Surficial Geologic Map of the Darwin Hills 30′ x 60′ Quadrangle, Inyo County, California

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Introduction

This map shows the distribution of surficial deposits within the Darwin Hills 30’ x 60’ quadrangle, Inyo County, California, located between 36° to 36.5° latitude and 117° to 118° longitude. The quadrangle extends from the southern Owens Valley and Coso Range on the west to the northern and central Panamint Range on the east. Four additional 7.5’ quadrangles are included along the westernmost edge of the quadrangle adjacent to the Sierra Nevada range front to completely show the west side of the Owens Valley basin area. A limited time period was available for mapping the quadrangle; field studies were conducted during the field seasons from 2001 until 2004. Remote sensing images, digital orthophoto quadrangles, and 1:80,000-scale air photos were used extensively to delineate map units in addition to field observations.

The map area consists of four principal geologic and geomorphic domains: Quaternary and Pliocene basin deposits, Quaternary and Pliocene volcanic rocks, late Miocene and early Pliocene erosional surfaces or peneplains, and Mesozoic or older plutonic and metamorphic rocks. There is no preserved lithologic record between about 80 Ma and 13 Ma in the map area and most of the Tertiary record is not much older than about 6 to 7 Ma, or early Pliocene and very latest Miocene age. Late Miocene rocks of about 12 to 13 Ma have been identified on the east flank of the Argus Range near Shepherd Canyon, but they occupy less than 1 percent of the map area, although they do occur in much greater abundance in adjacent regions south and east of the map area.

This map shows both conventional geologic units and several geomorphic units that show the distribution of pediment surfaces, paleotopography, or other features of tectonic significance. Most of the surficial deposits were shed from present-day mountain ranges. Older Tertiary sedimentary deposits may in part be derived from an ancestral landscape with significantly different headwaters and fluvial systems than are present in the area today.

The basins are dominated by late Quaternary alluvial fan and playa deposits. These deposits are regionally differentiated by geomorphic expression, weathering, and erosional characteristics in addition to other stratigraphic properties (Birkeland and others, 1991; Bull, 1991). The ages of the fan units mainly represent the age of the material exposed at the surface (Bull, 1991). Extensive areas consist of a thin veneer of alluvial sediment that overlies erosionally developed pediment surfaces. The pediments are annotated with a unit symbol that identifies the primary lithology underlying the clastic veneer to provide additional information about the subsurface geology.

In addition to surficial deposits, areas of late Tertiary paleo-erosional surfaces or peneplains have also been mapped based on their geomorphic expression, presence of lag gravels, and lateral continuity with unconformably overlying late Miocene and (or) Pliocene deposits. These relict peneplains provide important strain markers for identifying step-faulting, warping, and tilting of blocks within the ranges (a widespread component of the late Neogene and Quaternary tectonic activity).

Significant chronologic studies and geologic mapping preceded this work. The geology of five 1:62,500 scale quadrangles within this map area are published (fig. 1). Tertiary deposits were mapped in the western part of the quadrangle by Stinson (1977a, b). Duffield and Bacon (1981) mapped the Quaternary alluvium and volcanic rocks of the Coso Volcanic center at 1:50,000 scale. Tertiary volcanic and clastic alluvial deposits were mapped in the northeastern part of the quadrangle by Hall (1971). Tertiary, mainly Pliocene, basaltic flows are extensive throughout the western and northern parts of the map area (Duffield and others, 1980; Bacon and others, 1982; Schweig, 1989) and provide important structural and chronological event boundaries. A map showing Quaternary faults and lineaments has been published for the east half of the quadrangle at 1:100,000 scale by Reheis (1991); otherwise, little of the extensive surficial basin deposits have been previously mapped in any detail.

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DESCRIPTION OF MAP UNITS

[Some unit exposures on the plotted map are too small to distinguish the color for unit identification. These units are labeled where possible, and unlabeled units are attributed in the database.]

SURFICIAL DEPOSITS

ALLUVIAL DEPOSITS

Qaw **Active wash deposit (Holocene)—**Alluvial wash deposits characterized by surfaces and wash channels that are active and have received alluvial deposits within the last few decades to a century. Composed of moderately to poorly sorted buff-colored silt, coarse and fine sand, gravel, cobbles, and rare boulders. Unconsolidated. Prone to active flooding. Light to moderately vegetated. Little or no soil development. Interfingers with Qav and Qaa. Thickness probably 1 to 2 m

Qav **Active valley-axis deposit** (**Holocene)—**Fine-grained deposits in valley axes characterized by anastamosing washes and gentle interfluves, primarily transported by water; locally reworked by wind activity to form complex interfingering eolian deposits. Composed of moderately to poorly sorted cobbles, pebbles, buff or light-colored fine to coarse sand, and silt, but dominated by pebbles and finer grained sediment. Boulders generally very rare or absent. Unconsolidated. Prone to active flooding. Moderately vegetated. Interfingers with Qaw and Qaa. Thickness probably 1 to 2 m

Qaa **Active alluvial fan deposit (Holocene)**—Alluvial fan deposits characterized by surfaces and wash channels that are active, eroding, or received stream transported deposits within the last few decades or as much as a century. Unconsolidated. Prone to active flooding. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders. Generally lacks vegetation (commonly active on annual basis) or moderately vegetated (active on decadal basis). Rough microtopography; strongly developed gravel bar and swale (Bull, 1991). The annually active surfaces are typically a small part of the unit, and they form discrete channels. Very little or no desert varnish on clasts. Little or no soil development

Qaae where eolian reworking of silt and sand is predominant

Qaa1 where intermediate between Qaa and Qya. Thickness probably 1 to 2 m

Qyw **Young wash deposit (Holocene and late Pleistocene)**—Infrequently active alluvial wash deposits composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders.

Anastamosing, well developed gravel and cobble bars and swales (Bull, 1991). Material transported by water. Unconsolidated. Moderately vegetated. May have very weak, dark or blackish desert varnish development on clasts. Weakly developed soil, expressed as incipient to weak sandy A_v horizon; stage I calcic soil weak or absent (Birkeland and others, 1991). Thickness probably 2 to 4 m

Qya **Young alluvial fan deposit (Holocene and late Pleistocene)—**Alluvial fan deposits characterized by alluvial surfaces that no longer receive materials. Unconsolidated to slightly compact. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Weakly developed soil, expressed as incipient to weak sandy A_v horizon; stage I calcic soil typical (Birkeland and others, 1991). Distinct gravel bar and swale microtopography. Moderate to sparsely vegetated, with creosote bush and smaller desert shrubs. No desert pavement. Incipient to weak desert varnish on clasts (Bull, 1991). Thickness probably 2 to 6 m

Qyao **Young alluvial fan deposit (Holocene and late Pleistocene)—**Alluvial fan deposits characterized by surfaces that are no longer receiving sediment. Unconsolidated to slightly compact. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Weakly developed soil, expressed as incipient to weak sandy A_v horizon and weak cambic horizons; stage I calcic soil typical (Birkeland and others, 1991). Undulatory microtopography, with moderate to faint remnants of bar and swale topography. Moderately to sparsely vegetated by creosote bush and smaller desert shrubs. No desert pavement or weak pavement on surface of deposit (Bull, 1991). Incipient to weak desert varnish on clasts. Thickness probably 2 to 6 m

Qiw **Intermediate wash deposit (late to middle Pleistocene)—**Mainly consists of inactive alluvial wash deposits. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Unconsolidated to slightly compact. Weakly developed soil, expressed as incipient to weak sandy A_v horizon and weak cambic horizons; stage I calcic soil typical (Birkeland and others, 1991). Fairly smooth microtopography with moderate to faint remnants of bar and swale topography (Bull, 1991). Moderately to sparsely vegetated, especially with creosote bush and smaller shrubs. Weak pavement on surface of deposit. Weak to moderate desert varnish on clasts. Surfaces of deposits range from 0.5 to 10 m above active wash

Qia **Intermediate alluvial fan deposit (late to middle Pleistocene)—**Alluvial fan deposits characterized by surfaces that have been abandoned by active stream or wash activity. Unconsolidated to compacted or cemented. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Characterized by moderately to well developed desert pavement with moderate to strong desert varnish on clasts dominated by manganese oxide on the top of clasts and iron oxide on the base (Bull, 1991). Eolian silts and clays underlying cobbles on pavement surface are commonly stained with iron oxides. Flat smooth pavement surface may be partly incised by narrow channels or rills. Sparsely vegetated. Well-developed silty A_v horizon. Moderately to strongly developed B_t horizon and weak to strong Stage I calcic horizon (Birkeland and others, 1991). Surfaces of deposits range from 0.5 to 10 m above active wash

Qiao **Intermediate alluvial fan deposit, older (late to middle Pleistocene)—** Alluvial fan deposits characterized by surfaces that have been abandoned. Unconsolidated to compacted. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Characterized by moderately to well developed desert pavement with moderate to strong desert varnish on clasts. Flat smooth surface is partly incised by narrow channels (Bull, 1991). Sparsely vegetated. Well-developed silty A_v horizon. Moderately to strongly developed B_t horizon and Stage I+ to II+ calcic horizon (Birkeland and others, 1991). Surfaces of deposits range from 0.5 to 10 m above active wash

Qoa **Old alluvial fan deposit (middle to early Pleistocene)—**Alluvial fan deposits characterized by degraded remnants of abandoned surfaces. Compact to cemented. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Moderately vegetated. Commonly forms pale-colored bahada above active washes in upper parts of alluvial fans near mountain fronts (Bull, 1991). Many clasts on surface commonly made up of disaggregated pieces of the pedogenic calcic horizon. Upper soil horizons may be stripped off by erosion. Forms rounded, deeply dissected terrain with little or no remnant depositional geomorphology; a few meters to tens of meters higher than surrounding surfaces. Near Ballarat fan, reworked lenticular tuff beds near the base of the exposed section have a u-series date of about 0.924 Ma (Vogel and others, 2002) correlative with the Glass Mountain Tuff and are overlain by a 1- to 1.5- m-thick tuff inferred to be Bishop Ash and a 3- to 5-m thick tuff inferred to be Lava Creek B (about 0.665 Ma, Sarna-Wojcicki and others, 2001). Thin-bedded tuff and gray-green mudstone are present locally near Lava Creek B Tuff. The deposit is overlain by a flight of beach deposits and shoreline benches inferred to be about 150 to 180 ka or equivalent to marine oxygen isotope stage-6 (Jayko and others, 2005). Surfaces of deposits range from about 6 to 150 m above active wash

Qau **Alluvial fan deposit undifferentiated (Quaternary)—**Alluvial fan deposits, undifferentiated. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Thickness ranges from 0.5 to 35 m

QToa **Extremely old alluvial fan deposit (early Pleistocene to Pliocene)—** Alluvial fan deposits characterized by eroded surfaces. Compact to consolidated or cemented. Composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and rare boulders; moderately to poorly stratified. Moderately vegetated. Forms deeply dissected terrain; deposits generally did not form in present topography. Most or all soil horizons stripped off by erosion. Unit thickness ranges from about 3 to 60 m

QTs **Sedimentary rocks (early Pleistocene and (or) late Pliocene)—**Clastic sedimentary rocks composed of moderately to poorly sorted silt, coarse and fine sand, gravel, cobbles, and boulders; moderately to poorly stratified. Boulders exposed at the surface may be split and disaggragated. Clasts are angular to subrounded, moderately to well bedded or massive; matrix supported carbonate cement may be present, and carbonate matrix may be 25 to 40 percent of exposure. Carbonate cement may be whitish to whitish gray, locally laminated. Generally strongly indurated. Maximum thickness about 80 m

PLAYA, PALUDAL, AND LACUSTRINE DEPOSITS

Qasl **Active saline lake deposit (Holocene)—**Poorly sorted clay, silt, and fine sand in zones of groundwater discharge. Generally pale gray-green colored; thin bedded or laminated. Evaporites common at surface**.** Thickness ranges from 10 to 40 cm

Qsm **Active saline marsh deposit (Holocene)—**Poorly sorted clay, silt, and fine sand in zones of groundwater discharge. Generally pale gray-green colored; thin bedded or laminated; intermittent standing saline water**.** Thickness ranges from 10 to 40 cm

Qap **Active playa deposit (Holocene)—**Playa deposits that are active and have received flood deposits within the last few decades. Generally composed of poorly sorted clay, silt, and fine to coarse sand; evaporites common. Compact. Generally pale buff white to buff colored; may be massive or thin bedded and laminated. Prone to flooding. Generally flat, with little or no vegetation. Common saline crusts. Thickness ranges from 10 to 30 cm

Qaps **Sandy facies of playa**, typically supports sparse vegetation.

Qapf **Active playa fringe** with complexly mixed eolian, lacustrine, playa, alluvial, groundwater discharge

Qyp **Young playa deposit (Holocene and late Pleistocene)—**Playa deposits that are occasionally flooded. Composed of silt, clay, and sand; evaporites common; may be massive or thin bedded and laminated. Generally pale buff white to buff colored. Compact. Generally flat, lacks vegetation. Thickness ranges from 10 to 40 cm

Qysl **Playa fringe**, saline facies

Qyb **Young lacustrine beach deposit (Holocene to late Pleistocene)**—Very well rounded, locally cross-bedded sand, and gravel to cobble deposits, commonly fossiliferous with locally very abundant *Anodonta sp.* (bivalve) and gastropod beds found near the margins of the Owens Dry Lake and gastropod-bearing horizons common in the intermediate to highstand deposits of Panamint Valley; also locally abundant ostracode remains; cobbles occasionally rimmed with stromatolitic algal tufa; in Owens Valley lower elevation shoreline locally oolitic; commonly associated with colonial charophytic algal tufa; deposits occur between about 3,550 and 3,800 feet in elevation in Owens Valley (Orme and Orme, 1993; Bacon and others, 2006), and between about 1,100 and 1,650 feet elevation in Panamint Valley. Mainly 24 ka to recent in Owens Valley (Bacon and others, 2006). Thickness ranges from 1 to 4 m

Qyl **Young lacustrine deposit (Holocene to late Pleistocene)**—Lake deposits, consists of clay, silt and fine sand, may be marly in nearshore facies, commonly whitish, whitish-buff to pale gray green colored. Locally tuffaceous. Commonly thin-bedded, may be laminated. Mainly about 24 to 12 ka in Panamint Valley (Jayko and others, 2005). Thickness ranges from about 1 to 4 m

Qibg **Intermediate lacustrine beach deposit (late to middle Pleistocene)**—Very well rounded, moderately sorted gravel to cobble deposits, commonly fossiliferous with locally very abundant gastropod and ostracode remains; cobbles occasionally rimmed with stromatolitic algal tufa; commonly associated with colonial charophytic algal tufa; deposits occur between about 1,800 and 2,000 feet elevation in Panamint Valley, especially prominent at Ash Hill, but unit also occurs elsewhere in the basin. Deposits are younger than Qoa (924 to 665 ka) near the former town of Ballarat and inferred to be about 150 to 180 ka or equivalent to marine oxygen isotope stage-6 (Jayko and others, 2005). Thickness ranges from about 2 to 15 m

Qit **Intermediate nearshore tufa deposit (late to middle Pleistocene)**—Mainly charophytic or stromatolitic algal tufa, occasionally has colonial or reefal aspect; strongly indurated. Generally pale buff to pale pinkish-buff colored; may be laminated or tubular with secondary silicious lamina. In close spatial and temporal association with Qibg; deposits occur between about 1,800 and 2,000 feet elevation in Panamint Valley, especially prominent at Ash Hill but also present elsewhere in the basin. Thickness ranges from about 5 cm to 3 m

Qil **Intermediate lacustrine and deltaic deposits (late to middle Pleistocene)**—

Lake or wetlands deposits, consists of clay, silt and medium to coarse sand, local conglomerate beds; thin bedded and laminated, locally crossbedded. May be marly or tufa-bearing in nearshore marsh or wetlands facies, may be mollusc-bearing with locally abundant gastropod beds. Bivalve (*Anodonta* ?) is present in deltaic deposits east of Panamint Springs resort at about 1,800 feet elevation. Siliceous tuffs and diatomite present locally in high-stand shorelines of Panamint Valley around 1,800 to1,900 feet in elevation

Qol **Intermediate lacustrine, wetlands and playa deposits (late(?) or middle to early Pleistocene)—**Lake or wetlands deposits, consists of clay, silt and medium to coarse sand, local conglomerate beds; thin bedded and laminated, locally crossbedded. May be marly or tufa-bearing. Siliceous tuffs and porcelanite present in lake beds exposed in faulted horst blocks in southern Panamint Valley. Commonly whitish and (or) pale grayish-green colored. Commonly thin-bedded, may be laminated. Maximum thickness probably exceeds 40 m

EOLIAN DEPOSITS

Qae **Active eolian deposit (Holocene)—**Eolian sand deposits that are active and subject to migration. Unconsolidated. Generally lacks vegetation. Composed of light yellowish-buff colored, moderately to well sorted fine and medium sand and silt; commonly crossbedded or laminated. No soil development. Maximum thickness about 25 m

Qaed **Active eolian dune deposit (Holocene)—**Dune morphology distinctive. Active eolian sand deposits that are subject to migration. Unconsolidated. Generally lacks vegetation. Composed of light yellowish-buff colored, moderately to well-sorted fine- and medium-grained sand and silt; commonly crossbedded or laminated. No soil development. Maximum thickness about 25 m

Qye **Young eolian deposit (Holocene and latest Pleistocene)—**Eolian sand deposits that are generally inactive. Unconsolidated. Sparsely vegetated. Composed of light yellowish-buff colored, moderately to well sorted fine and medium sand and silt; commonly crossbedded or laminated. Little or no soil development. Maximum thickness about 15 m

Qyae **Young mixed alluvial and eolian deposit (Holocene and latest Pleistocene)—**Alluvial and eolian deposits with alluvial processes dominating. Tends to form flatter surfaces than strictly alluvial systems lacking significant eolian sand contribution, due to infilling of small scale bar and swale microtopography with fine sand and silt. Unconsolidated; sparsely vegetated. Little or no soil development. Maximum thickness about 5 m

Qyaoe **Young mixed alluvial and eolian deposit (Holocene and latest**

Pleistocene)—Slightly older alluvial and eolian deposits with alluvial processes dominating. Slightly incised; infilling of small scale bar and swale microtopography by unconsolidated sand and pebbles. Gravelly sand with vague to well-defined thin bedding. Unconsolidated; sparsely vegetated. Little or no soil development. Thickness ranges from about 0.5 m to 3 m

Qiae **Intermediate alluvial and mixed eolian deposit (late to middle Pleistocene)—**Eolian and alluvial deposits in near equal proportions with alluvial processes dominating. Alluvial channels muted or sand and pebble filled; deposit mostly sand with sparse gravel. Marked by flat surface, inconsistently developed pavement and B_t horizon. Moderately compact. Sparsely vegetated. Thickness ranges from about 0.5 m to 5 m

Qoae **Old mixed alluvial and eolian deposit (late to middle Pleistocene)—**Old alluvial deposit with a thin veneer of eolian sand and silt. Poorly sorted, boulders, cobbles, coarse and fine sand, silt and clay. Forms smoother and lighter colored surfaces than alluvium lacking significant eolian sand. Depositional surface lies about 6 to 25 m above the active wash

GROUNDWATER AND SPRING DEPOSITS

Qsgp **Sag pond (Holocene)—**Fault controlled groundwater discharge, commonly ponded and(or) marshy area adjacent to active faults; deposits occurs along the Sierra Nevada Range front on the west side of the map area

Qag **Active groundwater discharge deposit (Holocene)—**Silt and fine sand in moist zones of groundwater discharge. Compact. Abundant vegetation. Thickness unknown

Qags **Spring mound deposits**

Qagw **Wetland deposits**

Qygw **Young groundwater discharge deposit (Holocene and latest Pleistocene)—**Silt and fine sand in zones of former groundwater discharge. May be marly or diatomaceous. Clastic sediments may be leached and whitish color. Unconsolidated to compact. Commonly forms light-colored, flat areas or dissected badlands. Little vegetation. Thickness ranges from about 0.5 to 5 m

Qigw **Intermediate groundwater discharge deposit (late to middle Pleistocene)—**Silt, marl, and fine sand in former zones of groundwater discharge. Compact, may have carbonate cement or charophytic tufa present. Clastic sediments may be leached. Little vegetation, generally dissected. Occurs near outlet of McCloud Flat and China Gardens area and in the Wildrose graben area. Thickness ranges from about 0.5 to 15 m

Qogw **Old groundwater discharge deposit (middle Pleistocene or older)**—Silt, marl, and fine sand in former zones of groundwater discharge. May have carbonate cement and laminated silica. Compact. Little vegetation, generally dissected. Thickness ranges from about 0.5 to 15 m

MADE LAND, HILLSLOPE, AND MASS WASTING DEPOSITS

ml **Made land**—Material moved for construction, agricultural, or other disturbances extensive enough to modify natural landforms and make deposits difficult to identify

Qc **Colluvial deposits (Holocene and Pleistocene)**—Colluvium and talus, poorly sorted, angular clasts, generally gritty sand, gravel, cobble and boulder sized, clast supported, may be nonbedded or crudely stratified. Commonly unvarnished to moderately varnished clasts. Unconsolidated. May be infilled with eolian material. May be locally reworked by debris flow activity. Thickness ranges from 0.25 m to tens of meters

Qls **Mass-movement deposits (Holocene and Pleistocene)**—Landslide deposits; generally poorly sorted, matrix supported; generally blocks mixed with fine sediment. Commonly characterized by hummocky topography, lobate at the base. Generally unconsolidated. Thickness generally tens of meters

Qoc **Older colluvial deposits (Pleistocene ?)**—Older colluvium and talus, poorly sorted, angular clasts, generally gravel, cobble and boulder sized. Commonly moderately to strongly varnished or iron-stained. May be infilled with eolian material and(or) may have Stage III, IV, or greater pedogenic calcite cement west of the Owens Valley. May have reddish argillaceous weathering on slopes flanking the Sierra Nevada on the west side of the quadrangle. Thickness ranges from 0.25 m to tens of meters

QTsbk **Block slide deposits (Pleistocene and or late Pliocene**)—Large block slide deposits in the Coso and Panamint Ranges. Two large-block slide deposits of granitic rock occur on the northwest edge of the Coso Range south of the Owens Dry Lake. Large block slides are also present in the Panamint Range south of Wildrose Canyon mapped by Albee and others (1981). Thickness about 12 to 50 m

VOLCANIC AND OLDER SEDIMENTARY ROCKS

Coso Range

Qash **Volcanic ash (Quaternary)**—Pyroclastic deposits, rhyolitic ash, pumice and obsidian (apache teardrops) and friable or nonlithified tuff deposited in the basins surrounding the Coso Geothermal area, locally reworked, equivalent to unit Qrp of Duffield and Bacon (1981). One of the younger large rhyolitic extrusives, Sugarloaf Mountain, has been dated as 44±22 ka (Lanphere and others, 1975; Bacon and others, 1982; Duffield and Bacon, 1981). Unconformably overlies basement rocks. Thickness variable

Qb **Basalt and other mafic volcanic rocks (mainly Quaternary)**—Mainly small volume basaltic cinder cone and local flows southwest of Coso Range (Duffield and Bacon, 1981). One flow north of Little Lake gives a K/Ar age of 0.140±0.89 Ma and other nearby flow gives 1.08±0.06 and 2.06±0.34 Ma (Duffield and Bacon, 1981). Unconformably overlies basement rocks where exposed and overlain by late Quaternary alluvium. Thickness variable

Qvu **Volcanic rocks (Quaternary)**—Rhyolitic lava flows and domes of obsidian covered by perlite; emplaced between 1.04 and 0.044 Ma, but most about 0.33 Ma (Lanphere and others, 1975; Bacon and others, 1982; Duffield and Bacon, 1981) Intrusive or unconformably overlying basement rocks. Thickness variable

QTbc **Volcanic center**, **basalt and other mafic volcanic rocks (Quaternary and (or) late Pliocene)**—Small volume basaltic cinder cones and local flows around 1.75 Ma in southeastern Coso Range west of Echerron Valley (Duffield and Bacon, 1981), delineates the geomorphic expression of the volcanic cone, source area or edifice. Thickness variable

QTb **Basalt and other mafic volcanic rocks (Quaternary and or late Pliocene)**—Small volume basaltic cinder cones and lava flows in southeastern Coso Range and southwest of the Coso Range (Duffield and Bacon, 1981). One flow gives a 2.06±0.34 Ma K/Ar age (Duffield and Bacon, 1981). Unconformably overlies basement rocks where exposed and overlain by late Quaternary alluvium. Thickness variable

Tcgl **Conglomerate (Pliocene ?)**—Undifferentiated conglomerate, boulder conglomerate, or bouldery alluvium overlying 3 to 4 Ma basalt in the Coso Wash area. Locally includes granitic boulder lag. Thickness one to tens of meters

Ts **Sedimentary rocks (Pliocene)**—Clastic sedimentary rocks, mainly course alluvial fan deposits consisting of sand, pebbles, gravel, cobbles and boulders; moderately to poorly stratified. Locally interbedded rhyolitic ash and basaltic flows. Commonly Stage III to Stage IV or greater calcic horizons in the Ash Hill and Wildrose horst area. Includes the Nova Formation (Hall, 1971) in the northern Panamint Range where it unconformably overlies basement rocks and locally conformably overlies Tb; overlies about 4.0 Ma basalt on Ash Hill in Panamint Valley and 3 to 4 Ma basalt in the Coso Wash area; unit age probably around 2 to 4 Ma. Maximum thickness may exceed 1,600 m in the Panamint Range

Coso Formation (Pliocene)—Divided informally into:

Tvd **Rhyodacite (Pliocene)**—Massive, dark weathering, cliff-forming rhyodacitic indurated tuff, approximately 2.5 Ma (Duffield and Bacon, 1981); unconformably overlies Tvrc and Tca in the west part of the Coso Range. Generally 10 to 30 m thick

Tcs **Mainly sedimentary rocks (Pliocene)**—Generally light buff to whitish, fine-grained fluvial, deltaic, and wetlands deposits, lesser olive-colored lacustrine mudstones; also reddish weathering siltstone, sandstone, and pebble conglomerate with interbedded volcanic ash; contains early Pliocene (Blancan) mammalian faunal remains (Schultz, 1937; Evernden and James, 1964) on the north and west flank of the Coso Range, overlies about 3.5 to 5.8 Ma basalt in the northern Coso Range, and has intercalated middle Pliocene, about 3.14$\pm$0.15 Ma ash-flow tuff on the west side of the Coso Range near Haiwee Reservoir (Duffield and Bacon, 1981); unconformably overlies Tca east of the Haiwee Reservoir and east of Bird Hill; overlies Tb north of Cactus Flat. Maximum thickness probably greater than 300 m

Tcu **Coso Formation, undifferentiated (Pliocene)**—Volcanic and clastic rocks of the Coso Formation undifferentiated. Maximum thickness greater than 300 m

Tcv **Coso Formation, undifferentiated volcanic rocks (Pliocene)**—Siliceous volcanic rock found along the north eastern Coso Range and southern Lower Centennial Flat. Maximum thickness probably about 150 m

Tvrc **Red weathering rhyodacitic volcanic rock (Pliocene)**—Rhyodacitic volcanic rock that underlies Tvd and overlies Tca on the west flank of the Coso Range. From 10 to 30 m thick

Tca **Mainly volcanic ash and tephra (Pliocene)**—Friable whitish weathering, slope-forming siliceous volcanic ash, includes airfall pumice dated at about 3 Ma (Duffield and Bacon, 1981; unit Tcp) near the base of the unit on the west flank of the Coso Range. Unconformably overlies basement on an old erosion or peneplain surface. Also, locally overlies Tb on east side of Coso Wash and the headwaters of Darwin Wash east of Coles Flat; and overlies Tcr east of Haiwee Reservoir. Locally overlain by Tcs east of Haiwee Reservoir. Generally 10 to 30 m thick and locally as thick as about 50 m

Tcla **Lower volcanic ash and tephra (Pliocene)**—Friable, whitish-weathering, slope-forming siliceous volcanic ash and pumice on the west flank of the Coso Range. Unconformably overlies basement on an old erosion or peneplain surface. Only mapped east of the southern extent of Haiwee Reservoir along the west flank of the Coso Range. Generally 10 to 30 m thick and locally as much as about 50 m

Tvdo **Older dacitic volcanic rock (Pliocene)—**Reddish weathering dacite mapped by Duffield and Bacon (1981), moderately porphyritic; overlies about 3.3- to 3.5-Ma Tb and is overlain by about 3.0 Ma pumice of Tca (Duffield and Bacon, 1981) on the east side of Coso Wash (Duffield and Bacon, 1981); may be correlative in age with Tcla of the Coso Formation. Thickness ranges from about 5 to 60 m

Tb **Mainly flood-like basalt flows and other mafic volcanic rocks (Pliocene)—** Flood-like basalt flows, typically a few to several meters thick but commonly covering large areas on the order of several tens to hundreds of square miles; around 3 to 4 Ma in the southwestern part of the quadrangle, and 4 to 6 Ma in the northern and northeastern part of the quadrangle (Hall, 1971; Larsen, 1979; Duffield and others, 1980; Duffield and Bacon, 1981; Schweig, 1982, 1989); and one locality in Rainbow Canyon on the west side of the Darwin Plateau gives a 7.2 Ma K/Ar age (Schweig, 1982, 1989) conical geomorphic extrusive edifice delineated as (Tbc). Individual flows typically 3 to 5 m; thickness ranges from about 3 to 150 m

Tbc **Eruptive centers of basalt flows and other mafic volcanic rocks (Pliocene)—**Vent and near vent area

Tcvr **Volcanic ash flow and ash (early Pliocene and (or) late Miocene)—** Unconsolidated or poorly indurated siliceous ash underlying Tb in the northern part of the Coso Range; may also underlie Tcs in the northwestern part of the Coso Range. Thickness ranges from about 10 to 75 m

Tvcf **Volcanic ash flow and ash (early Pliocene and (or) late Miocene)—** Unconsolidated or poorly indurated siliceous ash underlying Tb in the northern part of the Coso Range west of Centennial Flat (Tvcf?). Thickness ranges from about 10 to 25 m

Trb **Sedimentary rocks (early Pliocene and (or) late Miocene)—**Clastic rocks consisting of red beds that underlie the Coso Range. Mainly well bedded, also locally crossbedded, ripple laminated arkosic sandstones. Clasts moderately sorted, sub-angular to well- rounded; fine to coarse sand, grit, pebbles, and small cobbles. Moderately consolidated. Local interbedded siliceous tuffs. Bedding and facies suggest fluvial origin. Locally weathered to deep rusty red. Unit on the northwest edge of the Coso Range south of Owens Dry Lake; unit first mapped by Stinson (1977a). Thickness ranges from about 5 to 50 m

Tsa **Sedimentary rocks (late Miocene ?)—**Clastic rocks consisting of arkosic sediments with intercalated siliceous ash that locally underlies basalt (about 6 Ma in age) in the Darwin Wash area. Locally well bedded and (or) crossbedded, moderately sorted sandstone, mudstone and scarce conglomerate. Bedding characteristics suggest fluvial origin. Basal contact is locally strongly modified by secondary brownish-yellow jasper, which forms deposits 1 to 2 meters thick. Locally cut by mafic dikes that feed the overlying basalt. Thickness ranges from about 0.5 to 10 m

Tv **Volcanic rock (early Pliocene to late middle Miocene)**—Andesite and other undifferentiated siliceous volcanic rocks. Tv underlies Tsa in the lower Darwin Canyon Wash. Overlies Paleozoic rocks and underlies Ts on Ash Hill. Also located on the southeast range front of the Argus Range around Shepherd Canyon where the rocks are middle and late(?) Miocene age (Evernden and James, 1964; about 12.6 to 13.0 Ma uncorrected K/Ar whole-rock ages, p. 970). Unconformably overlies Paleozoic rocks. Thickness ranges from about 0.5 to 10 m

GEOMORPHIC FEATURES

Qapd **Pediment surfaces (middle and late Quaternary)**—Erosional surface in various stages of active erosion and burial

ff **Faceted bedrock spur (Pleistocene and (or) late Pliocene)**—Geomorphic feature consisting of a triangular ridge spur, generally a fault-controlled surface along a range front; commonly eroded and rilled or gullied if older, may be slickensided if younger

ve **Volcanic vent area (Quaternary and (or) late Pliocene)**—Geomorphic area of closed depression situated within a generally conical volcanic edifice

Tvpd **Pediment inset onto Tertiary volcanic rock (Quaternary and (or) late Pliocene)**—Erosional surfaces in various stages of erosion and burial, inset onto unit Tvd and (or) Tvrc and inferred to be mainly late Quaternary age

Tcpd **Pediment inset onto Coso Formation (Quaternary and (or) late Pliocene)**—Erosional surfaces in various stages of erosion and burial developed or inset onto unit Tcs

Tbpd **Pediment inset onto basalt (Quaternary and (or) late Pliocene)**—Erosional surfaces in various stages of erosion and burial inset into unit Tb and inferred to be mainly Quaternary age

KJpd **Pediment developed on granitic substrate (Quaternary and (or) late Pliocene)**—Erosional surfaces in various stages of erosion and burial developed on unit KJg, inferred to be mainly Quaternary age

MzPzpd **Pediment developed on Paleozoic and (or) Mesozoic substrate (Quaternary and (or) late Pliocene)**—Erosional surfaces in various stages of erosion and burial developed on unit MzPz, inferred to be mainly Quaternary age

Tves **Pediment developed on Tv (Quaternary and (or) late Pliocene)**—Gently sloping erosional surfaces developed on unit Tvd and (or) Tvrc in various stages of erosion and burial

Tbes **Old erosion surface developed on top of basalt (early or middle Pliocene)**—Gently sloping erosional surfaces developed on unit Tb in various stages of erosion and burial; queried where uncertain (Tbes?)

Tblag **Cobble lag deposit (late Miocene and early Pliocene)**—Thin, discontinuous scattering of basalt and restate clasts overlying Es

Es **Old erosion surface on bedrock (late Miocene and early Pliocene)**—Exhumed and denuded paleo-surfaces in various stages of erosion and burial. Surface commonly overlain by Tb and (or) Tv in the western half of the quadrangle; locally overlain by basaltic lag gravels

Kgu **Old relief above Es (late Miocene and early Pliocene)**—Geomorphic area inferred to have been a paleo-highland, relative to the Es geomorphic surface; locally overlain by late Miocene and Pliocene sedimentary and volcanic rock; area inferred to be in geomorphic continuity with upper erosion surface (Es) but area of higher paleo-elevation, developed on unit KJg

BEDROCK LITHOLOGIES

KJg **Mainly plutonic rocks (Cretaceous and (or) Jurassic)**—Undivided plutonic rocks

MzPz **Sedimentary and metamorphic rocks (Mesozoic and Paleozoic)**—Undivided meta-sedimentary and very subordinate meta-volcanic rocks of mainly Mesozoic and Paleozoic age

ca **Meta-sedimentary, Metamorphic, and Plutonic Rocks of the Panamint Range (Mesozoic, Paleozoic, and Precambrian)**—Undivided meta-sedimentary rocks of mainly Paleozoic and Precambrian age, plutonic rocks of Precambrian, Mesozoic, and Cenozoic age, and subordinate meta-volcanic and meta-sedimentary rocks of Mesozoic age in the Panamint Range

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