 miles south of the Eagle Springs oil field (Duey *et al.* 1988). The discovery well, (1 Grant Canyon Unit) was completed by Northwest Exploration Company on September 11, 1983, flowing 1,816 BOPD, probably from the Devonian Simonson Dolomite (4,375 to 4,448 feet). The trap is a "high" fault block in the boundary fault zone that separates Railroad Valley from the Grant Range to the east. The Devonian Simonson reservoir is an intensely fractured, vuggy dolomite with some inter-crystalline porosity. The top seal is the Tertiary valley fill, which unconformably overlies the Simonson Dolomite.

Shell Oil Company discovered Eagle Springs oil field, Nevada's sole producing area, in 1954 (Murray and Bortz 1967). Shell's discovery was drilled on a seismic anomaly reportedly mapped in Miocene valley-fill deposits. Most of the production is from carbonate rock of the Eocene Sheep Pass Formation and from porous zones in Oligocene tuff. A well in the southwest part of the field has produced a small amount of oil from Pennsylvanian carbonate strata. The Sheep Pass Formation, which is characterized by the absence of volcanic material, was deposited in a local lacustrine basin that covered parts of the present-day Railroad Valley, White River Valley, and adjacent mountain ranges. The Oligocene tuffs are part of an extensive ignimbrite sequence that once covered much of Nevada and western Utah. Pay zones in the field are discontinuous, being absent in some of the Eagle Springs Unit wells as well as in several of the exploratory tests drilled in the region. The oil trap at Eagle Springs appears to have resulted from a combination of folding, faulting, truncation, and overlap; impermeable Miocene "valley fill" overlaps truncated Oligocene and Eocene reservoir beds along a northwest-plunging anticlinal nose at the base of the Miocene. Closure on the east is provided in part by a major boundary-fault zone exhibiting 10,000-15,000 ft of apparent stratigraphic displacement. This fault zone separates the field from the uplifted Grant Range on the east. Within the central part of the "Sheep Pass basin," little or no angular discordance separates the Eocene from the upper Paleozoic sediments. However, at the edge of this depositional basin these same rock units are separated by a distinct angular unconformity. Oligocene pyroclastic rocks disconformably overlie Eocene Sheep Pass sediments both in the field and at most observed outcrops within the "Sheep Pass basin."

TABLE 3-20
Host Rocks for Petroleum in the Planning Area

Oil Field Name	Depth to Top of Field	Host Rock	Thickness
Eagle Springs	5,780' (1,762 m)	Oligocene Garrett Ranch Group; Eocene Sheep Pass Formation lacustrine carbonates; Pennsylvanian Ely Limestone carbonate (minor production)	1,500'
Kate Spring	4,450' (1,356 m)	Neogene Horse Camp Formation breccia and Devonian Guilmette Formation (carbonate, dolomite)	413' of Pennsylvanian carbonate breccia; 560' of Devonian dolomite & limestone
Trap Spring	3,210' (978 m)	Oligocene Tuff of Pritchards Station, ash flow tuff (ignimbrite)	2,490'
Currant	6,850' (2,088 m)	Eocene Sheep Pass Formation calcareous shale and shaly limestone	439'
Bacon Flat	4,960' (1,512 m)	Devonian Guilmette Formation carbonate, dolomite; possibly also Sheep Pass Fm	73'
Blackburn	5,776' (1,761 m)	Devonian Telegraph Canyon Formation dolostone; Mississippian Chainman Shale and Dale Canyon Formation shale, sandstone & siltstone; Oligocene Indian Well Formation tuff and tuffaceous sandstone	1,275'
Grant Canyon	4,374' (1,333 m)	Devonian Simonson and Guilmette Formation vuggy brecciated dolomite	448'
Tomera Ranch	1,150' (351 m)	Oligocene Indian Well Formation chert and tuffaceous sandstone	189'
North Willow Creek	6,290' (1,917 m)	Mississippian Chainman Shale	604'
Three Bar	5,720' (1,743 m)	Miocene Humboldt Formation sandstone and volcanic rock; Oligocene Indian Well Formation, and Cretaceous Newark Formation sandstone and carbonate	6,000'
Duckwater Creek	5,680' (1,731 m)	Oligocene Garrett Ranch Group volcaniclastic rocks and ignimbrites	3,125'
Sans Spring	5,640' (1,710 m)	Oligocene Garrett Ranch Group volcaniclastic rocks and ignimbrites	933'
Ghost Ranch	4,350' (1,326 m)	Late Tertiary landslide breccia blocks of Devonian Guilmette Formation limestone and dolomite	265'
Sand	5,970'	Permian and Pennsylvanian limestones	465'

Exploration Drilling

Wells permitted within the planning area since 2007 are shown in **Table 3-21**.

TABLE 3-21
Oil Well Permit Notices for 2007-2011

Type	Notice #	Date	Well Name/Comment
Oil	0921	5/4/2011	VF Neuhaus.E Hogback 31-2.921.5.4.11
Oil	0920	4/8/2011	HBF Charity No2 Approved Permit
Oil	0919	4/8/2011	HBF Charity No2 Approved Permit
Oil	0918	10/28/2010	Emergent Value.FLT-1.918.10.28.10
Oil	0917	7/1/2010	Geyser Petro.SMDLA 2.917.7.1.10
Oil	0916	6/4/2010	Empire Petro.Paradise 2-12.916.4.7.10
Oil	0915	4/5/2010	Cabot Oil Gas.Lk Vly 10-29.915.4.5.10
Oil	0914	11/17/2009	True Oil.DY 43-36.914.11.17.09
Oil	0913	3/23/2010	Fakdin Oil. Papoose Cyn 1-14.913.3.23.10
Oil	0912	3/9/2009	
Oil	0910-0911	12/19/2008	
Oil	0908-0909	10/15/2008	
Oil	0906-0907	9/29/2008	
Oil	0904-0905	9/25/2008	
Oil	0903	9/16/2008	
Oil	0902	5/14/2008	
Oil	0901	5/8/2008	
Oil	0900	4/29/2008	
Oil	0899	4/15/2008	
Oil	0898	8/28/2007	
Oil	0897	7/13/2007	
Oil	0896	7/11/2007	(updated 01-02-2008)

Leasing

A total of 1,565 leases totaling 2.5 million acres have been awarded since 1990. **Figure 3-4** shows the location of current leases.

In most areas within the planning area it is anticipated that leasing will take place with only standard stipulations. In some areas special stipulations are anticipated to protect seasonal wildlife habitat or other sensitive resource values. In highly sensitive resource areas where the resource could not be protected by special stipulations, it is anticipated that a no surface occupancy stipulation would be attached to the leases. In addition, it is assumed that issuance or attachment of appropriate stipulations would continue to be decided on a case by case basis considering existing documents including the Regional Geothermal/Oil and Gas Leasing Environmental Assessment of June 1982 (EA-NV-020-2-38, N-11821) as amended.

As a result of 1987-1988 litigation (*Connor vs. Burford*) against the BLM's leasing policy and program, the number of leases and the number of acres under BLM lease in the US has dramatically declined. Under the decision handed down in 1988, the BLM has been directed by the U.S. District Court and Ninth Circuit Court of Appeals to make predictions of where oil and gas occurrences and subsequent

development may occur before leasing public land to evaluate the long-term cumulative impact of individual oil and gas leasing decisions (*Connor vs. Burford*, 848 F.2d 1441, 9th Cir., 1988). Leasing in the planning area has not been affected by this action.

Oil and gas occurrence and development potential within the planning area is discussed in the Chapter 4 - *Mineral Resource Potential*.

3.3.3 Oil Shale

The outlook for production of petroleum products from oil shale within the planning area is poor in the short-term and probably poor in the long-term. Oil shale contains significant crude oil and may be used as a source of petroleum although the economics of the process is not very attractive at this time. Oil shale production will require a very large resource, access to energy, and access to large volumes of water. Oil shale has been reported in the Chainman Formation (Mississippian), Vinini Formation (Ordovician), Woodruff Formation (Devonian), Sheep Pass Formation (Eocene), and the Elko Formation (Eocene-Oligocene) are potential sources of oil shale (Anna *et al*, 2007). The Chainman, Vinini, Woodruff, and Sheep Pass Formations all occur within the planning area. The Sheep Pass Formation hosts some oil in the Railroad Valley area. The Elko Formation may occur within the planning area in the lower stratigraphy of Pine Valley but the bulk of the Elko Formation is northeast of the planning area. Oil production was attempted from the Elko Formation from 1917 to 1924 (Garside 1983) but was unsuccessful because of low yields and poor product quality. No other attempts have been made to exploit oil shale in Nevada.

Anna *et al*. (2007) indicate that the Chainman, Vinini, Woodruff, Sheep Pass, and Elko Formations are attractive sources for petroleum and may have contributed to the petroleum in the Railroad Valley fields, but thermal maturation of most of these units, especially the Sheep Pass and Elko Formations is not adequate to produce significant petroleum across the entire region. Some of the basins in the planning area may be deep enough to raise the temperatures to the point where petroleum can mature in the Sheep Pass and Elko Formation, but those are somewhat restricted in aerial extent.

The Paleozoic formations are typically fragmented due to the complex tectonic history of the region and thus limited in aerial extent. Yields are typically low (Anna *et al.* 2007)

Significant deposits of oil shale occur in Colorado, Wyoming, and Utah which limit the possibilities for development of lesser quality material in Nevada. Those deposits would need to be exhausted before the Nevada deposits become attractive which means that the outlook for short-term is quite poor. Long-term prospects are marginally better, but still not good.

3.3.4 Sodium Minerals

No sodium mineral operations are currently permitted within the planning area. **Table 3-22** summarizes past production of sodium minerals (Papke and Castor 2003). Although there is potential for mining of salt from playas within the planning area (Nash 1996), no current production of salt or other sodium materials is occurring at the present time.

TABLE 3-22 Mines with Reported Sodium Mineral Production		
County	**Mine, Prospect, or Area Name**	**Deposit Type**
Esmeralda	Alkali Spring Valley	Sodium Chloride
Esmeralda	Silver Peak	Sodium Chloride
Eureka	Williams Marsh	Sodium Chloride
Eureka	Diamond Valley	Sodium Sulfate
Nye	Spalding Marsh	Sodium Chloride
Nye	Railroad Valley	Sodium Carbonate

3.3.5 Sulfur

Sulfur is used to make sulfuric acid, other chemicals, fertilizer, paper products, and explosives (Nash 1996). No sulfur leases are active in the planning area. Papke and Castor (2003) report past production from the Deep Gulch (Cuprite) deposit in Esmeralda County and an occurrence at Hot Springs Point in Eureka County.

Native sulfur deposits are most commonly associated with Miocene to Recent age volcanic centers (Nash 1996). Most economic sulfur occurrences in Nevada occur as fumarole-type deposits that precipitate sulfur on the surfaces of host-rock in vents, vesicle, breccia, and other open volcanic structures adjacent to volcanoes. Deposits are tabular to pipe-shaped with dimensions of 30 to 300 feet (Nash 1996). Fumarole sulfur deposits are small and typically contain mercury, arsenic and other impurities that are difficult to remove and can inhibit their development.

Other documented sulfur sources in the planning area are considered secondary deposits and are associated with metallic ore deposits. In these deposits, sulfur occurs as accessory sulfide minerals in mercury and precious metal deposits. These sulfide mineral sources for sulfur are not the most favorable for development, because they require substantial processing.

3.3.6 Phosphate

No phosphate production is reported from the planning area. Shawe *et al.* (1969) report phosphatic nodules in the barite deposits in East Northumberland Canyon in Nye County, but those occurrences are unlikely to be economic.

3.3.7 Coal

No coal is currently leased within the planning area. Tingley (1998) reports coal near the town of Coaldale in Esmeralda County, but no production is reported.

3.3.8 Potash

Potential for significant potash production is low within the planning area. Potash (KCl) is primarily used for fertilizer and is typically mined from large evaporite potash beds containing sylvite or carnallite which have not, as yet, been discovered in the planning area. These deposits are typically associated with thick

beds of halite and are the result of continuing evaporation of water after halite has precipitated from the water. Both minerals are permittable in some of the playas within the planning area although it is doubtful that economic tonnages would be available. Potash can also be produced by processing minerals such as alunite ($KAl_3(SO_4)_2(OH)_6$) or kalinite ($KAl(SO_4)_2 \cdot 11H_2O$) which are also sources of aluminum. Papke and Castor (2003) and Price *et al.* (2009) report minor production of kalinite, but grades were too low to sustain production. Evaporation of brines used for lithium production produces small amounts of potash that are marketable, but the brines are not adequate grade to sustain potash production alone.

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4. MINERAL RESOURCE POTENTIAL

4.1 LOCATABLE MINERALS

Nevada was the leading US gold, barite, lithium, and gypsum producer in 2010 and the second largest producer of silver. In addition, planning area mines also produce aggregate, and copper. In total, Nevada's mineral industry production was valued at $5.8 billion in 2009 (**Table 4-1**) and precious metal production accounted for about $5.0 billion of this total (Price *et al.* 2010b).

TABLE 4-1
2008 and 2009 Mineral, Geothermal, and Petroleum Production in Nevada

Commodity	Units	2008		2009	
		Quantity [1]	Value (millions $US)	Quantity	Value (millions $US)
Gold	thousand troy ounces	5,698	4,968.2	5,033	4,893.7
Silver	thousand troy ounces	7,965	119.4	7,310	107.3
Copper	thousand pounds	175,538	568.7	145,733	345.4
Aggregate	thousand tons	43,400	256.1	28,740	193.5
Barite	thousand tons	595	26.5	476	38.8
Gypsum	thousand tons	1,152	15.3	983	12.1
Geothermal	thousand megawatt-hours	1,383	95.1	1,669	110.8
Petroleum	thousand 42-gal barrels	436	33.3	455	21.8
Other Minerals[2]		-----	207.2	-----	86.9
Total		**-----**	**6,289.8**	**-----**	**5,810.3**

[1] Production is measured by mine shipments, sales, or marketable production.
[2] Building stone, cement, clay, diatomite, lime, lithium, magnetite, mercury, molybdenum, iron ore, perlite, salt, and silica sand
Source: Price *et al.* 2010b.

The prospects for sustaining these production rates in the short run are excellent and in the long run (15-20 years) also quite likely. Commodity prices are currently very high, as is demand for these products. As older mines are taken out of production and reclaimed, new mines would be discovered and brought into production.

A report of active metal exploration programs is prepared annually by the NBMG the most recent of which was for 2009 (Driesner and Coyner 2010). Exploration expenditures are regarded as one of the two main indicators of exploration activity, the other being the number of geologists employed. Exploration expenditures reported for Nevada for 2009 totaled $110.9 million, down 30 percent from the $158.1 million reported for 2008. Actual expenditures reported for 2009 were lower than the $133.6 million which had been projected by the previous survey. In this current survey, respondents project their 2010 expenditures will be $153.6 million (actual expenditures have not yet been compiled). Expenditures reported for 2009 marked the second yearly decrease after six consecutive years of increases. Exploration spending is important to Nevada's economy, particularly in the rural areas.

The number of mining claims held in Nevada declined in 2009. According to the BLM, Nevada State Office, 176,958 claims were active in Nevada as of October 1, 2009, compared to 196,849 in 2008. Projections for 2010 show a decrease in the number of claims held by respondents. In February 2010, the Nevada Legislature passed legislation imposing an additional fee on mining claim filings. This fee ranges from $0 per claim for those holding less than 11 claims to $195 per claim for those holding 1,300 or more claims. This legislation will likely cause additional reductions in the numbers of claims held by mining companies, especially larger companies with thousands of claims.

Because of the dominance of precious metals in the mineral economy of Nevada, most of the discussion of mineral potential is focused on precious metal deposits. Potential for development of locatable, saleable, and leaseable industrial minerals are also discussed.

4.1.1 Precious Metals

Lode Gold

The price of gold has increased from an average of $310/oz in 2002 to more than $1,700 /oz today (18 Aug 2011). This increase in gold price has initiated a shift in precious metal exploration from high-grade, vein-type targets to low-grade, large tonnage targets. Company dollars spent for exploration have been increasing since 2001 and were about $110.9 million in 2009 and estimated to be $153.6 million in 2010 (Driesner and Coyner 2010). Expenditures in 2009 were less than in 2008 largely because of the difficulty obtaining credit and other types of financing.

Because of Nevada's favorable geologic setting, its stringent but predictable regulatory climate and the political stability of the US, Nevada continues to receive a substantial portion of worldwide exploration expenditures.

The Nevada Division of Minerals reported that the mining industry held 65.2 million ounces in gold reserves at the end of 2009 (Price *et al.* 2010b), enough to sustain production at current levels for about 13 years. These reserves are down from the 80.3 million ounces reported in BLM (2006). This is largely due to production increases in 2003-2007 when metal prices were high. Driesner and Coyner (2010) reported that, in 2009, companies mining in Nevada replaced the reserves depleted by mining. Much of that replacement was due to expansion of current reserves by additional exploration. Grass roots exploration utilized about 17 percent of the 2009 exploration budgets.

Based on mining industry projections, it appears that market conditions for gold will remain relatively consistent, with gold priced in the $1,000 to $1,200/ounce range. It is anticipated that mining and exploration activity will gradually increase.

Within the next 10 years it is anticipated that 2 to 3 currently active mines within the planning area will go into closure and be reclaimed. These mine closures would likely be offset with either new projects being developed and placed into production, or expansion of existing mines.

Lode gold deposits produce almost all of the gold currently mined in Nevada. Lode gold deposits can be subdivided into three broad types in Nevada:

- Pluton-related deposits (skarns and porphyry deposits);
- Sediment-hosted deposits (Carlin-type deposits); and

- Epithermal deposits (Round Mountain-type deposits).

Models for these types of deposits and delineation of areas of mineral potential for each of the model types are discussed in some detail below.

Placer Gold

No large scale commercial placer operations are currently operating in Nevada. The NV Rae Gold Black Rock Canyon mine is a placer gold mine, but it is a small operation when compared to the bedrock mines in the region. The Manhattan Gulch placer mine was recently authorized (NVN-87759). It is likely that most major placer deposits have already been discovered and worked, and many modern placer mines operate by reworking previously mined deposits or working previously mined deposits deeper. Any drainage away from a bedrock gold deposit is prospective for placer gold, but most in Nevada are related to the presence of low-sulfide high grade vein-type deposits of gold in nearby bedrock outcrop areas.

Most modern placer mines operate under "Casual Use" criteria and involve individuals or clubs that mine at a small scale using little or no equipment other than hand tools and sluice boxes. Larger scale operations typically mine 60 to 150 ounces (1.7 to 4.3 kilograms) of gold per year, and do so under a Notice where the operator is permitted to use mechanized equipment if those operations are grandfathered, otherwise, the use of mechanized equipment requires a Plan of Operations. These types of operations are often restricted and have mitigations in place to protect other resources. Site reclamation work is bonded by the responsible permitting agency to ensure completion. The planning area could see 10 to 20 placer operations operating under a Notice during any given year, with the actual number being a function of the price of gold.

Silver

Most of Nevada's silver production in recent years was produced as a by-product of gold mining. For deposits to qualify as a primary silver deposit, it must have silver/gold ratios where silver is more valuable than gold in the ore. That ratio changes with metal prices. Today, that ratio is about 45:1. Approximately 7.3 million ounces of silver were produced in Nevada in 2009 (Price *et al,* 2010b). The Coeur Rochester mine in Pershing County was the only primary silver mine in 2009 and produced about 2.2 million ounces at a ratio of 173 Ag: Au. All of this production was from residual leaching; no new ore was mined (Price *et al*. 2010b)

Like gold, the price of silver is gradually increasing ($40.50; LME, 17 Aug 2011). This may affect the expansion potential of the existing silver mines and would likely increase exploration activities for new silver deposits in other areas and encourage greater recovery of silver produced as a by-product of gold mining.

Assessment of Potential for Undiscovered Gold Deposits

Other areas in Nevada have been the focus of studies designed to predict potential for new discoveries. The three major studies include: 1) Metallic mineral resources in the US Bureau of Land Management's Winnemucca District and Surprise planning areas, northwest Nevada and northeast California (Peters *et al.* 1996); 2) An Analysis of Nevada's Metal-Bearing Mineral Resources (Singer 1996); and 3) Assessment of Mineral Resources in the Humboldt River Basin, Northern Nevada (Wallace *et al*. 2004).

Each of the three studies develops deposit models based on knowledge-based and expert-based information. The knowledge-based information includes characteristics of known deposit types (*e.g.,* geologic setting, lithology, mineralogy, alteration, geochemical data, geophysical data, and structural data) and uses this data to look for other areas with similar characteristics that might indicate favorable areas for undiscovered resources of a similar deposit type. Each of the three studies is also expert-based in that recognized experts are used to interpret deposit models and to identify prospective areas based on the knowledge-based information and their general and specific knowledge of ore deposits.

While interesting, each of the studies fail to account for new technologies, exploration strategies, new deposit types and, in the end, cannot be proven to be right or wrong. For that reason, those types of studies will not be used here.

Within the planning area, there is a strong correlation of lithology to the types of mineralization found in a particular region. While there is some overlap, the correlation is striking. For that reason, this work is based on regional lithology and known mineralization.

Sediment-hosted Gold Deposits

Sediment-hosted gold and silver deposits are by far the largest precious metal producers within the planning area and are also of the greatest economic importance in Northern Nevada and in the US. These deposits are typically low-grade, (as low as 0.7 grams per tonne; 0.02 ounces per ton) and large tonnage deposits usually developed as large-scale open pit mines. Sediment-hosted gold deposits commonly occur in thin-bedded carbonate-siliciclastic Paleozoic rock sequences (although host rocks of argillite and volcanic rock are also known). Gold is usually sub-micron and is commonly found within the structure of disseminated pyrite grains or alternatively, localized along thin fractures and disseminated throughout the host-rock. Hydrothermal alteration associated with these deposits includes jasper replacements, argilization, decalcification of limestones, and dolomites. Many deposits are localized in sedimentary rocks along the Roberts Mountain Thrust where carbonaceous deep water sediments have been thrust over shallow water shelf carbonate sediments, with the Roberts Thrust or subsidiary faults presumably acting as conduits for ore-bearing fluids perhaps derived from connate water associated with distant plutons.

Examples of sediment-hosted gold deposits within the planning area include those of the Cortez District, Elder Creek Deposit, Tonkin Springs, Gold Bar, and Pipeline which are along the Battle Mountain-Eureka trend (**Figure 4-1**).

Figure 4-1 shows areas containing identified sediment hosted gold deposits and also indicates areas both prospective and favorable for potential sediment hosted deposits. In addition to obvious trend of deposits in the Battle Mountain – Eureka trend, erratic sediment hosted gold deposits like Big Springs have been discovered throughout the extent of the early Paleozoic rocks in the planning area. All of the upper Paleozoic rocks from central Nye County and north are prospective. It is unlikely that outcropping new deposits will be discovered because of the intense exploration throughout the region. Favorable areas must include areas covered by Quaternary deposits as thick as possibly 500-1,000 feet. Exploration will not be easy and improvements in technology and, possibly, new concepts will be important for discovery of new deposits.

Figure 4-1 Gold Potential Areas by Deposit

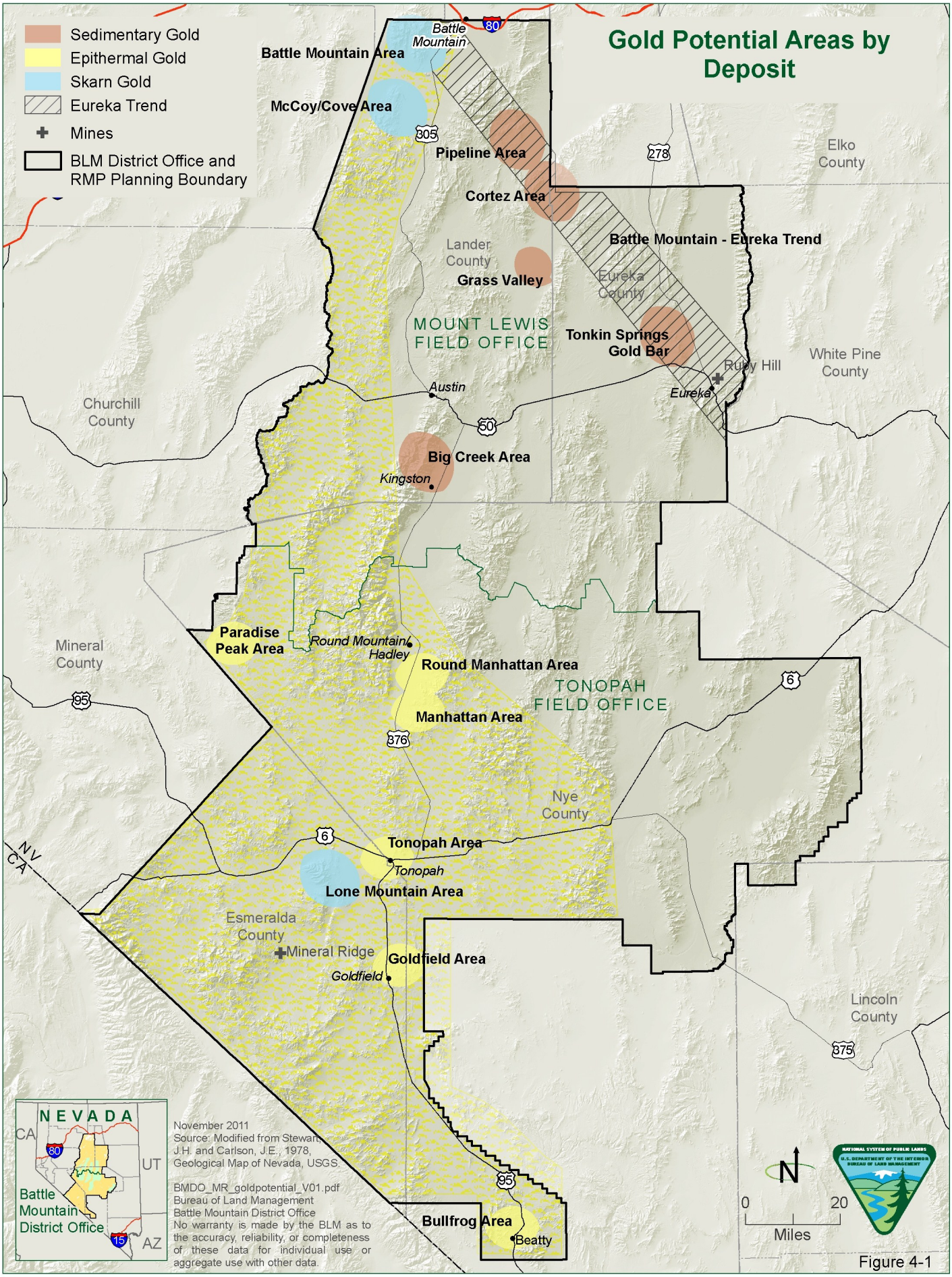
Gold Potential Areas by Deposit
Sedimentary Gold
Epithermal Gold
Skarn Gold
Eureka Trend
Mines
BLM District Office and RMP Planning Boundary
Battle Mountain Area
McCoy/Cove Area
Pipeline Area
Cortez Area
Battle Mountain - Eureka Trend
Grass Valley
Tonkin Springs
Gold Bar
Big Creek Area
Paradise Peak Area
Round Mountain
Hadley
Round Manhattan Area
Manhattan Area
Tonopah Area
Tonopah
Lone Mountain Area
Goldfield Area
Goldfield
Mineral Ridge
Bullfrog Area
Beatty
Battle Mountain
Austin
Kingston
Eureka
Ruby Hill
MOUNT LEWIS FIELD OFFICE
TONOPAH FIELD OFFICE
Elko County
White Pine County
Lander County
Eureka County
Churchill County
Mineral County
Nye County
Esmeralda County
Lincoln County
NV
CA
NEVADA
CA
UT
AZ
Battle Mountain District Office
November 2011
Source: Modified from Stewart, J.H. and Carlson, J.E., 1978, Geological Map of Nevada, USGS.
BMDO_MR_goldpotential_V01.pdf
Bureau of Land Management
Battle Mountain District Office
No warranty is made by the BLM as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data.
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Figure 4-1

Epithermal, Hot Springs and Volcanic Systems

Epithermal deposits are typically formed from shallow (1 – 2 km), relatively low temperature, fossil hot springs-related hydrothermal systems. The hydrothermal fluids typically move through various faults and fractures and are commonly associated with subaerial volcanic flows or pyroclastic rocks and sub-volcanic intrusions (Sherlock *et al.* 1996). Epithermal deposits are inferred to have formed at or near the paleo-surface at the time of mineralization. High heat flow from basin and range structures generated from nearby volcanic activity is thought to have created deep hydrothermal circulation along these faults through which the water circulated. These deposits include shallow veins, stock works, breccias, and disseminations (Sherlock *et al.* 1996). Host rocks are typically volcanics or permeable sedimentary units.

Areas favorable for epithermal gold deposits therefore include areas with deep basin and range type structures associated with high heat-flow generated from nearby volcanic centers. These criteria particularly fit the western part of the planning area (**Figure 4-1**). Very young epithermal systems seem to be concentrated in the southern portion of the planning area. Recently mined epithermal gold deposits within the planning area include Paradise Peak, Bullfrog, Daisy/Motherlode, Goldfield, Mineral Ridge, and Manhattan. Round Mountain and Mineral Ridge are currently being mined.

As with pluton related deposits, epithermal deposits are associated with a variety of metals other than gold and silver including antimony, mercury, manganese, sulfur, and uranium. These deposits are discussed by commodity below.

Gold Associated with Intrusives

Gold deposits associated with intrusive rocks in the planning area are dominantly skarn deposits. Skarns are formed when magmatic fluids deposit gold and copper (and other minerals) in the rocks surrounding the intrusive. Contact metamorphism is common. The Phoenix Mine is currently producing from skarn deposits in the Battle Mountain District (**Figure 4-1**). Fortitude, McCoy, and Cove mines were past producers in the planning area. The Lone Mountain District reportedly has skarn deposits (Sherlock *et al.* 1996).

Recent exploration has occurred in the Battle Mountain and McCoy areas and is likely to continue; McCoy may reopen due to improved metal prices. All of the intrusive areas shown on **Figure 4-1** are prospective for skarn copper, gold, and/or base metal deposits. Most have been explored, but with current copper and gold prices, old projects may be reactivated and production can be anticipated.

4.1.2 Other Metals

Copper

In Nevada, the Yerrington and Robinson mines were developed on porphyry deposits that are, or have, produced substantial amounts of copper. Within the planning area, porphyry copper occurrences are restricted to the Battle Mountain and Fairplay Districts (**Figure 4-2**). The Hall-Tonopah deposit is a copper-rich portion of a porphyry molybdenum deposit that was mined for a short time. Porphyry copper deposits form when a particularly copper-rich intrusive mineralizes itself and surrounding rocks with stockwork veinlets containing disseminated copper minerals. These can be very large deposits and some of the largest copper deposits in the world are porphyry copper deposits (*e.g.*, Chuquicamata in

Chile, Morenci in Arizona). Most of the intrusives indicated on **Figure 4-2** are prospective porphyry copper deposits and have been extensively explored. It is unlikely that a significant new deposit will be found; however, with current copper and gold prices, deposits like those reported in the Lone Mountain and Huntington Creek districts may be of interest. Renewed interest may spur some companies to have a new look at several of the intrusives and a new discovery may be possible.

Copper skarn deposits such as those in the Battle Mountain District are not significant producers of copper, but Phoenix is producing copper and there are possibly additional skarns to be discovered. Copper skarn mineralization has been reported in the Lone Mountain and Tokop districts. New discoveries in one or both of those districts are likely. Skarn copper deposits tend to be somewhat small, but can be very high grade.

Molybdenum

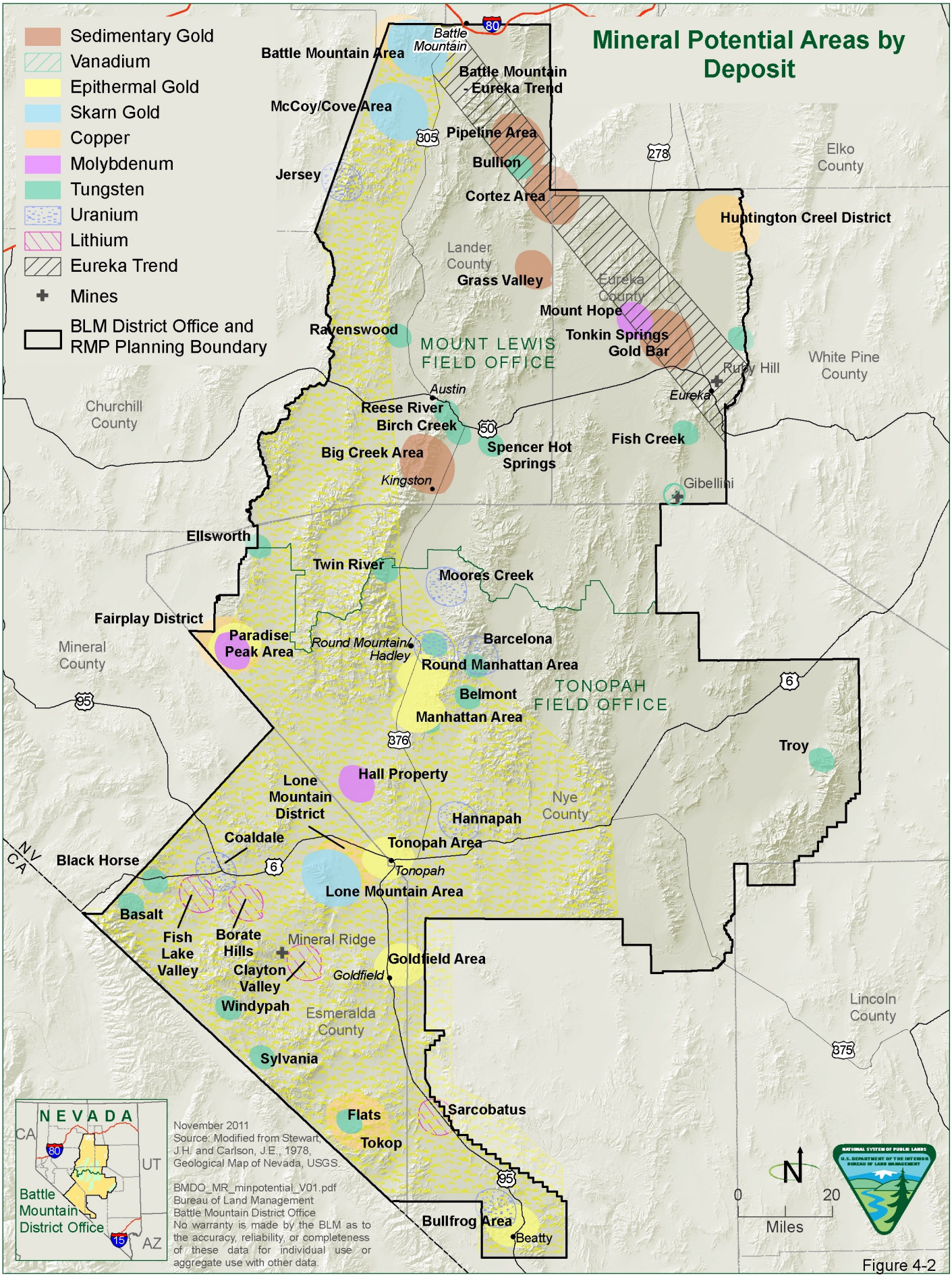
The Mount Hope deposit in Eureka County is classified as a Climax-type molybdenum deposit (**Figure 4-2**; Sherlock *et al.* 1996). It is associated with an isolated small potassic high-silica porphyritic intrusive body of Tertiary age. The Climax molybdenum deposit type is characterized by stockworks of molybdenite and quartz associated with fluorite in granite porphyry. Host intrusive complexes frequently show evidence for multistage intrusion of magma and exhibit zoned alteration in a shell-like pattern over the top of the complex. The only other Climax-type molybdenum deposit in Nevada is Majuba Hill in Pershing County.

The Hall Property and molybdenum deposits reported in the Fairplay District (Sherlock *et al.* 1996) are examples of low-fluorine porphyry molybdenum deposits. These deposits are characterized by molybdenite-quartz stockwork veinlets in calc-alkaline porphyritic intrusive rocks and in adjacent country rock. Compared to Climax-type deposits, they are deficient in fluorine and have lower molybdenum. Host rocks contain less silica than is typical of Climax-type deposits.

Recent price increases have spurred new interest in molybdenum; indeed, the Climax Mine in Colorado is reopening and Mount Hope is being developed in preparation for production. Nevada has been thoroughly explored for molybdenum, but opportunities exist within all of the intrusive areas shown on **Figure 4-2**. The likelihood that a new deposit will be discovered is low, but with new exploration tools and concepts, it is possible to discover new deposits or to discover economic portions of known low-grade deposits.

Tungsten

Potential exists for development of tungsten deposits within the planning area. Numerous deposits of tungsten mineralization occur predominantly as scheelite-bearing metasomatic skarn-type deposits associated with Cretaceous age quartz-monzonite intrusives throughout the planning area (**Figure 4-2**). Seventeen (17) tungsten skarn occurrences and 16 vein deposits have been identified within the planning area. Tungsten skarn-type deposits occur within Black Horse, Sylvania, Tokop, Windypah, Diamond, Birch Creek, Bullion, Reese River, Spencer Hot Springs, Barcelona, Troy, and Twin River districts (**Figure 4-2**).


Mineral Potential Areas by Deposit
Sedimentary Gold
Vanadium
Epithermal Gold
Skarn Gold
Copper
Molybdenum
Tungsten
Uranium
Lithium
Eureka Trend
Mines
BLM District Office and RMP Planning Boundary
Battle Mountain Area
Battle Mountain
Battle Mountain - Eureka Trend
McCoy/Cove Area
Pipeline Area
Jersey
Bullion
Cortez Area
Huntington Creel District
Elko County
Lander County
Grass Valley
Eureka County
Mount Hope
Tonkin Springs
Gold Bar
Ruby Hill
White Pine County
Ravenswood
MOUNT LEWIS FIELD OFFICE
Eureka
Austin
Churchill County
Reese River
Birch Creek
Big Creek Area
Spencer Hot Springs
Fish Creek
Kingston
Gibellini
Ellsworth
Twin River
Moores Creek
Fairplay District
Paradise Peak Area
Round Mountain
Hadley
Barcelona
Round Manhattan Area
Mineral County
Belmont
TONOPAH FIELD OFFICE
Manhattan Area
Troy
Hall Property
Lone Mountain District
Nye County
Hannapah
Coaldale
Tonopah Area
Black Horse
Tonopah
Lone Mountain Area
Basalt
Fish Lake Valley
Borate Hills
Mineral Ridge
Clayton Valley
Goldfield Area
Goldfield
Windypah
Esmeralda County
Lincoln County
Sylvania
Flats
Sarcobatus
Tokop
Bullfrog Area
Beatty
NEVADA
CA
UT
AZ
Battle Mountain District Office
November 2011
Source: Modified from Stewart, J.H. and Carlson, J.E., 1978, Geological Map of Nevada, USGS.
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Battle Mountain District Office
No warranty is made by the BLM as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data.
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Figure 4-2

A number of tungsten skarn deposits in Nevada have been mined historically and a few have had production particularly during World War II and during a mid-1950s government stockpiling program. Many of the deposits in Nevada are small, but a few are of moderate size by world-wide standards (*i.e.,* greater than one million tons).

The price of tungsten has increased in the last few years and has stimulated production of tungsten elsewhere in the world where deposits are larger and higher grade than those found in Nevada. If prices were to remain high and demand increases somewhat, some companies might be encouraged in bringing some of the larger, higher grade deposits in the planning area into production.

Lead-Zinc

Lead and zinc are found in every mining district in the planning area. Most of the deposits are small polymetallic vein deposits and have little potential for future development unless they are accompanied by precious metals credits.

Vanadium

One significant vanadium deposit occurs in the planning area. The Gibellini deposit is located close to Eureka, Nevada and is being actively explored. The Carlin vanadium deposit is located just outside the planning area in northern Eureka County and is also being actively explored. Both deposits will likely be in production in the near future. Exploration for additional deposits is likely, but the market is small and thus, exploration will likely be undertaken by few exploration groups.

Uranium

Little potential for the development of uranium deposits exists within the planning area. Uranium deposits within the planning area are predominantly volcanogenic or pluton-related deposits, although some small discontinuous sediment hosted deposits are also known.

Favorable sites in the planning area for volcanogenic uranium include the Jersey, Moores Creek, Round Mountain, Barcelona, Hannapah, Coaldale, and Bullfrog districts (**Figure 4-2**).

The uranium boom in the early 1950s was in large part, driven by government price subsidies and incentives for what was considered a strategic mineral for military use. A second boom in the early 1970s saw additional exploration in Tertiary volcanic host-rocks of the planning area. As a result of these two periods of exploration, many uraniferous occurrences or deposits were identified. However, none of the deposits in the planning area reported production. Most of the deposits in the planning area are too low grade and/or small to be economically competitive with higher grade and tonnage deposits located elsewhere in the U.S.

The price of uranium has increased in the past two years causing a new uranium boom in much of the Southwest US and the world. Stockpiles have been depleted and several countries, including China, are building new power plants. Nuclear power is seen by many as being "greener" than most other power sources. Recent events in Japan which caused the meltdown of three reactors dampened nuclear enthusiasm, but the price has remained high and exploration has continued. New operations are being explored and permits are being sought in several states. The quality and size of the known deposits is somewhat discouraging, but additional exploration in the planning area is reasonably anticipated and it is likely that economic deposits will be discovered within the planning area in the foreseeable future.

Other Metals

Antimony, arsenic, and mercury occur with precious metals deposits throughout the planning area (Tingley 1998). These metals are typically deleterious components in the ore. The market for these metals is limited so they must be discarded in an environmentally responsible manner. The likelihood that these metals will be explored for as a primary product is limited. By-product mercury may be viable in some deposits, but antimony and arsenic will not likely be produced as a product for market.

Iron skarns occur throughout the planning area, but they are typically small magnetite bodies with contaminants. A small micro-mill might be set up near one or more of these bodies, but this is unlikely due to the cost of addressing contaminants. Iron ore from Australia and Brazil is of equal grade and does not contain contaminants so there is little likelihood that iron ore will be produced in the planning area in the foreseeable future.

Manganese shares much of the same characteristics as iron. Manganese deposits in the planning area are small and contain contaminants. Production in Nevada cannot compete with overseas operations. It is possible that a small mining operation might be constructed on a deposit that is high grade and pure producing specialty manganese products.

Gems and Semi-Precious Stones

Gems and semi-precious stones will likely continue to be mined on a small scale in the planning area. Turquoise occurs in Tertiary to recent volcanic rocks throughout the planning area. Deposits are small, usually hand operated as rockhound sites. Great care must be taken when extracting the stones so as not to damage and devalue the pieces. Permitted turquoise mining occurs at the Blue Ridge and Carico Lake mines in Lander County and the Lone Mountain and Royal Blue mines in Esmeralda County. Existing deposits will likely be extended and remain small with labor intensive mining methods. Other small gemstone deposits are found in the planning area and produce beryl, scheelite, chalcedony, and specimen gold principally for mineral collectors. Specimen quality gold is typically collected from historically mined high grade quartz vein deposits. It is likely that the same level of demand for gemstones and specimen quality samples will require the same small scale level of activity into the foreseeable future. Gem and semi-precious stone deposits have high unit values and therefore, their viability does not rely on proximity to transportation corridors (Nash 1996).

4.1.3 Locatable Industrial Minerals

Lithium

Lithium production in the planning area includes the Silver Peak operation in Clayton Valley which is largest lithium producer in the US. Lithium is produced from brines in the playa. **Figure 4-2** shows the locations of Clayton Valley and other known exploration areas including the Borate Hills which hosts undisclosed lithium and boron minerals. Exploration will likely expand to other playas in the region. Increased exploration has been reported in the past few years and it is reasonable to anticipate continued exploration and another lithium operation in the region.

Barite

Barite is produced at the Argenta and Greystone mines in Lander County. Both deposits are in the Shoshone Range. Production will likely continue and possibly expand. Expansion depends on continued

petroleum drilling because most of the market for barite is in drilling fluids. Expansion of existing operations is the most likely scenario for increased production. Additional barite occurrences are known in the Shoshone and Toquima ranges. Additional exploration is expected to be limited, but continuous to ensure continued production. It is reasonable to anticipate one new operation in the region.

Other Minerals

Diatomite, carbonate minerals, fluorspar, gypsum, silica, and talcose minerals all are dependent on local markets and infrastructure such as local transportation corridors, available power, and fuel. Much of the planning area is extremely remote from markets and infrastructure. Although some very high-grade deposits may be exploited, there is little possibility of significant production from any of these types of deposits in the planning area.

4.2 SALEABLE MINERALS

Saleable mineral extraction and use will increase along with increasing mining activity, commercial development, recreation activities, and private property development especially along the Interstate 80 corridor within the planning area. Saleable mineral sites with a priority for use will likely include sand, gravel, and rock quarries located along State, County, and BLM managed roads.

Potential for development of saleable industrial rocks and mineral resources of the planning area are summarized below. These include the following: aggregate (sand and gravel), clay, pumice and cinder, and building and ornamental stone.

4.2.1 Aggregate, Sand, and Gravel

Demand for mineral materials will increase as the pending geothermal energy boom develops. Additional increased demand is in the forecast with increased mining, exploration and community growth. A need for road maintenance will continue along Interstate Highway 80 and US Highway 50 corridors as well as along State Highways 305, 374, and 376.

BLM managed public land contains vast amounts of permissive tracts for sand and gravel exploration. Virtually all of the basins/valleys in the planning area have potential aggregate deposits (yellow areas on **Figure 2-11**). However, because the market value for sand and gravel is not very high and transportation costs are high, deposits adjacent to their end uses or those located along good transportation corridors will have the greatest development potential. High transportation cost and abundant resources also result in the dominance of small-scale local operations in the sand and gravel market. If local demand exists, small scale operations would not have to sustain large transportation costs, thereby creating an economically feasible and desirable situation for the planning area's sand and gravel development. If there is no local demand, only the larger quarries, particularly those near major transportation corridors and urban centers will be economically beneficial.

The source of favorable aggregate would be Pliocene to Recent alluvium (**Figure 2-11**). Favorable geologic environments would include existing and paleo-stream channels, beach terraces, and alluvial fans containing hard, siliceous material. Weathered "granite" is also desirable and found in altered intrusive and volcanic rock terranes. Economic value is also dependent upon sorting, grain and clast composition, clast strength, consolidation, and amount of cover (Nash 1996).

4.2.2 Clay

Potential for development of known clay deposits and exploration for additional clay deposits in the planning area is good. Little clay mining has occurred in the planning area, but clay is mined for a variety of purposes near the planning area. Operations would likely be small and designed to produce specialty products.

Economic clay deposits in Nevada are primarily hosted in hydrothermally altered predominantly volcanic rocks or fine-grained, clastic, lacustrine rocks. Clay deposits are also derived from glassy volcanic ash and tuffs (Nash 1996). The most favorable geologic terranes occur where Miocene-Pliocene volcanic rocks and volcaniclastic sediments outcrop. These rocks have the greatest potential in the vicinity of faulting that provided a pathway for hydrothermal solutions and alteration or in areas of hydrothermal alteration.

The economic feasibility of some deposits has been limited by transportation costs. As a result, more accessible and valuable deposits are developed most frequently. High quality pure clays are used as drilling mud in oil refining and ceramics while lower purity clays may be used for absorbents such as cat litter and industrial fillers. Hectorite, a type of clay, may be used as a source of lithium if the grade is high enough.

4.2.3 Pumice and Cinder

Potential for development of significant pumice and cinder deposits is low to moderate although there are a number of occurrences and former mines within the planning area. Currently, pumice deposits are not being mined in Nevada (Nash 1996); however, a pumice mine is being authorized about 5 miles north of Beatty.

Pumice in the planning area occurs in the Tertiary and Quaternary tuffs. The best deposits are coarse, non-welded tuffs from a local rhyolitic volcanic source. Pumice deposits can occur as small to large cones, or sheets extending laterally from the volcanic vents.

Economic viability of pumice deposits are controlled by purity, thickness, and lack of consolidation. Economic development requires that these deposits be amenable to bulk mining and simple screening methods. Low cost transportation is required (Nash 1996) and a nearby market is desirable.

4.2.4 Building and Ornamental Stone

Potential for development of building and ornamental stone deposits in the planning area is low and there is no appreciable current production. No significant local markets are available to support this type of commodity except in the extreme southern part of the planning area where D&H Mining produces decorative stone for the Las Vegas market. The mine pits are located 6 to 8 miles North of Beatty.

Optimal stone includes sandstone, volcanic sandstone, and volcanic rocks that are well-bedded, with prominent partings, and coloration (*i.e.*, flat volcanic rock and columnar jointed rock). The resource must be at the surface to allow open-cut mining to keep the rock pieces intact. Mining is low volume and labor intensive. The low unit value of this resource generally requires proximity to its end users with inexpensive transportation in order to be economic (Nash 1996).

4.3 LEASABLE MINERALS

4.3.1 Geothermal Resources

Geothermal resource exploration and development operations are on the rise and are expected to increase in the future. Additional geothermal exploration is reasonably anticipated in areas identified as having a high potential. This is particularly true in areas with adjoining power transmission facilities with excess capacity. The 2003 BLM/National Renewable Energy Laboratory study identified the Battle Mountain District as one of the BLM planning areas with the highest potential for geothermal resources. Top sites for geothermal development include Beowawe and Fish Lake Valley. In addition, hot springs and existing geothermal lease and lease application areas have the highest potential for future use.

Various national and state incentives are in place in Nevada that encourages development of renewable energy resources. Given that incentives to businesses and consumers combined with anticipated population increases, renewable energy development is expected to increase over the planning period and management actions are necessary to provide for future renewable energy growth while protecting sensitive resource values. The economic stimulus bill signed by the president in February of 2009 includes $65 billion in energy spending and tax relief to help change our dependence on foreign oil and to curb the nation's greenhouse gas emissions.

State incentives include property tax exemptions, tax deductions for donations to the Green Power program, requirements that electric utilities disclose the mix or resources used to generate power, and net metering for electric utility consumers who also have wind or solar power generators (BLM and DOE 2003). In 2001, the Nevada legislature established a renewable energy portfolio standard. This standard requires that as much as 25 percent of all electricity generated in Nevada be derived from renewable energy resources by 2025. Known geothermal areas, hot springs, existing geothermal lease and lease application areas have the current highest potential for future use. Extensive areas of unexplored, relatively high potential exist within the planning area. Beowawe and Jersey Valley are operating geothermal plants on the boundaries of the planning area and McGinnis Hills is being constructed. Clayton Valley 1 is in the permit process.

4.3.2 Oil and Gas

Introduction

Most of the planning area lies within the Eastern Great Basin Oil and Gas Province (Anna *et al.* 2007) with the westernmost part of Lander, Nye, and all of Esmeralda counties in the Western Great Basin Oil and Gas Province. The USGS Central Energy Team provides periodic assessment of the oil and natural gas occurrences and potential for the US, including Nevada. The most recent US assessment was completed in 2007. From the perspective of the USGS and others, the Eastern Great Basin Oil and Gas Province is thought to be prospective for hydrocarbons because both source rocks and traps are known to occur within the province as evidenced by a small number of producing fields in the planning area. Assessments conducted by the USGS identify areas of oil or gas potential (plays) which provide BLM with the basis to evaluate effectiveness of available stipulations in balancing responsible development of those resources with protection of other valuable resources in the planning area. These federal land inventories also allow resource managers to identify areas of low oil and gas potential but high potential for other resources or uses (e.g., wildlife or recreation). These reports are a critical step in evaluating

whether existing rules are appropriate or need to be changed to provide greater protection to the environment or to promote appropriate resource development.

The intensity of oil and gas drilling in the future will be determined by a combination of economic and geologic factors. The fact that the BLM has land available for leasing does not guarantee that oil and gas drilling will occur within the planning area. The economics of oil and gas exploration and development are highly variable and play a very large role in determining the likelihood and number of exploratory wells that will be drilled in a given area. The consistent availability of land for leasing and exploration also plays a role in how many wells will be drilled.

While the geology itself will not change, understanding and interpretation of geologic data pertaining to oil and gas exploration and development can change dramatically each time a new drill test is completed. This is especially true in the deep sediment filled basin portions of the planning area. In addition, technological advances occurring over the last ten years, such as horizontal and long reach directional drilling, can turn previously uneconomic deposits into viable economic ventures.

Later in this report a reasonably foreseeable development (RFD) scenario will be discussed for the planning area. To prepare a RFD, assumptions are necessary to deal with geologic uncertainties. The assumptions must be reasonable, supportable, and based on best present knowledge. Earlier in this mineral assessment report, the general geologic setting for oil and gas resources and historical exploration activity of the planning area were discussed. This combined with an analysis of geologic occurrence potential and various oil and gas exploration plays will be used to make a reasonable projection of future oil and gas development activity for the planning area.

It is expected that the search for oil and gas will continue strongly in the US even though the push for renewable energy is the focus of the administration in Washington. Energy consumption is expected to increase substantially in the next 20 years with the increase in population. Meeting the increased energy demand will require development of all forms of energy including exploring for new hydrocarbon reserves or development of existing oil and gas fields.

The majority of the oil in the State of Nevada is produced from the oil fields located in the Railroad Valley in Nye County. Railroad Valley has been the most actively explored valley in the great basin since the discovery of the Eagle Springs field in 1954. Currently, ten producing oil fields are located in the district; all in Railroad Valley. These include Trap Springs, Eagle Springs, Grant Canyon, Kate Spring, Ghost Ranch, Sand Dune, Bacon Flat, San Spring and smaller fields such as Duckwater and Currant. Pine Valley has four discoveries; Blackburn, Tomera Ranch, Three Bar, and North Willow Creek; each of which has produced but only Blackburn has had substantial production (**Table 3-19**).

Occurrence Potential Summary

Areas with potential for oil and gas occurrence are shown on **Figure 4-3**. This map shows basins that are at least 8,500 feet deep, which is the minimum depth that oil can be generated in the Chainman Shale (Anna *et al.* 2007). This map suggests that petroleum potential within the planning area is likely limited to two or three additional oil fields because not all of the thirteen outlined areas will produce and most have had limited tests that were unsuccessful.

USGS Estimated Resources

The USGS (Anna *et al*. 2007) estimated that the Eastern Great Basin Petroleum Province may produce about 1.6 million barrels of oil. The methodology for that estimate is in Anna *et al*. (2007) and is not repeated here. The important aspect of the estimate is that when the estimate is combined with **Figure 4-4**, potential petroleum resources in the planning area are a small proportion of the total estimated resource.

International Market Conditions

Over the past 25 years, oil prices have been highly volatile and it is expected that price volatility will remain into the future; due to unforeseen natural, political, and economic circumstances. For example, circumstances in the Middle East could create disruptions of normal oil production and trading patterns. When leadership in Egypt was forcibly changed early in 2011, uncertainty in the market caused price increases which have moderated in recent times in part due to relative calm in North Africa and an obvious price ceiling that US drivers were willing to tolerate. **Figure 4-5** shows that in February 2011, the price of crude increased from about US$85 to US$105 from about 15 February to 17 February. That spike occurred during the initial unrest in Egypt when the leadership was forced to change. The sharp drops in May and July were reported in the popular press to be due to lack of consumption by US drivers.

Low oil prices would have the opposite effect. Growth in global oil demand has outstripped supply in recent years, decreasing spare production and refining capacities causing prices to rise sharply in 2006-2007 (**Figure 4-5**). The current price (19 Aug 2011) is approximately $80/barrel and is dropping marginally on a weekly basis. Pundits are in serious disagreement as to where the drop will stop, but it may be in the $70 range.

Natural gas is expected to be the fastest growing component of world primary energy consumption according to the Energy Information Administration (EIA 2004). Consumption of natural gas worldwide is projected to increase by an average of 2.2 percent annually from 2001 to 2025, compared with projected annual growth rates of 1.9 percent for oil consumption and 1.6 percent for coal. Natural gas consumption in 2025 is projected to be 151 trillion cubic feet and will be nearly 70 percent higher than the 2001 total of 90 trillion cubic feet. The natural gas share of total energy consumption is projected to increase from 23 percent in 2001 to 25 percent in 2025 (EIA 2004).

Recent Leasing and Drilling Trends

Historical leasing and drilling trends have been discussed above in the Historical Exploration and Other Activities section. In summary, at the present time, there are currently 674 authorized oil and gas leases and 2 pending leases covering more than 1,210,805 acres in the Battle Mountain district. A total of 22 oil and gas exploration wells have been permitted since 2006.

Figure 4-3: Valleys in the Eastern Great Basin in Which Depths from the Surface to the Top of the Paleozoic Carbonates are 8,200 Feet and 8,700 Feet.

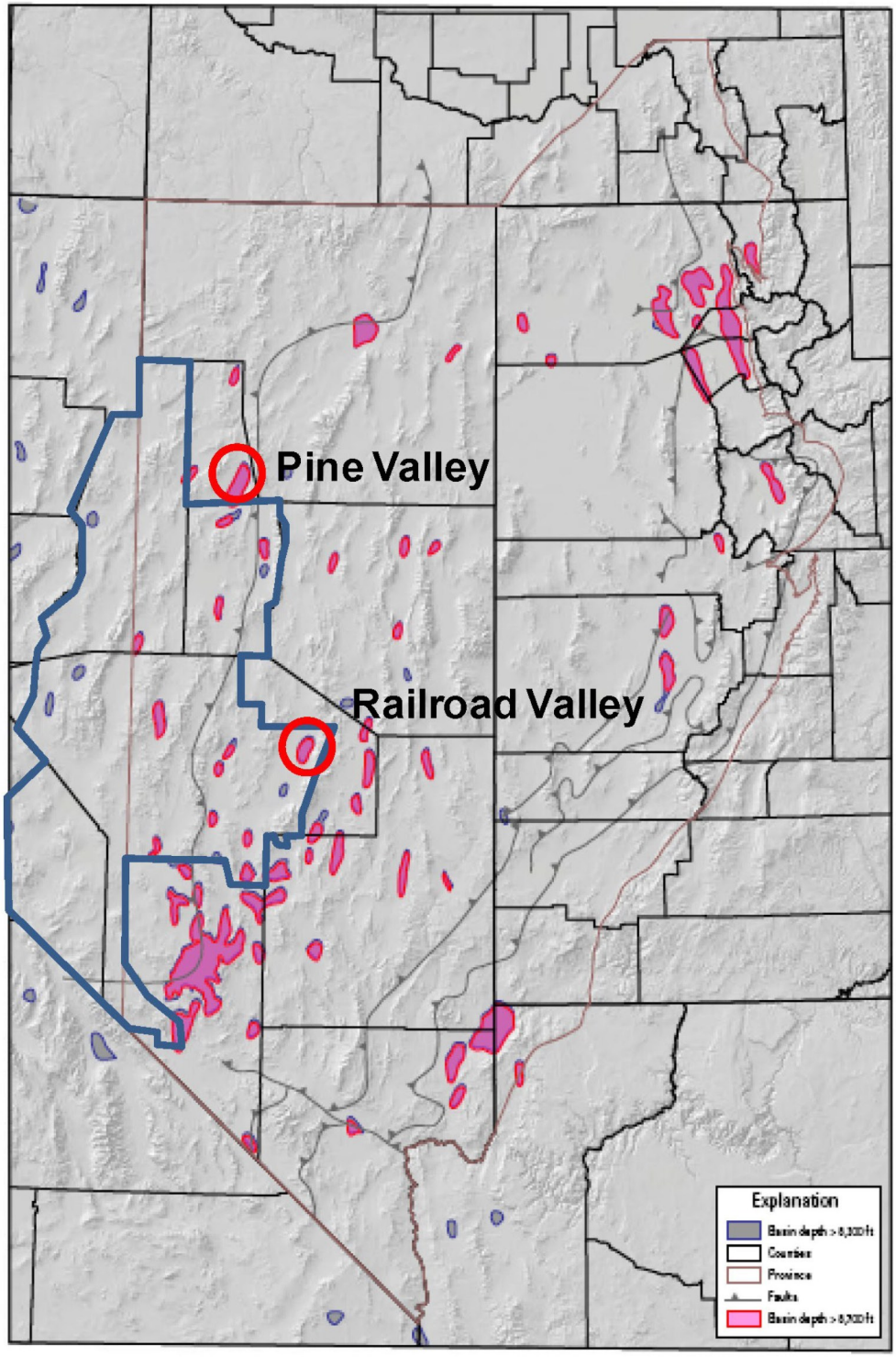
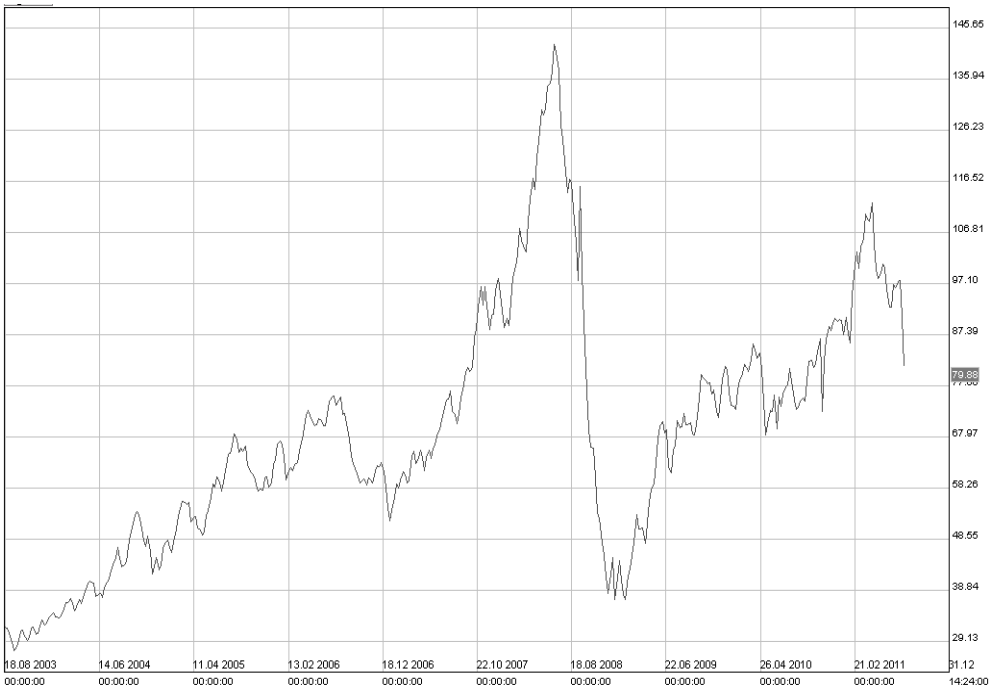


Figure 4-4: Crude Oil Pricing from 6 April 2010 to 11 Aug 2011

Figure 4-5: Oil Prices from August 2003 to Present



Reasonably Foreseeable Development Scenario

Development potential is not a prediction of precise future drilling locations and should not be used as a gauge of future interest or lack of interest in leasing. Oil and gas companies have numerous sources of proprietary data not available to BLM (such as seismic data or internal geologic reports), which are used prior to making financial commitments to lease or drill. Therefore, even though an area is rated as very low for development potential at this time with a low probability for any wells being drilled, a company may still be interested in leasing that area, should it be made available. BLM analysis of potential for development of oil and gas resources within the planning area is based on bedrock geologic mapping, geophysical data, and results of oil and gas tests drilled in the planning area.

In order for BLM to analyze potential effects of oil and gas leasing and possible impacts related to exploration, development, and cumulative effects, it is necessary to estimate how many wells may be drilled in the next 15 to 20 years within the planning area. These estimates are based on scenarios devised by the US Geological Survey and documented in Anna *et al.* (2007). Based on this work and past performance, it is likely that 25 wells would be drilled in the coming decade.

Surface Disturbance Impacts

Construction of temporary road access and a drilling location for each wildcat well may disturb about 6 acres for each well, or 150 acres for the anticipated wells.

Oil and Gas Summary

The planning area has theoretical potential for 2 or 3 additional oil fields the size of Railroad Valley. Because most of the basins in the planning area have at least one petroleum test hole and the fact that the geology is complex, finding those additional fields will require additional thought and possibly new technologies or concepts. Oil and gas companies are not likely to make major expenditures for exploration in the near term.

4.3.3 Sodium Minerals (salt)

Potential for development of salt deposits in the planning area is good. Salt deposits occur in the playas of which the planning area has several; each basin in the planning area has a playa (**Figure 2-1**). Although there is no current production of salt in the planning area, the best possibilities for salt production are in the southern part of the planning area where evaporation rates are high and precipitation is low.

4.3.4 Sulfur

Potential for development of fumarole-related, sulfur deposits in the planning area is considered low. Fumarole environments, considered the best source of sulfur, have been thoroughly prospected for gold-silver-mercury deposits. Undiscovered deposits within 600 feet (200 meters) of the surface are predicted to either be small or buried by younger alluvium. Fumarole sulfur deposits tend to be small and can be rich in metals that are costly to remove. An economic deposit must be near an efficient transportation route (Nash 1996).

5. REFERENCES

Ahn, S.Y. 2010. Ediacaran-Cambrian Stratigraphy and Paleontology of Western Nevada and Eastern California; Unpublished Ph.D. Dissertation, The Ohio State University, 122 p.

Albers, J.P., and J.H. Stewart. 1972. Geology and Mineral Deposits of Esmeralda County, Nevada; Nevada Bureau of Mines and Geology Bulletin 78, 88p

American Lithium Co. 2011. Press release 11 February 2011. Website: www.americanlithium.com/images/AMLM-ExecutiveSummary.pdf.

Anna, L.O., Roberts, L.N.R., and C.J. Potter. 2007. Geologic Assessment of Undiscovered Oil and Gas in the Paleozoic–Tertiary Composite Total Petroleum System of the Eastern Great Basin, Nevada and Utah; Chapter 2 of Geological Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada, Utah, Idaho, and Arizona, U.S. Geological Survey Digital Data Series DDS–69–L, 55 p.

Arbonies, D.G., Creel, K.D., and M.L. Jackson. 2011. Cortez Hills Lower Zone Discovery and Geological Update; in Steininger, R. and Pennell, B., eds., Geological Society of Nevada 2010 Symposium: Great Basin Evolution and Metallogeny, pp 447-462.

Bloomstein, E.I., Massingill, G.L., Parratt, R.L., and D.R. Peltonen. 1991. Discovery, geology, and mineralization of the Rabbit Creek gold deposit, Humboldt County, Nevada; in Raines, G. L., Lisle, R. E., Schafer, R.W., and Wilkinson, W. H., eds., Geology and Ore Deposits of the Great Basin: Reno, Geological Society of Nevada Symposium Proceedings, p. 821–843.

Boden, D.R. 1986. Eruptive history and structural development of the Toquima caldera complex, central Nevada; January 1986, GSA Bulletin, v. 97; no. 1; pp 61-74.

Bonham, H.F. 1969. Geology and Mineral Deposits of Washoe and Storey Counties, Nevada, with a section on industrial rock and mineral deposits by K. G. Papke; Nevada Bureau of Mines Bulletin 70, 140 p.

Breit, F.J., Jr., Alvarez, K.M., Gilmore, A.M., and M.B. McComb. 2011. A Geological Update from the Battle Mountain District, Newmont's Phoenix Project; *in* Steininger, R. and Pennell, B., eds., Geological Society of Nevada 2010 Symposium: Great Basin Evolution and Metallogeny, pp 463-487.

Bureau of Land Management (BLM). 1982. Oil and gas leasing EA.

_____**1994.** Mineral Reports- Preparation and Review, BLM Manual 3060.

_____**1999**, Revised Sonoma-Gerlach and the Paradise-Deniio Management Framework Plans (MFP).

_____**2006**, Mineral Assessment Report to accompany the Resource Management Plan Winnemucca Field Office Northern Nevada; September 2006, 149 p.

Bushnell, K.O. 1967. Geology of the Rowland Quadrangle, Elko County, Nevada; Nevada Bureau of Mines Bulletin 67, 38 p.

Burrow, C.J. 2003. Poracanthodid Acanthodian From the upper Silurian (Pridoli) of Nevada; September 2003, Journal of Vertebrate Paleontology, v. 23, no. 3, pp. 489-493.

Carpenter, A.S. 1994. Lander County Mineral Resources Inventory 1994; Unpublished Report, 33 p.

Carpenter, J.A., Carpenter, D.G., and S.W. Dobbs. 1993. Structural analysis of the Pine Valley area, Nevada, *in* Gillespie, C.W., ed., Structural and stratigraphic relations of Devonian reservoir rocks, east central Nevada: Nevada Petroleum Society Field Conference Guidebook, p. 9–48.

Castor, S.B. and G.C. Ferdock. 2003. Minerals of Nevada; Nevada Bureau of Mines and Geology Special Publication 31, 519 p.

Castor, S.B. and D.D. LaPointe. 2001. Rocks, Gemstones, Minerals, and Fossils in Nevada; Nevada Bureau of Mines and Geology Special Publication 29,

Chamberlain, A.K. and C.W.Gillespie. 1993. Evidence of Late Mesozoic Thrusting, Timpahute Range, South Central Nevada; *in* Gillespie, C.W., ed., Structural and stratigraphic relationships of Devonian reservoir rocks, east-central Nevada: Nevada Petroleum Society, 1993 Field Conference Guidebook, p. 139–156.

Coolbaugh, Mark F., G. Raines, L. Shevenell, T. Minor, D. Sawatzky, and G. Oppliger. 2002. Regional assessment of exploration potential for geothermal systems in the Great Basin using a geographic information system (GIS); Great Basin Center for Geothermal Energy. Reno, Nevada.

Cope, E., Dobak, P., Bettles, K., Hipsley, R., Marlowe, K., and K. Creel. 2011. Unlocking the Hidden Value in Joint Ventures and Acquisitions: A Case History of Barrick's Reserve and Resource Growth in Nevada; *in* Steininger, R. and Pennell, B., eds., Geological Society of Nevada 2010 Symposium: Great Basin Evolution and Metallogeny, pp 125- 140.

Cornwall, H.R. 1972. Geology and Mineral Deposits of Southern Nye County, Nevada; Nevada Bureau of Mines and Geology Bulletin77, 57 p.

Davis, D.A. and R.H. Hess. 2009. Nevada Active Mines and Energy Producers; Nevada Bureau of Mines and Geology, Educational Series E-49.

Davis, D.A., and J.V. Tingley. 1999. Gold and silver resources in Nevada: Nevada Bureau of Mines and Geology Map 120, scale 1:1,000,000.

Davis, J.R., Friedman, I. and J.D. Gleason. 1986. Origin of the Lithium-Rich Brine, Clayton Valley, Nevada; in Shorter Contributions to Isotope Research, US Geological Survey Bulletin 1622, p 131-138.

Decker, R.W. 1962. Geology of the Bull Run Quadrangle, Elk County Nevada; Nevada Bureau of Mines Bulletin 60, 65 p.

Department of the Interior. 2003. Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extent and Nature of Restrictions or Impediments to their Development. U.S. Department of Interior, Agriculture and Energy. January 2003. 54p and appendices.

Doebrich, J. L. 1995. Geology and mineral deposits of the Antler Peak 7.5 minute quadrangle, Lander County, Nevada; Nevada Bureau of Mines and Geology Bulletin 109, 44 p.

Doebrich, J.L., and T.G. Theodore. 1996. Geologic history of the Battle Mountain mining district, Nevada, and regional controls on the distribution of mineral systems, in Coyner, A.R., and Fahey, P.L., eds., Geology and Ore Deposits of the American Cordillera: Geological Society of Nevada Symposium Proceedings, Reno/Sparks, Nevada, April 1995, p. 453–483.

Dott, R.H., Jr. 1955. Pennsylvanian Stratigraphy of Elko and Northern Diamond Ranges, Northeastern Nevada; American Association of Petroleum Geologists Bull., v.39, no. 11, p. 2211-2306

Driesner, D. and A. Coyner. 2009. Major Mines of Nevada 2009 Mineral Industries in Nevada's Economy; Nevada Commission on Mineral Resources, http://minerals.state.nv.us/forms/mining/MajorMinesOfNevada/mm2009.pdf.

_____**2010.** Nevada Exploration Survey 2009; Nevada Commission on Mineral Resources report.

Duey, H.D., Veal, H.K., Bortz, L.C., and N.H. Foster. 1988. Grant Canyon Oil Field, Nye County, Nevada (abstract); AAPG Search and Discovery Article, AAPG-SEPM-SEG Annual Convention.

Elliott, J. 2011. Market Sources Say Indian Barytes price at "Disturbing" Level; Industrial Minerals, 04 August 2011.

Eureka County. 2007. Eureka County, Nevada Mineral Assessment Report; October 2007, Mineral Assessment Report prepared by Lumos & Associates for Eureka County, 50 p.

Faulds, James E., L. Garside, G. Johnson, J. Muehlberg, G. Oppliger. 2002. Geologic setting and preliminary analysis of the Desert Peak-Brady geothermal field, western Nevada; Nevada Bureau of Mines and Geology, Department of Geological Sciences, University of Nevada, Reno, NV 89557.

Faulds, J.E., Hinz, N.H., and M.F. Coolbaugh. 2011. Structural Investigations of Great Basin Geothermal Fields: Applications and Implications: *in* Steininger, R. and Pennell, B., eds., Geological Society of Nevada 2010 Symposium: Great Basin Evolution and Metallogeny, pp 361-372.

Fifarek, R.H. and G.N. Gerike. 1991. Oxidation of Hydrothermal Sulfides at Round Mountain, Nevada – Origin and Relation to Gold Mineralization; in, Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin Symposium Proceedings, Geological Society of Nevada, pp. 1111-1119.

Finney, S.C., Berry, W.B., Cooper. J.D., Ripperdan, R.L., Sweet, W.C., Jacobson, S.R., Soufiane, A., Achab, A., and P.J. Noble. 1999. Late Ordovician Mass Extinction: A New Perspective from Stratigraphic Sections in Central Nevada; March 1999, Geology v. 27, no. 3, pp 215-218.

Garrett, D.E. 2004. Handbook of Lithium and Natural Calcium Chloride; Their Deposits, Processing, Uses and Properties, Academic Press 488 p.

Garside, L.J. 1983, Nevada Oil Shale; Nevada Bureau of Mines and Geology Open-File Series 83-5.

Garside, L.J., and R.H. Hess. 2007, Petroleum Data Map of Nevada; Nevada Bureau of Mines and Geology Map 162.

Garside, L.J., Hess, R.H., Fleming, K.L., and B.S. Weimer. 1988. Oil and Gas Developments in Nevada; Nevada Bureau of Mines and Geology Bulletin 104, 136 p.

General Moly. 2011. Website: www.generalmoly.com

Gilluly, J., and H. Masursky. 1965. Geology of the Cortez Quadrangle; Nevada Geol. Survey Bulletin 1175, 117p.

Great Western Mining. 2011. Website: (http://www.greatwesternmining.com/index.php/uranium-mining-and-exploration

Horton, R.C. 1963. An Inventory of Barite Occurrences in Nevada; Nevada Bureaus of Mines Report 4, 21 p.

John, D.A. 2008. Supervolcanoes and Metallic Ore Deposits; February 2008, Elements, v. 4, p. 22.

John, D.A., Henry, C.D. and J.P. Colgan. 2008. Magmatic and Tectonic Evolution of the Caetano Caldera, North-Central Nevada: A Tilted, Mid-Tertiary Eruptive Center and Source of the Caetano Tuff; 1 February 2008, Geosphere, v. 4(1) pp 75-106.

Keast, T. 2011. Independent Technical Report on the Clayton Valley Lithium Property Esmeralda County, Nevada; NI 43-101 Report for Rodinia Lithium Inc., 38 p.

Ketner, K.B., and J.F. Smith, Jr. 1982. Mid-Paleozoic age of the Roberts thrust unsettled by new data from northern Nevada; Geological Society of America Bulletin v. 10, p. 298–303.

Kleinhampl, F.J. and J.I. Ziony, 1967. Preliminary Geologic Map of Northern Nye County, Nevada; U.S. Geological Survey Open-File Map.

_____**1984**. Mineral Resources of Northern Nye County, Nevada; Nevada Bureau of Mines and Geology Bulletin 99B, 243p.

_____**1985**. Geology of northern Nye County, Nevada, Nevada Bureau of Mines and Geology Bulletin 99A, 172 p.

Lander County. 2005. Policy Plan for Federally Administered Lands.

LaPointe, D.D., Price, J.G., and R.H. Hess. 2007. Assessment of the Potential for Carbon Dioxide Sequestration with Enhanced Oil Recovery in Nevada; Nevada Bureau of Mines and Geology Open-File Report 07-7, 24 p.

Lithium Corp. 2011. Website: www.lithiumcorporation.com.

Live Charts. 2011. Website: www.livecharts.co.uk/MarketCharts/crud.php

Lund, K., Beard, L.S., and W.J. Perry. 1993. Relation Between Extensional Geometry of the Northern Grant Range and Oil Occurrences in Railroad Valley, East Central Nevada; American Association of Petroleum Geologists Bulletin, v. 77, no. 6, p. 945–962.

McKee, E.H. 1992. Potassium-Argon and 40Ar/39Ar Geochronology of Selected Plutons in the Buckingham Area; in Theodore, T.G., Blake, D.W., Loucks, T.A., and Johnson, C.A., Geology of the Buckingham stockwork molybdenum system and surrounding area, Lander County, Nevada: United States Geological Survey Professional Paper 789-D., p. 36–40.

_____**1996.** Cenozoic Magmatism and Mineralization in Nevada; in, Coyner, A.R., and Fahey, P.L., eds., Geology and Ore Deposits of the American Cordillera Symposium Proceedings Vol. II, Geological Society of Nevada, pp 581-588.

Means, W.D. 1962. Structure and Stratigraphy in the Central Toiyabe Range, Nevada; California University Pubs. Geol. Sci. v. 42, no. 2, pp 71-110.

Micklethwaite, S. 2011. Fault-Induced Damage Controlling the Formation of Carlin-Type Ore Deposits; *in* Steininger, R. and Pennell, B., eds., Geological Society of Nevada 2010 Symposium: Great Basin Evolution and Metallogeny, pp 221-231.

Miller, C.F. and D.A. Wark. 2008. Supervolcanoes and Their Explosive Supereruptions; February 2008, Elements, v. 4, pp. 11-16.

Miller, E.L., Gans, P.B., Wright, J.E., and J.F. Sutter. 1988. Metamorphic History of the East Central Basin and Range Province—Tectonic Setting and Relationship to Magmatism; *in* Ernst, W.G., ed., Metamorphism and crustal evolution of the Western United States, Ruby Volume, v. 7: Englewood Cliffs, New Jersey, Prentice–Hall, p. 649–682.

Murray, D.K., and L.C. Bortz. 1967. Eagle Springs Oil Field, Railroad Valley, Nye County Nevada; AAPG Bulletin, V. 51, no. 10, pp 2133-2145.

Nash, J.T. 1996. Resource assessment of the U.S. Bureau of Land Management's Winnemucca District and Surprise Resource Area, northwest Nevada and Northeast California; Resources of industrial rocks and minerals, US Geological Survey Open File Report 96-721.

Noble, D.C., Vogel, T.A., Weiss, S.I., Erwin, J.W., McKee, E.H., and L.W. Younker. 1984. Stratigraphic Relations and Source Areas of Ash-Flow Sheets of the Black Mountain and Stonewall Mountain Volcanic Centers, Nevada; 30 September 1984, Journal of Geophysical Research, v. 89, v B10, pp 8593-8602.

Pacific Gold Corp. 2011. Website: www.pacificgoldcorp.com/properties/nevadarae/overview.html)

Paleo Portal. 2011a. Website: (http://www.paleoportal.org/index.php?globalnav=time_space&sectionnav=state&name=Nevada

_____2011b. www.paleoportal.org/index.php?globalnav=time_space&sectionnav=period&period_id=11).

_____2011c. (www.paleoportal.org/index.php?globalnav=time_space&sectionnav=state&name=Nevada

Papke, K.G. and S.B. Castor. 2003. Industrial Mineral Deposits in Nevada, NBMG Map 142.

Peters, S.G., Nash, J.T., John, D.A., Spanski, G.T., King, H.D., Connors, K.A., Moring, B.C., Doebrich, J.L., McGuire, D.J., Albino, G.V., Dunn, V.C., Theodore, T.G., and S. Ludington. 1996. Metallic mineral resources in the U.S. Bureau of Land Management's Winnemucca District and Surprise Resource Area, northwest Nevada and northeast California; U.S. Geological Survey Open-File Report 96-712, 147 p.

Potter, C.J., Dubiel, R.F., Snee, L.W., and S.C. Good. 1995. Eocene Extension of Early Eocene Lacustrine Strata in a Complexly Deformed Sevier-Laramide Hinterland, Northwest Utah and Northeast Nevada; Geology, v. 23, no. 2, p. 181–184.

Price, J.G., Muntean, J.L., Davis, D.A., Hess, R.H., and L. Shevenell. 2009. The Nevada Mineral Industry 2008; Nevada Bureau of Mines and Geology Special Publication MI-2008, 178 p.

Price, J.G., Coyner, A.R., Muntean, J., and D. Driesner. 2010a. Update on Nevada Mineral Production and Exploration; Nevada Bureau of Mines and Geology Presentation, 93p.

Price, J.G., Muntean, J.L., Davis, D., Shevenell, L., Zehner, R., Price, L., and L. Wells. 2010b. The Nevada Mineral Industry 2009; Nevada Bureau of Mines and Geology Special Publication MI-2009, 180 p.

Price, J.G., Lechler, P.J., Lear, M.B., and T.F. Giles. 2000. Possible Volcanic Source of Lithium in Brines in Clayton Valley, Nevada; in Cluer, J.K, Price, J.G., Struhsacker, E.M., Hardyman, R.F., and Morris, C.L., eds., Geology and Ore Deposits 2000: the Great Basin and Beyond: Geological Society of Nevada Symposium Proceedings, May 15-18, 2000, Reno, p. 241-248.

Randabel, J. and D. Vukovic. 2009. Apex Deposit Lander County, Nevada, USA Geological Review and Resources Estimate; Report for Monaro Mining NL, 84 p.

Roberts, R. J. 1964. Stratigraphy and structure of the Antler Peak quadrangle, Humboldt and Lander counties, Nevada; United States Geological Survey Professional Paper, 459-A, 93 p.

Roberts, R.J., and D.C. Arnold. 1965. Ore deposits of the Antler Peak Quadrangle, Humboldt and Lander Counties, Nevada: United States Geological Survey Professional Paper, 459-B, 94 p.

Roberts, R.J., Hotz, P.E., Gilluly, J., and H.G. Ferguson. 1958. Paleozoic rocks in north-central Nevada: American Association of Petroleum Geologists Bulletin, v. 42, p. 2813–2857.

Roberts, R.J., Montgomery, K.M., and R.E. Lehner. 1967. Geology and Mineral Resources of Eureka County, Nevada; Nevada Bureau of Mines and Geology Bulletin 64, 164p.

Shaver, S.A. 1991. Geology, Alteration, Mineralization, and Trace Element Geochemistry of the Hall (Nevada Moly) Deposit, Nye County, Nevada; in, Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin Symposium Proceedings, Geological Society of Nevada, pp. 303-332.

Shawe, D.R., Poole, F.G., and D.A. Brobst. 1967. Bedded Barite in East Northumberland Canyon, Nye County, Nevada; US Geological Survey Circular 555, 8 p.

_____**1969.** Newly Discovered Bedded Barite Deposits in East Northumberland Canyon, Nye County, Nevada; Economic Geology, v. 64, no 3, pp. 245-254.

Sherlock, M.G., Cox, D.P., and D.F. Huber. 1996. Known Mineral Deposits and Occurrences in Nevada; in Singer, D.A., ed., 1996, An analysis of Nevada's metal-bearing mineral resources: Nevada Bureau of Mines and Geology Open-file Report 96-2.

Silberling, N.J. 1959. Pre-Tertiary Stratigraphy and Upper Triassic Paleontology of the Union District, Shoshone Mountains, Nevada: U.S. Geological Survey Professional Paper, 322, 63 p.

Silberling, N.J., and Roberts, R.J. 1962. Pre-Tertiary Stratigraphy and Structure of Northwestern Nevada; Geological Society of America Special Paper 72, 58 p.

Singer, D.A. (ed.). 1996. An analysis of Nevada's metal-bearing mineral resources, NBMG Open-File Report 96-2, 178 p.

Stager, H.K. Mineral Deposits (of Lander County) in Geology and mineral deposits of Lander County, Nevada; Nevada Bureau of Mines and Geology Bulletin 88, 106p.

Stewart, J.H. 1980. Geology of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 126 p.

Stewart, J.H. and J.E. Carlson. 1978. Geological Map of Nevada; US Geological Survey, Scale 1:500 000.

Stewart, J.H., and E.H. McKee. 1977. Geology and Mineral Deposits of Lander County, Nevada; Nevada Bureau of Mines and Geology Bulletin 88, 114 p.

Taylor, W.J. 2001. Mesozoic Thrusting in the Hinterland of the Sevier Orogenic Belt—The Central Nevada Thrust Belt [abs.]; Geologic Society of Nevada, 2001 annual meeting abstracts.

Theodore, T.G., Silberman, M.L., and D.W. Blake. 1973. Geochemistry and K-Ar ages of plutonic rocks in the Battle Mountain mining district: United States Geological Survey Professional Paper, 798-A, 24 p.

Tingley, J.V. 1998. Mining Districts of Nevada; Nevada Bureau of Mines and Geology Report 47,

TNR Gold. 2009. Press release, 16 April 2009.

Tonogold Resources Inc. **2009**. Press release 11 Nov 2009.

Turner, S. and M. A. Murphy. 1988. Early Devonian Vertebrate Microfossils from the Simpson Park Range, Eureka County, Nevada; November 1988, Journal of Paleontology, v. 62, no 6, pp. 959-964.

UCMP. 2011. Website: www.ucmp.berkeley.edu/science/parks/berlin_ichthyosaur.php).

U.S. Climate Data. 2011. Website accessed August 24, 2011. http://www.usclimatedata.com/climate.php?location=USNV0007.

U.S. Department of Energy. 2004. Nevada state fact sheet. Office of Energy Efficiency and Renewable Energy: Geothermal Technologies Program (GeoPowering the West). Washington, D.C. http://www.eere.energy.gov/geothermal/gpw_nevada.html

U.S. Geological Survey. 2003. US Geological Survey Minerals Yearbook – 2003; US Geological Survey.

Wallace, A.R., Luddington, S., Mihalasky, M.J., Peters, S.G., Theodore, T.G., Ponce, D.A., John, D.A., Berger, B.R., with a contribution from Zientek, M.L., Sidder, G.B., and R.A. Zierenberg. 2004. Assessment of metallic resources in the Humboldt River Basin, Northern Nevada. US Geological Survey Bulletin 2218, 295 p.

Wernicke, B.P. 1992. Cenozoic Extensional Tectonics of the U.S. Cordillera, *in* Burchfiel, B.C., Lipman, P.W., and Zoback, M.L., eds., The Cordilleran orogen—Conterminous U.S.: Geological Society of America, The Geology of North America, v. G–3, p. 553–581.

Willis, G.C. 1999. Utah Thrust System—An Overview; *in* Spangler, L.W., and Allen, C.J., eds., Geology of northern Utah and vicinity: Utah Geological Association Publication, v. 27, p. 1–10.

Zimmermann, R.A. 1969. Stratabound Barite Deposits in Nevada; Mineralium Deposita, v. 4, no. 4, pp 401-409.