Quenched and Disrupted Dacitic to rhyolitic hyaloclastite complex emplaced at shallow levels beneath the seafloor in a Devonian submarine island arc sequence in the northern Sierra Nevada, California

Sierra Buttes Formation Sediments

SBF sediments sit atop the complex forming a cap. In this area, the sediments are dominantly black radiolarian chert, ash fall tuffs, and polymict breccia. The lack of sediment rework structures implies that the complex formed below storm wave base and the chert means that everything developed ≥ 1km depth.

Figure X. SBF bedded chert

Andesite Dikes

A complex network of basaltic andesite to andesite dike cross cut every unit within the complex. Dikes trend roughly 30° NE in the complex and parallel to bedding in SBF sediments There are four lithologic varieties including, aphanitic, plagioclase-phyric, augite-phyric, and diopside-phyric. Dike margins are highly fluidal, forming chilled margins against the host rock. In rare cases, the dikes form peperitic margins with the host hyaloclastite.

Figure X. Andesite Dike.

Type 4 and 5 Intrusion

The Type 4 andesitic intrusion occurs only once within the complex. It is made up of minor plagioclase phenocrysts, augite phenocrysts and orange amygdules in a silicified groundmass.

The Type 5 intrusion is a quartz porphyry dacite. Type 5 has one large intrusion, removing what was originally the base of the complex, and several other smaller intrusions. The intrusion is made of abundant quartz and plagioclase phenocrysts in a siliceous groundmass.

Figure X. Type 4 hand sample.

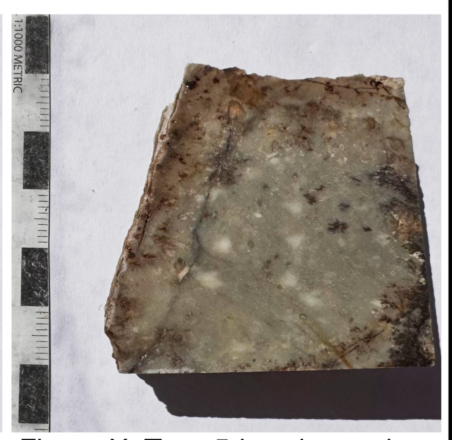


Figure X. Type 5 hand sample.

Peperite

Peperite forms when magma intrudes, quenches and fragments against unconsolidated wet sediment.[4]

In the case of this complex, the peperite formed when the dacitic magma of Type 3 intruded, mixed with, and quench fragmenting in silicious ooze, now black radiolarian chert. This peperite forms multiple discontinues pockets along the upper contact between the complex and the overlying SBF sediments.

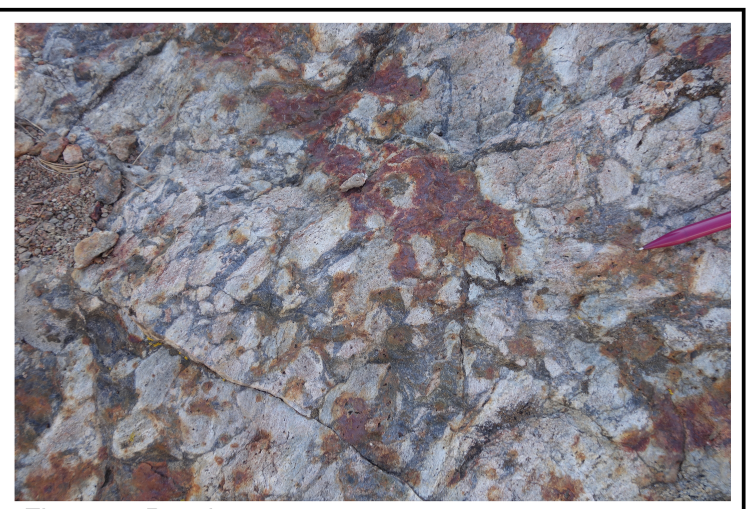


Figure x. Peprite outcrop.

Type 3 Intrusion

The Type 3 intrusion dominates the top of the complex, forming a carapace of hyaloclastite and peperite as well as a chilled margin against the Type 1 Intrusion, confirming it as an intrusive unit. Type 3 is identified by its abundant ~1mm quartz phenocrysts. Flow banding and flow folding are common in this unit. In one excellent outcrop, the heavily flow banded and folded intrusion has begun to brecciate, grading into the surrounding hyaloclastite.

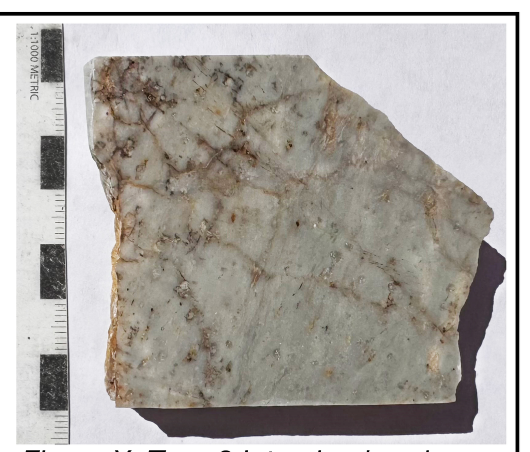


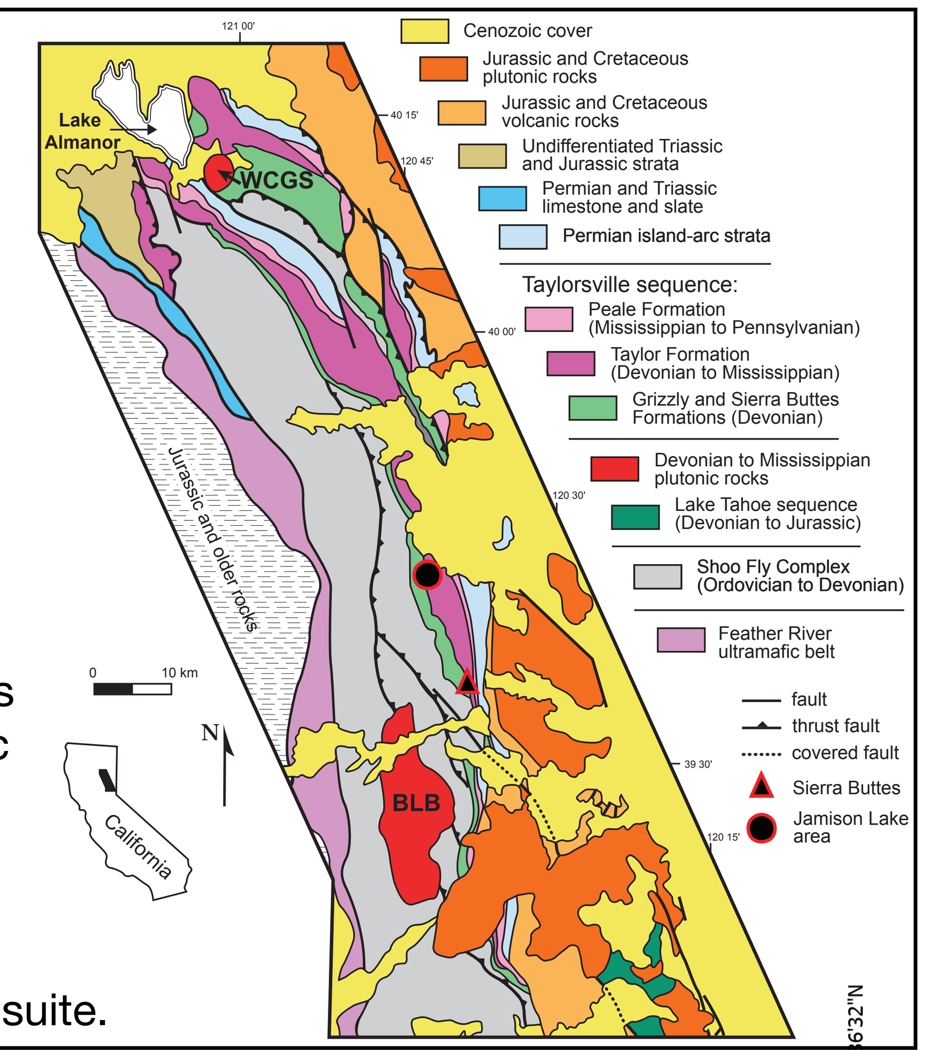
Figure X. Type 3 intrusion hand sample.

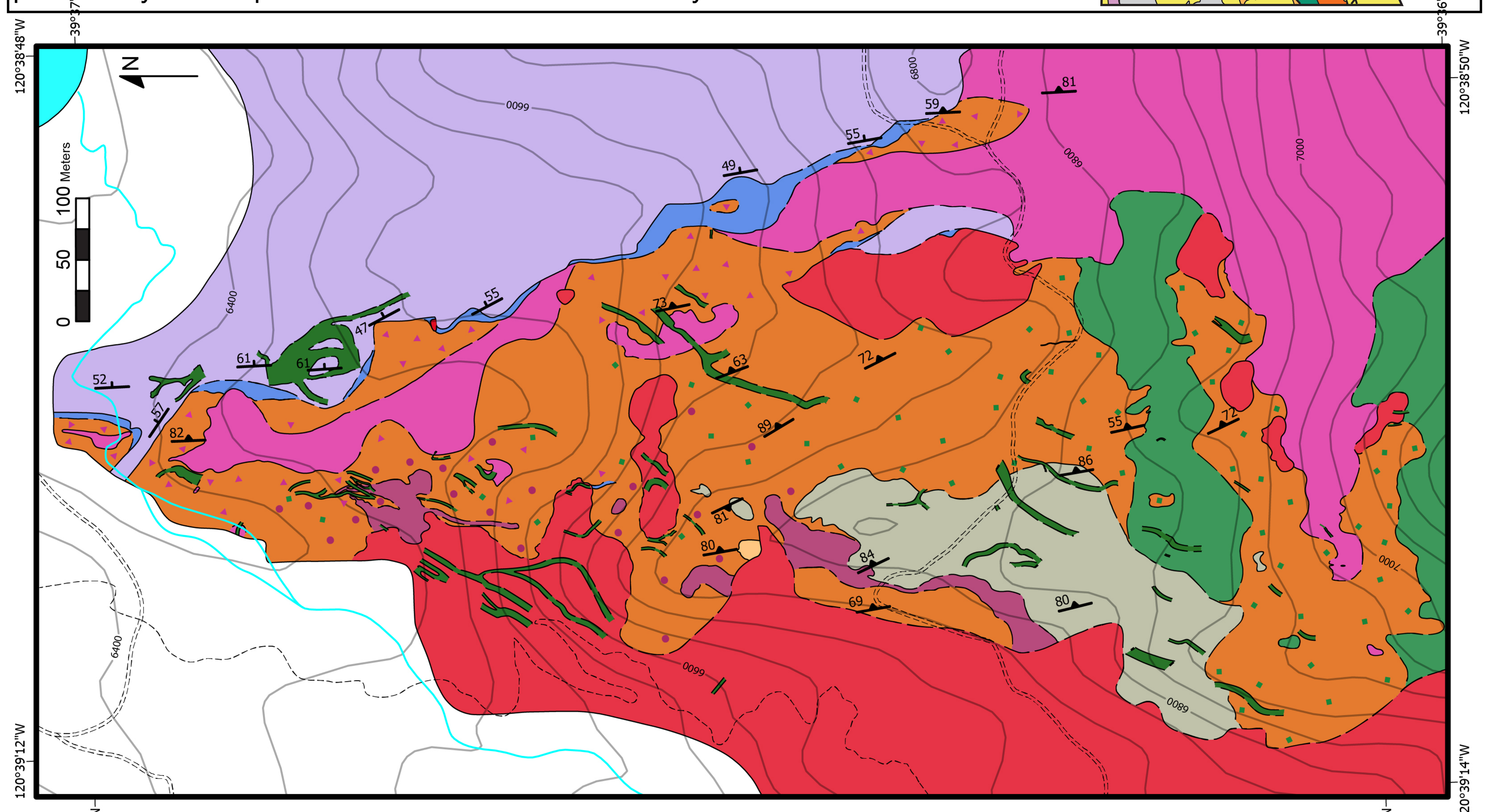
Introduction

The Northern Sierra Terrane (NST) is one of a series of suspect terranes within the North American Cordillera that developed somewhere outboard of the North American margin. The NST contains a thick succession of Paleozoic-Mesozoic island arc deposits tilted to the east.[1]

The oldest of these island arc deposits is the Sierra Buttes Formation (SBF), which is a succession of deep marine radiolarian chert and interbedded subaqueous island arc volcaniclastic deposits.[2] Excellent exposures of these rocks on the glaciated Sierra Buttes, type locality of the SBF, reveal the presence of a series of large scale intrusive andesitic-rhyolitic hyaloclastite and cogenetic hypabyssal bodies that intruded beneath the seafloor while the sediments were still unlithified.[3]

Here I report detailed mapping, down to the meter scale, of a particularly well-exposed area within the dacitic to rhyolitic intrusive suite.





Cenozoic cover

Sierra Buttes Fm. (Late Dev.)
- Member C
- Basaltic Andesite Dikes
- Type 5 Intrusion
- Type 4 Intrusion
- Peperite
- Type 3 Intrusion
- Type 2 Intrusion
- Type 1 Intrusion
- Hyaloclastite

Disruspet Fludal Feeder Bodies
- Type 3
- Type 2
- Type 1

Lapillistone

Creek

Dugan Pond

Strike and Dip

Tectonic Clevage

Unmaintained Road

Pacific Creat Trail

Conclusions

Deep marine island-arc settings can produce extremely complicated deposits such as this. With ought detailed mapping and field observations, deciphering the whole story of these events can be nearly impossible. This complex has volcanic and intrusive rocks interacting with seawater and sediments and >1 km water depth. Our details work here at the Sierra Buttes has revealed a event where fire fountaining started then magma erupted onto the seafloor or stalled just below, v=forming a interconnected branching network that supplied the massive amounts of hyaloclastite. This was followed by sediment deposition and further intrusion into the complex by cogenetic units and latter ones.

References

[1] Powerman, V., Hanson, R., Nosova, A., Girty, G.H., Hourigan, J., and Tretiakov, A., 2019, Nature and timing of Late Devonian–early Mississippian island-arc magmatism in the Northern Sierra terrane and implications for regional Paleozoic plate tectonics: Geosphere, v. 16, p. 258–280, doi:10.1130/ges02105.1. **[2]** Hanson, R.E., and Schweickert, R.A., 1986, Stratigraphy of mid-Paleozoic island-arc rocks in part of the northern Sierra Nevada, Sierra and Nevada Counties, California: Geological Society of America Bulletin, v. 97, p. 986, doi:10.1130/0016-7606(1986)97.**[3]** Hanson, R.E., 1991, Quenching and hydroclastic disruption of andesitic to rhyolitic intrusions in a submarine island-arc sequence, northern Sierra Nevada, California: Geological Society of America Bulletin, v. 103, p. 804–816, doi:10.1130/0016-7606(1991)103. **[4]** Skilling, I.P., White, J.D.L., and McPhie, J., 2002, Peperite: a review of magma–sediment mingling: Journal of Volcanology and Geothermal Research, v. 114, p. 1–17, doi:10.1016/s0377-0273(01)00278-5.

Type 2

The Type 2 dacite intrusion is present along the bottom left side of the complex with very fluidal shapes and margins. It is completely aphanitic with space xenoliths present. Spherulites, a texture that forms when glass devitrifies, is prevalent in this unit, implying that the unit was originally glassy. Pockets of internal explosion breccia are present, similar to Type 1, but less prevalent.

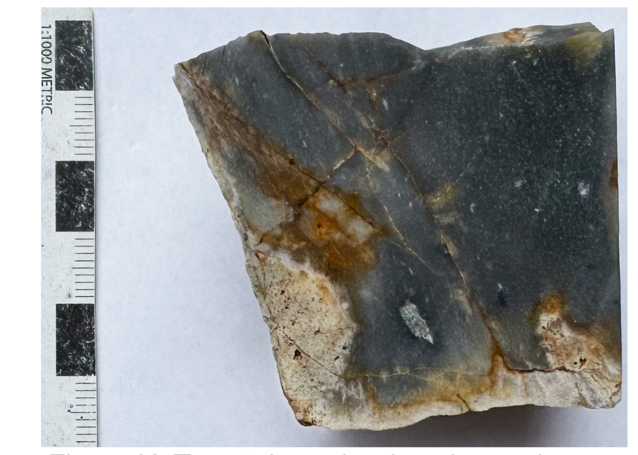


Figure X. Type 2 intrusion hand sample.

Type 1

The Type 1 andesite intrusion is restricted to the southern end of the complex. It is identified by sparse quartz xenocrysts which have a distinct shattered glass appearance and plagioclase phenocrysts which can only be seen in thin section. Flow banding, columnar jointing, and pockets of internal explosion breccia occur in restricted areas through the Type 1 intrusions.

Figure X. Type 1 intrusion hand sample

Hyaloclastite

Hyaloclastite form quench fragmentation during magma water interaction.[3] Hyaloclastite is the most abundant unit within the complex, consisting of lapel sized angular glassy shards. These shards commonly exhibit jigsaw-fit texture, meaning that this deposit formed from non-explosive quench fragmentation.

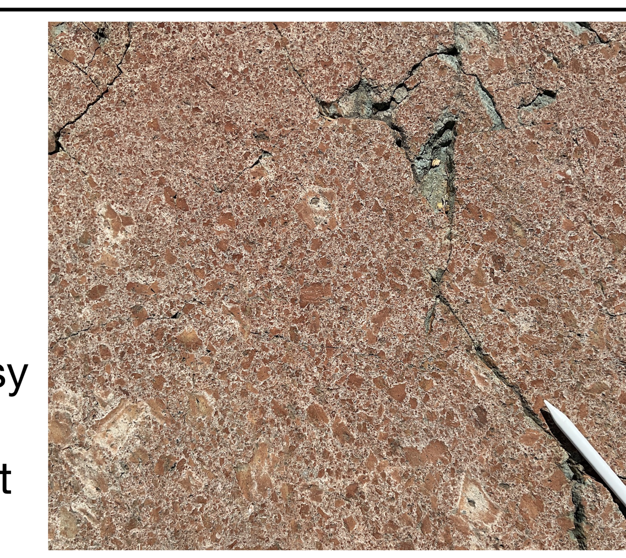


Figure X. Hyaloclastite outcrop.

Disrupted Fluidal Feeder Bodies

Dispersed throughout the Hyaloclastite are fluidal bodies who's shape range from ellipsoidal, to tubular, and ameboid. Fluidal bodies can range from 25 mm to 5 m wide while rare tubular complexes can be up to 15 m In length. There are three lithologic verities, being identical to the Type 1, 2, and 3 intrusions. The fluidal bodies have chilled margins that in some cases, are spalling off feeding the surrounding hyaloclastite.

Larger tube complexes branch out from one another and break apart at some of the tubes ends, creating the fluidal bodies seen throughout the complex.

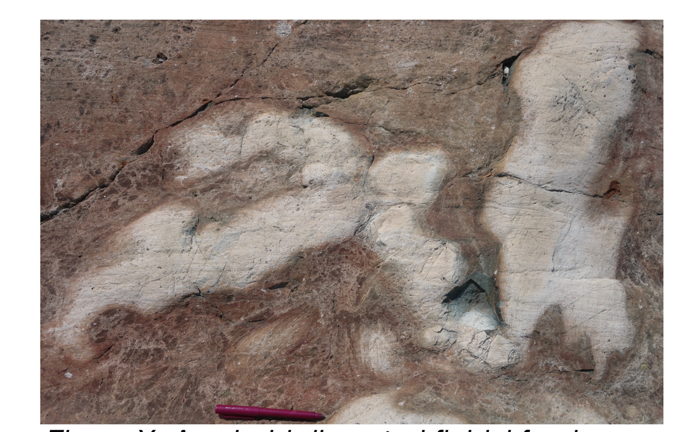


Figure X. Ameboid disrupted fluidal feeder bodie

Figure X. Interconnected tubular network

Lapillistone

Andesitic lapillistone occurs as a large mass at the base of the complex. Individual lapilli are fluidal teardrop to ameboid shaped droplets, 1-35 mm long. Wispy to blocky spatter occur throughout the unit. The lapillistone forms a gradational contact with the hyaloclastite and has DFFB's mixed with the margin of the lapillistone.

Figure X. Lapilistone with fluidal droplets and spatter.