The nature and origin of pebble dikes and associated alteration: Tintic mining district, Utah

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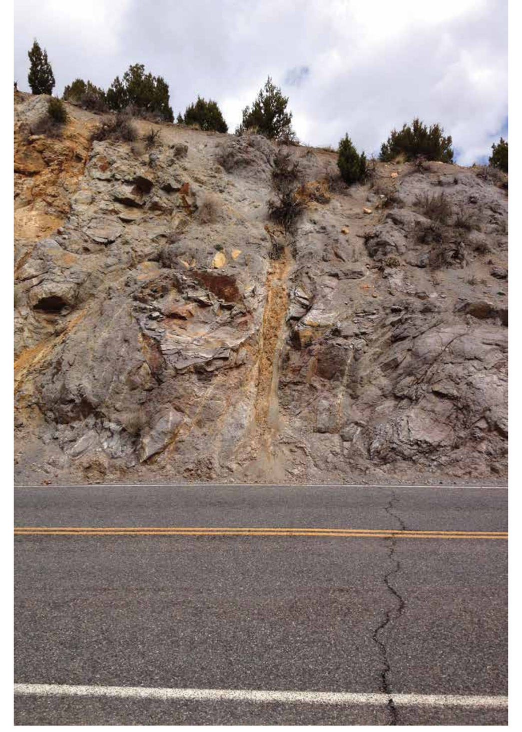
Introduction

Pebble dikes are tabular bodies of breccia dominated by rounded fragments of multiple rock types enclosed in a fine-grained clastic matrix. They appear to be common in many productive mining districts that bear some association to igneous systems. In the Tintic mining district (Pb-Zn-Ag-Cu-Au), Utah, pebble dikes consist of subangular to rounded fragments of quartzite, shale, carbonate, and two types of igneous rock. All fragments appear to have been derived from underlying units. Pebble dikes are thin, typically less than 0.3 m wide to as much as 1 m. Some dike segments exceed 100 m in length. Clast sizes average around 3 cm with clast size increasing with dike width. Contacts are sharp, and an envelope of fractured rock surrounds roughly half of the dikes. Fracture systems parallel and splay out above and below 'blades' of pebble dike. Fragments from immediate wall rock that have been incorporated into the dikes are angular in contrast to rounded clasts transported up from depth.

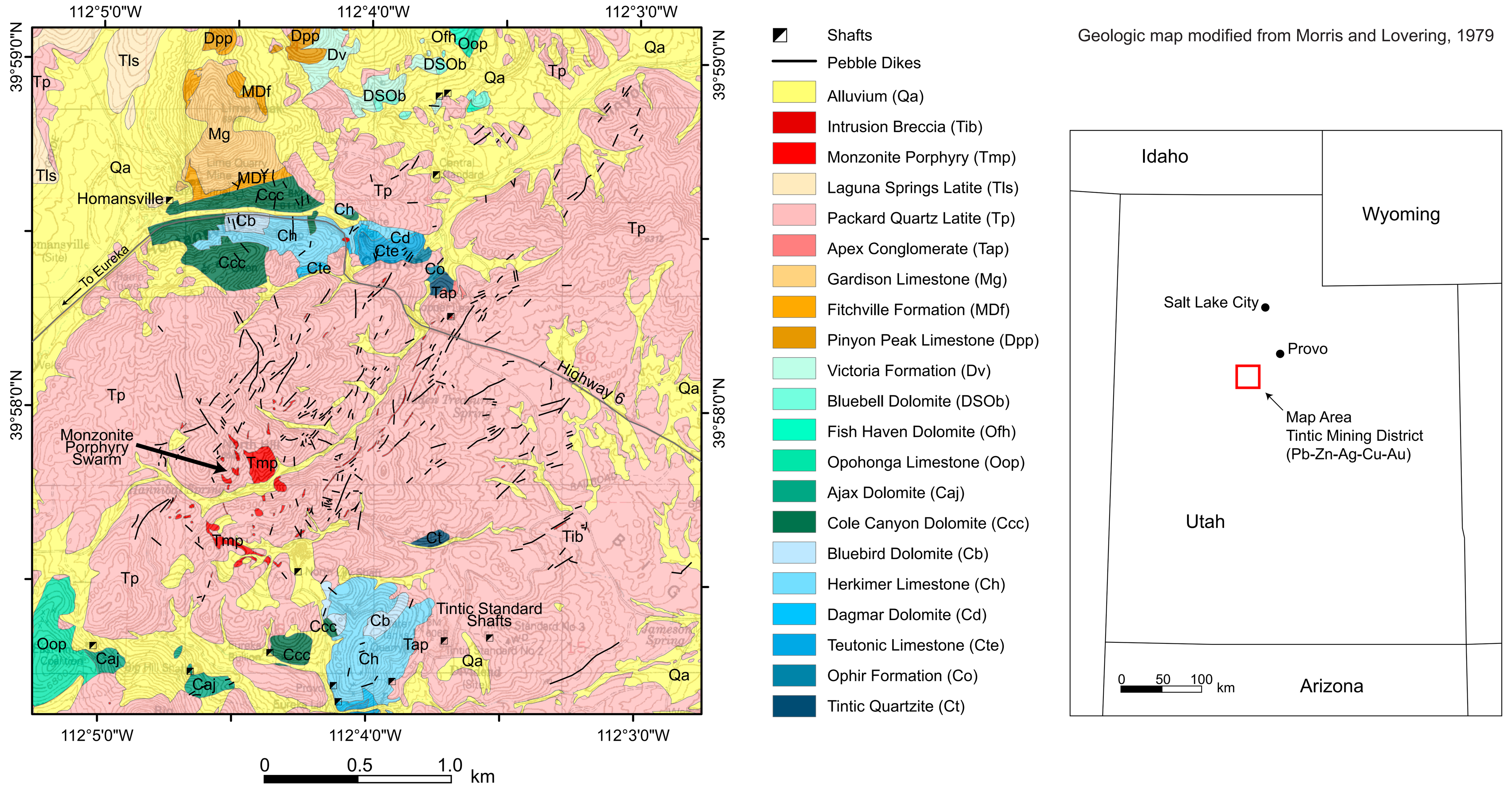
The pebble dikes cut an Eocene rhyolite lava flow (the Packard Quartz Latite) as well as underlying Paleozoic sedimentary rocks. They display a strong northeast trend and often appear in close association with a swarm of narrow dikes and plugs made of monzonite porphyry (see map below). The swarm is roughly 1 km by 2.5 km and is centered on a small shallow intrusion of porphyritic biotite-hornblende monzonite. Locally, pebble dikes grade into monzonite porphyry dikes and at least one monzonite dike contains rounded quartzite pebbles similar to those seen in pebble dikes. Multiple pebble dikes contain rounded pebbles of monzonite porphyry. Pebble dikes are often enveloped by a halo of low-grade argillic and silicic alteration accompanied by the introduction of minor sulfides.



Pebble dike cutting Packard Quartz Latite at characterisitic near-vertical dip. Note alteration staining associated with the dike.

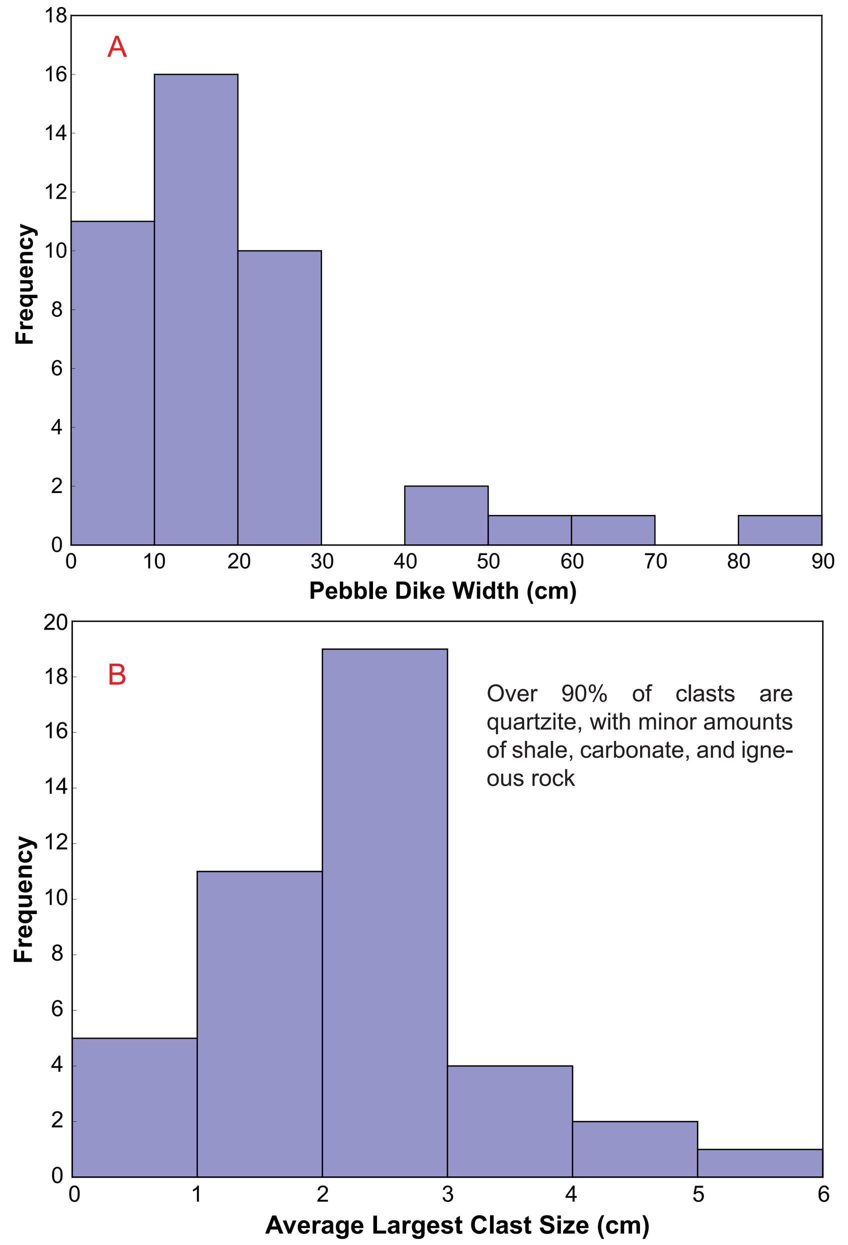
Close-up of pebble dike seen at left. This pebble dike features a finer margin and coarser interior. Clasts are dominantly quartzite with minor shale, carbonate, and igneous rocks.

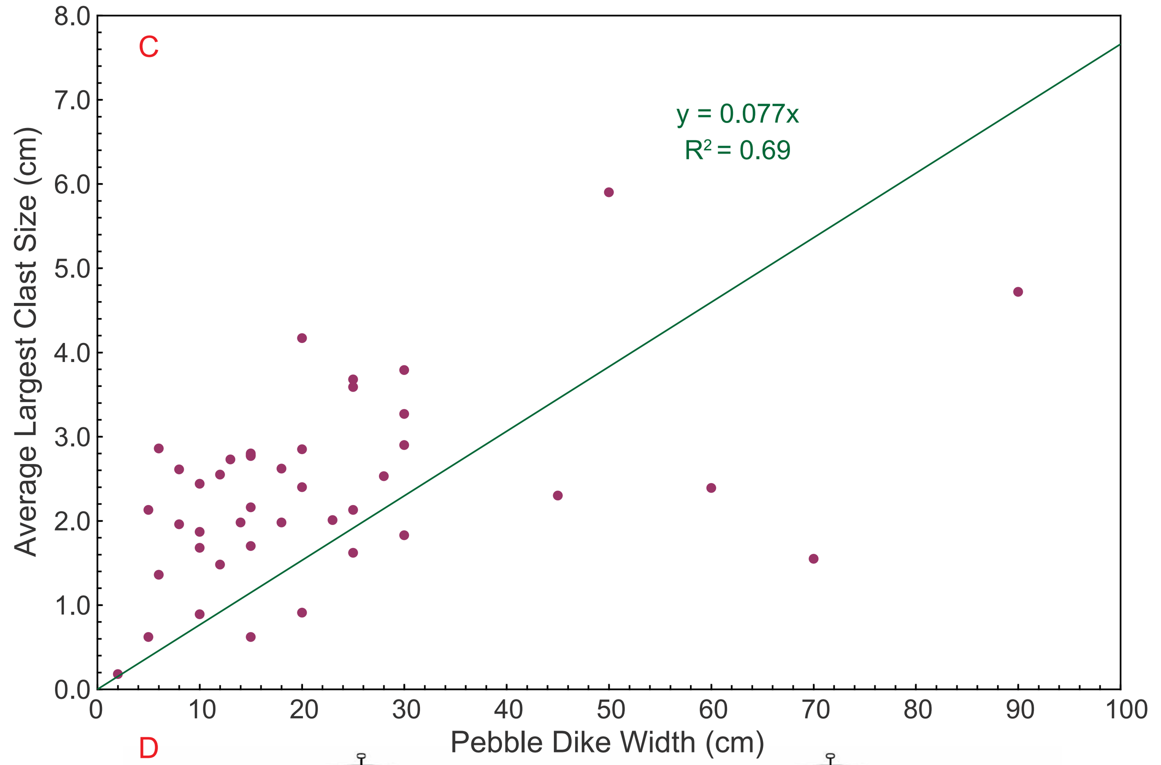
Pebble dike cutting Paleozoic carbonate against bedding. Note laminated reaction margin, clast roundness, variety of clast sizes, and fracturing in adjacent carbonate.

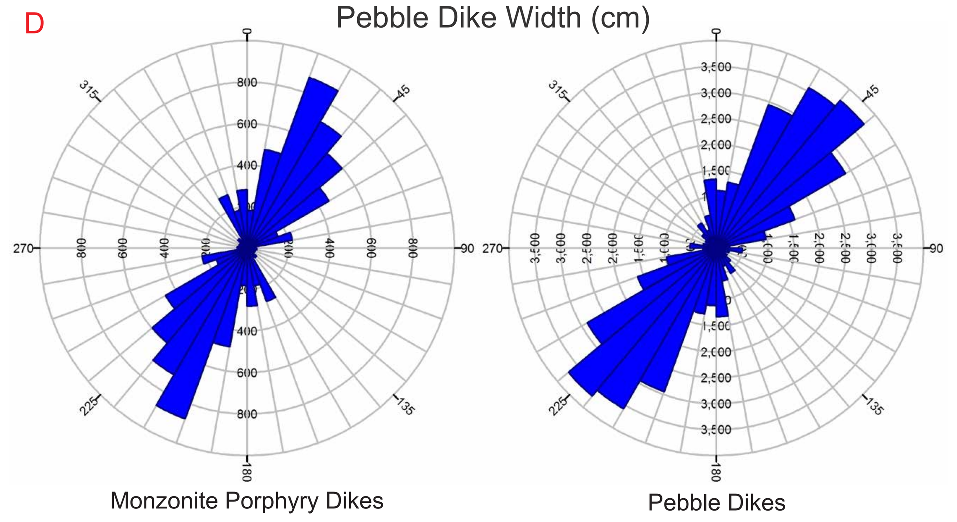


Field Evidence

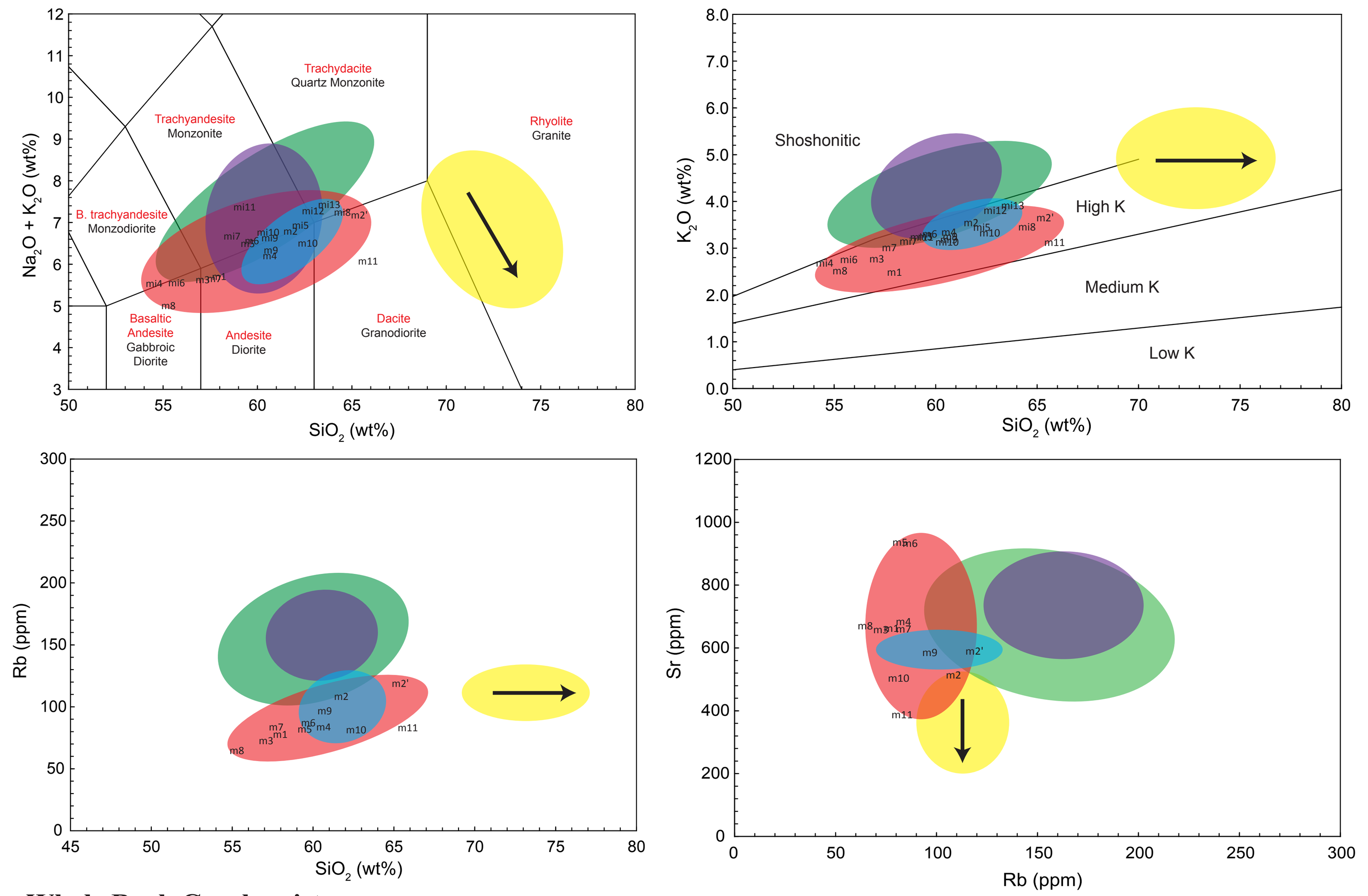
Pebble dikes, denoted by black lines in the map above, are closely associated with a porphyritic monzonite (mapped in red). This monzonite porphyry has been historically mapped as Silver City Stock based solely on its proximity to the actual Silver City Stock which outcrops to the southwest of the map area. The monzonite, however, differs both texturally and mineralogically from the Silver City Stock. Both monzonite dikes and pebble dikes display a strong northeast trend, and both are only found in close proximity to one another. Pebble dikes appear to cut all exposed units in the map area, although their direct cross-cutting association with the monzonite porphyry is unclear. Pebble dikes contain clasts of monzonite material and the monzonite porphyry has been found to contain clasts of rounded quartzite.







A - Histogram of 40 pebble dike widths. Pebble dikes are consistently 20 - 30 cm wide, but widths can reach up to 1 m. B - Histogram of average largest clast size within pebble dikes. Average largest clast size was determined by measuring the longest axis of the ten largest clasts in a 50 cm long section of 40 pebble dikes. Largest clast size averages around 3 cm. The largest clast encountered measured 15 cm. C - Correlation between average clast size and pebble dike width. Although the correlation is weak, clast size correlates positively with width. R^2 was determined using Excel's LINEST function, bounded to zero. D - Rose diagrams of both igneous dike (left) and pebble dike (right) orientations, produced using RockWorks software. Both igneous dikes and pebble dikes display a strong northeast trend with a subordinate north-south trend.



Laguna Springs Latite (33.29 ± 0.09 Ma; Moore, 2007)

Monzonite Porphyry
Black letter symbols denote actual monzonite porphyry values

Rock Canyon Latite (33.80 ± 0.10 Ma; Moore, 2007)

Silver City Stock

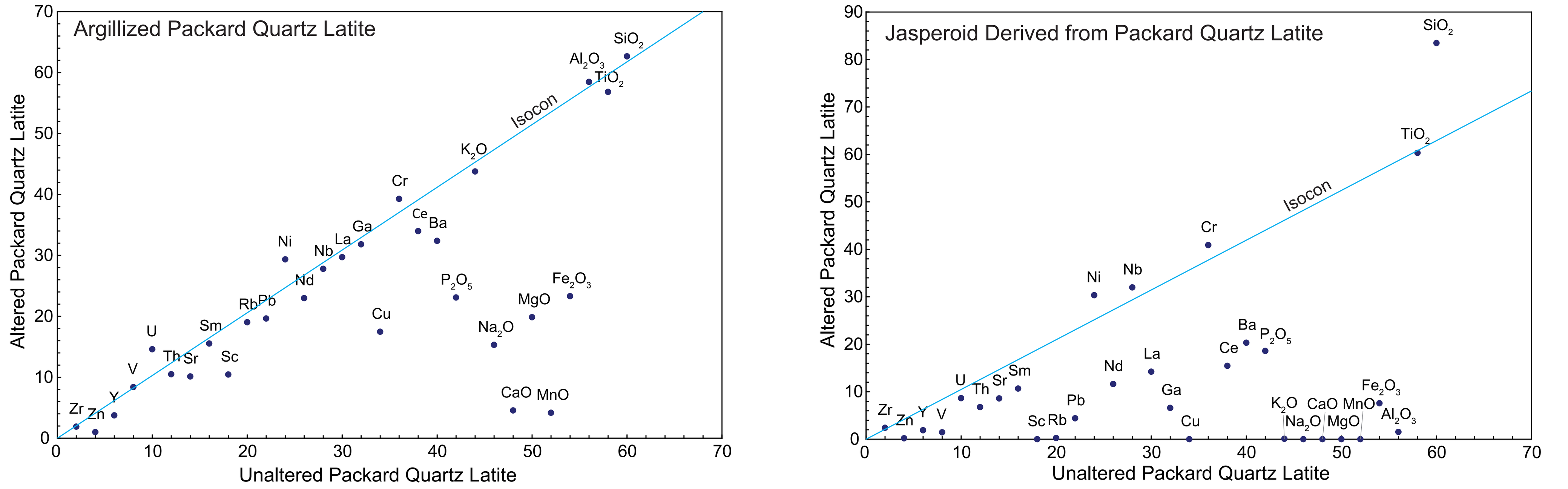
Packard Quartz Latite (35.27 ± 0.03 Ma; Allen, 2012)
Black arrows denote alteration due to pebble dike emplacement. See isocon diagrams above and to the right for further clarification.

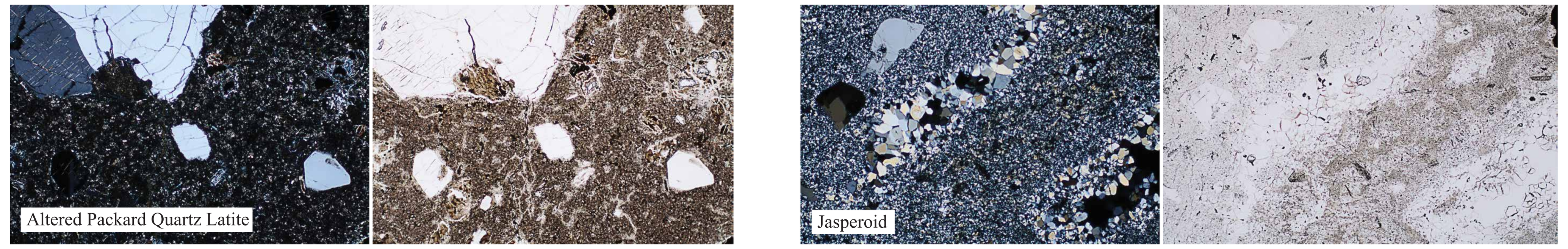
These variation diagrams demonstrate chemical differences between the monzonite porphyry and the Silver City Stock, particularly in alkali and alkaline earth elements. They also show that volcanic equivalents exist for both the monzonite porphyry and the Silver City Stock. Note how the monzonite porphyry (red) plots with the Laguna Springs Latite (blue) and how the Silver City Stock (green) plots with the Rock Canyon Latite (purple).

Whole rock geochemistry was determined via XRF analysis at Brigham Young University.

Whole Rock Geochemistry

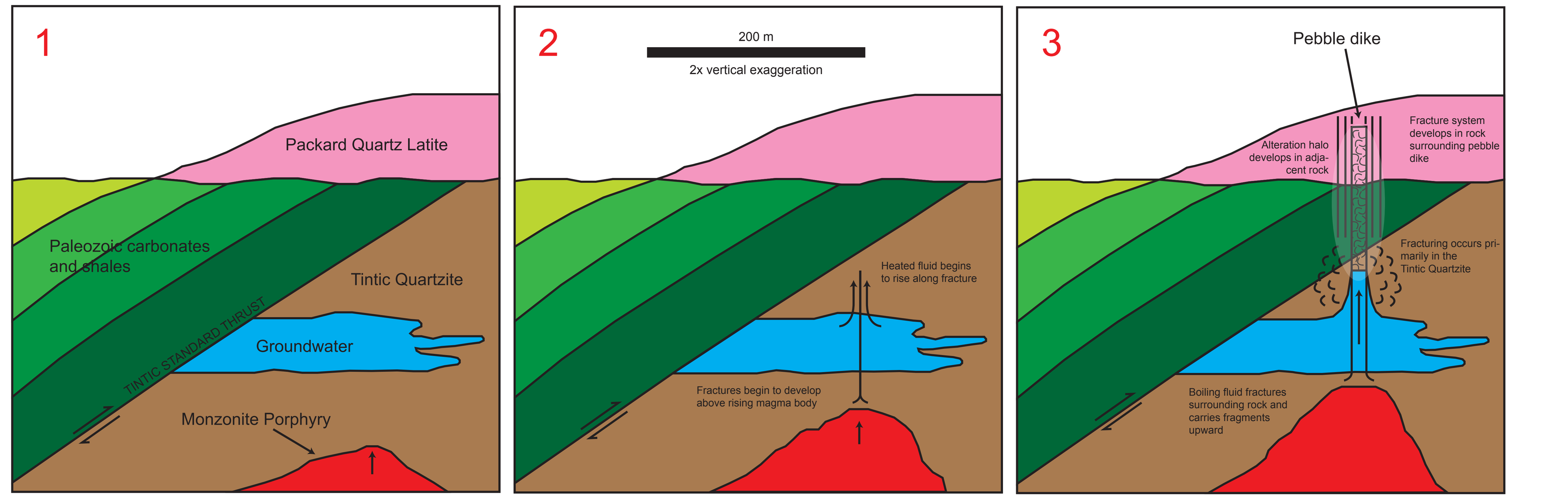
Although the monzonite porphyry (plotted in red) has been historically mapped as Silver City Stock (plotted in green), whole rock geochemical analysis has shown that the monzonite porphyry differs significantly from the Silver City Stock. Coupled with textural and mineralogical differences, we conclude that the monzonite porphyry and the Silver City Stock are distinct units emplaced at different times. Therefore, pebble dikes are not associated with the Silver City Stock, but rather with the unnamed monzonite porphyry. Additional geochemical work has identified volcanic equivalents for both the monzonite porphyry and the Silver City Stock. The volcanic equivalent for the monzonite porphyry appears to be Laguna Springs Latite (plotted in blue). The Laguna Springs Latite outcrops in the northern portion of the map area. The volcanic equivalent for the Silver City Stock appears to be the Rock Canyon Latite (plotted in purple). The Rock Canyon Latite outcrops to the south of the map area near the Silver City Stock. Since both volcanic equivalents have been dated, they provide age constraints for both the monzonite porphyry and the Silver City Stock. Packard Quartz Latite (plotted in yellow), the most common host for pebble dikes, is included for reference.





Alteration Due to Pebble Dike Emplacement

Alteration haloes in Packard Quartz Latite around pebble dikes display multiple alteration types. The most common type is argillic, displayed in the upper left isocon plot and corresponding photomicrographs. Argillic alteration results in the replacement of plagioclase feldspar and mafic silicates with clays. Potassium feldspar remains relatively unaffected (note constant K_2O and Rb concentrations in both the plot above and in the variation diagrams to the lower left). Higher grade alteration from pebble dike emplacement produces jasperoid, displayed in the upper right isocon plot and corresponding photomicrographs. The production of jasperoid results in the replacement of all mineral phases with quartz. Note that magmatic quartz remains. Jasperoid is relatively rare in the map area. Other alteration types include chloritization and carbonitization, which are not displayed here. Although pebble dike emplacement results in the alteration of host rock and sometimes even the pebble dike itself, both the host and pebble dike are barren; the bulk of mineralization is in Paleozoic carbonates below. The isocon plots were produced following the method outlined by Grant (2006).



This simplified cross section (above) demonstrates the probable development of a pebble dike. 1 - Monzonite porphyry begins to ascend into Tintic Quartzite and other deformed Paleozoic sedimentary rocks (various shades of green). Packard Quartz Latite sits above an erosional unconformity at the surface. All labels defined in frame 1 apply to frames 2 and 3. 2 - The rising monzonite porphyry begins to approach and heat groundwater (perhaps an aquifer). The magma creates fractures in the overburden along which heated water begins to ascend. 3 - When the fractures above the rising magma body reach the surface, lithostatic pressure disappears, allowing the heated water to boil and expand rapidly. Rapid expansion fractures surrounding rock, and the fluid escapes to the surface carrying fragments of rock along with it. Rock fragments are rounded during transport, and 'cemented' in place along the main fracture. Adjacent rock is altered during pebble dike emplacement.

Conclusions

1. Pebble dikes are composed of subangular to rounded fragments of quartzite, shale, carbonate, and two types of igneous rock, all derived from underlying units. Fragments are suspended in a fine-grained clastic matrix. Dike widths average around 0.3 m and larger clast sizes average around 3 cm. Both pebble dikes and igneous dikes trend dominantly northeast. Outside of alluvium, pebble dikes appear to be the youngest features in the map area.
2. The monzonite porphyry is chemically, mineralogically, and texturally distinct from the Silver City Stock. The volcanic equivalent of the monzonite porphyry is the Laguna Springs Latite, with an age of 33.29 ± 0.09 Ma (Moore, 2007). Considering the equivalency, this age also constrains the emplacement of the monzonite porphyry. The volcanic equivalent of the Silver City Stock is the Rock Canyon Latite at 33.80 ± 0.10 Ma (Moore, 2007).
3. Pebble dikes are specifically related to the chemically unique monzonite porphyry and appear to have formed simultaneously with monzonite porphyry emplacement at or after 33.29 ± 0.09 Ma.
4. Pebble dike emplacement results in the alteration of nearby host rock. Host alteration is most developed in the Packard Quartz Latite. Alteration in carbonate hosts is minor to nonexistent. Alteration in Packard Quartz Latite is dominantly argillic, although rare jasperoids also develop. Argillization replaces plagioclase feldspar and mafic silicates with clay minerals. Jasperoid alteration replaces all phases with quartz.
5. Pebble dikes are likely formed during the violent expansion (boiling) of a superheated fluid as it convects from depth to the surface, carrying brecciated rock debris with it. Clast roundness is developed during transport. Heat to drive pebble dike emplacement was provided by the intrusion of the monzonite porphyry.