DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Geologic Map of the Chemehuevi Mountains area, San Bernardino County, California and Mohave County, Arizona

by

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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

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INTRODUCTION

The Chemehuevi Mountains on the Arizona border in southeastern California expose a metamorphic core complex, where the relative timing of low-angle normal or detachment faulting, mylonitic deformation, and attendant plutonism have been determined. The range is underlain by Proterozoic- through Tertiary-age igneous and metamorphic rocks. Three stacked low-angle normal or detachment faults cut these rocks. Tertiary volcanic and sedimentary strata lie both unconformably and in fault contact above the crystalline basement in the hanging walls of the two structurally highest faults (from structurally deepest, the Chemehuevi and Devils Elbow detachment faults). Rocks below these faults in the core of the range consist of variably mylonitized gneiss and migmatite of probable Proterozoic age. Locally these rocks have a subhorizontal mineral elongation lineation trending southwest. An irregularly zoned granitic body of Late Cretaceous age, the plutonic suite of the Chemehuevi Mountains, intrudes and locally shares the mylonitic fabric. Felsic and intermediate phases of the suite are undeformed, and intrude the thick (>1.5 km) sequence of mylonitized gneiss. This relationship suggests that these mylonitic rocks are no younger than Late Cretaceous and apparently are unrelated to mid-Tertiary crustal extension.

The major structural feature in the Chemehuevi Mountains is the mid-Tertiary extensional fault system. Extension was accomplished here along a stacked sequence of very low-angle normal faults, with unidirectional slip. Above the regionally developed Chemehuevi detachment fault, the hanging wall block is distended by innumerable high-angle faults. Structurally below the Chemehuevi detachment fault lies the smaller displacement Mohave Wash fault. Little deformation occurred in the footwall to this fault system.

FOOTWALL TO THE CHEMEHUEVI DETACHMENT FAULT

METAMORPHIC ROCKS

Gneissic rocks in the footwall to the Chemehuevi detachment fault consist of strongly foliated, variably mylonitized, layered orthogneiss and paragneiss of Proterozoic age (unit Xgn). These amphibolite-facies rocks form a coherent, gently (15°) southwest-dipping sequence in the eastern part of the range, a steeply dipping (60°-90°), northeast-striking zone in the northern part of the range, and a long screen within the Cretaceous plutonic suite. The mylonitic gneisses crop out beneath the detachment faults only in the northern and eastern parts of the range. Both the gently and steeply dipping mylonitic gneisses are dominantly L-S tectonites with a subhorizontal NE-SW trending mineral elongation lineation.

INTRUSIVE ROCKS

Intruding the layered gneiss and migmatite complex and underlying most of the southern and central Chemehuevi Mountains is the plutonic suite of the Chemehuevi Mountains, of probable Late Cretaceous age. The suite forms a concordant, irregularly zoned plutonic body. The suite comprises five phases, spanning a wide compositional range from hornblende- and sphene-rich quartz diorite and granodiorite, through biotite granodiorite, to leucocratic garnet-bearing, muscovite-biotite monzogranite. These intrusive phases are crudely concentric, the younger and more highly differentiated rocks toward the center.

Foliated granodiorite is the oldest phase of the suite (unit Kgd). Locally this unit is foliated and lineated with the same mylonitic fabric as the layered gneiss and older Whale Mountain sequence. A porphyritic granodiorite to monzogranite mass (unit Kpg) intrudes the older granodiorite. It is the most voluminous phase of the suite. The eastern contact of this phase, against the floor of mylonitic gneisses, is defined by fine-to-medium-grained granitic sills in a *lit-par-lit* arrangement. The floor dips gently southwestward under the pluton. The porphyritic granodiorite unit contains and intrudes small enclaves as well as a very large screen of mylonitized layered gneiss and is, therefore, post-mylonitic. Two-mica granodiorite to monzogranite and garnet-two-mica monzogranite (units Kg and Kgg) form the youngest members of the suite. The geographic distribution of distinctive compositional types and the attitudes of plutonic contacts are the main means for measuring separation on the low-angle normal faults.

The porphyritic granodiorite (unit Kpg) yielded a 64 Ma K-Ar cooling age on biotite (John, 1982). This date, indicates that the mylonitic gneisses acquired their fabric by the end of Cretaceous time. The mylonitic fabric is apparently unrelated to mid-Tertiary extensional faulting that coincidently parallels the lineation direction.

The youngest intrusions recognized in the footwall to the Chemehuevi detachment fault form dense swarms of mafic and silicic dikes in the western and central part of the range. The dikes are centered in the plutonic suite, and locally account for as much as 10% of the rock volume. The dikes form two subvertical, roughly orthogonal sets oriented east-northeast, and north to west-northwest. Intrusive relations between some of the northeast-trending dikes and phases of the plutonic suite suggest that these dikes may be synplutonic, i.e., late Cretaceous or older. The northwest-trending dikes cut them and are possibly Miocene based on K-Ar data (John, 1986). In the southern Chemehuevi Mountains is a second set of northeast-trending mafic dikes, presumably Miocene, which intrude the Chemehuevi detachment fault, but also exhibit substantial fracturing from subsequent fault movement.

HANGING WALL TO THE CHEMEHUEVI DETACHMENT FAULT

Crystalline rocks crop out above the Chemehuevi detachment fault in the western Chemehuevi Mountains and above the Chemehuevi and Devils Elbow faults in the eastern part of the area. Proterozoic granites and gneisses without a mylonitic fabric, and therefore texturally unlike those in the footwall to the Chemehuevi detachment fault, are the major crystalline rocks in the hanging wall. Distinctive Proterozoic ophitic diabase sheets, striking northwest and dipping steeply, intrude the nonmylonitic gneisses and granites. Unlike rocks below the Chemehuevi detachment, none of the crystalline rocks exposed in the hanging wall bear a mylonitic fabric.

Volcanic and sedimentary rocks of Tertiary age encircle the range above the Chemehuevi detachment fault and Devils Elbow fault, and lie both nonconformably and in fault contact above the crystalline rocks just described. The deformed Tertiary rocks are divided into three major lithologic sequences, from oldest to youngest, mafic and intermediate lavas, an ash flow tuff considered to be the Peach Springs tuff of Young and Brennan (1974), and a thick sequence of alluvial fan deposits and breccias with thin interbedded mafic and silicic flows and tuffs. An estimated thickness for the Tertiary section is on the order of 2 to 3 km. The age of the older sequence of volcanic rocks is poorly known. Most of the faulted Tertiary rocks in the region around the Chemehuevi Mountains are between 17 and 22 Ma (Howard and John, 1987).

FAULTING

All rock types in the Chemehuevi Mountains, barring the Plio-Pleistocene deposits, were mildly to intensely deformed during middle to late Tertiary time. The deformation produced a fault system comprised of at least three allochthons, separated by three brittle, low-angle normal faults (from structurally deepest to most shallow), the Mohave Wash, Chemehuevi and Devils Elbow detachment faults. Criteria for the recognition of each fault separating the allochthons include types of rocks juxtaposed, style and intensity of the brittle deformation and related fault rocks, amount of reworking of fault rocks, relative structural position, and continuity of outcrop. Of the three faults, the Chemehuevi detachment fault is of the greatest significance regionally and is the youngest.

Based on offset markers, preserved striae, drag folds, minor faults within related cataclasites, and the southwest dip of Tertiary strata in the Chemehuevi Mountains, slip on each of the low-angle normal faults resulted in northeastward (040° - 060°) transport of successive hanging walls or higher allochthons. The detachment faults cut gently down section in the direction of tectonic transport, and together record unidirectional extension of the upper and middle crust. The upper and mid-crust as a whole extended nonuniformally -- rocks above the

Chemehuevi detachment fault were extended along a series of steep normal faults, while the footwall apparently remained little deformed. Plutonic contacts in the footwall are separated along the Mohave Wash fault by ~2 km. Separation along the Chemehuevi detachment fault is at least 8 km. Movement of the structurally highest plate above the Chemehuevi detachment on the Devils Elbow fault is likewise believed to be many kilometers.

At outcrop scale, each of the detachment faults is approximately planar, but when viewed at map scale, the two structurally deepest faults are corrugated parallel to the NE transport direction. Orthogonal to these are broad north-northwest-trending antiformal and synformal undulations of the fault surfaces (John, 1987). Dips on each detachment fault vary from horizontal or very gently inclined along the trough or crest of the mullion structures, to as much as 40 degrees on the steeper flanks or strike-slip portions of the faults.

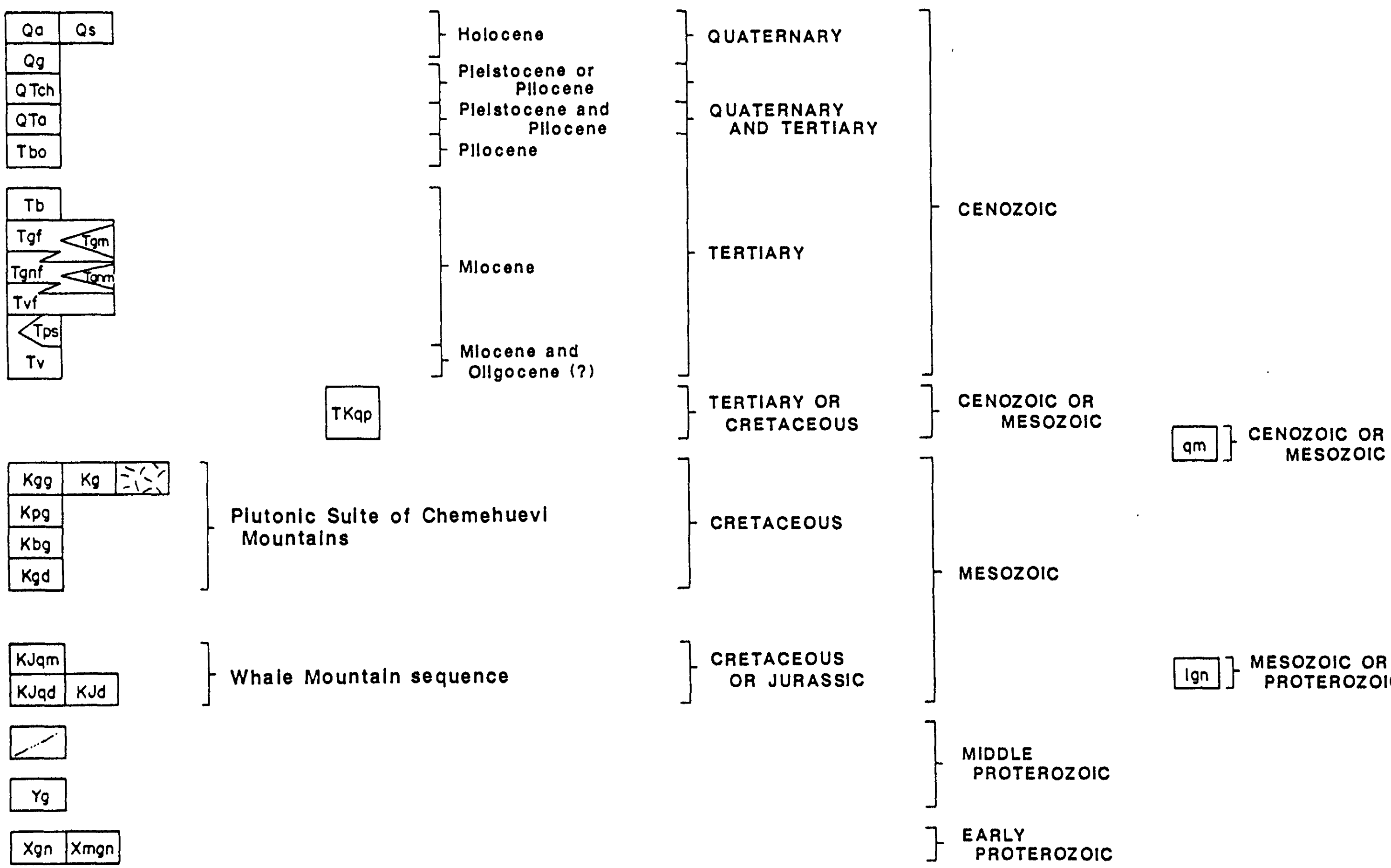
The footwall to the Chemehuevi detachment fault (comprised of the 'autochthon' and hanging wall to the Mohave Wash fault) is little deformed internally by Tertiary extension. Sparse, discontinuous ductile shear zones or mylonites (up to 1 m thick) cut all rock types in the footwall, and are considered to be minor accommodation structures to the Tertiary extensional deformation. These mylonites are concentrated zones of high strain, locally with variably oriented foliation and mineral-elongation lineation. Stereoplots of the foliation and lineation show no consistent orientation. Where dikes or compositional layering in the crystalline rocks are cut by these shear zones, separations up to tens of centimeters have been measured. Numerous small microfaults and vein-like intrusions are common throughout the autochthon and lowest allochthon, and are concentrated near both the Mohave Wash and Chemehuevi detachment faults.

The Mohave Wash fault is cut by both the normal and strike-slip faults, planar discontinuities marked by coherent breccias and cataclasites. The cataclasites are composed primarily of quartz, plagioclase and potassium feldspar, the milled-down equivalent of the wallrock, in a matrix of hematite (or specular hematite) ± calcite ± quartz ± azurite ± malachite ± barite. In contrast, the low-angle faults contain coherent cataclasites composed of quartz, plagioclase and potassium feldspar, with the retrograde mineral assemblage of chlorite ± albite ± epidote ± clinozoisite ± sericite and rare calcite.

The Chemehuevi detachment fault lies 0 to 750 m above the older Mohave Wash fault. The fault juxtaposes Miocene ash flow tuffs and lavas directly on the plutonic suite and underlying mylonitized gneisses. The depth at which the fault was initiated is estimated as at least 6 km, because structurally intact blocks above the Chemehuevi detachment fault in the western Chemehuevi Mountains and along the Colorado River have minimum paleothicknesses (measured perpendicular to the Tertiary unconformity) up to 6 km. The "toes" of these blocks have either been eroded, or are covered by structurally higher blocks; the paleothickness of the blocks provides a minimum estimate of crustal thickness above the fault prior to their detachment, rotation and northeastward translation. From regional arguments put forward by Howard and John (1987), it can be inferred that the easternmost exposures of the Chemehuevi detachment fault was initiated at depths of 10 and 15 km. Juxtaposition of Tertiary strata down against the footwall implies that the Chemehuevi detachment fault has at least 6 and perhaps 10 to 15 km of crustal excision and vertical displacement.

Horizontal separation of crystalline rocks on the Chemehuevi detachment fault is a minimum of 8 km northeast, and displacement is probably on the order of 20 to 40 km. Broad areas of slickensides crop out along the fault. The striae are subhorizontal, and trend 220°- 240° parallel regionally to the dip direction of the overlying rotated Tertiary strata.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qa **Alluvium (Holocene)** -- Silt, sand, and gravel in modern drainages. Poorly sorted, angular to subrounded, unconsolidated material of local origin

Qs **Sand dunes and river sand (Holocene)** -- Stabilized and active dunes, sand sheets, and river sand. Deposits along the Colorado River up to 20 meters thick

Qg **Gravel (Quaternary)** -- Gravel, sand, and silt associated with the Colorado River. Well-sorted, subrounded to rounded material of sedimentary origin, characterized by limestone and quartzite clasts, and rare volcanic material

QTch **Chemehuevi Formation of Longwell (1963) (Pleistocene and Pliocene)** -- Sand, silt, clay, and ancestral Colorado River gravel and cobbles

QTa **Older alluvium (Pleistocene and Pliocene)** -- Poorly sorted, poorly consolidated alluvium. Commonly forms terraces with extensive covering of desert pavement consisting of varnished cobbles. Unit also includes older partially consolidated and extensively dissected alluvium in the southern part of the range

Tbo **Bouse Formation (Piocene)** -- Pale-red to tan calcareous clay, silt, sand and marl, moderately to poorly indurated, well-bedded

Tb **Basalt (Miocene)** -- Dark-purplish brown augite-olivine basalt flows, dikes, and plugs. Includes mudstone below basalt in the southwest part of the map area. Flows with conspicuous columnar joints. Locally intrudes and fuses cataclasites associated with the Chemehuevi detachment fault. K-Ar whole-rock age of 11.1± 0.4 and 14.5± 1.0 Ma by M.A. Pernokas (written communication; in John, 1986)

Tgf **Granite-clast fanglomerate (Miocene)** -- Light-tan- and orange-weathering, virtually monomictic alluvial-fan deposits, comprising white to tan granite and granodiorite clasts, and clasts of dike rock types, equivalent of rocks below the Chemehuevi detachment fault, and clasts of altered cataclasite. Locally contains thin siliceous tuff beds, and basalt flows

Tgm **Granite megabreccia (Miocene)** -- Light-tan- and pale orange-weathering granite-clast landslide-megabreccia deposits; silicified. Granite blocks up to ~ 1 km x 20 m within the deposits. Megabreccia deposit comprises granitic debris characteristic of rocks below the Chemehuevi detachment fault. Locally, includes altered granitic cataclasite debris, possibly derived from exhumed fault scarps

Tgnf **Gneiss-clast fanglomerate (Miocene)** -- Dark red to red-brown weathering, poorly sorted alluvial-fan deposits. Includes subangular to subrounded clasts of Proterozoic gneisses (Xgn), granite (Yg) and amphibolite, characteristic of rocks above the Chemehuevi detachment fault

Tgnm **Gneiss-clast megabreccia (Miocene)** -- Dark-reddish-brown weathering gneissic- and granite-clast landslide-megabreccia deposits; silicified. Landslide blocks up to 500 m x 20 m within the deposits. Megabreccia deposit comprises gneissic and granitic debris characteristic of rocks above the Chemehuevi detachment fault

Tvf **Volcanic-clast fanglomerate (Miocene)** -- Dark reddish-brown, poorly sorted alluvial-fan deposits, comprising mainly intermediate and mafic-volcanic clasts in a sandy matrix. The fanglomerate is in gradational contact with unit Tgnf, and contains clasts characteristic of rocks above the Chemehuevi detachment fault, including Peach Springs Tuff (unit Tps)

Tps **Peach Springs Tuff of Young and Brennan (1974) (Miocene)** -- Non-welded to densely welded, white to pink ash-flow and air-fall tuff. Commonly devitrified and shows vapor-phase alteration. Phenocrysts 5 to 10 percent, predominately blue sanidine, plagioclase, and quartz, with rare biotite, hornblende, pyroxene and sphene. Sample 79-298 in the westernmost Chemehuevi Mountains, has a K-Ar sanidine age of 18.1 ± 0.6 Ma (Howard and others, 1982)

Tv **Volcanic flows and intrusions (Miocene and Oligocene?)** -- Mafic, intermediate and silicic volcanic flows and small hypabyssal intrusions. Locally includes intensely altered and fractured biotite dacite porphyry intrusions along and below the Chemehuevi detachment fault, in the southern Chemehuevi Mountains. Some dacite flows and intrusions are syntectonic with detachment faulting

TKqp **Quartz porphyry dikes (Tertiary ? or Cretaceous?)** -- Thin, light-gray- to tan- weathering dacite dikes with 30-50 % phenocrysts of plagioclase, potassium feldspar, biotite and euhedral quartz in an aphanitic groundmass. The dikes crop out north and west of Chemehuevi Peak, above the Chemehuevi detachment fault

Plutonic suite of the Chemehuevi Mountains (Cretaceous) -- Consists of:

Aplite and pegmatite dikes, and quartz veins (Cretaceous) -- Pattern shows areas of occurrence, in other rock units. Swarms of white garnet-two-mica aplitic dikes, and coarse to very coarse-grained garnet-two-mica pegmatite dikes, locally with very coarse muscovite to 6 cm in long dimension. Quartz veins up to 10 cm thick are associated with sericite-rich joints north and west of Chemehuevi Peak

Kgg **Garnet-two-mica monzogranite (Cretaceous)** -- White to tan, leucocratic subequigranular biotite-garnet, muscovite monzogranite. Occurs as dikes and small bodies less than 2 km across in the central part of the plutonic suite of the Chemehuevi Mountains. This unit is in gradational contact relation with the two-mica granitodiorite and monzogranite (unit Kg), but clearly intrudes the porphyritic biotite granodiorite and monzogranite (Kpg). Locally, biotite-rich schistose inclusions with large (1.5 to 3 cm) red-brown euhedral garnet define an igneous foliation. Accessory minerals include euhedral muscovite (1-3%), biotite (less than 1%), garnet (1-2%), apatite, allanite, magnetite, zircon, and very rare monazite

Kg **Two-mica granodiorite and monzogranite (Cretaceous)** -- Medium- to coarse-grained, leucocratic subequigranular to porphyritic two-mica granodiorite and monzogranite. The rocks weather light-tan and contain microcline phenocrysts up to 1.5 cm across, in a coarse-grained (5 to 8 mm) groundmass of quartz, plagioclase, orthoclase (2-4%), biotite (1-2%), muscovite (1-2%), and accessory magnetite, apatite, allanite, epidote, zircon, and rare sphene and monazite. Locally, surrounds irregular blocks of porphyritic biotite granodiorite and monzogranite (unit Kpg), suggesting that unit Kpg is older. Elsewhere the contact relations are ambiguous

Kpg **Porphyritic biotite granodiorite and monzogranite (Cretaceous)** -- Forms the most voluminous unit of the plutonic suite of the Chemehuevi Mountains: light-tan to gray, medium- to coarse-grained, subporphyritic to porphyritic biotite-sphene granodiorite and monzogranite. Zoned microcline megacrysts, measuring up to 6 cm across, make up as much as 40% of the volume of the rock; they are set in a medium-grainedgroundmass consisting of quartz, plagioclase, microcline, and biotite (5 to 12%) , with coarse accessory sphene and allanite-cored epidote euhedra (up to 2 mm), magnetite, apatite, zircon, and rare primary muscovite. Along the eastern margin or floor of the intrusion, the porphyritic granodiorite is characterized by mineralogic layering defined by 10 to 20 cm wide discontinuous bands of plagioclase+potassium feldspar+quartz and 2 to 5 cm thick biotite rich bands. To the west at structurally higher levels in the suite, only sparse phenocrysts occur (to 1 cm), with large equant β-shaped quartz to 5 mm. Southwest of Chemehuevi Peak at the highest structural levels in the suite, allanite occurs without epidote overgrowths

Kbg **Biotite granodiorite (Cretaceous)** -- Light-gray to tan, subequigranular biotite granodiorite. Biotite is the most abundant mafic phase (up to12 %) and is typically euhedral (to 5 mm), associated with rare blue-green hornblende. Perthitic microcline and quartz are interstitial. Sphene (up to 2%) occurs as euhedral crystals (as large as 2 mm) and as overgrowths on magnetite. Apatite and zircon occur in and near the magnetite. Metamict subhedral allanite grains up to 1-2 mm are rare throughout this phase and commonly have euhedral epidote overgrowths. Borders of this unit against the porphyritic hornblende-biotite granodiorite and Proterozoic gneisses are fine- to medium-grained, and contain rare potassium feldspar megacrysts up to 4 cm long. Inward, away from the older rocks, these phenocrysts increase in abundance and primary igneous flow structures appear. Mineralogically, the biotite granodiorite is nearly identical to the porphyritic granodiorite, but has rare hornblende

Kgd **Porphyritic hornblende-biotite granodiorite (Cretaceous)** -- The border unit to the plutonic suite of the Chemehuevi Mountains. Gray, medium-grained, quartz-poor, variably porphyritic, hornblende-biotite granodiorite. The granodiorite includes small equant microcline phenocrysts (up to 1 cm), stubby blue-green hornblende (4 to 20%), euhedral biotite (2 to 5%), coarse sphene (1 to 3%), and accessory magnetite, allanite, epidote, and zircon. The epidote is considered late magmatic based on textural relations. The granodiorite is deformed and bears a mylonitic foliation and subhorizontal lineation

Whale Mountain sequence (Cretaceous and/or Jurassic) -- Consists of:

KJqm **Porphyritic hornblende-biotite monzogranite and quartz monzonite (Cretaceous or Jurassic)** -- Tan to pale-pink, medium- to coarse-grained, porphyritic hornblende-biotite monzogranite. Characterized by unzoned microcline megacrysts measuring up to 3 cm, and mafic enclaves up to 10 % of the rock volume. Locally has a steeply-dipping mylonitic foliation and subhorizontal lineation

KJqd **Hornblende-biotite quartz diorite and quartz monzodiorite (Cretaceous or Jurassic)** --Dark gray to brown concordant bodies (up to 1 km by 4 km in plan view) of hornblende-biotite quartz diorite and quartz monzodiorite. This phase is characterized by plagioclase phenocrysts up to 3-4 mm, in a matrix of 18-38% medium-grained, blue-green hornblende and blue-green biotite, with accessory sphene, magnetite, apatite, and zoned allanite with overgrowths of epidote. Along the northern flank of the Chemehuevi Mountains these rocks bear a steeply dipping mylonitic foliation and subhorizontal lineation. Rocks south of Chemehuevi Peak, in the lowlands along the south flank of the range, are undeformed, and intrude nonmylonitic Proterozoic gneisses and amphibolites (unit Xgn)

KJd **Hornblende diorite and gabbro (Cretaceous or Jurassic)** -- Dark-gray hornblende diorite and gabbro. The diorite is medium grained, with 5 to 10 % each modal quartz and potassium feldspar, and contains biotite, and accessory sphene, magnetite, apatite, and zoned allanite with overgrowths of epidote. As with unit KJqd, these rocks locally have a steeply-dipping mylonitic foliation and subhorizontal lineation in the northern Chemehuevi Mountains. Small intrusions south of Chemehuevi Peak, along the south flank of the range, are undeformed, and intrude nonmylonitic Proterozoic gneisses and amphibolites (unit Xgn)

qm **Biotite monzogranite to syenogranite (Cenozoic or Mesozoic)** -- Tan, coarse-grained, weakly foliated, subequigranular monzogranite to syenogranite. Contains sparse euhedral biotite (up to 2 %)

lgn **Biotite monzogranite and leucogneiss (Mesozoic or Proterozoic)** -- Coarse-grained, biotite monzogranite, garnet-spotted leucogneiss, and finely layered, locally garnetiferous gneiss. Locally includes small pods of amphibolite. Exposed along the southern flank of the Chemehuevi Mountains and in Chemehuevi Valley

Ophitic diabase dikes (Middle Proterozoic) -- Dark gray to black, massive, medium-grained ophitic diabase dikes. The dikes vary from one to tens of meters thick, and trend northwest. They intrude units Yg and Xgn, and are considered equivalent to the 900 Ma to 1.1 Ga ophitic diabases discussed by Howard and others (1982), Hammond (1986) and Fitzgibbon and Howard (1987) based on textural, compositional, and mineralogical similarities

Yg **Porphyritic monzogranite (Middle Proterozoic)** -- Tan to pale-red, coarse-grained porphyritic biotite granodiorite to monzogranite. Dark-gray, tabular potassium-feldspar megacrysts (up to 4 cm) are typically rimmed by plagioclase, and sit in a matrix of plagioclase, quartz, potassium feldspar, biotite, rare hornblende, magnetite, and sphene. These rocks are considered equivalent to the 1.4 to 1.5 Ga anorogenic granites discussed by Anderson (1983), based on textural, compositional, and mineralogical similarities to granites at Parker Dam and Davis Dam

Xgn **Gneiss and migmatite (Early Proterozoic)** -- Heterogeneous crystalline rocks including migmatite, granite, and amphibolite-facies orthogneiss and paragneiss. Layered gneiss, the most common rock, consists of leucocratic, biotite ± garnet- bearing quartzo-feldspathic gneiss, and is associated with subordinate coarse pegmatite, biotite schist, amphibolite to hornblendite, and rare augen gneiss. Lowlands along the south flank of the Chemehuevi Mountains expose a complex of garnet-bearing leucocratic granitic gneiss, amphibolite, pegmatite, and fine-grained, laminated, biotite quartzo-feldspathic gneiss. The age of the unit is uncertain; south of Red Rock Wash, near Devils Elbow, the gneisses are intruded by undeformed coarse-grained porphyritic monzogranite (Yg). This relationship suggests that the unit of gneissic rocks is older than 1.4 Ga and based on regional knowledge, is probably ~ 1.7 Ga

Xmgn **Mylonitized gneiss and migmatite (Early Proterozoic)** -- Mylonitized, heterogeneous crystalline rocks including migmatite, granite, and amphibolite-facies orthogneiss and paragneiss. Probably mylonitic equivalent to Xgn. In the central and eastern Chemehuevi Mountains, layered gneiss has a superposed shallow-dipping, northwest-striking mylonitic foliation, and locally a subhorizontal mylonitic lineation. Equivalent rocks in the northwestern part of the range near Whale Mountain have a steep, northeast-striking foliation and a subhorizontal mylonitic lineation

Note: Not shown on this map are swarms of Tertiary and Cretaceous(?) dikes that intrude rocks below the Chemehuevi detachment fault. The dikes are dark greenish gray to black, gray, and tan. The dikes are highly variable in composition and texture, and range in composition from coarse grained hornblende diorite and olivine gabbro to biotite-bearing dacite porphyry, and are centered in the plutonic suite of the Chemehuevi Mountains. Dark- weathering diabase dikes form a major intrusive phase. Diabase dikes are typically fine-to medium-grained, subophitic and contain plagioclase and pyroxene. In the western part of the range, massive, subvertical northeast-trending lamprophyre dikes are common. They are characterized by two generations of amphibole, a very heterogeneous texture, and extreme local alteration. Intermediate to silicic andesite to dacite dikes are gray to tan weathering, with variable phenocryst mineralogy including plagioclase, hornblende, biotite and potassium feldspar

REFERENCES CITED

Anderson, J.L., 1983, Proterozoic anorogenic granite plutonism of North America: Geological Society of America Memoir 161, p. 133-154.

Fitzgibbon, T.T., and Howard, K.A., 1987, Tectonic significance of Middle Proterozoic diabase sheets in southeastern California and Arizona: Geological Society of America Abstracts with Programs, v. 19, no. 6, p. 372.

Hammond, J.G., 1986, Geochemistry and petrogenesis of Proterozoic diabase in the southern Death Valley region of California: Contributions to Mineralogy and Petrology, v. 93, p. 312-321.

Howard, K.A., Stone, P., and Pernokas, M.A., and Marvin, R.F., 1982, Geologic and geochronologic reconnaissance of the Turtle Mountains area, California: west border of the Whipple detachment terrane, in Frost, E.G., and Martin, D.L., eds., Mesozoic-Cenozoic Tectonic Evolution of the Colorado River Region, California, Arizona and Nevada (Anderson- Hamilton volume): San Diego, Calif., Cordilleran Publishers, p. 341-354.

Howard, K.A., and John, 1987, Crustal extension along a rooted system of imbricate low-angle faults: Colorado River extensional corridor, California and Arizona, in Coward, M.P., Dewey, J.F., and Hancock, P.L., eds., Continental Extensional Tectonics; Geological Society of London Special Paper No. 28, p. 299-311.

John, B.E., 1986, Structural and intrusive history of the Chemehuevi Mountains area, southeastern California and western Arizona: unpublished Ph.D.dissertation, University of California, Santa Barbara, 295 pages, one plate.

John, B.E., 1987, Geometry and evolution of a mid-crustal extensional fault system: Chemehuevi Mountains southeastern California, in Coward, M.P., Dewey, J.F., and Hancock, P.L., eds., Continental Extensional Tectonics; Geological Society of London Special Paper No. 28, p.312-339.

Longwell, C.W., 1963, Reconnaissance geology between Lake Mead and Davis a Dam, Arizona-Nevada: U.S. Geological Survey Professional Paper 374-E, p. E1-E51.

Young, and Brennan, 1974, Peach Springs Tuff: It's bearing on the structural evolution of the Colorado Plateau and development of Cenozoic drainage in Mohave County, Arizona: Geological Society of America Bulletin, v. 85, p. 83-90.