

# Evidence of synextensional deposition of the Pickhandle and Jackhammer formations in the northern Calico Mountains, central Mojave Desert, California

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## Abstract

The precise timing of extension in the central Mojave metamorphic core complex (CMMCC) is unclear. Previous thermochronology studies suggest that extension occurred between ~21 - 17.5 Ma, while stratigraphic studies suggests that extension was active between ~24 - 19 Ma. These previous stratigraphic interpretations imply that the timing of initial extension in the CMMCC is related to the depositional age of the volcanic and coarse-grained volcanoclastic deposits of the early Miocene Pickhandle Formation, inferred to represent synextensional supradetachment basin deposits. However, direct stratigraphic evidence of synextensional deposition has not yet been documented for this formation; therefore, the relation between deposition and inception of extension in the CMMCC warrants further investigation.

The Calico Mountains of the central Mojave Desert, CA are located on the hanging wall block of the Waterman Hills detachment fault in the CMMCC. New geologic mapping in the northern Calico Mountains has found direct evidence of synextensional deposition of the Pickhandle Formation and underlying Jackhammer Formation in an intra-hanging-wall half-graben basin bounded on the east by a high-angle NW-trending, SW-dipping normal fault. The Jackhammer Formation is deposited on nonmylonitic basement composed of Paleozoic metasedimentary and metavolcanic rocks and Mesozoic plutonic rocks. It is composed of fluvially-reworked tuff and lapilli tuff that transitions eastward into a welded ignimbrite, tuffaceous sandstone, and local conglomeratic sandstone, mafic lava flows, avalanche breccia, and lacustrine limestone. In the Calico Mountains, the Pickhandle Formation is deposited conformably over the Jackhammer Formation. It consists of a lower section of dacitic volcanoclastic breccia with a local dacitic block and ash flow deposits and an upper section of tuffaceous sandstone, conglomeratic sandstone, and fluvially-reworked tuff and lapilli tuff. Evidence of growth strata indicates synextensional deposition of both formations, including sedimentary and volcanic deposits that thicken and coarsen toward the basin-bounding normal fault to the east with some deposits thinning on the half-graben footwall, fanning bedding dips that decrease upsection, and internal angular unconformities.

## 1. Geologic Setting

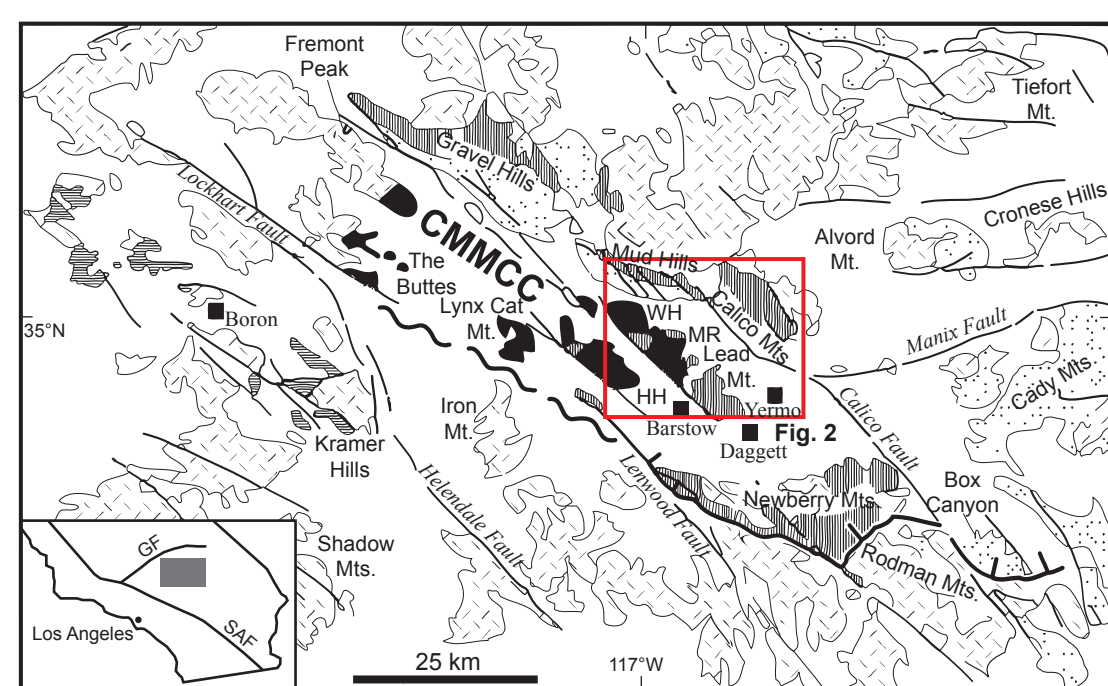
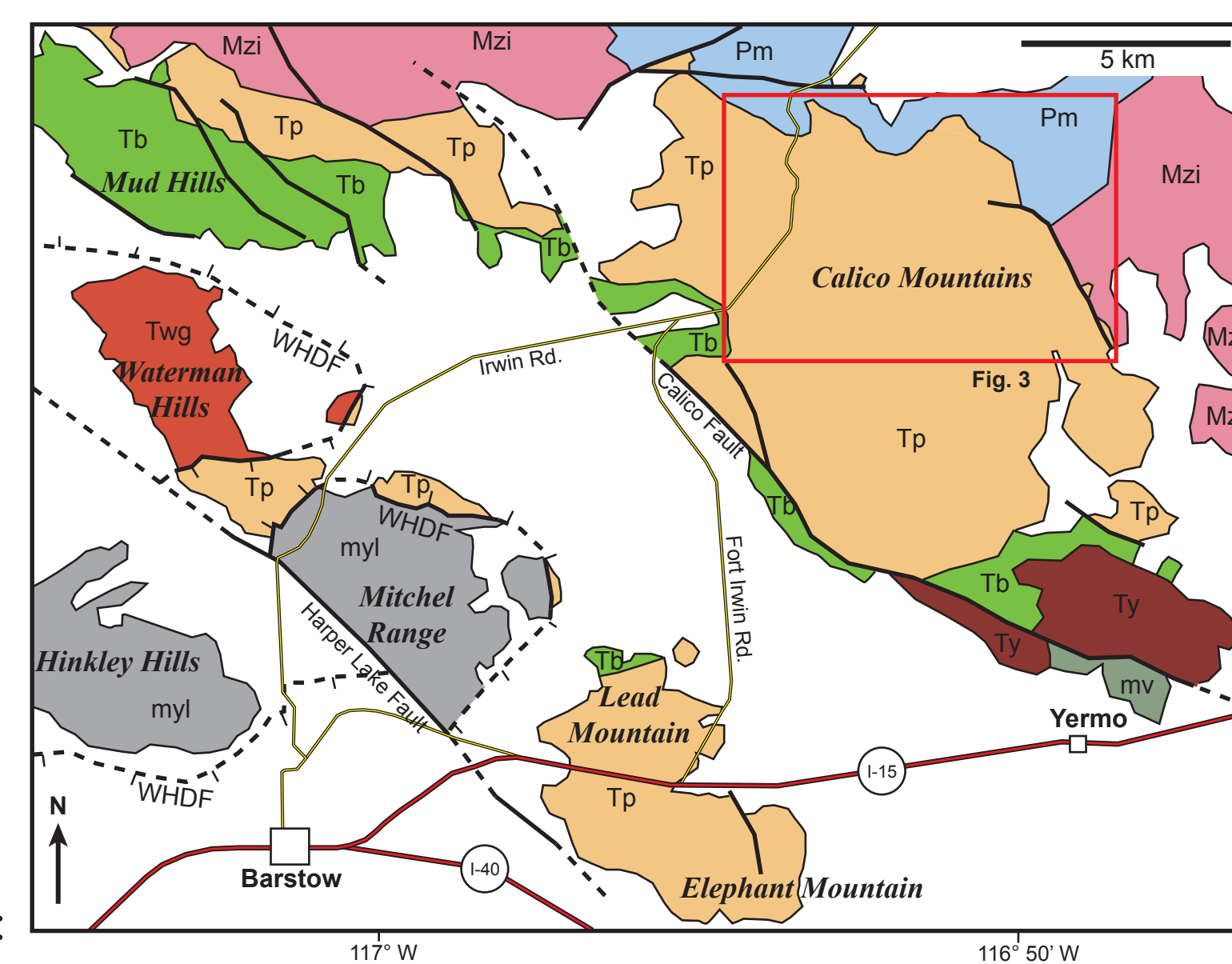


Fig. 1 (left): Regional geologic map of the central Mojave Desert showing the mylonitic and nonmylonitic segments of the Miocene extensional belt from the Buttes to Rodman Mountain. The distribution of mylonitic rocks and synkinematic intrusions from the footwall of the central Mojave metamorphic core complex (CMMCC) are shown in black and the Pickhandle Formation in the hanging wall of the CMMCC are 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). Red box shows location of Fig. 2 (below).

Fig. 2 (right): 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). myl: mylonite footwall of WHDF, mv: metavolcanics (Jurassic Sidewinder Fm.), Mzi: Mesozoic plutonic rocks, Pm: Paleozoic metasedimentary and metavolcanic rocks, Tb: Barstow Formation, Tp: Pickhandle Formation volcanoclastic and intrusive rocks (includes Jackhammer Formation), Twg: Waterman Hills granodiorite, Ty: dacite of Yermo volcanic center. Red box shows location of Fig. 3.



## REFERENCES CITED:

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.

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.

## 2. Geologic Map

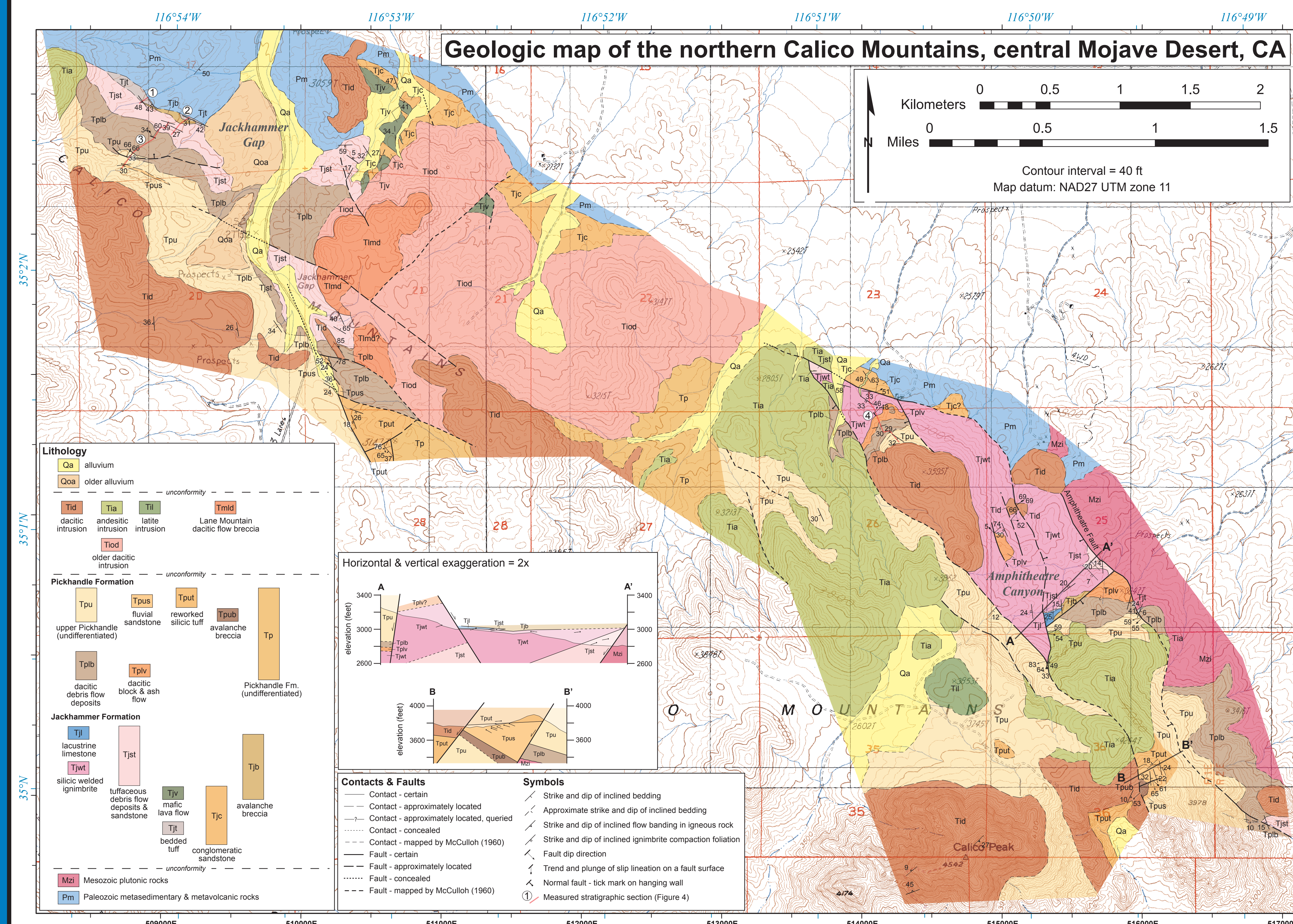


Fig. 3: Geologic map of the northern Calico Mountains, central Mojave Desert, CA, showing structural relationships, cross-sections A-A' and B-B', and location of four measured stratigraphic sections (Fig. 4, right). Modified from McCulloh (1960).

## 4. Field photos



Fig. 5 (left): Annotated photograph of the Jackhammer and Pickhandle formations at measured section 4 (Fig. 4), north of Amphitheatre Canyon. Tjw: Jackhammer Formation, welded silicic ignimbrite; Tpu: lower Pickhandle Formation; Tid: dacitic intrusion.

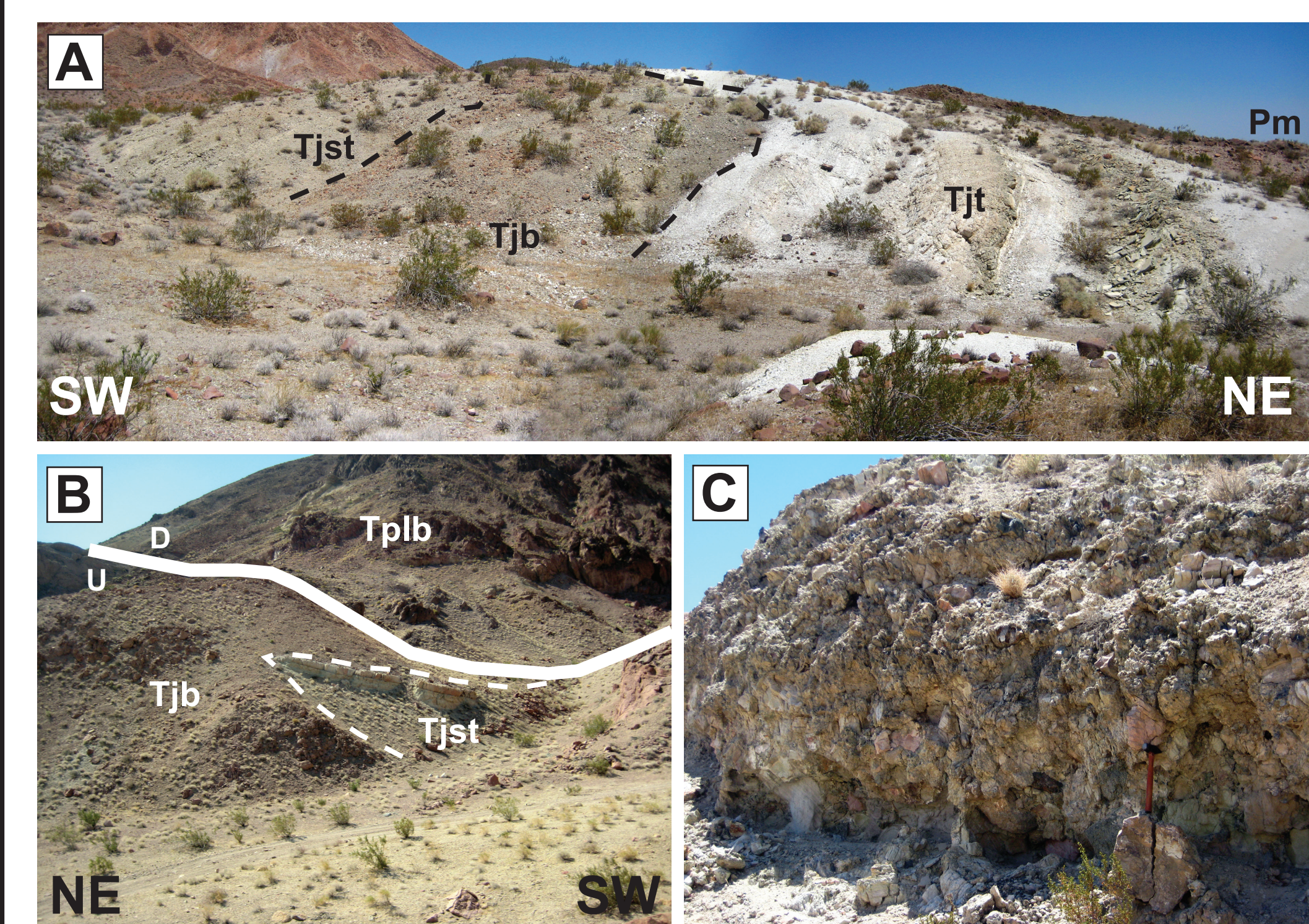


Fig. 6 (left): Jackhammer Formation: (A) Annotated photograph of basal Jackhammer Formation at Section 1 in Jackhammer Gap, with white bedded tuff (Tjt) deposited unconformably on metamorphic basement. (B) Interfingering avalanche breccia (Tjb) and tuffaceous sandstone and debris-flow deposits (Tjst) in Amphitheatre Canyon along cross-section A-A'. (C) Avalanche breccia (Tjb) with basement and silicic ignimbrite boulders (up to 5 m), at 22 m in Jackhammer Gap measured section (Fig. 4).

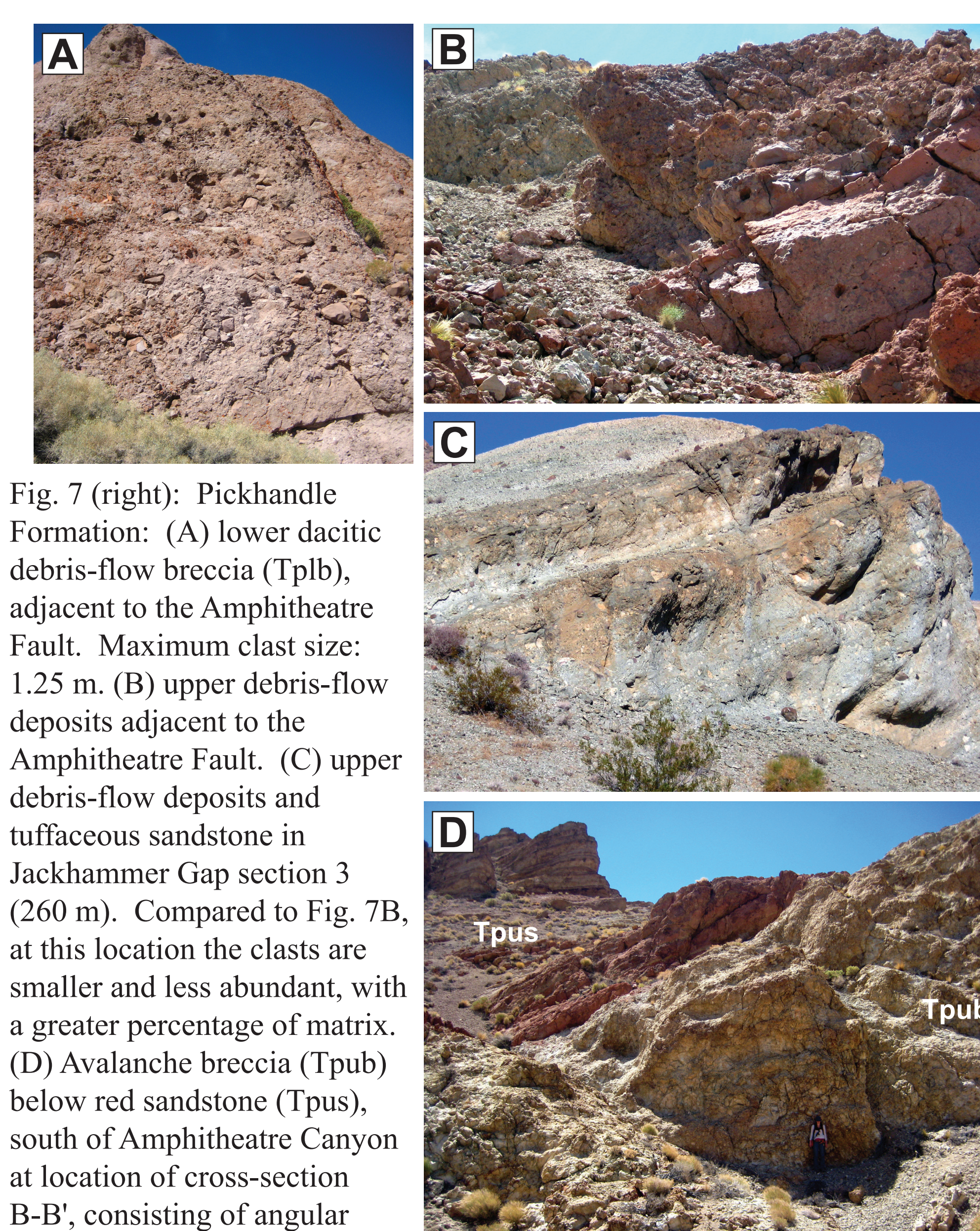


Fig. 7 (right): Pickhandle Formation: (A) lower dacitic debris-flow breccia (Tpb), adjacent to the Amphitheatre Fault. (B) upper debris-flow deposits adjacent to the Amphitheatre Fault. (C) upper debris-flow deposits and tuffaceous sandstone in Jackhammer Gap section 3 (260 m). Compared to Fig. 7B, at this location the clasts are smaller and less abundant, with a greater percentage of matrix. (D) Avalanche breccia (Tpb) below red sandstone (Tpus), south of Amphitheatre Canyon at location of cross-section B-B', consisting of angular white silicic ignimbrite blocks (cobble to boulder; up to 1 m).

## 3. Stratigraphic Sections

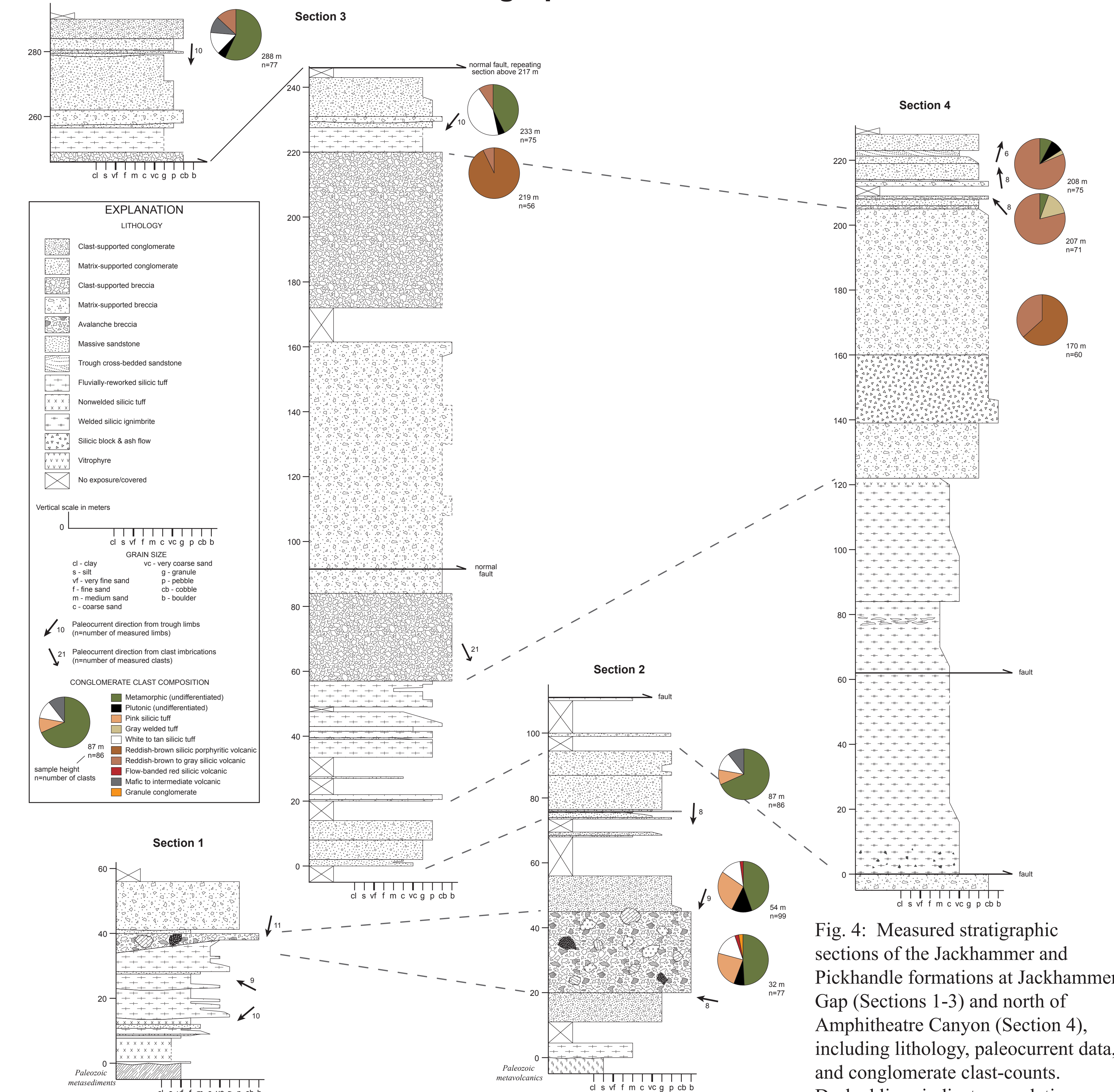


Fig. 4: Measured stratigraphic sections of the Jackhammer and Pickhandle formations at Jackhammer Gap (Sections 1-3) and north of Amphitheatre Canyon (Section 4), including lithology, paleocurrent data, and conglomerate clast-counts. Dashed lines indicate correlations between the sections.