Petrogenetic relationships of Pliocene volcanic debris-avalanche deposits in the northern Sierra Nevada, California

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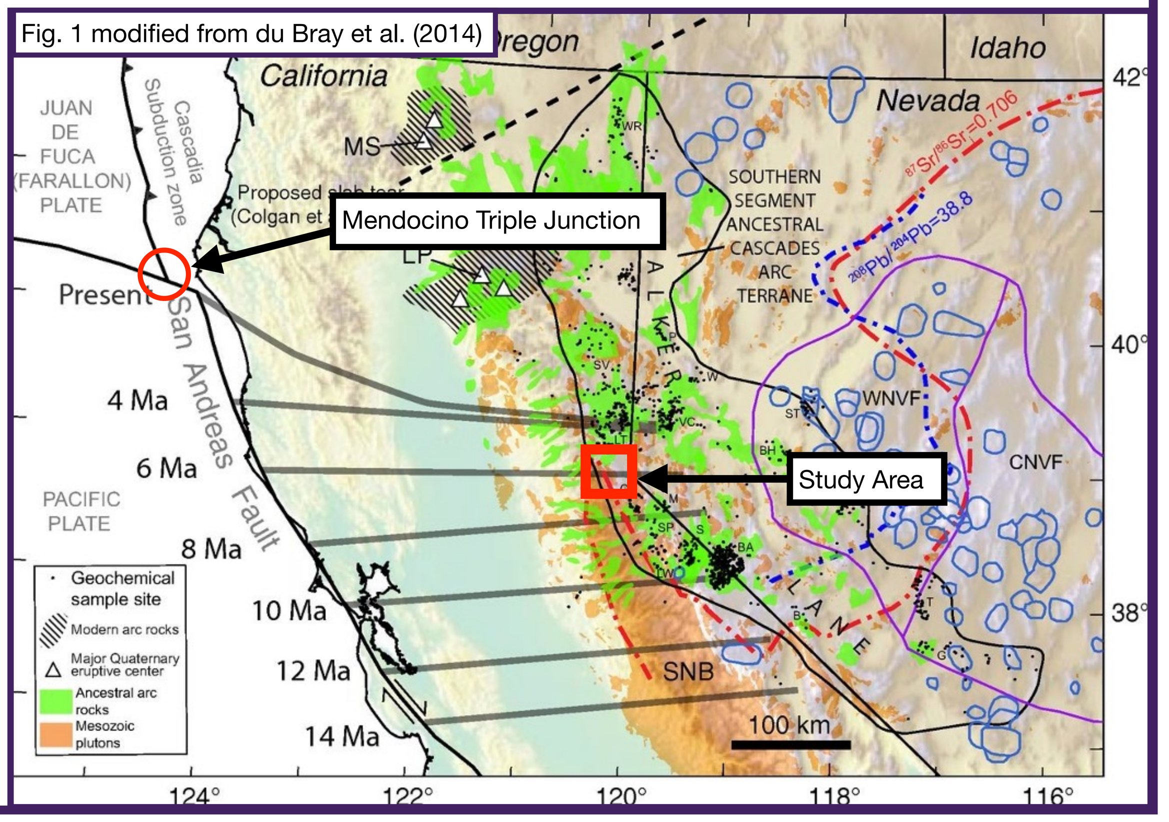
Abstract

The Sierra Nevada in California has a rich Cenozoic volcanic history including important arc sequences related to the southern Ancestral Cascades dating as far back as 30 Ma (du Bray et al., 2014). The present study focuses on Pliocene volcanic debris-avalanche deposits in the northern Sierra Nevada that fill paleocanyons west and northwest of Lake Tahoe (Figure 1). The paleocanyons trend west, west-southwest, and west-northwest from an unknown volcanic source to the east (Berkebile, 2003; Harwood et al., 2014). The main objective of this study is to examine petrogenetic relations of the debris-avalanche deposits and obtain isotopic ages for them. Another purpose is to determine if the three debris-avalanche deposits are from the same eruptive event or possibly the result of separate eruptions and multiple source vents. To acquire detailed data for this study, I am using whole-rock major and trace-element chemistry and electron microprobe analysis of phenocryst phases in volcanic rocks.

Fig. 1 modified from du Bray et al. (2014)



Geologic Background and Introduction to Volcanic Debris-avalanche Deposits

Shutdown of the Ancestral Cascade arc around Lake Tahoe occurred approximately 6.0-4.0 Ma as the southern edge of the Farallon plate migrated north-northwest in a transition from continental arc to post-arc extensional volcanism (Fig. 1) (du Bray et al., 2014). The present day range-front fault system, formed between 2.4 and 3.0 Ma, truncates Pliocene volcanic deposits resulting in volcanic centers being disconnected from their deposits and buried by younger rocks (Harwood et al., 2014). My study focusses on large-scale Pliocene volcanic-debris avalanche deposits associated with the Ancestral Cascades near Lake Tahoe, California.

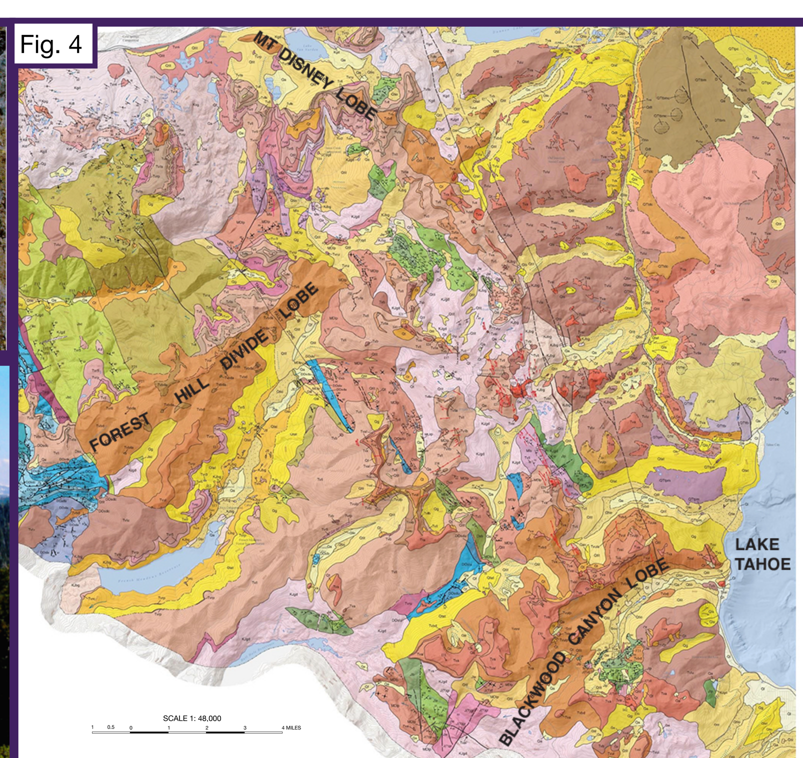
Volcanic-debris avalanches (VDAs) are initiated when unstable sections of stratovolcanoes collapse for a variety of reasons (Glicken, 1996; van Wyk de Vries and Davies, 2015). They consist of high-particle-concentration flows in which coarser clasts are supported by a fine-grained matrix along with high-energy clast interactions (acoustic fluidization) and possibly by high-temperature volcanic gas during transport. Deposits are normally polymict with clasts or blocks up to a kilometer or more in scale, which are termed megaclasts and are normally derived from the volcanic edifice (e.g. lava flows, pyroclastic deposits, volcaniclastic sediments) (Glicken, 1996). Megaclasts characteristically show intense brecciation and clasts commonly have jigsaw fragmentation textures.

The volcanic debris-avalanche deposits in the study area are found in three widely separated lobes west of the Sierran crest, and the range-front fault zone (Fig. 4). These three lobes are named; the Mt. Disney lobe to the north, the Blackwood Canyon lobe to the south, and the Forest Hill Divide lobe to the west-southwest (Fig. 4). All three lobes fill older canyons and are potentially the result of a single, catastrophic eruptive event from a currently unknown volcanic source to the east. Whole-rock K-Ar dating on units above and below the deposits indicates formation of the avalanche deposits between ~5.0 Ma and ~4.0 Ma (Harwood et al., 2014). Characteristic blue-grey dacite/andesite megablocks occur in all three lobes with other megablocks consisting of andesitic to basaltic debris-flow deposits and lavas (Fig. 2, 3, 16, and 17) (Berkebile, 2003; Harwood et al., 2014).

Fig. 2

Fig. 3

Fig. 4



LEGEND
- Yellow - Upper Pleistocene and Holocene cover
- Reds, browns, and purples - younger volcanics (0.92 to ~4.0 Ma)
- Orange - volcanic debris-avalanche deposits (this study)
- Pink - Cretaceous granitoids
- Greens and blues - Jurassic and older rocks

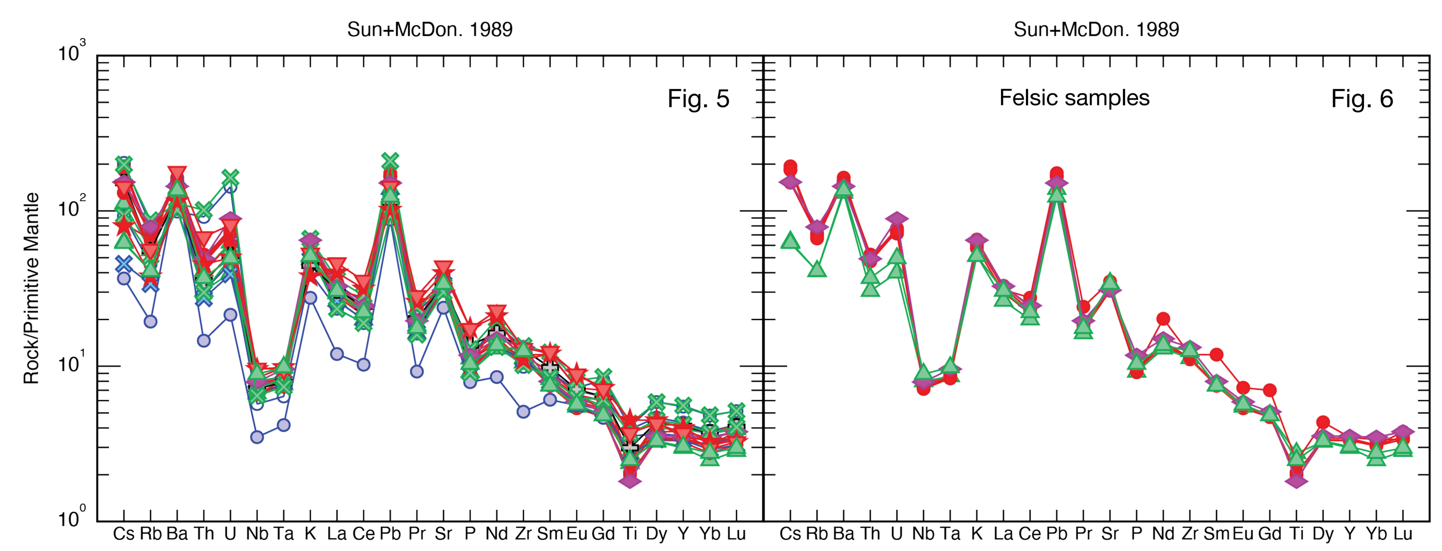
Modified from Harwood et al. (2014)

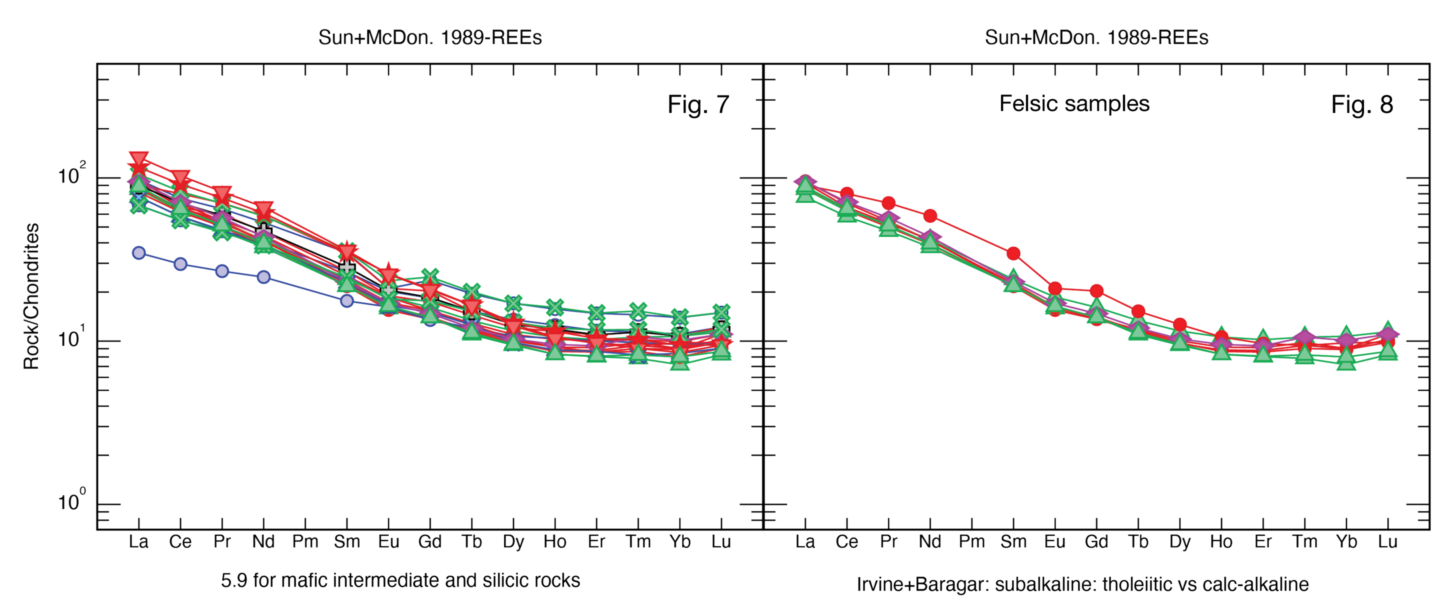
Methods

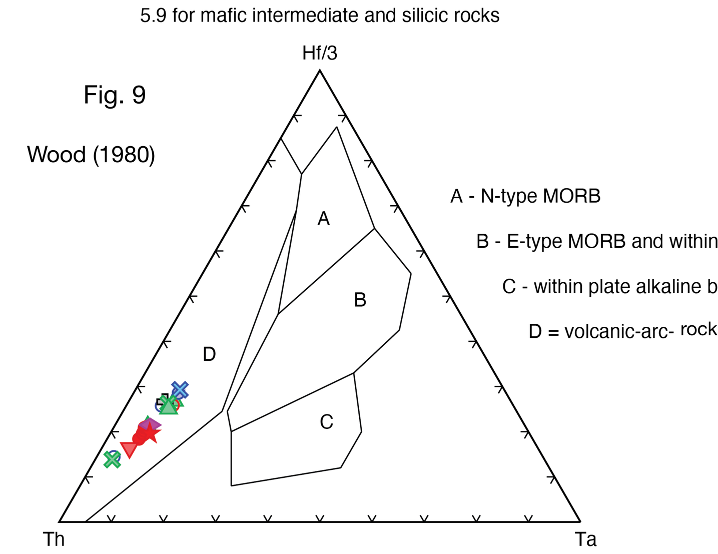
- **Field work (June 2021)**
  - Drove to California with Dr. Richard Hanson to collect megablock samples of varying compositions (andesite, dacite, and basalt).
  - Total of 18 samples collected, including at least one andesite and/or dacite sample from each lobe. Two samples collected were from younger volcanics at an Anderson Peak lava flow and an andesitic dike feeding a scoria cone.
- **Whole-Rock Geochemistry**
  - GeoAnalytical Laboratory at Washington State University. X-ray fluorescence (XRF) was used for major and some trace elements. Additional trace elements will be measured using inductively couple plasma-mass spectrometry (ICP-MS).
  - Four samples collected from Berkebile (2003) were sent in addition to the 18 samples collected.

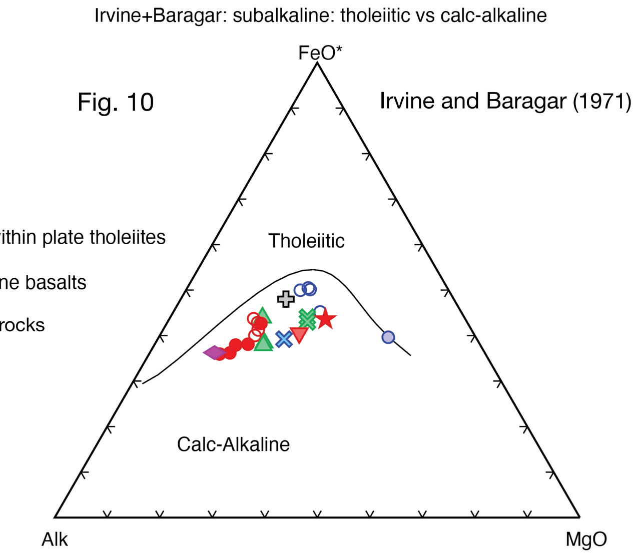
Results

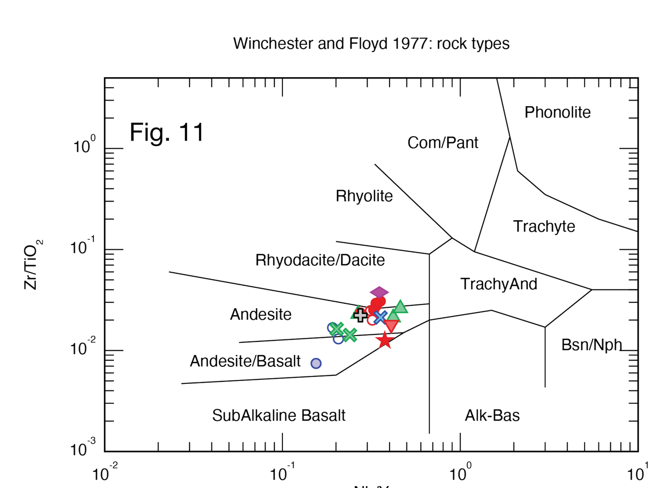
*22 samples used in this study

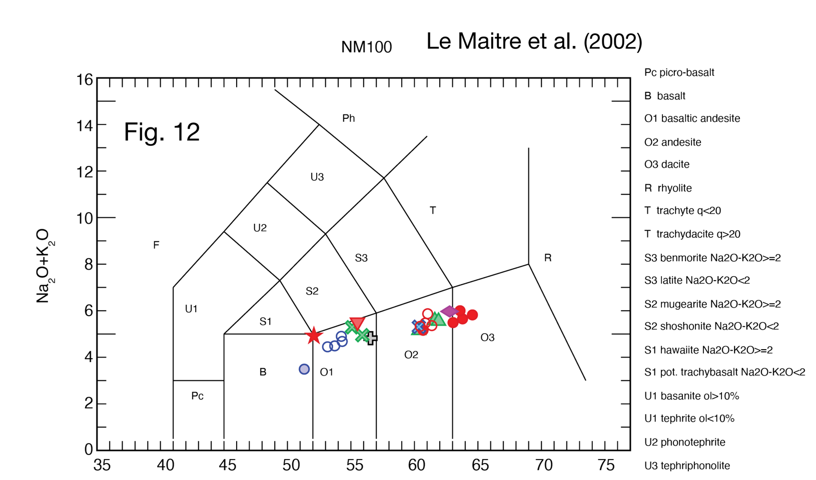


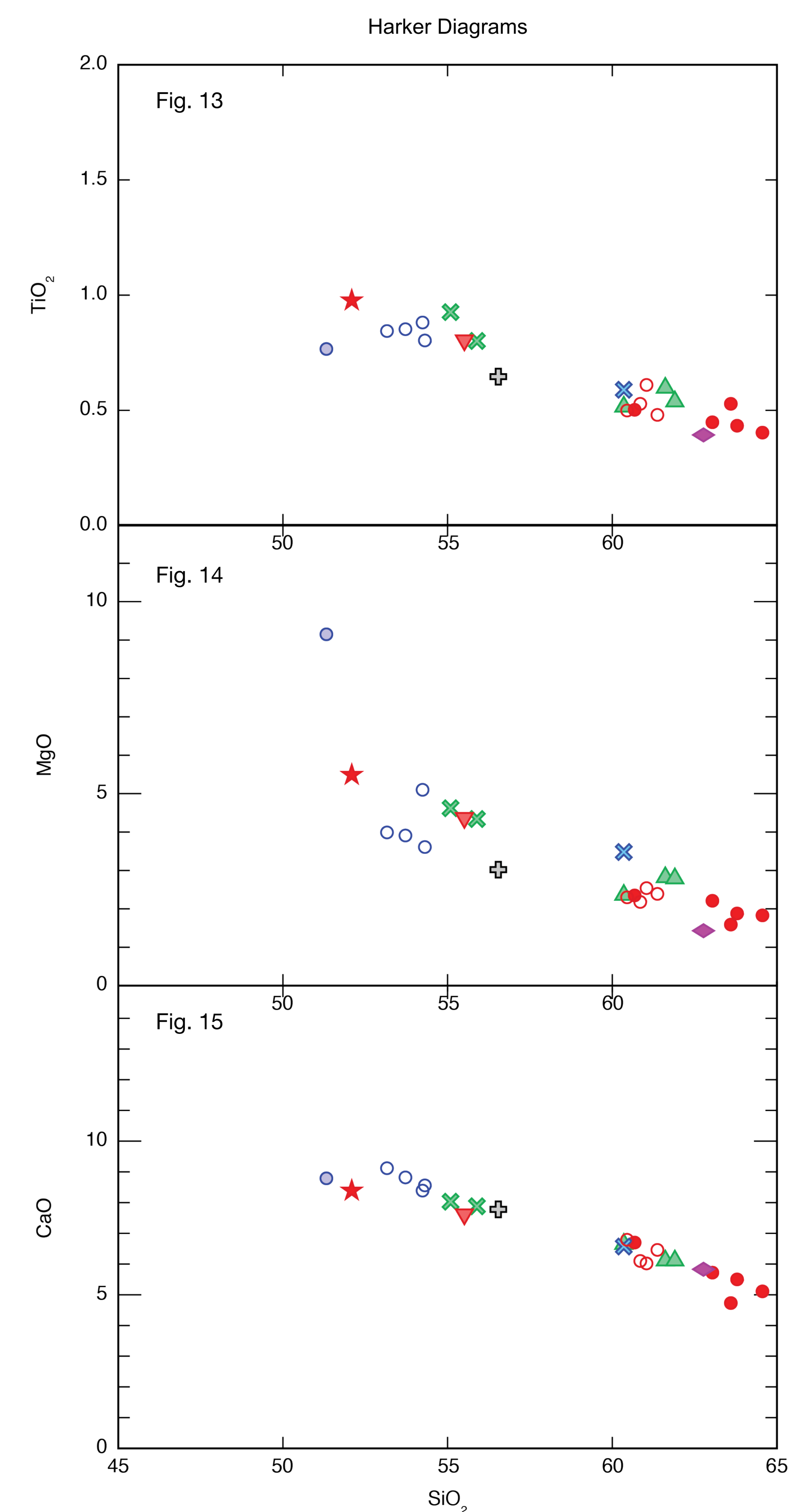












Megaclasts
- FHD-B
- FHD-BA
- FHD-A
- FHD-D
- BWC-BA
- BWC-A
- MD-BA
- MD-A
- MD-D

Younger Volcanics
- AP-A
- BWC-BA

*The legend key reads as location followed by the rock type
-Locations of megaclasts: FHD (Forest Hill Divide lobe), BWC (Blackwood Canyon lobe), and MD (Mt. Disney lobe)
-Rock type: B (Basalt), BA (Basaltic Andesite), A (Andesite), and D (Dacite) e.g. FHD-B reads as Forest Hill Divide Basalt
-Red star is for andesitic dike
-Grey cross is for Anderson Peak lava flow

Discussion and Conclusions

Dacite samples from Forest Hill Divide and Mt. Disney plot closely together on a TAS diagram (Fig. 12) and on Winchester and Floyd (1977) (Fig. 11) rock type diagram. On REE and multi-element diagrams (Fig. 5, 6, 7, and 8), trends for the higher SiO_2 content samples tend to plot on top of each other (Fig. 6 and 8). The Irvine and Baragar (1971) AFM diagram (Fig. 10) shows normal calc-alkaline differentiation trends that correlate with volcanic-arc magmas from Wood (1980) diagram (Fig. 9). Harker diagrams also displayed normal differentiation trends (Fig. 13, 14, 15). The multi-element diagram and REE diagram show very tightly clustered points indicating the likelihood of a single magma source and the megaclasts are all derived from the collapse of the same stratovolcano. Felsic samples were tightly grouped on both multi-element and REE diagrams suggesting they were erupted from a single large magma flow or by-a hypabyssal intrusion. One sample from Forest Hill Divide displayed anomalous values of Ce, Pr, Sm, Eu, Gd, Tb, and Dy which could be attributed to this megablock being in a zone of hydrothermal alteration prior to the stratovolcano collapse (Fig. 8).

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Fig. 16

Fig. 17