MOJAVE NATIONAL PRESERVE
GEOLOGIC RESOURCES MANAGEMENT ISSUES
SCOPING SUMMARY

Sid Covington
Geologic Resources Division
November 6, 2003

Executive Summary

In a Geologic Resources Evaluation scoping meeting held in Barstow, California, April 30, 2003, the scoping meeting participants identified the following geologic resources management issues.

1. Caves in the Preserve are being impacted by human (recreational) use and by drought. At present there is no estimate of the amount of use that caves receive.

2. Windblown dust is an important source of nutrients as well airborne toxins and radioactivity.

3. Desert crusts are very sensitive to human disturbance, especially recreational activities such as ORV use and hiking as well as from grazing.

4. Paleontological resources are not well-known in the Preserve and a baseline inventory is needed. Location and identification of vertebrate fossils are a high priority. There may be collecting (theft) by visitors.

5. Sand dunes are prominent geologic features in the Preserve. There is a need to monitor the continuing impact of visitors as well as document impacts from past mining.

6. There are abandoned mines that may pose visitor safety issues. Some are being preserved as cultural resources (headframes, draw works, abandoned vehicles, etc.). Tailings, especially uranium may be a health hazard.

7. There is potential for groundwater contamination especially in high use areas. Pesticides, waste oil, trash, fertilizer, and nitrates are possible pollutants.

Introduction

The National Park Service held a Geologic Resources Evaluation scoping meeting at the headquarters of Mojave National Preserve on Wednesday, April 30, 2003. The purpose of the meeting was to discuss the status of geologic mapping in Preserve, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the Preserve; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resources Evaluation Report which brings together all of these products.

The Mojave National Preserve was established under Title V of the California Desert Protection Act (Public Law 103-433) on October 31, 1994. The area covers most of East Mojave National Scenic Area previously administered by the Bureau of Land Management. The Preserve, as established, covers about 1,419,800 acres lying between Interstate 40 on the south and Interstate 15 on the north (see attached map). The Preserve is very diverse consisting of mountain ranges, broad valleys, lava flows and cinder cones, playas, and world-class sand dunes.

Mojave National Preserve is covered by 64 quadrangles of interest. Park staff identified six additional quads of interest: Searchlight (NV), Ivanpah Lake, Desert (NV), State Line Pass, Roach (NV) and West of Baker. There are several geologic maps available covering all or portions of the Preserve. David Miller (*et. al*., 1991) has a "Preliminary Geologic Map of the East Mojave National Scenic Area" at a scale of 1:125,000 and also "Surficial Geologic Map of the Mojave National Preserve Area, California and Nevada (2002) at a scale of 1:100,000.

Physiography

Mojave National Preserve lies entirely in the Mojave Desert physiographic province. The Mojave is bounded on the north and west by the Garlock Fault and on the south and west by the San Andreas fault. On the south the Transverse Ranges form the boundary. To the east, the Mojave Desert merges with the Basin and Range Province near the Colorado River. The Mojave area contains Precambrian though Cenozoic rocks. Elevations range from 7,929 feet in the Clark Mountains (in the Preserve) to about 600 feet in the Bristol Playa (and others) south of the park.

There is no uniform characteristic of the Mojave province. Although dominated by broad alluvial basins and playas separated by mountain ranges, there are a large variety of landforms to be found including late Cenozoic cinder cones and lava flows, fault scarps, sand dunes, playas, etc. Most sediments are non-marine and often more or less metamorphosed.

Geologic History

Nearly all major divisions of geologic time are represented in the rock record of the Mojave Desert province.

Precambrian - Outcrops of Precambrian crystalline basement rocks are widely scattered throughout the province. These rocks represent the Proterozoic western margin of the North American craton. Generally, the Precambrian rocks were deformed and metamorphosed about 1.7 billion years ago (b.y.) and were later intruded by granitic rocks at about 1.65 b.y., again at 1.2-1.4 b.y., then intruded by diabase at 1.1 b.y. (U.S.G.S., 1991). Following emplacement of the basement complex, the region experienced a long period of uplift. Between 1.4 b.y. and 1.2 b.y., the surface of the region lay above sea level and was deeply eroded.

In the late Precambrian, initiation of Cordilleran geosynclinal down-warping caused the land surface of the region to subside below sea level (Wright, *et al*., 1953). A shallow sea transgressed across the region and deposited up to 6,000 feet of sediments unconformably across the Proterozoic crystalline craton. These early deposits of conglomerate, sandstone, shale, limestone, and dolomite, known as the Pahrump Group (Norris and Webb, 1976), are not represented, and probably were never deposited, in the Mojave Desert province. Therefore, the province was still above sea level at this time. Geosynclinal down-warping and shallow-sea (less than 100 feet deep) deposition continued through the end of the Precambrian and into the Paleozoic. Late Precambrian strata younger than the Pahrump Group and Paleozoic strata are present in the province but are widely scattered and in relatively small areas.

Paleozoic Era - By the beginning of the Paleozoic Era, the Proterozoic subsidence had progressed into a huge, north-northwest trending trough across western North America (the Cordilleran Geosyncline). The Cordilleran Geosyncline persisted through the Paleozoic and into the Mesozoic with several transgressions and regressions of the shallow sea. The region accumulated large volumes of near shore and offshore marine sediments with up to 23,000 feet attributed to the Cambrian and Ordovician periods, and over 7,000 feet in the Silurian and Devonian (Nolan, 1943). From late Paleozoic through early Mesozoic time, the western edge of the continent was characterized by a complex pattern of offshore island arcs and marginal seas, similar to the western Pacific Ocean today (Dellinger, 1988). By the end of the Devonian, crustal compression and geanticlinal uplift in this offshore region, known as the Antler orogeny, resulted in few Carboniferous and Permian deposits. Crustal compression, exotic terraine accretion, and geanticlinal uplift persisted into the Mesozoic associated with another mountain-building event called the Sonoma Orogeny. Eventually the geosynclinal seas that covered the region though most of the Paleozoic Era disappeared.

Mesozoic Era - As a result of converging tectonic plates and the accretion of island arc terraines, a series of compressional pulses affected the west coast between mid-Jurassic and Cretaceous time. This compression produced uplift of the region and caused folding and faulting of both Paleozoic and Precambrian strata. At the height of this episode of compressional mountain-building, known as the Nevadan orogeny, deeply buried and subducted geosynclinal sediments were melted and emplaced as batholiths or extruded as volcanics. Most Mesozoic volcanic rocks have been removed by erosion during the Cenozoic era (Dellinger, 1988). These Mesozoic plutonic igneous rocks are now unroofed and form the Sierra Nevada batholith, the Teutonia batholith, the granitic rocks that form the majority of the southern Providence Mountains and other Mesozoic intrusives throughout the region (Clark, 1960). Another compressional episode, the Laramide Orogeny, affected the region in the late Cretaceous to Paleocene epochs, manifested by high angle reverse faults.

Cenozoic Era - The early Cenozoic (Paleocene, Eocene and Oligocene epochs) is mostly lacking in the stratigraphic record. Very little magmatic or tectonic activity is documented for the Mojave region until early Miocene. The region was probably above sea level, exhibited low relief, and was eroding with little deposition. This regional topographic high continued through the Eocene. The early to middle Miocene, however, was a period of intense volcanism as well as a brief episode of compressional deformation, then extensional faulting throughout much of the Mojave and Sonoran Desert region. This episode was probably caused by the North American continental plate colliding with, then overriding the Gulf of California spreading center. In late Cenozoic time, the entire region was transformed into an area of internal drainage by relative uplift along it's west margin (Dellinger, 1988). Continued crustal tension resulted in so-called basin and range topography created by normal faulting, down-dropped graben basins, and relatively uplifted horst block ranges which are elongated north-south, perpendicular to the primary direction of extension. Thick, non-marine basin deposits were formed reminiscent of those being formed today. Associated saline, borate, and shallow lake deposits indicate an arid or semi-arid climate. These conditions have persisted through the late Tertiary into Recent geologic time.

Stratigraphy

Precambrian Metamorphic and Crystalline Basement Complex - The Early Proterozoic rocks of the province are a complex of high-grade, deformed, supracrustal and plutonic rocks, intruded by younger plutonic rocks (U.S.G.S., 1991, Norris and Webb, 1976). These Precambrian rocks constitute one third or more of bedrock exposed in the Mojave National Preserve. Rock types include amphibolite-grade meta-igneous and metasedimentary gneisses and amphibolite. The complex is mostly gray, granitic to dioritic gneiss. Regionally, much of the gneiss is a distinctive feldspar augen gneiss. Also included in the complex are subordinate quartzite, mica schist, migmatite, amphibolite, marble and intrusive granitics. The metamorphism of the schist has been dated in the south Panamint Range as 1,700 million years (MY) by potassium/argon dating and 1,480 MY by strontium/rubidium methods (Wasserburg, *et al*., 1959; Hunt and Mabey, 1966). The majority of the Precambrian crystalline rocks in the Mojave Desert province range in age from 1.2 to 1.6 billion years (Burchfiel and Davis, 1981).

Structure

The geologic features of this region indicate that it has undergone profound deformation during at least four periods in it's geologic history (Hewett, 1954, 1956). Disturbances occurred: (1) after deposition of Lower Precambrian rocks; (2) after deposition of Upper Precambrian rocks; (3) during the Laramide orogeny; and (4) during the late Tertiary period . Each disturbance deformed the pre-existing rocks and was accompanied by, or quickly followed by, intrusion or extrusion of igneous rocks. After each disturbance the region experienced erosional periods, followed (except for the last) by the deposition of sedimentary sheets of great aerial extent.

Within the province are north to northeast-trending folds, steeply dipping faults and some major thrust faults of middle Jurassic to late Cretaceous age as well as open folds, low-angle thrust faults, and steeply dipping faults of late Cenozoic age. Many of the high-angle faults trend northwest and show evidence of recent movement (Jahns, 1954).

Late Mesozoic - Laramide Orogeny - The Paleozoic and Mesozoic sedimentary rocks of the region are greatly deformed. Wherever these sediments are in contact with course intrusives, it appears that emplacement of the igneous rocks is related to the deformation (Hewett, 1954). The area has been thrown into large open folds and broken by impressive thrust faults. Middle Cretaceous strata are deformed by these structures, therefore the principal deformation was post-Middle Cretaceous or within the period of Laramide orogeny. These faults have traces from 15 to 40 miles in length and dip westward at 10º to 30º. The belt of thrusts extends from Las Vegas Wash on the north, through the Spring Mountains, as far as Kelso Wash on the south.

Late Tertiary (Miocene) orogeny - Following deposition of the middle Tertiary sedimentary and volcanic rocks, these units were broadly warped and briefly subjected to erosion before extensive thrust faults developed in the region. Generally, the middle Tertiary rocks of the Mid Hills have been warped, tilted eastward, and broken by normal faults. Several locations show local, sharp anticlinal features, indicating compressional stresses. Deformation associated with this episode increases to the west of the Providence Mountains, where large plates have been thrust over middle Tertiary sediments in the Shadow Mountains and the Kingston Range. Hewett (1956) mapped Tertiary thrust faults to the north, northwest and west of the Providence Mountains in the Shadow Mountains, Clark Mountain and at Old Dad Mountain. However, no thrusts or reverse faults associated with this compressional episode have been recognized in the area of the Providence Mountains or to the southeast. By the middle Miocene epoch, crustal forces converted to extensional as the North American continental plate collided-with, then overrode the Gulf of California spreading center. This crustal tension resulted in the initiation of normal faulting throughout the Basin and Range province and the eastern Mojave Desert province.

Quaternary

The extensional tectonics which began in the middle Miocene continued into the Quaternary period. Basin and Range type horst and graben block faulting, listric en-echelon faulting, and extensive right lateral faulting associated with the onset of San Andreas right-lateral transform faulting predominated. Normal faulting and right-lateral faulting continue to the present.

Significant Geologic Resource Management Issues in Mojave National Preserve

1. Cave and Karst Issues

The Preserve has about 44 caves including talus caves, rock shelters and lava tubes. There is at least one "live" cave that is actively depositing speleothems. The park is in the process of inventorying the caves and cave habitats using volunteers. Threats to cave resources come mostly from human activities but also from a period of drought in Southern California. The monitoring questions to ask are: (1) How are cave environments changing in response to drought?; and, (2) How are human activities impacting cave resources?

2. Wind Erosion and Dust Deposition

Dust storms and the deposition of wind-blown material have a great impact on ecology of Mojave National Preserve. Dust is an important source of nutrients for soil formation. It is also important in the formation of desert crusts and desert pavement. Since dust may carry pathogens as well as radioactive material from mine tailings and other sources, there may be issues with the health and survival of indigenous species such as the desert tortoise. The Preserve is, for the most part, a donor of dust rather than a recipient. Long-term dust transport to from the park to the southeast has resulted in more fertile soils. There are presently three dust monitoring station in the Preserve. Monitoring questions include: What is the impact of dust from Asia, carrying contaminants and pathogens? What is the magnitude, duration, and frequency of dust storms in the Preserve?

3. Desert Crusts (Rare Substrates)

The desert crusts in MOJA are mainly composed of silt and carbonate material. Although desert crusts are extensive, there is little knowledge of the size and locations of the crusts. U.S.G.S geologist Dave Miller is developing a program to map and describe desert crusts using substrate geology as a proxy for crusts that are difficult to identify. Major impacts come from human activity (e.g. ORV use, hiking, administrative use) and grazing (cattle, burros). Issues include status and conditions of the crusts, nitrogen fixing, stabilizing the crusts and recoverability. What is the relationship between past conditions and human-caused activities and the current location of desert crusts?

4. Paleontological (Fossil) Resources

Fossils are exposed in the Preserve but most are not in high use areas. Fossils have been identified from the Cambrian, Devonian, Mississippian through Lower Triassic, Miocene, and Pleistocene to early

Holocene. There are few known vertebrate fossil sites and those are in hard to reach locations. Vertebrates fossils are often associated with caves and archeological sites. There is a need for a comprehensive fossil inventory. A recently initiated cave survey may identify additional fossils. Threats to paleontological resources include erosion which exposes the fossils, collection and theft by visitors, and impacts from geology field trips. Questions include: How are human impacting the paleontological resources? Where are these resources located (need inventory)? Does the stratigraphy and paleontology indicate the location of paleo-shorelines?

5. Sand Dunes

The Kelso Dunes are one of the most prominent dune systems in the California Desert (the others being Dumont and Eureka dunes) and, at 500 feet high, the third highest dune system in North America. The dune field is about 3 miles wide and 5 miles long. The dune sand is composed of 70% to 80% quartz, 10% to 30% feldspar, 5% to 10% heavy minerals and about 5% rock fragments. The heavy minerals have been the objective of several mining ventures. The heavy mineral fraction is compose mainly of magnetite, hematite, ilmenite, and amphibole. Exploration and mining were for platinum and platinum group metals but had little success in extracting any values form the sands.

The dunes have formed from sand blown from the Mojave River flood plain and playas and trapped by the Granite and Providence Mountains. Estimates of the age of the dunes vary widely and different areas of the dunes are of different ages. Generally, ages range from about 800 years up to about 20,000 years. Since mining exploration has ceased and the mining claims have been extinguished, the dunes are protected from consumptive use. The dune have been closed to off-road vehicles since 1973. One unique feature of the dunes is the “booming” created when sand grains slide over the underlying surface. The “booming” is a low vibrational sound that has been compared to a chorus.

6. Abandoned Mines

The Mojave has long been an active mining area. Commodities cover the spectrum from gold, iron and rare earth elements, to volcanic cinders, sericite, and chemical grade limestone. Abandon mines include the open pits at Coliseum, north of Interstate 15, the Morning Star Mine and the Vulcan Mine. There are numerous adits and shafts that need to be closed. MOJA staff is actively pursuing an inventory, clean-up and closure of old mine sites.

7. Groundwater

The Mojave area has a history of grazing, requiring water wells and stock tanks. Groundwater withdrawal combined with drought has resulted in a drop in the groundwater table. As grazing is phased out, grazing permits expire and ranches are purchased, the water table may recover somewhat. The Mojave River is an important source of groundwater in the Preserve. Diversion and withdrawal of water upstream from the park has decreased the amount of groundwater available. Non-native plants such as tamarisk are also contributing to the lowering of the groundwater table. There is potential for groundwater contamination from human related activities. Livestock wastes, pesticides, fertilizer, nitrates, waste oil and trash all have impacts on groundwater quality.

The Preserve has an inventory of springs underway. There is a need to determine the sources of the spring water as well as the groundwater level. Most mountain front springs are directly dependent on precipitation for recharge, i.e., water percolates down through rock strata and emerges at fracture locations under a hydrostatic head . Some springs have been diverted and used for cattle prompting the need to monitor these springs to determine the impacts of diversion and the fluctuations in flow rates. Springs are important resources and are associated with greater biodiversity. Cornfield Springs has a unique vegetative community and Paiute Springs has the largest riparian habitat in the Preserve requiring protection. Monitoring questions include: How is groundwater quality changing over time? How are groundwater levels changing and how much is due to outside human activities? What is the source of water in springs and will natural springs recover after the removal of diversions and grazing?

8. Surface Water

Surface water is scarce and most surface water comes from springs. In an arid environment, flash floods and debris flows are natural, recurring events that may cover roads, cause rapid erosion on roads and ditches, and may obliterate cultural resources. Since this occurs mostly in areas of low public use, this is not a significant issue at present. Washes, sometime used as roads, can become hazardous in times flash flooding and may be pathways for the introduction of exotics. Individual flow do not show on small scale maps (e.g. 1:100,000), therefore larger scale maps are required as well as photo-monitoring data.

9 Hazards

In an arid environment, erosion and deposition due to flash flooding always present a potential hazard (see above). Other potential hazards include slope failure either induced by seismic activity, by precipitation or by human activity, such as leaving unnaturally steepened slopes in construction areas. Monitoring questions: How are park administrative actions impacting the movement of sediment? Is a hazards map needed? Although there is seismicity in the area (the Mojave province is bounded on three sides by major faults) is does not appear to present an issue in the park.

10. Volcanic Features

MOJA has large areas of volcanic features include lava flows, cinder cones, pyroclastic deposits, lava falls, and lava tubes. Volcanic activity has occurred as recently as about 1000 years ago as evidenced by pottery chards in basalt flows. There has been extensive mining of the cinder cones up to the present. Almost all the cinder cones have been notched by mining and recreational bulldozing. The Cinder Cones area is a listed as a National Natural Landmark.

Scoping Meeting Participants

Tim Connors	Geologist	NPS, Geologic Resources Division
Sid Covington	Geologist	NPS, Geologic Resources Division
Bruce Heise	Geologist	NPS, Geologic Resources Division
Kristina Heister	Network Coordinator	NPS, Mojave Network
Debra Hughson	Science Advisor	Mojave National Preserve
Andy Leszcykowski	Mining Engineer	Mojave National Preserve

David Miller	Geologist	USGS, Menlo Park
Bonnie Murchey	Geologist	USGS, Menlo Park
Paul Stone	Geologist	USGS, Menlo Park
Ted Weasma	Geologist	Mojave National Preserve
Larry Whalon	Chief, Resource Mgt.	Mojave National Preserve
James Woolsey	Chief, Interp.	Mojave National Preserve

References

Beckerman, G.M., Robinson, J.P., and Anderson, J.L., 1982, The Teutonia Batholith: a large intrusive complex of Jurassic and Cretaceous age in the eastern Mojave Desert, California: *in* Frost, E.G., and Martin, D.L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, Nevada: Cordilleran Publishers, San Diego, CA., p. 205-221

Bishop, C.C., 1963, Geologic map of the Needles 1°x2° sheet: *in* Jenkins, O.P., ed., Geologic map of California, California Division of Mines and Geology, 1:250,000

Burchfiel, B.C. and Davis, G.A., 1981, Mojave Desert and environs: *in* Ernst, W.G., ed., The geotectonic development of California, Rubey Vol. I, Prentice Hall, Inc., p. 217-252.

Dellinger, D.A., 1988, California's unique geologic history and its role in mineral formation, with emphasis on the mineral resources of the California Desert Region: U.S. Geological Survey Circular 1024, 16p.

Dickinson, W.R., 1981, Plate tectonics and the continental margin of California: *in* Ernst, W.G., ed., The geotectonic development of California, Rubey Vol. I, Prentice Hall, Inc., p. 2-28.

Hewett, D.F., 1954, General geology of the Mojave Desert Region, California: *in* Jahns, R.H., ed., Geology of southern California: California Division of Mines and Geology, Bulletin 170, v.II, p. 5-20.

Hewett, D.F., 1956, Geology and mineral resources of the Ivanpah quadrangle, California and Nevada: U.S. Geological Survey Professional Paper 275, 1:125,000, 167 p.

Hunt, C.B., and Mabey, D.R., 1966, Stratigraphy and structure, Death Valley, California, U.S. Geological Survey Professional Paper 494-A.

Jahns, R.H., 1954, Investigations and problems of southern California Geology, *in* Jahns, R.H., ed., Geology of southern California, California Division of Mines and Geology, Bulletin 170, v. I, p. 13-29.

Lancaster, Nicholas, 1995, Kelso Dunes, *San Bernardino County Museum Association Quarterly*, v.42, no.3, p. 47-51.

Miller, David M., Bedford, David R., Phelps, Geoffrey, Schmidt, Kevin M., Lidke, Davis J., McMackin, Matthew, and Dudash, Stephanie L., 2002, Surficial geologic mapping of the Mojave National Preserve, California, *Geological Society of America 2002 Annual Meeting and Exhibition*, Denver, CO Paper No.200-2.

Miller, D.M., Miller, R.J., Nielsen, J.E., Wilshire, H.G., Howard, K.A., and Stone, Paul, 1991, Preliminary geologic map of the East Mojave National Scenic Area, California, U.S. Geological Survey Open-File Report 91-0435, 8p., 1 over-size sheet.

Nolan, 1943, The Basin and Range Province in Utah, Nevada and California: U.S. Geological Survey Professional Paper 197-D, p. 141-196.

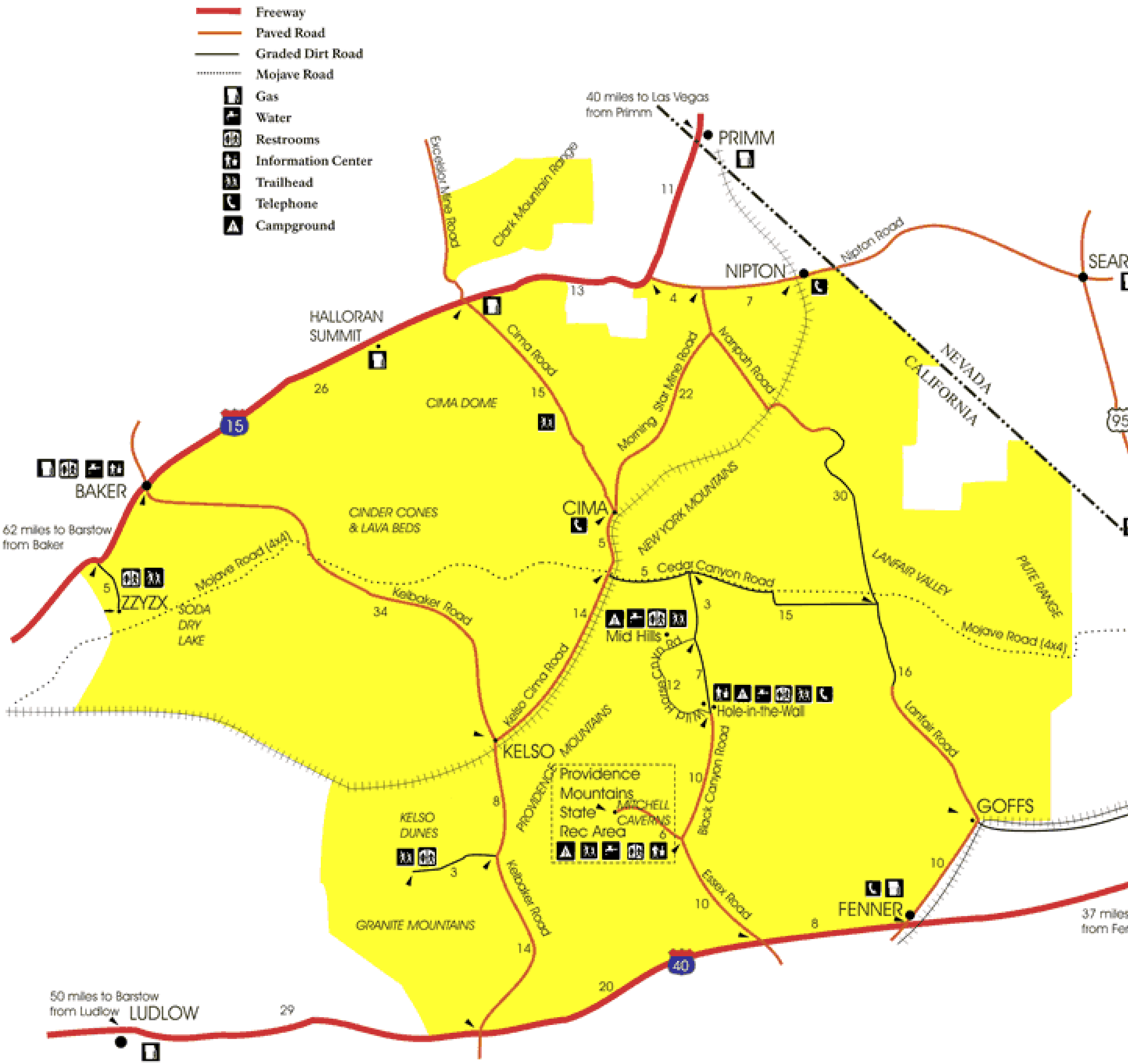
Norris, R.M., and Webb, R.W., 1976, *Geology of California*, John Wiley and Sons, Inc., p.91-122.

U.S. Geological Survey, 1991, Evaluation of metallic mineral resources and their geologic controls in the East Mojave National Scenic Area, San Bernardino Co., California, U.S. Geological Survey Open-File Report 91-427, 6 maps, 278 p.

Wasserburg, G.J., Wetherell, G.W., and Wright, L.A., 1959, Ages in the Precambrian terrain of Death Valley, California, *Journal of Geology*, v.67, no. 6, p.702-708. [H]

Wright, L.A., and others, 1974b, Precambrian sedimentary environments of the Death Valley region, eastern California: *Geological Society of America Guidebook: Death Valley region, California and Nevada*, p. 27-35.

Wright, L.A., Stewart, R.M., Gay, T.E., Jr., and Hazenbush, G.C., 1953, Mines and mineral deposits of San Bernardino County, California, *California Journal of Mines and Geology*, v.49, nos.1 and 2, 257p. and 192p.


Freeway
Paved Road
Graded Dirt Road
Mojave Road
Gas
Water
Restrooms
Information Center
Trailhead
Telephone
Campground
40 miles to Las Vegas from Primm
PRIMM
11
Excelsior Mine Road
Clark Mountain Range
NIPTON
Nipton Road
SEAR
13
4
7
HALLORAN SUMMIT
Cima Road
Ivanpah Road
NEVADA
CALIFORNIA
26
15
CIMA DOME
22
Morning Star Mine Road
15
95
BAKER
CINDER CONES & LAVA BEDS
CIMA
30
NEW YORK MOUNTAINS
62 miles to Barstow from Baker
5
Mojave Road (4x4)
5
Cedar Canyon Road
LANFAIR VALLEY
PIUTE RANGE
5
ZZYZX
SODA DRY LAKE
34
Kelbaker Road
14
3
15
Mojave Road (4x4)
Mid Hills
Wild Horse Canyon Rd
12
7
16
Hole-in-the-Wall
Kelso Cima Road
Lanfair Road
KELSO
KELSO MOUNTAINS
PROVIDENCE
Providence Mountains State Rec Area
MITCHELL CAVERNS
10
Black Canyon Road
GOFFS
8
6
KELSO DUNES
3
Essex Road
10
FENNER
10
GRANITE MOUNTAINS
Kelbaker Road
8
37 miles from Fen
14
40
20
50 miles to Barstow from Ludlow
LUDLOW
29