The Pickhandle and Jackhammer formations in the northern Calico Mountains, CA: Evidence of synextensional deposition and volcanism in the central Mojave metamorphic core complex

Bryan P. Murray

Department of Geological Sciences, California State Polytechnic University, Pomona

Abstract

The early Miocene Pickhandle Formation of the central Mojave Desert, CA is inferred to represent synextensional supradetachment basin deposits of the central Mojave metamorphic core complex (CMMCC); however, direct stratigraphic evidence of synextensional deposition of these rocks is not well documented. This study in the northern Calico Mountains, located on the hanging wall block of the Waterman Hills detachment fault in the CMMCC, provides evidence of synextensional deposition of the Pickhandle Formation and the underlying Jackhammer Formation during upper plate extension. The Jackhammer Formation is deposited on nonmylonitic pre-Tertiary basement rocks of the hanging wall block, and consists of interbedded reworked tuff and lapilli tuff, tuffaceous sandstone, conglomeratic sandstone, and localized basement-derived megabreccia, lacustrine limestone, and mafic lavas. In the east, a ~130 m-thick crystal-rich welded ignimbrite, herein named the "Mammut ignimbrite", dominates the Jackhammer Formation deposits. The Pickhandle Formation is conformable with the Jackhammer Formation, consisting of two members: a synvolcanic lower member of monomict clastic volcaniclastic breccia and block-and-ash flows, and an upper member of polymict conglomeratic sandstone, conglomerate, tuffaceous sandstone, and reworked tuff and lapilli tuff. Reddish porphyritic silicic plugs and lavas were emplaced during and after deposition of the upper Pickhandle Formation. Both of these formations represent coeval volcanic and alluvial deposits that appear to thicken and coarsen eastward toward a high-angle NW-trending, SW-dipping basin-bounding normal fault. Paleocurrent indicators suggest primarily SW-directed flow, with clasts mainly derived from nonmylonitic basement and intrabasinal dacitic rocks. Fanning bedding dips, intraformational angular unconformities, and intercalated alluvial and lacustrine deposits are located adjacent to the basin-bounding fault; several additional NW-trending normal faults in the study area were also active during and following deposition of these rock units. Many faults exhibit postextensional strike-slip reactivation, likely related to subsequent development of the right-lateral Calico Fault system located ~7 km to the southwest of the study area.

Geologic Setting

Figure 1: Regional geologic map of the Miocene extensional belt in the central Mojave Desert, CA, from The Buttes to the Rodman Mountains. Mylonitic rocks and synkinematic intrusions from the footwall of the central Mojave metamorphic core complex (CMMCC) are shown in black; the Pickhandle Formation in the upper plate of the CMMCC is shown with vertical striping. GF: Garlock Fault, HH: Hinkley Hills, MR: Mitchel Range, SAF: San Andreas Fault, WH: Waterman Hills (after Fletcher et al., 1995). Previous thermochronology studies suggest that CMMCC extension occurred between ~21 -17.5 Ma (Gans et al., 2005), while stratigraphic studies suggests that extension was active between ~24 - 19 Ma (Fillmore and Walker, 1995).

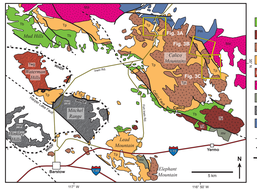

Figure 2: Generalized geologic map of the central Mojave Desert region near the Calico Mountains, showing the location of the Waterman Hills detachment fault (WHDF) and the distribution of early Miocene rocks in the area (modified from Singleton and Gans, 2008).

Geologic Maps

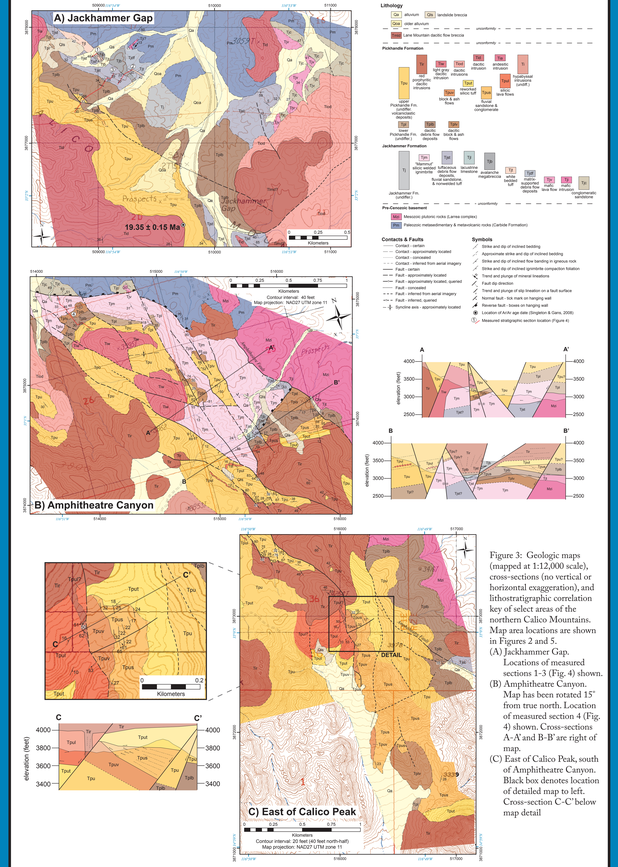

Figure 3: Geologic maps (mapped at 1:12,000 scale), cross-sections (no vertical or horizontal exaggeration), and lithostratigraphic correlation key of select areas of the northern Calico Mountains. Map area locations are shown in Figures 2 and 5.
(A) Jackhammer Gap. Locations of measured sections 1-3 (Fig. 4) shown. Cross-sections A-A' and B-B' are right of map.
(B) Amphitheatre Canyon. Map has been rotated 15° from true north. Location of measured section 4 (Fig. 4) shown. Cross-sections A-A' and B-B' are right of map.
(C) East of Calico Peak, south of Amphitheatre Canyon. Black box denotes location of detailed map to left. Cross-section C-C' below map detail

Stratigraphic Sections

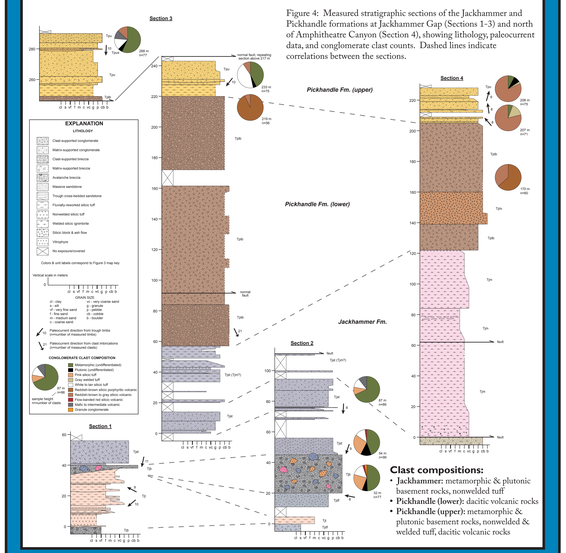

Figure 4: Measured stratigraphic sections of the Jackhammer and Pickhandle formations at Jackhammer Gap (Sections 1-3) and north of Amphitheatre Canyon (Section 4), showing lithology, paleocurrent data, and conglomerate clast counts. Dashed lines indicate correlations between the sections.

Paleocurrents

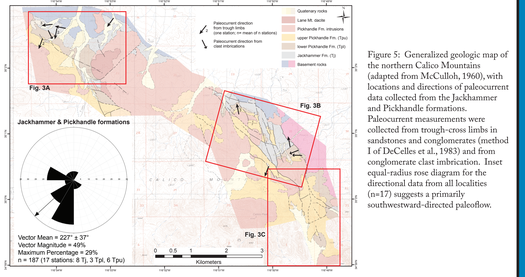

Figure 5: Generalized geologic map of the northern Calico Mountains (adapted from McCulloh, 1960), with locations and directions of paleocurrent data collected from the Jackhammer and Pickhandle formations. Paleocurrent measurements were collected from trough-cross limbs in sandstones and conglomerates (method I of DeCelles et al., 1983) and from conglomerate clast imbrication. Inset equal-radius rose diagram for the directional data from all localities (n=17) suggests a primarily southwestward-directed paleoflow.

Field photos

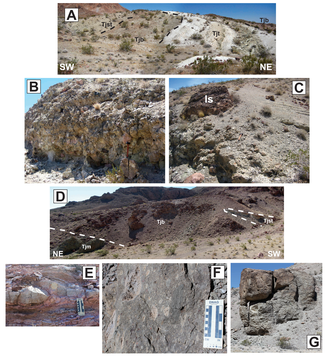

Figure 6: Jackhammer Formation: (A) Annotated photograph of Jackhammer Formation at Section 1 in Jackhammer Gap (Figs. 3A & 4). Avalanche megabreccia (Tjb) thickens in direction of viewer and pinches out on backside of hill, where tuffaceous debris flow deposits and sandstone (Tjst) overlie Tjt. Width of photograph is ~250 feet. (B) Avalanche megabreccia with basement and silicic ignimbrite boulders, at 22 m in Jackhammer Gap measured section 2 (Fig. 4). (C) Top of avalanche megabreccia at 45 m in Jackhammer Gap measured section 2 (Fig. 4), with a large 5 m-diameter limestone boulder (ls). (D) Interfingering avalanche breccia (Tjb) and tuffaceous sandstone (Tjst) in Amphitheatre Canyon near middle of cross-section B-B' (Fig. 3B). (E) Very thinly bedded lacustrine limestone in Amphitheatre Canyon (Fig. 3B) with possible soft-sediment deformation structure left of scale. (F) Close-up of eutaxitic texture in welded basal section of Mammut ignimbrite. This ignimbrite is crystal-rich (30–40% phenocrysts) with 15–20% lithic fragments (most 0.5–5 cm, max ~50 cm). (G) Distinctive rock outcrop of the Mammut ignimbrite in Amphitheatre Canyon (Fig. 3B) that inspired the name of this rock unit.

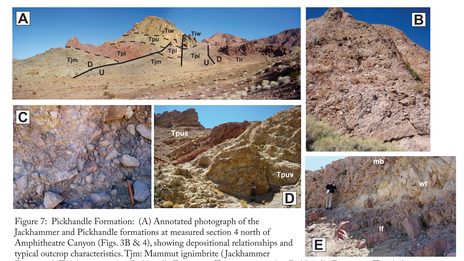

Figure 7: Pickhandle Formation: (A) Annotated photograph of the Jackhammer and Pickhandle formations at measured section 4 north of Amphitheatre Canyon (Figs. 3B & 4), showing depositional relationships and typical outcrop characteristics. Tjm: Mammut ignimbrite (Jackhammer Formation), Tpl: lower member Pickhandle Formation, Tpu: upper member Pickhandle Formation, Tiw: light gray dacitic intrusion, Tir: red porphyritic dacitic intrusion. (B) Lower member monomict (dacitic) debris flow breccia adjacent to the Amphitheatre Fault. Maximum clast size ~1.25 m. (C) Close-up of lower member monomict debris flow breccia at Figure 7B, with porphyritic dacitic clasts. (D) White silicic block-and-ash flow deposit (Tpuv; blocks up to 1 m) below red fluvial sandstone (Tpus) at the location of cross-section C-C' (Fig. 3C). (E) Silicic lava flow-top breccia (lf), white tuff layer (wt), and monomict breccia (mb) in the upper member. Breccia (mb) is clast-supported with flow-banded dacitic boulders (up to 1 m) similar in appearance to underlying lava (lf).

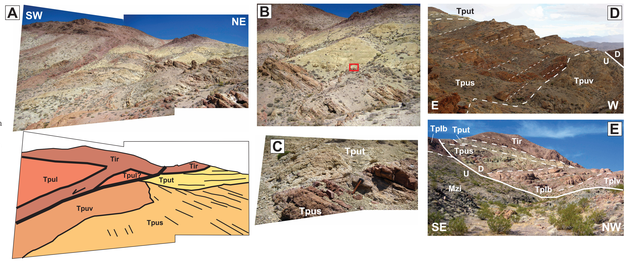

Figure 8: Evidence of growth strata in the Pickhandle Formation, suggesting syndepositional deformation of the Amphitheatre Fault in the northeastern Calico Mountains. Unit labels same as Figure 3. (A) Photograph and interpretation of intrusion, fault, & depositional relationships at the location of cross-section C-C' (Fig. 3C), west of the Amphitheatre Fault. Fanning bedding dips and intraformational angular unconformities in the upper Pickhandle Formation (Tput-Tpus) are present. Width of photograph is ~0.4 km. (B) Photograph looking NW at the intraformational angular unconformity in the upper Pickhandle Formation at cross-section C-C' (Fig. 3C). Vertical relief ~80 m. Red box denotes location of figure 8C. (C) Close-up of intraformational angular unconformity between upper Pickhandle Formation fluvial sandstone (Tpus) and overlying reworked silicic lapilli tuff (Tput). (D) Annotated photograph looking S at the location of cross-section C-C' (Fig. 3C), showing fanning bedding dips in the upper Pickhandle Formation (Tpus). Width of photograph is ~0.3 km along ridge. (E) Annotated photograph looking SW near the east end of cross-section B-B' (Fig. 3B) at eastward-tilted Pickhandle Formation (lower & upper members) on the hanging wall of the Amphitheatre Fault, which underlie westward-tilted reworked silicic lapilli tuff (Tput) & and dacitic lava (Tir). The Jackhammer Formation is generally absent on the footwall of the Amphitheatre Fault, where the lower Pickhandle Formation is deposited directly on basement Mesozoic granitoids. Width of photograph is ~0.3 km along fault.

Provenance Interpretations

- **Jackhammer Formation:**
  - underlying basement (Paleozoic metamorphic rocks & Mesozoic granitoids)
  - intrabasinal erosion of silicic tuff & mafic volcanic rocks
  - extrabasinal silicic pyroclastic eruptions (tuffs)
- **Lower Pickhandle Formation:**
  - dacitic volcaniclastic rocks reworked from intrabasinal volcanic deposits (lahars and/or debris flow deposits)
  - intrabasinal dacitic pyroclastic eruptions (block-and-ash flows)
- **Upper Pickhandle Formation:**
  - underlying basement (Paleozoic metamorphic rocks and Mesozoic granitoids)
  - intrabasinal erosion of Jackhammer & Pickhandle formations
  - intrabasinal silicic volcanic eruptions (lavas & domes)
  - intrabasinal & extrabasinal silicic pyroclastic eruptions (block-and-ash flows, tuffs)

Basin Development Interpretations

- Jackhammer and Pickhandle formations deposited in a synextensional basin within the upper plate of the CMMCC, likely a half-graben bounded on the east by the W-dipping Amphitheater Fault, thinning to the west. Evidence includes:
  - Paleoflow directions generally towards the southwest, away from the Amphitheatre Fault
  - Growth strata in Pickhandle Formation adjacent to Amphitheatre Fault
  - Lower Pickhandle Formation deposits thicker/coarser in Amphitheatre Canyon area in comparison to the Jackhammer Gap area
  - Pickhandle Formation (and local Jackhammer Formation) is thinner on the footwall of the Amphitheatre Fault
  - Mammut ignimbrite at the top of the Jackhammer Formation in Amphitheatre Canyon area is welded and at least ~130 m-thick, compared to a correlated ~35 m-thick nonwelded reworked tuff in the Jackhammer Gap area, suggesting ponding in the half-graben
  - Interfingering megabreccias, fluvial sandstone, and lacustrine deposits adjacent to the Amphitheatre Fault suggests an alluvial fan system in the hanging wall basin
  - Jackhammer Formation is nonconformable with Paleozoic metamorphic basement rocks in the Jackhammer Gap region, with the contact geometry, reworked nature of the deposits, and avalanche megabreccia clast compositions suggesting an alluvial channel system incised into the hanging wall block that created steep paleotopography in this area.

ACKNOWLEDGEMENTS:

Cal Poly Pomona Spring 2016 GSC 491L Field Mobile students, Howard Brown, Paul Stone, Phil Cass, John Singleton, Raymond Ng, Arianne Best, Frank Wille, Dana Roeber Murray

REFERENCES CITED:

DeCelles, P.G., Langford, R.P., and Schwartz, R.K., 1983, Two new methods of paleocurrent determination from trough cross-stratification: Journal of Sedimentary Petrology, v. 53, p. 629-642

Fillmore, R. P., and Walker, J. D., 1996, Evolution of a supradetachment extensional basin: The lower Miocene Pickhandle basin, central Mojave Desert, California, in Beratan, K. K., ed., Reconstructing the history of Basin and Range extension using sedimentology and stratigraphy: Geological Society of America Special Paper 303, p. 107-126

Fletcher, J. M., Bartley, J. M., Martin, M. W., Glazner, A. F., and Walker, J. D., 1995, Large-magnitude continental extension: An example from the central Mojave metamorphic core complex: Geological Society of America Bulletin, v. 107, p. 1468-1483

Gans, P., Dewecchio, D., Singleton, J., Van Pelt, J., Wong, M., and Reynolds, J., 2005, Cenozoic magmatic and structural evolution of the central Mojave desert, California: New constraints from 40Ar/39Ar geochronology and thermochronology: Geological Society of America Abstracts with Programs, v. 37, no. 4, p. 103

McCulloh, T. H., 1960, Geologic map of the Lane Mountain quadrangle, California: U.S. Geological Survey Open-File Report 60-95, scale 1:48,000

Singleton, J. S., and Gans, P. B., 2008, Structural and stratigraphic evolution of the Calico Mountains: Implications for early Miocene extension and Neogene transpression in the central Mojave Desert, California: Geosphere, v. 4, no. 3, p. 459-479