Map Unit Properties Table

Colored rows indicate map units within Manzanar National Historic Site.

Age	Unit Name (Symbol)	Features and Description	Erosion Resistance	Suitability for Development	Hazards	Paleontological Resources	Cultural Resources	Karst	Mineral Occurrence	Habitat	Recreation	Geologic Significance
QUATERNARY	Active alluvium (Qal) Eolian sand (Qes) Younger lake deposits (Qly) Rock glaciers (Qrg) Talus, regolith, and colluviums (Qt) Inactive alluvium (Qai)	***Qal*** forms floors of active channels, washes and fan surfaces comprised of sand and fine to coarse gravel. ***Qes*** contains sand sheets locally thicker than 2 m (7 ft)with some dunes. ***Qly*** contains bar and beach gravels, sand, clay, and silt with some cemented ooliths, and some local salt accumulations in the upper 1–2 m (3–7 ft). ***Qrg*** forms lobate masses of poorly sorted angular boulders and finer-grained material with some interstitial ice cores. ***Qt*** is composed of broken and weathered rock debris with some local buried soil horizons. ***Qai*** contains fine to coarse gravels atop inactive fan surfaces with some local fine sand to pebble grus and angular, poorly sorted gravel.	Very low	Suitable for light development unless exposed and/or undercut on a slope. Avoid for septic systems due to high permeability.	Units are prone to slumping and sliding when exposed on slopes. Especially when water-saturated, seismic activity may loosen thick masses of deposits, rendering them susceptible to mass wasting.	Modern remains; Pleistocene soil horizons may contain fossils and root traces; ice cores may contain paleoclimate information (oxygen isotopes, pollen, etc).	Modern artifacts	None	Sand, gravel, silt, clay, pebbles	Units provide burrow habitat and support some riparian habitat along streams.	Relatively sorted units are suitable for most recreation; jumbled units are unstable and unsafe for trail bases.	Units record Holocene conditions throughout the area. ***Qly*** records the presence of Owens Lake at larger size than today since diversion of Owens River into L.A. aqueduct in 1913. ***Qrg*** records local glaciation in Sierra Nevada cirques.
QUATERNARY	Very large boulder gravels (Qgvl) Debris-flow deposits (Qdf) Older lake deposits (Qlo) Younger alluvial and debris-flow gravels (Qgy)	***Qgvl*** forms gravel terraces 2–5 m (7–16 ft) above modern stream channel alluvium, boulders are locally 2–15 m (7–49 ft) in diameter. ***Qdf*** contains unsorted 2–4 m (7–13 ft) thick layers of angular clasts and little matrix. Clasts are as large as 0.5 m (1.6 ft) in diameter. ***Qlo*** contains massive to well-bedded deposits of light tan silt and sand with a few gravel layers near paleoshorelines, may be as much as 2,500 m (8,200 ft) thick. ***Qgy*** contains abundant subangular to subrounded cobbles and boulders derived from plutonic rocks in a sandy-gravely matrix. Boulders of two different ages (differentiated by degree of weathering and oxide staining) may approach 2 m (7 ft) in diameter and display igneous porphyritic textures and mafic inclusions.	Very low	Avoid most large boulder areas and debris flow deposits for heavy development due to instability of slopes, likelihood of future movement, and high permeability.	Units are associated with stream-edge slopes, and mass movements deposited by gravity, water, and debris-flow processes.	Lake fossils (fish, plant fragments, algae) are possible in this unit.	There is a slight chance units may contain modern artifacts.	None	Boulders (some with mafic igneous mineral inclusions), sand, gravel	Unit may support small mammal burrow habitat.	Unit may be attractive to climbers, but should be avoided for most recreation as unstable surfaces are an unsuitable trail base.	Exposed boulders date to 2,000–1,200 years ago. ***Qlo*** may contain Tertiary age deposits and record deposition in a structural depression between Owens Valley and Inyo-White Mountains fault zones.
QUATERNARY	Glacial moraines (Qm) Older alluvial and debris-flow gravels (Qgo)	***Qm*** contains poorly sorted massive gravel and boulder deposits as well as till deposits and ridge crests. ***Qgo*** contains coarse sand and fine gravel with occasional cobbles and boulders derived from felsic plutonic rocks. Beds are stained by iron oxide, yielding orange to greenish-gray tones.	Very low	Unit acts as an aquitard to groundwater percolation. Due to heterogeneity of units, avoid for most development including wastewater treatment facilities.	Poorly sorted nature of units render them unstable on slopes, ***Qgo*** is associated with mass wasting due to movement by water and gravity.	Pleistocene macrofauna remains are possible in this unit.	Oxides may have provided paint material for American Indians.	None	Sand, gravel, igneous rock boulders. Unit contains large subhedral feldspar crystals up to 6 cm (2 in) long.	Unit supports thick stands of vegetation where windblown soils have accumulated due to aquitard habit.	Units may be suitable for mountain bike course, avoid areas associated with mass movements.	Unit records Tahoe and Tioga glacial events.
TERTIARY – QUATERNARY	Landslide deposits (QTls)	***QTls*** forms dissected lobate hummocky masses of unsorted rock debris. Larger blocks are typically plutonic (gneissic or mafic) boulders.	Very low	Unsorted, jumbled mass of rock debris should be avoided for development.	Unit is associated with mass wasting processes facilitated by water and gravity, jumbled masses are unsafe to traverse on foot.	Fossil remains possible	None documented	None	Gravel and igneous rock boulders including fine-grained granitic boulders from the granite of French Spring	Unit may support small mammal burrow habitat.	Unit may be attractive to climbers, but should be avoided for most recreation.	Unit records slope processes of Pleistocene age and thus local tectonic activity.
CRETACEOUS	Whitney Granodiorite (Kwg) Paradise Granodiorite (Kpg) Granodiorite of Lone Pine Creek (Klp)	***Kwg*** contains porphyritic granodiorite and granite with an average of 71% quartz. ***Kpg*** is porphyritic granodiorite and granite at 70% quartz with abundant zonally arranged inclusions of biotite and hornblende. ***Klp*** contains dark granodiorite with locally finer-grained areas and abundant mafic inclusions with 64% quartz.	Very high	Unit may contain radon-emitting minerals, avoid for basements, suitable for most development unless highly fractured.	Unit is susceptible to sheet-like exfoliation weathering and may pose a blockfall hazard on slopes.	None	None documented	None	Fine-grained igneous rocks may be useful as building material. Potassium feldspar phenocrysts up to 8 cm (3 in) long and mafic inclusions also present.	None documented	Suitable for most recreation; plutonic rocks may attract climbers.	K-Ar date of 83 million years ago (Ma), Pb-U date of 83 Ma for ***Kw***. Biotite K-Ar date of 78 Ma, Pb-U age of 86 to 83 Ma, and hornblende K-Ar date of 84 Ma for ***Kpg***. ***Klp*** has a Pb-U age of 87 Ma.

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CRETACEOUS	Dragon Pluton (Kd) Independence Pluton (Kip) Granite of Carroll Creek (Kcc) Alabama Hills Granite (Kah) Kern Knob Granite (Kkg)	***Kd*** is quartz monzodiorite and quartz monzonite with average quartz content of 69%. ***Kip*** is light colored granite with approximately 74% quartz. ***Kcc*** contains 72% quartz in coarse-grained granite, cross cut by ***Klp***. ***Kah*** contains biotite monzogranite with hypidiomorphic seriate to faintly porphyritic textures that appears pale orange to pinkish-gray in outcrop. Some prominent pegmatite dikes present locally. ***Kkg*** contains medium-grained biotite monzogranite exposed on Kern Knob	High	Possibility of radon emission from alteration and decay of potassium, avoid for basements	Unit is susceptible to sheet-like exfoliation weathering and may pose a blockfall hazard on slopes, pegmatite may pose rockfall hazard if more resistant than surrounding rocks.	None	Large crystals may have provided trade material for American Indians	None	Fine-grained igneous rocks may be useful as building material. Potassium feldspar phenocrysts up to 1 cm (0.4 in) long, fluorite, garnet, hematite, amazonite, aplite, pegmatite dike minerals present.	None documented	Suitable for most recreation; plutonic rocks may attract climbers.	***Kd*** has Pb-U date of 103 Ma. ***Kip*** has Pb-U age of 112 Ma. ***Kah*** has biotite K-Ar age of 82 Ma and Pb-U age of 85 Ma. Mixed country rocks on margins of ***Kah*** record conditions of emplacement and ***Kkg*** has an Ar/Ar age of 91 Ma.
JURASSIC – CRETACEOUS	Felsic dike (KJf) Mafic, intermediate-composition, and minor felsic dikes (KJd)	***KJf*** is a light gray dike, aphanitic in texture and felsic in composition, approximately 4 m (13 ft) thick. ***KJd*** contains aphanitic to fine-grained porphyritic dikes of compositions ranging from diorite to granite. Some mafic areas locally present. Most dikes are vertical to subvertical and strike northwest. Swarms may constitute up to 90% of a local rock volume.	Moderately high	Avoid highly altered and/or fractured areas, heterogeneity of dike localities and morphologies may render units unstable for heavy foundations.	Unit may pose rockfall hazard if undercut or exposed on a slope.	None	Aphanitic rock may have been used by American Indians for tool material	None	None documented	Unit may form ledges attractive to birds if exposed on slopes.	Suitable for most recreation unless unit is resistant relative to surrounding rocks.	***KJf*** may correlate with 140 Ma felsic dikes or a 148 Ma French Spring granite. ***KJd*** may be associated with ***Javl***, has Pb-U age of 148 Ma.
JURASSIC	Volcanic complex of the Alabama Hills, upper part (Javu) lower part (Javl)	***Javu*** has upper layers of light to medium gray, massive slightly welded tuff at least 450 m (1,500 ft) thick with 18–28% phenocrysts in an aphanitic matrix. Lower layers of unit consist of muscovite schist, quartzite, and rare volcanogenic conglomerate with a thickness of about 10 m (33 ft). ***Javl*** contains an upper volcanogenic sedimentary sequence with volcanic rocks atop a lower subunit of rhyolite tuff beds. Sedimentary layers include weakly bedded to massive pebble to cobble conglomerate, siltstone, sandstone, and pebbly sandstone. Lower subunit is grayish-pink to yellowish-gray, massive and slightly welded with some phenocrysts.	Moderate	Unit may contain radon-emitting materials and shrink-and-swell clays if altered. Heterogeneous nature of unit may be undesirable for development on slopes.	Shrink-and-swell clays may buckle trail bases and be slippery when water-saturated; rockfall hazard associated with resistant units (massive conglomerate) underlain by weaker units.	Fossils possible, but unlikely in sedimentary units	Aphanitic rock may have been used by American Indians for tool material	None	Flattened pumice lapilli, lithic lapilli, quartz, potassium feldspar, plagioclase, and biotite phenocrysts, vesicles	Vesicles and vugs may provide burrow habitat and nesting areas if exposed on cliffs.	More resistant layers—con-glomerate—may attract climbers, avoid thinly bedded areas	***Javu*** has a Pb-U age of 170 Ma, ***Javl*** has a Pb-U age of 167 Ma for tuff layers.
JURASSIC	Inyo Mountains Volcanic Complex of Dunne and others (1998) upper part (Jivu) middle part (Jivm) lower part (Jivl)	***Jivu*** is 900–2,200 m (3,000–7,200 ft) thick unit of massive to faintly bedded, matrix-supported volcanogenic conglomerate, with some parallel-bedded to crossbedded sandstone and siltstone that comprises about 30% of the unit and some lenses of felsic to intermediate silica composition tuff. ***Jivm*** is comprised of andesite and rhyolite lava flows with some bedded to massive volcanogenic sandstone and conglomerate beds and rarer rhyolite tuff layers (about 20% of the unit). Total thickness is around 750 m (2,500 ft). ***Jivl*** contains predominantly matrix-supported, volcano-genic, massive pebble, cobble, and boulder conglomerate with some parallel-bedded to crossbedded volcanogenic sandstone and pebbly sandstone interbeds comprising close to 20% of the unit. Unit also contains sparse lenticular lava flows of basalt and andesite. Total thickness about 300 m (980 ft).	Moderate	Heterogeneous nature of unit may render it unstable in areas of thin bedding, pervasive alteration, heavy fracture density, and high degree of foliation and/or deformation.	Where altered, unit may contain shrink-and-swell clays.	Freshwater pelecypods, gastropods	None documented	None	Abrasives; Vesicles in basalt and andesite flows may contain secondary minerals.	Units support a wide variety of habitats; boulder con-glomerate may weather out forming vugs for nests.	Units may attract climbers and scramblers; avoid relatively heterogeneous areas for development of recreational facilities.	*Jivu* has Pb-U ages of 173, 148, and 150 Ma. ***Jivm*** has Pb-U age dates of 168 and 169 Ma

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JURASSIC	Pat Keyes Pluton (Jpk) Intrusive rocks marginal to Pat Keyes Pluton (Jir)	***Jpk*** contains plutonic rocks of varying compositions and textures from medium-grained, hypidiomorphic granular to seriate. Unit appears medium to light gray in outcrop and has monzogranite to granitic composition that grades irregularly into a mafic border facies of monzodiorite, quartz diorite, and diorite. ***Jir*** contains dark gray fine-grained, altered and recrystallized diorite and tonalite. These appear reddish-brown in outcrop and are sausseritized and sericitized in irregular masses. Some metasedimentary rocks and irregular light-colored intrusions locally present.	High to moderately high for altered areas	Unit may contain radon-emitting minerals, avoid for basements, (especially altered areas); suitable for most development unless highly fractured.	Unit is susceptible to sheet-like exfoliation weathering and may pose a blockfall hazard on slopes; sausseritized and sericitized areas are friable and prone to slides.	Fossils possible, but unlikely in locally present metasedimentary units	None documented	Not enough carbonate present	Igneous rocks may make attractive building stones. Minerals include clinopyroxene, biotite, hornblende, quartz, plagioclase, epidote, clinozoisite, calcite, sericite	Units support wide range of habitats	Units are suitable for most recreation; may attract climbers; avoid heavily altered areas for recreation area development.	Hornblende K-Ar ages of 178 and 163 Ma, Rb-Sr whole rock age of 183 Ma. ***Jir*** records metamorphic conditions and regional tectonic events, possibly contemporaneous with ***Jpk***
TRIASSIC	Union Wash Formation (TRu)	***TRu*** consists of a 90 m (300 ft) thick upper member of dark gray micritic limestone, pink shale, and light-brown siltstone, a middle member of medium to dark gray, thin-bedded mudstone, siltstone, very fine-grained to fine-grained sandstone, and micritic limestone about 680 m (2,200 ft) thick, and locally a 60 m (200 ft) thick lower member of ledge-forming, light gray to brown limestone and silty to fine-grained sandy limestone.	Moderate	Prominent cleavage, thin to massive bedding, heterogeneous composition and minor dissolution in these units may render them too weak on slopes for heavy development.	Slaty layers are prone to slides and conglomeratic blocks may pose rockfall hazard if underlain by weaker siltstone and mudstone units.	Ammonoids	None documented	Some dissolution is possible for this unit, pervasive cave formation is unlikely	Building material from ledge-forming limestone and sandstone. Hydrothermal and metamorphic talc also present.	Unit supports wide range of habitats.	Unit is suitable for most recreation unless exposed on a steep slope.	Records the development of Triassic basins in the area
TRIASSIC & PERMIAN	Owens Valley Group divided into: Conglomerate Mesa Formation (TRPc) Lone Pine Formation, Reward Conglomerate Member and member C, upper part (Plu) members A and B lower part (Pll)	***TRPc*** contains a 40 m (130 ft) thick upper unit of brown, ochre, and gray chert pebble conglomerate, pebbly calcareous sandstone and noncalcareous sandstone, as well as a 130 m (430 ft) thick lower unit of gray to brown limestone, silty and sandy limestone, and some grayish-orange-maroon shale. ***Plu*** contains 200 m (660 ft) of dark gray to brown, thick-bedded, medium to coarse-grained quartzite and chert and quartzite pebble conglomerate. ***Pll*** contains 180 m (590 ft) of greenish-gray to reddish-brown, thin-bedded calcareous mudstone, siltstone, and calc-hornfels rocks with some gray bioclastic limestone-marble up to 3 m (10 ft) thick. Lower beds are 500 m (1,600 ft) of metamorphosed gray to reddish-brown argillite, siltite, quartzite, and calc-hornfels with metamorphic grade decreasing eastwards.	Moderate to moderately high for quartzite layers	Unit is suitable for most types of development; avoid areas of relatively high slope, alteration, heterogeneity and/or fracture density.	Heterogeneity of rock types within these units render them prone to mass wasting on slopes. Especially if water-saturated, cobbles may weather out of conglomerate layers and pose a local rockfall hazard.	Brachiopods, gastropods, bryozoans, echinoderm debris	Chert pebbles may have provided tool material and trade goods for American Indians	Some dissolution is possible for this unit; pervasive cave formation is unlikely.	Marble, quartzite for building stones. Calc-hornfels and associated contact metamorphic minerals also present.	None documented	More resistant layers (quartzite, conglomerate) may attract climbers.	Units record Permian–Triassic transition in an open basin environment.
MESOZOIC	Metavolcanic rocks (MZv) Mafic plutonic rocks (MZm)	***MZv*** contains metarhyolite and metadacite with some minor metabasalt flows. ***MZm*** contains quartz diorite, diorite, and hornblende gabbro, crosscut by ***Kip*** and ***Klp***.	Moderately high	Suitable for most development unless highly altered; radon may be present from radioactive decay of certain minerals, avoid for basements.	Possibility of radon emission from metarhyolite and other K-bearing rocks; rockfall associated with outcrops present on slopes and ledges.	None	None documented	None	Amygdules may be present in metabasalt flows, calc-hornfels and associated contact metamorphic minerals	Units may weather to produce high Al, Ca, Mg, and Fe soils.	Suitable for most recreation; plutonic rocks may attract climbers.	Records metamorphism and deformation of Late Triassic-Jurassic.
PERMIAN & PENNSYLVANIAN	Keeler Canyon Formation (PPNk)	***PPNk*** is approximately 500 m (1,600 ft) of light to medium gray, medium- to thick-bedded limestone and silty and sandy limestone. Some calc-hornfels areas. All layers have undergone metamorphism.	Moderate	Unit is suitable for most development; avoid areas of relatively high heterogeneity or fracture density.	Units are associated with blockfall on slopes where more resistant layers form undercut ledges	Unit may contain metamorphosed fossil remains.	None documented	Some dissolution, perhaps even caves, is possible for this unit	Marble, calc-hornfels minerals	Unit weathers to produce Ca-, Mg- rich soils	Unit is suitable for most recreation unless fractured on a slope.	Unit records metamorphic conditions and a former basin depositional setting during the late Paleozoic.
PALEOZOIC?	Metasedimentary rocks (PZm)	***PZm*** contains undifferentiated calcitic marble and calc-hornfels metamorphic rocks forming a small pendant-shaped area within the ***Kah*** unit.	Moderately high	Suitable for most development unless locally fractured and/or heavily altered.	If undercut on a slope or highly fractured, unit may pose a rockfall hazard.	Unit may contain metamorphosed fossil remains.	None documented	Very minor dissolution is possible.	Marble and calc-hornfels minerals	Unit weathers to produce Ca-, Mg- rich soils.	Unit is suitable for most recreation.	Unit records sedimentary deposition environment throughout the Paleozoic as well as metamorphic changes.