LiDAR as an exploration tool: structural and volcanic evolution of a Miocene-Pleistocene age bimodal volcanic complex & implications for geothermal potential

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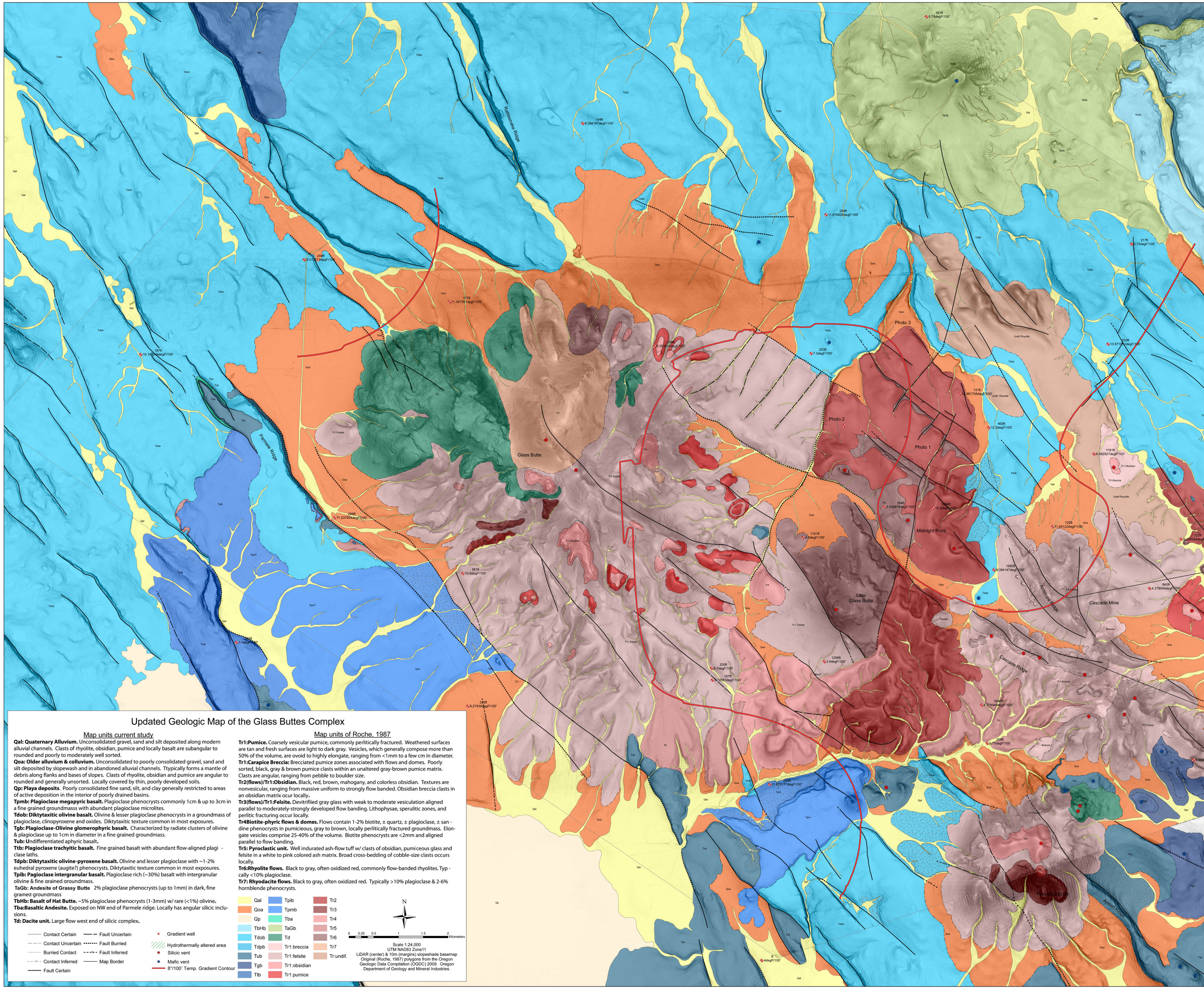


Updated Geologic Map of the Glass Buttes Complex

Map units current study

Qal: Quaternary Alluvium. Unconsolidated gravel, sand and silt deposited along modern alluvial channels. Clasts of rhyolite, obsidian, pumice and locally basalt are subangular to rounded and poorly to moderately well sorted.

Qoa: Older alluvium & colluvium. Unconsolidated to poorly consolidated gravel, sand and silt deposited by slopewash and in abandoned alluvial channels. Ttypically forms a mantle of debris along flanks and bases of slopes. Clasts of rhyolite, obsidian and pumice are angular to rounded and generally unsorted. Locally covered by thin, poorly developed soils.

Qp: Playa deposits. Poorly consolidated fine sand, silt, and clay generally restricted to areas of active deposition in the interior of poorly drained basins.

Tpmb: Plagioclase megapyric basalt. Plagioclase phenocrysts commonly 1cm & up to 3cm in a fine grained groundmasss with abundant plagioclase microlites.

Tdob: Diktytaxitic olivine basalt. Olivine & lesser plagioclase phenocrysts in a groundmass of plagioclase, clinopyroxene and oxides. Diktytaxitic texture common in most exposures.

Tgb: Plagioclase-Olivine glomerophyric basalt. Characterized by radiate clusters of olivine & plagioclase up to 1cm in diameter in a fine grained groundmass.

Tub: Undifferentiated aphyric basalt.

Ttb: Plagioclase trachyitic basalt. Fine grained basalt with abundant flow-aligned plagiclase laths.

Tdpb: Diktytaxitic olivine-pyroxene basalt. Olivine and lesser plagioclase with ~1-2% euhedral pyroxene (augite?) phenocrysts. Diktytaxitic texture common in most exposures.

Tpib: Pagioclase intergranular basalt. Plagioclase rich (~30%) basalt with intergranular olivine & fine grained groundmass.

TaGb: Andesite of Grassy Butte 2% plagioclase phenocrysts (up to 1mm) in dark, fine grained groundmass

TbHb: Basalt of Hat Butte. ~5% plagioclase phenocrysts (1-3mm) w/ rare (<1%) olivine.

Tba:Basaltic Andesite. Exposed on NW end of Parmele ridge. Locally has angular silicic inclusions.

Td: Dacite unit. Large flow west end of silicic complex.

Map units of Roche, 1987

Tr1:Pumice. Coarsely vesicular pumice, commonly perlitically fractured. Weathered surfaces are tan and fresh surfaces are light to dark gray. Vesicles, which generally compose more than 50% of the volume, are ovoid to highly elongate, ranging from <1mm to a few cm in diameter.

Tr1:Carapice Breccia: Brecciated pumice zones associated with flows and domes. Poorly sorted, black, gray & brown pumice clasts within an unaltered gray-brown pumice matrix. Clasts are angular, ranging from pebble to boulder size.

Tr2(flows)/Tr1:Obsidian. Black, red, brown, mahogany, and colorless obsidian. Textures are nonvesicular, ranging from massive uniform to strongly flow banded. Obsidian breccia clasts in an obsidian matrix ocur locally.

Tr3(flows)/Tr1:Felsite. Devitrifiied gray glass with weak to moderate vesiculation aligned parallel to moderately-strongly developed flow banding. Lithophysae, sperulitic zones, and perlitic fracturing occur locally.

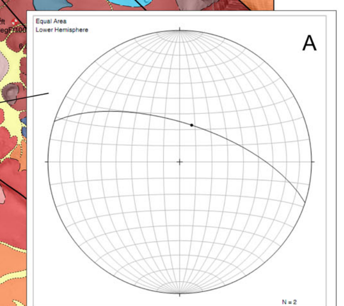
Tr4Biotite-phyric flows & domes. Flows contain 1-2% biotite, ± quartz, ± plagioclase, ± sanidine phenocrysts in pumicieous, gray to brown, locally perlitically fractured groundmass. Elongate vesicles comprise 25-40% of the volume. Biotite phenocrysts are <2mm and aligned parallel to flow banding.

Tr5: Pyroclastic unit. Well indurated ash-flow tuff w/ clasts of obsidian, pumiceous glass and felsite in a white to pink colored ash matrix. Broad cross-bedding of cobble-size clasts occurs locally.

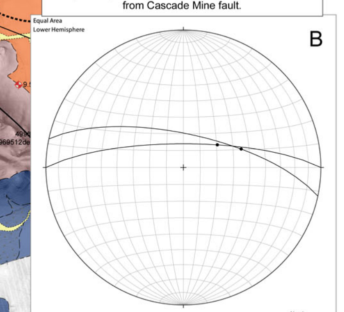
Tr6:Rhyolite flows. Black to gray, often oxidized red, commonly flow-banded rhyolites. Typically <10% plagioclase.

Tr7: Rhyodacite flows. Black to gray, often oxidized red. Typically >10% plagioclase & 2-6% hornblende phenocrysts.

Scale 1:24,000
UTM NAD83 Zone11
LiDAR (center) & 10m (margins) slopeshade basemap
Original (Roche, 1987) polygons from the Oregon Geologic Data Compilation (OGDC) 2009. Oregon Department of Geology and Mineral Industries.

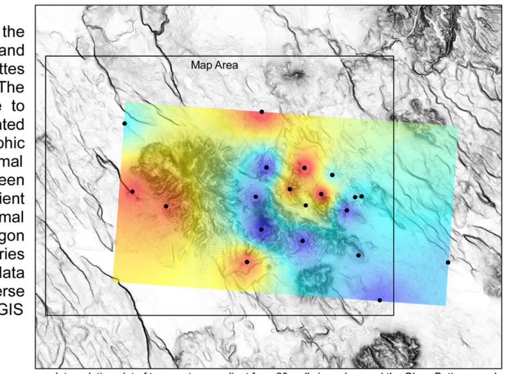


Stereonets showing strike & dip of faults with trend and plunge of slickenlines. A. Measurement taken in open adit, Antelope Ridge; B. Measurements taken from Cascade Mine fault.



Introduction

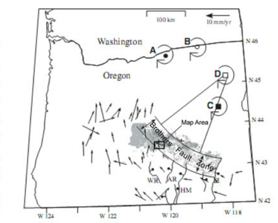
The current research aims to understand the relationships between volcanism, faulting and geothermal potential at the Glass Buttes volcanic complex in central Oregon. The complex is a cluster of bimodal, Miocene to Pleistocene age lava flows and domes located within the High Lava Plains physiographic province of central Oregon. A shallow thermal anomaly (max gradient 12F/100ft) has been defined at Glass Buttes by temperature gradient drilling completed by the Vulcan Geothermal Group, Phillips Petroleum, and the Oregon Department of Geology and Mineral Industries from 1977-1981 (Benoit, 1981). Gradient data of wells >300ft was interpolated through Inverse Distance Weighted operations in ArcGIS (neighbors=12, power=2).



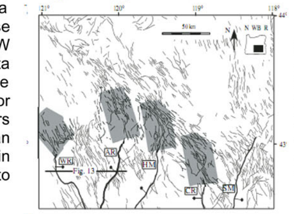
Interpolation plot of temperature gradient from 20 wells in and around the Glass Buttes complex. Only wells 299ft or deeper were used in ther interpolation.

Regional Tectonics

The region is cut by NW striking faults of the Brothers Fault Zone (BFZ), a ~300 km long, N60°W trending zone of en echelon faults. Individual fault segments strike NW and have only tens of meters of apparent normal separation. A smaller population of faults striking NE is likely an expression of northernmost Basin & Range extension. Field relations indicate the two fault sets have mutually cross-cutting relationships, suggesting that they may have formed coevally (Scarberry, 2008; this study). A variety of data suggest both fault sets have formed in response to right-oblique extension toward N60-70W (Pezzopane, Weldon, 1993). GPS data (McCaffrey, 2000) suggest a point near the Oregon-Idaho border as an rotational pole for extension increasing to the south. The Brothers Fault zone has also been interpreted as an intracontinental transform separating the Basin and Range Province from nonextended crust to the north (Lawrence, 1976).



Shaded areas: Quaternary basalt; thick lines: >150m fault escarpments; thin lines: <150m faults. WR-Winter Ridge, AR-Abert Rim, HM-Hart Mountain, SM-Steens Mountain. Image modified from Meigs, et al 2009



Major faults in the northwest Basin and Range and Brothers Fault zone. Shaded boxes indicate zones of transition from large-displacement, NNE striking Basin and Range faults to small displacement NW striking faults of the Brothers fault zone. Image from Trench, 2008

Methods

The current study combines LiDAR based geologic mapping, GIS analysis, and new 40Ar/39Ar age data to constrain the timing, rate and style of deformation in the Glass Buttes area. Geologic mapping began August 2010 with the goal of working out the volcanic, stratigraphic and cross cutting relationships between faults, basaltic lavas, silicic lavas and sedimentary deposits in the areas surrounding Glass Buttes. Surface fault expressions are identified using the 1 m resolution LiDAR bare earth model in ArcGIS and by field observation of offsets, fault scarps and lineaments. Fault identification is facilitated in arcGIS by variable illumination hillshading, elevation contouring and slope analysis tools including slope mapping and slope-shade visualizations. A 1:12000 scale, 1 m resolution LiDAR bare earth model is used as a base map during field studies. Whole-rock major and minor element chemistry for 23 volcanic rock samples was performed by X-ray fluorescence spectrometry (XRF) at Washington State University in Pullman Washington to suppliment existing whole rock chemistry data. Map unit correlation will be further facilitated by the use of a handheld XRF spectrometer to identify characteristic compositional fingerprints determined in laboratory analysis. New map information is added to a previously existing database of the geology of the main silicic complex (Roche, 1987), and where possible, existing map data is rectified to the LiDAR bare earth model based on geomorphic expression and field checking.

Preliminary Results & Discussion

Recent mapping of faults at Glass Buttes supports the mutually cross cutting relationship between NW & NE striking faults as reported by Scarberry 2008. The faults have low to moderate amounts of vertical separation (<60m throw) as measured by topographic relief. Slickenlines measured at two locations are consistent with normal to slight right-oblique slip (pitch 69-90deg). Cross-cutting faults to the northwest are consistent with right or left lateral slip.

Newly and previously mapped mafic and silicic vents tend to be aligned along major faults in the area.

The highest measured geothermal gradients (wells >300ft) appear to be coincident with intersecting northwest & northeast striking faults just north of Midnight point. Another gradient high is coincident with the long trace of a northwest striking fault bounding the southwest margin of Glass Butte and possibly extending northwest toward the Parmele Ridge relay structure.

Future work:
New Ar/Ar age dates for six basalt flow units combined with mapped stratigraphic relationships and cross-cutting relations of faults and volcanic units will be used to constrain the timing and rate of fault slip on select faults. The magnitude and direction of extension in the Glass Buttes area will be estimated using interpreted fault dips, measured kinematic indicators, and by measuring the offset across faults and tilting of fault blocks using 3D topographic data to quantify fault-block geometry and to measure separation across faults that vary in both orientation and displacement along strike.

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