Geology of Nevada

Jonathan G. Price
State Geologist and Director
Nevada Bureau of Mines and Geology
Mail Stop 178
University of Nevada, Reno
Reno, Nevada 89557-0088

ABSTRACT

Geology plays a central role in Nevada's human history, economy, and future. Cordilleran tectonics have created the Basin and Range landscape and interior drainage of the Great Basin, provided a rain shadow to make Nevada the nation's driest state, and generated frequent earthquakes along normal and strike-slip faults. Geology is key to reducing risks from Nevada's natural and anthropogenic hazards (earthquakes, flash floods, drought, land subsidence, erosion after wildland fires, landslides, swelling and collapsing soils, radon, arsenic, and others).

Nevada's geologic fortunes make it the leading state in the production of gold, barite, diatomite, and mercury and currently the only state that produces magnesite, lithium, and the specialty clays, sepiolite and saponite. Nevada is also a major producer of geothermal power and gypsum. The metals are primarily related to igneous activity, with major pulses of magma during the Jurassic, Cretaceous, and Tertiary. Barite is mined from Paleozoic sedimentary rocks, and gypsum occurs in sedimentary beds of Permian, Triassic, Jurassic, and Tertiary age. Lithium is extracted from brine beneath an unusual playa. Geothermal power production primarily occurs along Quaternary faults.

We are in the midst of the biggest gold-mining boom in American history. The Carlin trend is one of the world's premier gold-mining regions, and reserves along the trend and elsewhere in Nevada will sustain the boom for at least two more decades. Nevada's booming population will continue to increase demands for construction raw materials and for geological information to help manage growth while minimizing losses from geological hazards.

INTRODUCTION

The geology of Nevada is the foundation of its natural resources and is closely linked to its human history. The complex geologic history of the state relates to such resources as minerals, water, and energy; to environmental issues; and to natural hazards. This article draws heavily from the references listed in the bibliography for general information on the geology of the state, particularly Stewart (1980), Stewart and Carlson (1978), Price and others (1999), and Price (2002; 2004).

GEOMORPHOLOGY AND NEOTECTONICS

Mountain ranges in Nevada, commonly about 10 miles wide and rarely longer than 80 miles, are separated by valleys (Fig. 1). The geologic structure that controls this basin-and-range topography is dominated by faults. Nearly every mountain range is bounded on at least one side by a fault that has been active, with large earthquakes, during the last 1.6 million years. For the last several million years, these faults have raised and occasionally tilted the mountains and lowered the basins. Over the years, these basins have filled with sediments that are derived from erosion of the mountains and that are locally tens of thousands of feet thick.

Many of the range-bounding faults are still active (Fig. 2). Nevada is the third most seismically active state in the nation (behind California and Alaska); over the last 150 years, a magnitude 7 or greater earthquake has occurred somewhere in Nevada about once every 30 years. Most faults are normal, although some are strike-slip faults. The most apparent zone of strike-slip faults in Nevada is in a 50-mile wide swath along the northwest-trending border with California, the Walker Lane. These northwest-trending faults are accommodating part of the motion between the Pacific Plate, which is moving relatively northwest, and the North American Plate, which is moving relatively southeast. The San Andreas Fault takes up most of the motion between these two plates. The generally north-south trend of mountain ranges in most of Nevada transforms into northwest-trending ranges within the Walker Lane. Although the seismic hazard estimated by the U.S. Geological Survey appears to be less in Las Vegas than in the

Reno-Carson City area, potentially active faults do exist in Las Vegas Valley (Fig. 3) and nearby. With its larger population, Las Vegas is at higher risk than Reno or Carson City.

GEOLOGY, CLIMATE, AND WATER RESOURCES

The climate of Nevada is closely tied to the geologic structure and resultant topography. Judging from fossil evidence of plants that grew in different parts of California and Nevada in the past, the Sierra Nevada (in California and far western Nevada) rose to current elevations only within the last six million years. Fossil fish, which are abundant in some of Nevada's diatomite deposits, are evidence of wetter times in the Miocene (Fig. 4). Today the Sierra Nevada and other high mountains in California trap moisture coming off the Pacific Ocean and leave Nevada the driest state in the nation. Only a few rivers leave Nevada. These include the Bruneau, Jarbidge, and Owyhee Rivers in northeastern Nevada, which flow north into the Snake River in Idaho, and the White and Virgin Rivers in southeastern Nevada, which flow into the Colorado River (Fig. 1). The Colorado, which is the largest river in Nevada, gets the bulk of its water from the Rocky Mountains to the east and provides much of the municipal and industrial water for Las Vegas and other communities in southern Nevada before flowing southward into the Gulf of California. The headwaters of the Colorado have recently suffered a multi-year drought, and Lake Mead, from which Las Vegas gets the bulk of its drinking water, is lower than its intended level (Fig. 5).

Most of Nevada, however, is part of the Great Basin, a large area with no drainage to the ocean and centered on Nevada but including parts of California, Oregon, Idaho, and Utah. The Truckee, Carson, and Walker Rivers, which provide much of the drinking, industrial, and agricultural water for northwestern Nevada, flow generally eastward from the Sierra Nevada to terminal lakes and lowlands in the desert (Pyramid Lake, the Carson Sink, and Walker Lake, respectively). The Humboldt River, which supplies much of northeastern Nevada with drinking, agricultural, and industrial water, flows southwestward into Humboldt Lake, and, when the lake fills, into the Carson Sink.

During glacial times (most recently about 10,000 years ago), large expanses in the Great Basin were covered by water. Great Salt Lake and the Bonneville Salt Flats in Utah and parts of far eastern Nevada were once part of ancient Lake Bonneville, and Pyramid Lake, the Carson Sink, and Walker Lake were once connected in ancient Lake Lahontan. Native Americans occupied the shores of these lakes as early as 10,000 to 12,000 years ago (Fig. 6). Glaciers existed in the higher mountains, carving some of the spectacular U-shaped valleys in the Ruby Mountains and sculpting high-mountain topography in the Sierra Nevada. Glaciers are still present high in the Ruby Mountains and Snake Range in eastern Nevada. Native Americans lived in nearly are parts of Nevada, as evidenced by petroglyphs (Fig. 7) and abundant chips of arrowheads and other stone tools made from local obsidian, chert, and opal.

Groundwater, mostly from aquifers in alluvial basins, is used throughout the state. In some basins, groundwater has been pumped out more rapidly than it is naturally recharged from rain and snowmelt; this causes significant lowering of the groundwater table and can affect the land surface. In Las Vegas Valley, near Pahrump, and near some of the large mines, cracks have developed locally in the ground (Fig. 8), generally near preexisting faults, and in a few places the land has subsided more than 6 feet in the last 60 years.

On a percentage basis, Nevada is the fastest growing state in the country. The U.S. Census Bureau reported a population of 1,201,833 in 1990 and 1,998,257 in 2000, and they estimated the population to be 2.4 million in 2004. Most of the increase has occurred in and around the urban areas of Las Vegas and Reno-Carson City. Urban expansion in the Las Vegas area has been at a rate of about two acres per hour and is expected to continue at a rapid rate. The Nevada State Demographer has projected the population to be 2.8 million in 2010 and 3.6 million in 2024 (Fig. 9). This increasing population places demands on groundwater and other resources.

The ecological regions of Nevada are directly linked to the climate, elevations of the mountains, and rocks. A combination of precipitation and rock type (with the help of ubiquitous microbes) dictates the types of soils that develop and the plants that grow, which, in turn, affect the types of animals that survive. Geologic evidence (primarily fossils) shows us that climate has changed substantially even within the last 10,000 years. For example, mammoths and camels once lived near springs and now mostly dry lakes in Nevada, as recently as 11,000 years ago.

Although Nevada is, on the average, quite dry (with about 10 inches of rainfall across the state, but locally less than 5 inches in some lowlands and over 40 inches in high mountains), major storms have caused significant floods and occasional landslides. Geologic evidence (and recorded history) abounds for large floods on the major rivers and “dry” washes throughout the state. The most recent severe floods were in 2005 (Fig. 10).

GEOLOGICAL AND HUMAN HISTORY LINKED TO MINERAL AND ENERGY RESOURCES

Major events in the geologic history of Nevada are highlighted in Table 1. A western continental margin, similar to the Atlantic coast of today, persisted for hundreds of millions of years before the more active, Pacific coast margin of today began to take shape about 360 million years ago. Repeated and prolonged periods of interactions between the North American Plate and oceanic plates, expressed in folds, thrust faults, strike-slip faults, normal faults, igneous intrusions, volcanism, metamorphism, and sedimentary basins, are recorded in the rocks. Some of the oldest rocks in Nevada occur near Las Vegas (Fig. 11), and the same great unconformity that separates the Paleozoic from the Precambrian at the base of the Grand Canyon is exposed at the foot of Frenchman Mountain, just east of town. Evidence for major Mesozoic thrusting is easily seen in the Spring Mountains west of Las Vegas (Fig. 12).

Nevada rocks document volcanic and intrusive igneous activity intermittently and repeatedly from earliest geologic history to within the last few thousand years. Nevada’s igneous rocks are connected to sea-floor spreading about 450 million years ago (much like the Mid-Atlantic Ridge or the East Pacific Rise today), collisions of ancient and modern plates, and hot spots in the Earth’s mantle and perhaps outer core (some Nevada volcanic rocks can be correlated with the Yellowstone hot spot, which, as a result of plate tectonics, was once underneath and produced volcanoes in southern Idaho and northern Nevada). Some of the volcanic rocks in western Nevada represent the precursor of the Cascade Range, and significant intrusions about 40, 100, and 160 million years ago are probably linked to similar plate-tectonic settings, whereby oceanic plates were subducted beneath western North America.

Most, but not all, ore deposits in Nevada are associated with igneous activity. In some cases, metals came from the magmas themselves, and in other cases, the magmas provided heat for circulation of hot water that deposited metals in veins and fractured sedimentary rocks. Some spectacular mineral specimens occur in ore deposits that formed when magmas intruded and metamorphosed sedimentary rocks. Even today, driven locally by deep circulation along faults and perhaps locally by igneous activity, hot water shows up in numerous geothermal areas. Nevada produces approximately $70 million worth of geothermally generated electric power annually, and geothermal resources also are used for agriculture, industrial applications, and space heating.

Nevada produces approximately $3 billion worth of mineral commodities each year. Nevada is the nation's leading gold producer, accounting for approximately 87% of U.S. production and 9% of world production. Much of the gold comes from a northwest-trending belt of gold deposits in northeastern Nevada known as the Carlin trend. One of the interesting features of the Carlin trend is that nearly all of the gold is contained in microscopic particles within Paleozoic sedimentary rocks. Although the sedimentary hosts for the gold are more than 250 million years old, the actual mineralization may have occurred much later (approximately 40 million years ago) in association with igneous activity.

Apart from stone tools, salt for food preservation and flavoring, and turquoise for ornaments, few mineral resources were exploited by the Native Americans, and the Spaniards, who first crossed Nevada in 1776 and visited the meadows that became "Las Vegas" on their way between Santa Fe and Los Angeles, did not appear to have discovered any of Nevada's mineral wealth. Nevada became part of the United States (and Utah Territory) through the treaty with Mexico in 1848. Gold was discovered the next year by Mormon settlers near Dayton (east of Carson City), but the gold rush to the California Mother Lode prevented serious prospecting. In 1855 Mormon settlers discovered the lead-zinc-silver-gold ores in the Goodsprings district southwest of Las Vegas. The first big boom for Nevada mining began in 1859 with the discovery of silver and gold on the Comstock Lode, at Virginia City (upstream from Dayton). Nevada entered the Union in 1864, during the Civil War, earning the motto "Battle Born" and the nickname “Silver State.” Over the decades that followed, prospectors spread out from Virginia City, discovered other major mining camps, and established many nearby towns in Nevada (Austin, Battle Mountain, Beatty, Carlin, Elko, Ely, Eureka, Gabbs, Goldfield, Las Vegas, Lovelock, Pioche, Tonopah, Winnemucca, Yerington) and other parts of the western United States. Several gold and silver districts in southern Nevada were discovered in this era, including the Bullfrog district in 1904, site of the now-famous ghost town of Rhyolite (Fig. 13), named for the Tertiary rock that dominates the area.

We are currently in the midst of the biggest gold-mining boom in American history. The U.S. production so far in the current boom, the period from 1981 to present, has been over 186 million ounces. This is significantly greater than the total production during the era of the California gold rush (1849 to 1859, with 29 million ounces), the Comstock (Nevada) era from 1860 to 1875 (with 34 million ounces), and the period from 1897 to 1920, when Goldfield (Nevada), the Black Hills (South Dakota), Cripple Creek (Colorado), and by-product production from copper mines in Arizona and Utah contributed to cumulative production of 95 million ounces. U.S. production in the decade from 1995 to 2004 alone was 103 million ounces. Reserves on the Carlin trend and elsewhere in Nevada are sufficient to sustain the boom for at least two more decades.

Nevada is also the nation’s leading producer of barite (from Paleozoic marine sedimentary rocks), mercury (currently only as a byproduct of precious metal recovery), and lithium (extracted from brine that occurs in Tertiary valley-filling sediments near Silver Peak; Fig. 14) and second in silver (mostly a co-product or byproduct of gold production). Other commodities that are currently mined in Nevada include gypsum (from Paleozoic, Mesozoic, and Cenozoic sedimentary rocks; Fig. 15), limestone (for cement and lime, from both Paleozoic marine and Miocene lacustrine rocks; Fig. 16), clays (from Tertiary lacustrine sediments), copper (from porphyry-type deposits), salt (from an active playa), magnesite (from a contact-metamorphic deposit), diatomite (from Miocene lacustrine deposits), silica sand (from Mesozoic sandstone), dimension stone (including Mesozoic sandstone near Las Vegas; Fig. 17), and crushed rock, sand, and gravel for construction aggregate. In the past, Nevada has been a significant producer of lead, zinc, tungsten, molybdenum, and fluorite. Active exploration, stimulated by high prices for metals and the population boom in Nevada and neighboring states, and recent discoveries of new ore deposits attest to the potential for finding additional ones.

Nevada also produces some oil, although production is small relative to that in major oil states. An interesting aspect of Nevada petroleum production is that some of the oil is associated with hot water, although lower in temperature but otherwise much like the geothermal fluids that formed gold and silver deposits. Another curiosity is that some of the oil is trapped in fractured volcanic rocks, although the ultimate source of the petroleum was from organic matter in sedimentary rocks. Most of the oil has come from the eastern part of the state, primarily Railroad and Pine Valleys.

GEOLOGY AND OTHER ENVIRONMENTAL ISSUES

Some environmental hazards are associated with the abundant igneous rocks in Nevada. For example, many groundwaters in Nevada contain elevated concentrations of radon. Because radon is common in silica-rich igneous rocks, and because these rocks are widespread in the mountains and make up much of the sediment in the valleys, radon occurs in groundwater, soil, and air. Similarly, arsenic is relatively abundant in certain types of igneous rocks and is locally a problem as a dissolved natural constituent in Nevada groundwater and surface water.

The proposed repository for high-level nuclear waste at Yucca Mountain is in faulted, Tertiary ash-flow tuffs, and Quaternary cinder cones occur nearby (Fig. 18). Geological issues regarding Yucca Mountain include how quickly rainwater will penetrate into the repository, down to the groundwater table, then out to the surface; how frequently earthquakes will occur and how much ground shaking and fault displacement there will be; and whether there is a significant volcanic hazard.

Given Nevada’s mineral, energy, and water resources, its challenges in terms of environmental protection, and its exposure to natural hazards, geology will continue to play a central role in the state’s economy, growth, health, safety, and history.

ACKNOWLEDGMENT

I thank Chris Henry, Steve Castor, Larry Garside, Jim Faulds, Dick Meeuwig, Rick Schweickert, and Jim Carr for help with earlier versions of this manuscript.

BIBLIOGRAPHY

(references and suggested reading)

Dobra, J.L., 1998, The U.S. Gold Industry 1998: Nevada Bureau of Mines and Geology Special Publication 25, 32 p.

Faulds, J.E., Bell, J.W., and Olson, E.L., 2002, Geologic map of the Nelson SW Quadrangle, Clark County, Nevada: Nevada Bureau of Mines and Geology Map 134, 1:24,000-scale with text, 15 p.

Lush, A. P., A. J. McGrew, A. W. Snoke, and J. E. Wright 1988, Allochthonous Archean basement in the East Humboldt Range, Nevada: Geology v. 16, p. 349-353.

Price, J.G., 2002, Geology of Nevada: The Professional Geologist, v. 39, no. 4, p. 2-8.

Price, J.G., 2004, Geology of Nevada, *in* Castor, S.B., Papke, K.G., and Meeuwig, R.O., eds., 2004, Betting on Industrial Minerals, Proceedings of the 39th Forum on the Geology of Industrial Minerals, May 19–21, 2003, Sparks, Nevada: Nevada Bureau of Mines and Geology Special Pubication 33, p. 191-200.

Price, J.G., Meeuwig, R.O., Tingley, J.V., Castor, S.B., Hess, R.H., and Davis, D.A., 2004, The Nevada mineral industry - 2003: Nevada Bureau of Mines and Geology Special Publication MI-2003, 70 p. (Overview by J.G. Price and R.O. Meeuwig, p. 3-11.)

Price, J.G., Henry, C.D., Castor, S.B., Garside, L.J., and Faulds, J.E., 1999, Geology of Nevada: Rocks and Minerals, v. 74, no. 6, p. 357-363.

Price, J.G., Meeuwig, R.O., Tingley, J.V., La Pointe, D.D., Castor, S.B., Davis, D.A., and Hess, R.H., 2002, The Nevada mineral industry - 2001: Nevada Bureau of Mines and Geology Special Publication MI-2001, 66 p. (Overview by J.G. Price and R.O. Meeuwig, p. 3-12.)

Purkey, B.W., and Garside, L.J., 1995, Geologic and natural history tours in the Reno area: Nevada Bureau of Mines and Geology Special Publication 19, 211 p.

Ramelli, A.R., Bell, J.W., dePolo, C.M., and Yount, J.C., 1999, Large-magnitude, late Holocene earthquakes on the Genoa fault, west-central Nevada and eastern California: Seismological Society of America Bulletin, v. 89, no. 6.

Smith, G.H., and Tingley, J.V., 1997, The history of the Comstock Lode: Nevada Bureau of Mines and Geology Special Publication 24, 328 p.

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

Stewart, J.H., and Carlson, J.E., 1977, Geologic map of Nevada: Nevada Bureau of Mines and Geology Map 57, 1:1,000,000 scale.

Stewart, J.H., and Carlson, J.E., 1978. Geologic map of Nevada: U.S. Geological Survey, 1:500,000 scale.

Tingley, J.V., 1998, Mining districts of Nevada: Nevada Bureau of Mines and Geology Report 47, Second Edition, 128 p.

Tingley, J.V., Horton, R.C., and Lincoln, F.C., 1993, Outline of Nevada mining history: Nevada Bureau of Mines and Geology Special Publication 15, 48 p.

Tingley, J.V., and Pizarro, K.A., 2000, Traveling America's loneliest road, A geologic and natural history tour through Nevada along U.S. Highway 50: Nevada Bureau of Mines and Geology Special Publication 26, 132 p.

Tingley, J.V., Purkey, B.W., Duebendorfer, E.M., Smith, E.I., Price, J.G., and Castor, S.B., 2001, Geologic tours in the Las Vegas area. Expanded edition: Nevada Bureau of Mines and Geology Special Publication 16, 140 p.

www.nbmg.unr.edu (the Web site of the Nevada Bureau of Mines and Geology).

www.usgs.gov (the Web site of the U.S. Geological Survey).

Figure 1. Shaded relief map of Nevada (modified from Nevada Bureau of Mines and Geology Educational Series E-31). See www.nbmg.unr.edu for this and other free maps, including E-30, a generalized geologic map of Nevada.

Figure 2. Quaternary fault on the west side of the Ruby Mountains, exposed in a road cut at the Bald Mountain mine. Quaternary gravels are dropped down on the right against darker Paleozoic sedimentary rocks, which host gold at the mine. See www.nbmg.unr.edu/dox/sp27.pdf for Nevada Bureau of Mines and Geology Special Publication 27, a booklet on Living with Earthquakes in Nevada, for more information about earthquake hazards.

Figure 3. Quaternary fault at an excavation at a construction site in Las Vegas Valley, Burt Slemmons for scale; photo courtesy of Craig dePolo.

Figure 4. Two halves of a Miocene fossil fish in diatomite, collected in 2001 on an Earth Science Week field trip hosted by the Nevada Bureau of Mines and Geology, the Association of Engineering Geologists, and several other geoscience organizations that are active in Nevada.

Figure 5. Lake Mead, seen here at Hoover Dam on 23 May 2004, was approximately 100 feet below its intended level, as evidenced by the whitewashing of gypsum and calcite along its shores. Tertiary ash-flow tuffs occur in the foreground, and basaltic lava flows cap the mountain in the background to the east.

Figure 6. Petroglyphs carved in Tertiary andesite at Grimes Point on the shore of Lake Lahonton, one of the Pleistocene lakes in Nevada.

Figure 7. Petroglyphs carved in tuff in the Nelson area south of Las Vegas (from the area mapped by Faulds and others, 2002).

Figure 8. Fissure, widened by rainfall and irrigation, that destroyed a home in North Las Vegas, 1992 photo.

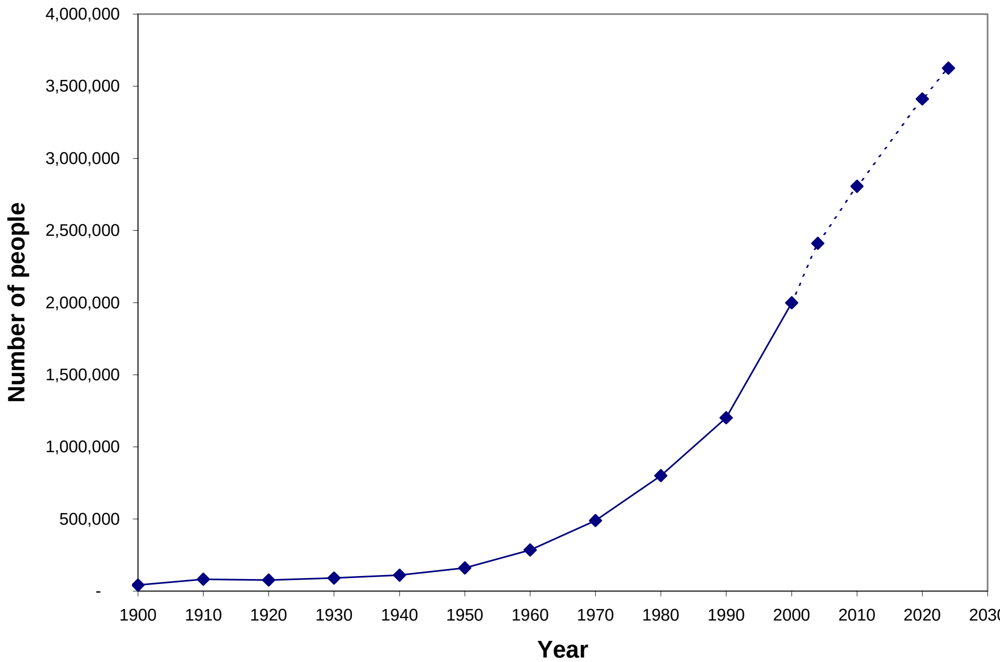

Figure 9. Nevada population. Data from the U.S. Census Bureau (www.census.gov) by decadal census plus estimate for 2004; projected to 2024 by the Nevada State Demographer.

Figure 10. Flooding of the Virgin River at Mesquite in January, 2005; photo courtesy of Gale Fraser, Clark County Regional Flood Control District.

Figure 11. Gneiss house, formerly occupied by a miner in the Virgin Mountains, east of Las Vegas. Discovered in 1901, copper, nickel, gold, and platinum were mined from massive sulfide deposits in Precambrian rocks in the Bunkerville district.

Figure 12. Mesozoic red sandstones in Red Rock Canyon, west of Las Vegas, are capped by Paleozoic carbonate rocks, which were thrust into place near the end of the Mesozoic.

Figure 13. The Bottle House at Rhyolite, a preserved ghost town near Beatty.

Figure 14. A Quaternary cinder cone at the north end of Clayton Valley, Esmeralda County, is reflected by the brine pool that is part of the lithium mining operation in the valley. Lithium-rich

brines are pumped to the surface, where they are allowed to evaporate in the sun. The solution precipitates halite, NaCl, before being processed to remove lithium.

Figure 15. Teachers get a blast at the PABCO gypsum mine east of Las Vegas during a Nevada Mining Association workshop. Gypsum in the Las Vegas area occurs in Miocene (as here) and Mesozoic sedimentary rocks.

Figure 16. Kiln at Apex, northeast of Las Vegas, where Paleozoic limestone is converted to lime.

Figure 17. Flagstone operation in Mesozoic sandstones near Las Vegas.

Figure 18. Black Cone, 1 million-year-old cinder cone, Yucca Mountain in distance, Nye County.

Table 1. Geologic time scale with major events in Nevada history.

PLEASE SEE SEPARATE FILE FOR THIS ONE-PAGE TABLE.