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Preliminary geologic map of the East Mojave National Scenic Area, California

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This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

INTRODUCTION

The East Mojave National Scenic Area is located in the northeastern part of the Mojave Desert of southeastern California. The Scenic Area is bounded by Interstate freeways and railroads on the north and south, but contains few roads and communities within it. Scenic grandeur, biologic diversity, and lack of disturbance by humans compared to the western Mojave Desert led the Bureau of Land Management to designate this part of the desert as a National Scenic Area. Broad alluviated basins separate rugged mountain ranges, the most prominent being the Clark, Ivanpah, New York, Providence, Woods, Hackberry, Granite, and Soda Mountains, the Piute Range, and Old Dad Mountain and Homer Mountain. The area is further endowed with sand-dune fields, youthful volcanic cinder cones, and unusual geologic features such as Cima dome, the largest of several domes forming broad uplands in the west-central part of the East Mojave National Scenic Area.

This preliminary geologic map portrays at 1:100,000-scale the major rock units and surficial deposits of the Scenic Area and immediately adjacent land. The map was prepared to aid in a mineral-resource assessment of the Scenic Area and represents a significant update from previous 1:250,000-scale compilations by Jennings (1961) and Bishop (1963), mostly on the basis of geologic mapping by the compilers. The map was assembled in digital form using the ALACARTE menu-driven interface (Fitzgibbon and others, 1990) for ARC/INFO so that it could be easily updated as geologic mapping progresses and to enable meshing with other digital data bases.

DESCRIPTION OF MAP UNITS

Qp Playa deposits (Holocene)--Unconsolidated clay, silt, and sand. Light-colored and sparsely vegetated

Qaf Alluvial fan deposits and alluvium (Holocene and Pleistocene)--Unconsolidated deposits of poorly sorted gravel, sand, and silt. Deposited as alluvial cones at mouths of canyons and gullies, as alluvial floodplains bordering streams, and as braided-stream sediment in stream channels. Older deposits form piedmonts flanking mountain ranges and typically underlie raised, paved, and varnished surfaces

Qes Eolian sand (Holocene and Pleistocene)--Unconsolidated fine- and medium-grained sand forming dunes and sand sheets. Most eolian sand is in vicinity of Kelso Dunes

QTbc Basalt cinder deposits (Pleistocene to late Miocene)--Unconsolidated deposits of basalt scoria fragments, consolidated pyroclastic breccia, and tuffaceous conglomerate formed by phreatic eruption during vent opening

QTbl Basalt lava flows (Pleistocene to late Miocene)--Alkaline basalt and hawaiite flows.

QTp Playa and pluvial lake deposits (Pleistocene and Pliocene)--Dissected deposits of claystone, fluvial siltstone, silty peat, sandstone, carbonate or siliceous tufa, and pebbly sandstone. Crops out east and west of southern Piute Range and north of Cima Dome

QTg Gravel (Pleistocene and Pliocene)--Moderately consolidated pebble, cobble, and sand deposits; typically underlies highly incised surfaces. Locally contains extensive pedogenic calcite

QTl Landslide and sedimentary breccia deposits (Pleistocene and Pliocene)--Displaced deposits of disaggregated rock and alluvium that form hummocky terranes. Composite of detached masses of brecciated bedrock west of Providence Mountains is probably made up of gravity-slide masses

Tg Gravel (Pliocene and Miocene)--Moderately consolidated, crudely bedded, fluvial boulder- to pebble-gravel and sand interbedded with coarse to extremely coarse debris flows deposits, avalanche breccia, and gravity-slide breccia. Sand is siliciclastic and volcaniclastic, locally arkosic. In and east of New York Mountains typically forms highly incised raised terraces. Intercalated gravity slide blocks between Cima Dome and Old Dad Mountain consist of breccias of dolomite, limestone, chert, quartzite, and volcanic, metamorphic, and granitoid rock

Tbr Sedimentary breccia deposits (Pliocene or Miocene)--Deposits of disaggregated rock and alluvium that form hummocky terranes. Deposits lie along north flank of Granite Mountains

VOLCANIC ROCKS IN THE MID HILLS-VAN WINKLE MOUNTAIN AREA

Tb Basalt (Miocene)--Alkali basalt and andesite lava flows. Olivine andesite overlying Tortoise Shell Mountain Rhyolite is about 10 Ma (McCurry, 1988).

Tts Tortoise Shell Mountain Rhyolite (Miocene)--Rhyolite lava flows and plugs, and interbedded pyroclastic material. Aphyric to porphyritic with sparse sanidine. Rhyolite is dated at 15.8 Ma (McCurry, 1988) and is chemically similar to the upper cooling unit of the Wild Horse Mesa Tuff

Tw Wild Horse Mesa Tuff (Miocene)--Prominently layered sanidine rhyolite ash-flow tuff containing common sanidine phenocrysts, and rare quartz, biotite, clinopyroxene, and magnetite phenocrysts. Mostly welded; forms three compound cooling units totalling as much as 320 m in thickness. Locally rich in lithic fragments. Forms conspicuous mesas in Woods Mountains area. Dated at about 15.8 Ma (McCurry, 1988). Probable source is a trap-door caldera in western Woods Mountains

Ths Hackberry Spring Volcanics (Miocene)--Interlayered lava flows, domes, ash flows, and dikes and plugs of trachyte, trachydacite, and rhyolite. Dated at about 16 Ma (McCurry, 1988). Crops out widely on Hackberry Mountain

Tdf Domes and flows (Miocene)--Extrusive domes and related lava flows composed of rhyodacite. Crops out near Wildhorse Mesa

Tps Peach Springs Tuff of Young and Brennan (1974) (Miocene)--Widely distributed welded ash-flow tuff composed of rhyolite containing conspicuous sanidine, with essential but minor sphene, and variable amounts of biotite and hornblende. Age is 18.5 Ma (Nielson and others, 1990). Includes underlying thin deposits of arkosic gravel in New York Mountains and limestone-clast conglomerate in Providence Mountains

Tal Airfall tuff and lava flows (Miocene)--White to buff, bedded rhyolite air-fall tuff and thin rhyolite lava flows. Includes distinctive flow-banded rhyolite at Van Winkle Mountain. Locally, olivine-pyroxene basalt flows form top of unit

Ttb Tuff breccia (Miocene)--Light-colored deposits of tuff breccia, minor air-fall tuff, and tuffaceous sedimentary rocks. Locally includes rhyolite, basalt, dacite, and andesite flows. Sedimentary rocks include waterlain tuffaceous rocks, conglomerate, and lacustrine siltstone and sandstone. Crops out at Van Winkle Mountain and south of the Granite Mountains

Tda Dacite and andesite flows (Miocene)--Thin lava flows and associated domes of intermediate composition. Crops out south of the Granite Mountains

VOLCANIC ROCKS IN THE CASTLE MOUNTAINS-PIUTE MOUNTAINS AREA

Tdr Dacite and rhyolite (Miocene)--Shallow intrusions and extrusive plugs and domes, and adjacent flows and breccia. Composed of rhyolite, rhyodacite, and dacite. Crops out mainly in Castle Mountains. Age of unit between 16.1 ± 0.4 and 12.8 ± 0.2 Ma (Turner and Glazner, 1990)

Tab Andesite and basalt (Miocene)--Lava flows and breccia composed of hornblende-pyroxene andesite and andesitic basalt. Includes sedimentary breccia deposits composed largely of andesite. Locally includes interbedded conglomerate, fanglomerate, sandstone, and siltstone. Present in New York Mountains and Piute Range

Tga Arkosic gravel (Miocene)--Generally coarse, locally-derived fluvial conglomerate and gruss, mainly consisting of Proterozoic and Mesozoic gneiss and granite. Variably indurated. Present in Piute Range

Td Dacite (Miocene)--Dacite to andesite breccia, domes, and lava flows

Tv_1 Younger volcanic rocks, undivided (Miocene)--Rhyolite lava and ash flows, basalt flows, and dacite lavas that overlie the Peach Springs Tuff

Tv_2 Older volcanic rocks, undivided (Miocene)--Rhyolite lava and ash flows, tuffaceous sedimentary rocks, tuff breccia, basalt flows, and andesite flows

Ti Shallow intrusive rocks (Miocene)--Felsic, intermediate and mafic igneous rocks emplaced as shallow intrusions and domes. Present in Granite Mountains and Lanfair Valley

f Felsite (Tertiary and/or Cretaceous)--Fine-grained felsitic igneous rocks that form dikes and irregular-shaped intrusions

Kpg Porphyritic granodiorite (Cretaceous)-- Light-colored, coarse-grained biotite granodiorite and monzogranite containing potassium feldspar phenocrysts. Present in the Fenner Hills, Piute Range, Homer Mountain, and nearby areas. Feldspar phenocrysts are 1-2 cm across except in the southern Piute Range, where phenocrysts are 2-4 cm

GRANITOID ROCKS IN THE GRANITE MOUNTAINS AREA

Kem Equigranular monzogranite (Cretaceous)--Interior unit of zoned pluton in eastern Granite Mountains. Consists of medium-grained biotite monzogranite

Kpm Porphyritic monzogranite (Cretaceous)-- Light-gray , coarse-grained biotite monzogranite containing potassium feldspar phenocrysts. Crops out widely in eastern Granite Mountains and part of Providence Mountains. It was termed the Granite of Arrowweed in southern Providence Mountains (Miller and others, 1985). Locally fine-grained

Kgd Granodiorite (Cretaceous)--Forms exterior unit on south side of zoned pluton in the eastern Granite Mountains and also forms a sheet-like pluton in the western Granite Mountains. Consists of equigranular hornblende-biotite granodiorite. Intruded by the porphyritic monzogranite unit

Kg_1 Granitoid rocks (Cretaceous)--Monzogranite, granodiorite, and more mafic rocks probably of Late Cretaceous age. Crops out east of Piute Range and at north end of Piute Mountains

Kgm Garnet two-mica monzogranite (Cretaceous)--Medium-grained syenogranite to monzogranite that crops out east of Blind Hills. A minimum age is suggested by a K-Ar age of 83 Ma on muscovite

GRANITOID ROCKS OF THE TEUTONIA BATHOLITH

Kmh Mid Hills Adamellite of Beckerman and others (1982) (Cretaceous)--Medium- to coarse-grained, porphyritic to equigranular, light tan, leucocratic monzogranite. Locally contains minor hornblende. Contains common aplite and pegmatite dikes. Crops out over much of the Mid Hills and southern New York Mountains. Unit includes intrusive breccia and brecciated felsite plugs in northern Providence Mountains. Dated as about 93 Ma by U-Pb on zircon (Ed DeWitt, 1985, oral commun.)

Kt Teutonia Adamellite of Beckerman and others (1982) (Cretaceous)--White to light tan, equigranular to porphyritic (pink alkali feldspar phenocrysts) biotite monzogranite, generally medium and coarse grained. Locally ranges in composition to syenogranite and quartz monzonite. Minor muscovite present in places. Termed "granitic rocks of Kelso Peak" by Dunne (1972). Crops out over much of Cima Dome, where it was dated as 97 Ma by U-Pb on zircon (DeWitt and others, 1984)

Klo Live Oak Canyon Granodiorite of Beckerman and others (1982) (Cretaceous)-- Equigranular, medium- to coarse-grained, light gray biotite granodiorite. Crops out in central New York Mountains. Contains rare hornblende. Contacts with Mid Hills Adamellite are gradational

Kks Kessler Springs Adamellite of Beckerman and others (1982) (Cretaceous)--Strongly porphyritic, white, biotite monzogranite and granodiorite. Phenocrysts of pink alkali feldspar are set in gray, medium-grained groundmass. Contains minor hornblende. Crops out northeast of Cima Dome. K-Ar age of biotite about 92 to 93 Ma (Burchfiel and Davis, 1971) and K-Ar age of hornblende is 92.1 ± 0.5 (Beckerman and others, 1982)

Kbc Black Canyon Hornblende Gabbro of Beckerman and others (1982) (Cretaceous)--Texturally and compositionally variable black hornblende gabbro, with minor quartz diorite, and monzodiorite. Medium grained and equigranular. Contains abundant hornblende and lesser clinopyroxene or biotite

Krs Rock Spring Monzodiorite of Beckerman and others (1982) (Cretaceous)--Porphyritic, dark-gray to brown, compositionally variable rock comprising a compositionally zoned pluton in the Mid Hills. Common rock types are hornblende-biotite monzodiorite, quartz monzodiorite, and quartz monzonite; mafic hornblende-clinopyroxene diorite is present along the north edge of the pluton. Contains abundant mafic inclusions. Considered to be Jurassic in age by Beckerman and others (1982), but dated as about 97 Ma by U-Pb on zircon (Ed DeWitt, 1985, oral commun.). Intruded by Mid Hills Adamellite

Kb Biotite-rich granitoid (Cretaceous)--Gray equigranular to porphyritic (small pink alkali feldspar phenocrysts) biotite granitoid rocks, generally medium or coarse-grained. Biotite content 10% by volume or greater; biotite-rich schlieren widely present, abundant in places. Mapped in Halloran Wash and to south. Considered Cretaceous by DeWitt and others (1984)

Kd Diorite (Cretaceous)-- Hornblende diorite west of Cima Dome

Kg_2 Granitoid rocks (Cretaceous)--Monzogranite, granodiorite, and more mafic rocks similar to granitoids of the mid-Cretaceous Teutonia batholith

JURASSIC GRANITOID ROCKS OF THE PROVIDENCE MOUNTAINS AREA

Jsd Sheeted dikes (Jurassic)--Felsic to intermediate dikes in complex sheeted mass along west side of southern Providence Mountains

Jtn Granite of Tough Nut Spring (Jurassic)--Dark pink to medium brown, coarse-grained, subequigranular to porphyritic biotite syenogranite and monzogranite. Potassium feldspar phenocrysts typically pink or purple. Mapped as Ivanpah Granite by Goldfarb and others (1988), but is less porphyritic

Jfp Fountain Peak Rhyolite (Jurassic)--Dark pink, hypabyssal granite and siliceous, generally aphyric, flow-banded rhyodacite. Locally contains biotite. Feeder dike dated as Jurassic (J.D. Walker, 1988, oral commun.)

Jwb Quartz syenite of Winston Basin (Jurassic)--Coarse-grained, markedly porphyritic quartz syenite, syenogranite, and monzogranite. Melanocratic with purple to pink phenocrysts. Contains augite, hornblende, and biotite

Jcf Felsic rocks of Colton Hills (Jurassic)--White, coarse-grained, porphyritic biotite monzogranite and finer grained felsic rocks of gray color. Includes yellow to pink, quartz-rich, coarse-grained biotite monzogranite near Bonanza King Well, east side of Providence Mountains

Jgo Quartz monzonite of Goldstone (Jurassic)--Dark-colored, medium- and coarse-grained, porphyritic to subequigranular rock of variable composition; quartz monzonite predominates but rock ranges to quartz syenite and quartz monzodiorite. Mafic phases are biotite, hornblende, and augite. K-Ar age for biotite is 157.0 ± 3.9 Ma; U-Pb age for zircon is approximately 162 to 164 Ma (Miller and others, 1985)

Jcm Mesocratic rocks of Colton Hills (Jurassic)--Dark-colored, fine- to coarse-grained, complexly variable monzonite, quartz monzonite, quartz syenite, monzogranite, and minor gabbro. Biotite, hornblende, and augite are chief mafic minerals. Rocks are widely altered

Jqs Syenogranite of Quail Spring (Jurassic)--Dark-colored, medium- to coarse-grained, hornblende-biotite syenogranite; ranges to quartz monzonite and quartz monzodiorite. Commonly extensively altered

Jd Diorite (Jurassic)--Dark brown to black hornblende diorite, hornblende-biotite monzodiorite, and mafic porphyritic hornblende-biotite quartz monzonite

Jh Hypabyssal and metavolcanic rocks (Jurassic)--Dark-weathering, highly chloritized, quartz-poor hypabyssal and volcanic rocks. Crops out in southeastern Providence Mountains

Js Sands Granite of Hewett (1956) (Jurassic)--Pale pink, coarse-grained, leucocratic alkali-feldspar granite characterized by perthitic potassium feldspar phenocrysts and granophyric texture (Dunne, 1972; Novitsky-Evans, 1978). Crops out in Devils Playground area

Jlg Leucocratic granite (Jurassic)--Pale pink, medium-grained, leucocratic granite in Granite Mountains

Jig Ivanpah Granite (Jurassic)--Dark pink to tan, coarse-grained, porphyritic biotite syenogranite to monzogranite in the Ivanpah Mountains and east of Cima. Common weakly developed magmatic foliation is defined by aligned feldspar and biotite. Minor hornblende or muscovite is present. K-Ar ages of 136 to 138 Ma (Sutter, 1968) interpreted here as minimum ages; preliminary U-Pb data for zircon suggest crystallization age of 145 Ma (J.D. Walker, 1991, oral commun.)

Jqd Quartz diorite gneiss (Jurassic)--Hornblende quartz diorite and quartz monzodiorite containing megacrysts of potassium feldspar. Age about 160 Ma. Present in the Granite Mountains

Jsq Spotted quartz monzonite (Jurassic)--Medium- to fine-grained hornblende-biotite quartz monzonite, buff-colored. Small mafic mineral clots are conspicuous. Present in the Granite Mountains

Jqg Quartz monzodiorite and granodiorite (Jurassic)--Foliated medium-grained rocks ranging in composition from granodiorite to diorite. Locally porphyritic. Present in the Clipper Mountains. Forms the Goldhammer pluton

Jsm Striped Mountain pluton (Jurassic)--Hornblende diorite that crops out in Striped Mountain. K-Ar age of hornblende about 162 to 167 Ma so we consider it to be similar in age to other Jurassic granitoids, but Burchfiel and Davis (1971) suggested that it might be as old as 200 Ma

Jbp Breccia pluton (Jurassic)--Hornblende diorite in Mescal Range. K-Ar age of hornblende at about 190 to 200 Ma may indicate a Triassic age (Burchfiel and Davis, 1971). Map unit includes similar rocks in Clark Mountain

Jg Granitoid rocks, undivided (Jurassic)--Hornblende-biotite granodiorite, porphyritic granite and alkali granite, biotite-hornblende monzodiorite and related rocks. Potassium feldspar phenocrysts in porphyritic granitoids typically pink or purple

KJg Granitoid rocks, undivided (Cretaceous and Jurassic)--Monzogranite, granodiorite, and more mafic rocks of Mesozoic age. Present in Soda, Ivanpah, and Kelso Mountains

KJgr Granite (Cretaceous and/or Jurassic)--White, medium- to coarse-grained granite near Baker (Grose, 1959)

KJcm Granitoid rocks of Cowhole Mountains (Cretaceous and/or Jurassic)--Hornblende-bearing monzogranite, quartz monzonite, and quartz monzodiorite that is pink to purplish pink, medium-grained, and equigranular to porphyritic with phenocrysts of potassium feldspar (Dunne, 1972). Locally contains secondary epidote and chlorite (Novitsky-Evans, 1978). Age uncertain but pinkish color suggests possibly Jurassic (cf. Miller and others, 1982)

Ja Aztec Sandstone (Jurassic)--Prominently cross-bedded quartz arenite, typically red, yellow, or buff in color. Contains lenses of conglomerate in Old Dad Mountain exposures and interbeds of felsic volcanic rocks in several places. Also present at Cowhole Mountain and Mescal Range

TRm Moenkopi Formation (Triassic)--Thin-bedded limestone, sandy and silty limestone, calcareous shale, and sandstone present at Old Dad Mountain and Mescal Range. Metamorphosed calcsilicate rocks in New York Mountains are tentatively correlated with the Moenkopi (Burchfiel and Davis, 1977)

Mzv Volcanic and sedimentary rocks (Mesozoic)--Volcanic flows, flow-breccia, tuff, volcaniclastic rocks, quartzite, and conglomerate. Includes rocks (termed the Delfonte Volcanics locally) interfingering with or overlying Aztec Sandstone and metavolcanic rocks lying above the Moenkopi Formation and equivalent sedimentary rocks. Volcanic rocks lying above the Aztec Sandstone in the Cowhole Mountains were dated at 167 Ma by Busby-Spera (1988). Metavolcanic rocks lying below the Moenkopi Formation are considered Jurassic or Triassic (Dunne, 1977). Locally includes hypabyssal rocks. Unit in central New York Mountains consists of felsic metavolcanic rocks with lesser sedimentary rocks, all underlain by basal conglomerate (Burchfiel and Davis, 1977). Sedimentary rocks included in this unit at Providence Mountains are shale, sandstone, conglomerate, and impure limestone; part of this section probably correlates with the Moenkopi Formation (Hazzard, 1954). Also present at Soda Mountains and Ivanpah Mountains

PDl Limestone (Permian to Devonian)--Consists of the Permian and Pennsylvanian Bird Spring Formation (thick-bedded cherty, sandy and pure limestone); the Mississippian Monte Cristo Limestone (massive pure, coarse limestone, cherty in lower part); and the Devonian Sultan Formation (medium-bedded, interlayered limestone and dolomite)

-Cd Dolomite (Cambrian)--Buff and gray, generally thin bedded dolomite; argillaceous in lower part. Consists of the Nopah and Bonanza King Formations. Widely distributed over map area

-CZs Siliciclastic rocks (Cambrian and Late Proterozoic)--Interbedded limestone, siltstone, and shale in upper part of unit and quartzitic rocks in lower part. Includes the Carrara Formation, Zabriskie Quartzite, Wood Canyon Quartzite, and Stirling Quartzite. Probably includes thin equivalents of one or both of the Johnnie Formation and the Noonday Dolomite in Old Dad Mountain and Providence Mountains (Dunne, 1977; Stewart, 1970)

Pzc Carbonate rocks (Paleozoic)--Undivided dolomite, limestone, and marble; metamorphosed in many places

Zs Sedimentary rocks (Late Proterozoic)--Shale, siltstone, diamictite, and dolomite. Corresponds to the Johnnie Formation, Noonday Dolomite, and Kingston Peak Formation. Outcrop is in thrust sheets of the Ivanpah Mountains, Mescal Range, and Clark Mountain.

Yg Granitoids (Middle Proterozoic)--Alkalic igneous rocks including granite, syenite, shonkinite, and carbonatite. Outcrop is in the Mountain Pass area. About 1400 Ma (DeWitt and others, 1987)

Xg_1 Younger granitoids (Early Proterozoic)--Granite, granodiorite, and diorite between 1660 and 1695 Ma (Wooden and Miller, 1990). Common rock types are strongly porphyritic biotite granite, inequigranular leucocratic granite, and hornblende-biotite granodiorite. Locally foliated. Crops out widely from northern New York Mountains south to Vontrigger Hills

Xg_2 Intermediate-age granitoids (Early Proterozoic)--Augen gneiss and subequigranular gneiss of biotite granite and biotite granodiorite composition, about 1700 to 1715 Ma (Wooden and Miller, 1990). One pluton crops out in northern New York Mountains, and an igneous complex of this age crops out in the northern Providence Mountains. Orthogneiss of this age was identified in the Halloran Hills (DeWitt and others, 1984) but is grouped with surrounding undivided gneiss and granitoids (unit Xg) here

Xa Amphibolite (Early Proterozoic)--Massive amphibolite and layered amphibolite gneiss containing amphibole, pyroxene, garnet, and biotite in varying ratios. Includes granulite facies mafic rock containing orthopyroxene. Intrudes older granitoids and is interlayered in migmatite

Xg_3 Older granitoids (Early Proterozoic)--Pyroxene diorite, biotite-hornblende tonalite, and biotite granodiorite augen gneiss older than 1730 Ma (Wooden and Miller, 1990). Crops out as mafic complex west of Ivanpah Valley

Xm Migmatite (Early Proterozoic)--Highly metamorphosed, compositionally-layered rocks of supracrustal protolith. Includes quartzo-feldspathic gneiss, garnet-bearing leucocratic layers and dikes, pelitic biotite-sillimanite-potassium feldspar gneiss, tonalitic gneiss, and biotite-garnet gneiss. Compositional range for many rocks is similar to intermediate volcanic rocks such as dacite or immature sedimentary rocks such as graywacke (Wooden and Miller, 1990)

Xg Gneiss and granitoids (Early Proterozoic)--Undivided migmatite, granitoid gneiss, and granitoids mapped in many poorly known locations across Scenic Area. Includes quartzite and quartzofeldspathic paragneiss in Old Dad Mountain

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