OLIGOCENE VOLCANIC ROCKS, THE BEAR CANYON CONGLOMERATE, AND THE CHOCOLATE MOUNTAINS ANTICLINORIUM, SE CALIFORNIA: EVIDENCE FOR NEOGENE REACTIVATION OF A REGIONAL SCALE LONG-LIVED FOLD AND ITS TECTONIC IMPLICATIONS

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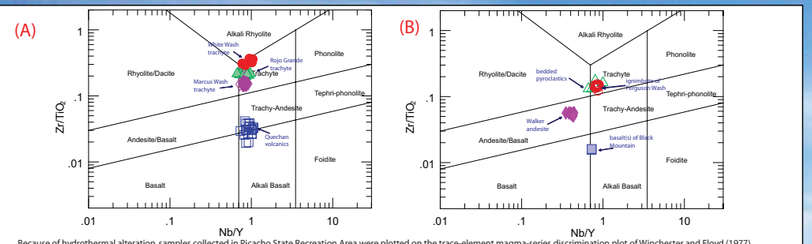
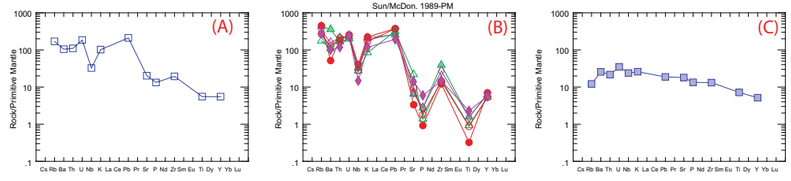
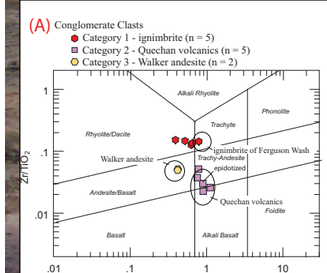


Because of hydrothermal alteration, samples collected in Picacho State Recreation Area were plotted on the trace-element magma-series discrimination plot of Winchester and Floyd (1977) as revised by Pearce (1996). The 21 Quechan samples plot as trachy-andesites to alkali basalts (A). The Marcus Wash, Rojo Grande, White Wash, bedded pyroclastics, and ignimbrite of Ferguson Wash units form distinct groups within the trachyte field (A and B). All of the samples of the Walker unit plot closely together in the andesite field (B). The samples of basalt(s) of Black Mountain form a tight group in the alkali basalt field distinct from the Quechan volcanics (B).

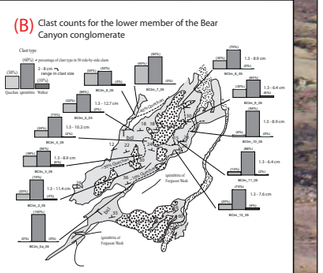


Major- and trace-element chemistry of (A) the Oligocene Quechan volcanics, (B) intermediate-aged Oligocene volcanics, and (C) the middle to late Miocene basalt of Black Mountain plotted on spider diagrams normalized to the primordial mantle of Sun and McDonough (1989). Note that the trends for the Quechan volcanics and all of the Oligocene intermediate-aged units display a Nb-trough, suggesting that Nb was either crystallized in a mineral phase or was locked as a compatible element in a mineral phase in the source rock. Additionally, the basalt(s) of Black Mountain has a unique chemical trend that lacks the Nb-trough of the older volcanic units.



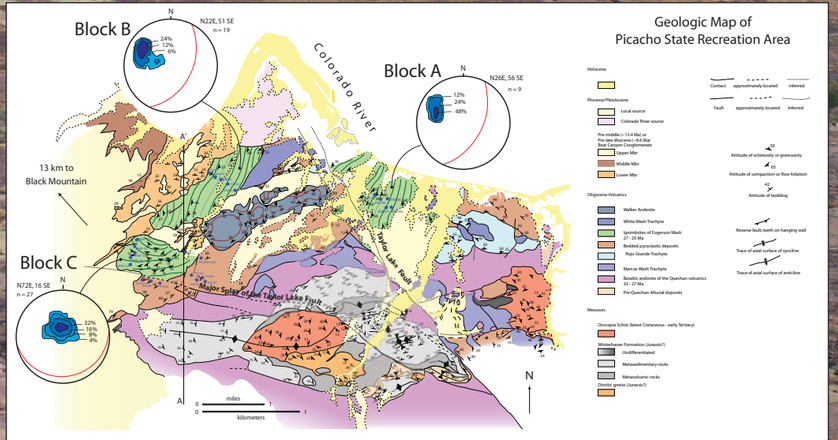
(A) Major and trace-element chemistry of clasts from the lower member of the Bear Canyon conglomerate are plotted on the trace-element magma-series discrimination plot of Winchester and Floyd (1977) as revised by Pearce (1996). The lower member of the Bear Canyon conglomerate unconformably overlies Oligocene volcanics and is tilted on average ~21° NW, reaching a thickness of ~300 m in the NW. It consists mostly of poorly sorted paraconglomerates with sub-round to sub-angular clasts ranging in size from pebbles to boulders. Note that clasts from categories 1, 2, and 3 fall approximately within the chemical fields defined by the ignimbrite of Ferguson Wash, Quechan volcanics, and Walker andesite, respectively.

(B) This figure reports the relative clast populations of the lower member of the Bear Canyon counted by Cameron Campbell and Gary Girty. The trendlines delineate increasing proportions of Quechan clasts. While ignimbrite clasts dominate the lower 2-3 meters, Quechan clasts increase to the NE, stratigraphically up through the section. This relationship suggests that the lower member of the Bear Canyon Conglomerate represents the successive unroofing of the Oligocene volcanic complex.

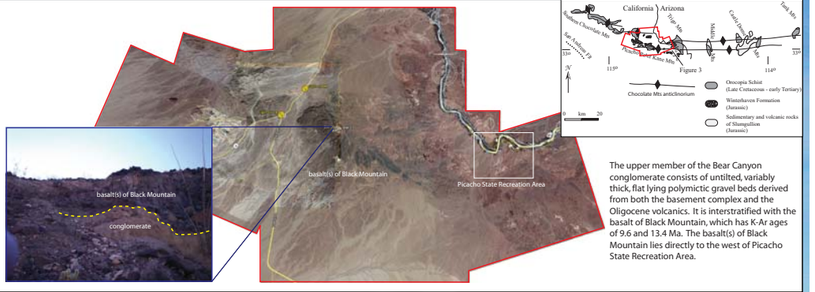


Abstract

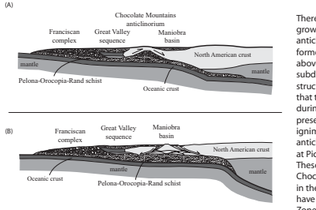
The following models have been proposed to explain the tectonic evolution of the Chocolate Mountains anticlinorium: (1) the anticlinorium is a fault-bend-fold that formed during the Paleogene low-angle subduction of the Farallon plate, (2) the anticlinorium formed during Neogene extensional exhumation, and (3) the anticlinorium is a long-lived feature that may have been reactivated during Neogene exhumation and strike-slip faulting related to the Eastern California Shear Zone. At Picacho State Recreation Area, Oligocene volcanics and an unconformably overlying sequence of Neogene alluvial sediments referred to as the Bear Canyon conglomerate lie on the north limb of the anticlinorium. Our mapping of the volcanic section suggests the following stratigraphic hierarchy: Quechan volcanics (33 - 27 Ma), trachyte of Marcus Wash, trachyte of Rojo Grande, bedded pyroclastic deposits, trachyte of White Wash, ignimbrite of Ferguson Wash (27 - 25 Ma), and Walker andesite (the probable youngest unit). In order to assess the reliability of our stratigraphic framework we and other students at SDSU analyzed a total of 104 samples representative of the volcanic section. On a Zr/TiO_2 vs Nb/Y diagram, samples from each unit cluster and do not overlap with other mapped units, a relationship that supports our stratigraphic subdivisions. Textural analysis of the youngest dated Oligocene unit, the ignimbrite of Ferguson Wash, shows that it is a welded vitric lapilli tuff. Chemical analyses of the ignimbrite, and samples from the underlying bedded pyroclastic sequence, indicate that both units have a similar trachytic composition that is distinctive relative to other Oligocene volcanic units mapped at Picacho. The lower member of the Bear Canyon conglomerate unconformably overlies the ignimbrite of Ferguson Wash, and is tilted more steeply to the NW (~21°) than is the middle member (~15°), while the upper member is flat lying and may be interstratified with the ~13.4 - 9.6 Ma basalt(s) of Black Mountain. Chemical and petrological data show that clasts in the lower member were derived from the unroofing of the underlying Oligocene volcanic section, while the middle member contains abundant clasts derived from mylonitic dioritic granitoids that may have been exposed in the core of the Chocolate Mountains anticlinorium. Map relationships show structural blocks of the ignimbrite off set ~1 km in a dextral sense along the main branch of the Taylor Lake fault system. In addition, a major splay off the fault system deflects foliation defined by flattened pumice into the trend of the splay in a manner that is consistent with ~ 500 m of dextral slip. We interpret the above relationships to indicate Neogene reactivation (between ~27-25 and ~13-9 Ma) of the anticlinorium during formation of the Taylor Lake fault system, and suggest that reactivation and distributed dextral shear may reflect early NS shortening associated with the development of the Eastern California Shear Zone.



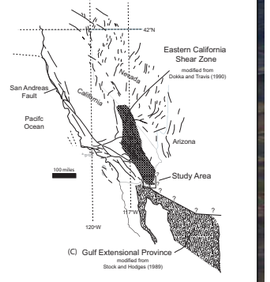
A foliation defined by flattened pumice fragments in the ignimbrite strikes ~NE in block A and block B. Foliation attitudes plotted on lower hemisphere equal area stereonets suggest little to no rotation about a vertical axis occurred during the off-set of the ignimbrite along the main branch of the Taylor Lake fault. However, the same foliation in Block C displays a ~50 degree rotation. Block C is bounded along its southern margin by a major splay of the Taylor Lake fault, and this prominent foliation appears to have been dragged into the strike of the fault in a manner that is consistent with dextral slip.



The upper member of the Bear Canyon conglomerate consists of untilted, variably thick, flat lying polymictic gravel beds derived from both the basement complex and the Oligocene volcanics. It is interstratified with the basalt of Black Mountain, which has K-Ar ages of 9.6 and 13.4 Ma. The basalt(s) of Black Mountain lies directly to the west of Picacho State Recreation Area.



There are two disparate models for the formation and growth of the anticlinorium. According to Yin (2002) the anticlinorium represents a Paleogene fault-bend-fold that formed above a ramp in the floor thrust of a duplex lying above and parallel to the low-angle portion of the subducting Farallon plate (A). Thermochronological and structural data from Jacobson et al. (2006), however, suggests that this area was undergoing extensional exhumation during this time frame (B). The purpose of this study is to present new structural and geochemical evidence from the ignimbrite of Ferguson Wash that indicates that the anticlinorium and the newly defined Taylor Lake fault system at Picacho State Recreation Area formed after ~27-25 Ma. These data will help to constrain the age of the activity of the Chocolate Mountains anticlinorium. Structural relationships in the Picacho region suggest that the anticlinorium may have been reactivated as part of the Eastern California Shear Zone (C).



Summary
Basement structural features are folded about the anticlinorium
The Sortan fault was active ~ 28-24 Ma
Folding must have been initiated after ~28-24 Ma
The Taylor Lake fault system cuts through the entire Oligocene volcanics package, including the ignimbrite of Ferguson Wash (27-25 Ma)
The fault must have been active after the deposition of the volcanics
The Taylor Lake fault system has not been folded by the anticlinorium, therefore folding must have ceased by the time the Taylor Lake fault was active
The Taylor Lake fault does not cut through the upper member of the Bear Canyon conglomerate, thus activity of the fault must be older
The middle and lower members of the Bear Canyon conglomerate are tilted, but the upper member is flat-lying
Growth of the anticlinorium is restricted to after the deposition of the ignimbrite and before the deposition of the upper member of the Bear Canyon conglomerate

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