

geology

Quaternary Volcanism in the Southernmost Cascade Range, California

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Volcanism in the southernmost Cascade Range can be characterized on two scales. On a regional scale volcanism is basaltic to andesitic. Individual volcanoes have small volumes and relatively short lifetimes. Many eruptive centers coalesce to form the crest of the Cascade Range. Individual volcanoes range from monogenetic basalt and basaltic andesite cinder cones to larger lava cone and shield volcanoes of basaltic to andesitic composition. Rocks with greater than approximately 60 per cent SiO_2 are sparse. Superimposed on the regional mafic volcanism are long-lived, larger volume volcanic centers that have produced eruption products spanning a wide range of composition from mafic andesite to rhyodacite or rhyolite.

Each volcanic center consists of a large andesitic composite cone and flanking silicic domes and flows. Three of these volcanic centers younger than about 3 Ma have been recognized in the Lassen area. Each has had a similar history, consisting of three stages: (1) an initial cone-building period of mafic andesite and andesite lava flows and pyroclastics; (2) a later cone-building period characterized by thick andesite and silicic andesite lava flows, and (3) silicic volcanism flanking the main cone. The silicic magma chamber of the third stage provides a heat source for development of a hydrothermal system within the core of the main cone. Alteration of permeable rocks of the cone facilitates increased glacial and fluvial erosion of the central area of the volcano. The result is preservation of a resistant rim of the thick later cone-building lava flows and flanking silicic rocks surrounding a depression in the altered and eroded core of the composite cone.

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The two older volcanic centers have reached this stage, and their hydrothermal systems are extinct. The younger Lassen volcanic center (LVC) however, hosts active silicic volcanism and a well developed hydrothermal system, including the thermal features in Lassen Volcanic National Park (LVNP) and Mill Canyon.

The LVC developed in three stages. Stages I and II produced the Brokeoff Volcano, an 80 km^3 andesitic stratocone. Stage I deposits consist of olivine-augite and olivine-hypersthene-augite andesite lava flows and pyroclastic rocks erupted from a central vent during the period from about 0.7 to 0.55 Ma. Stage I culminated in eruption of a small volume of hornblende-pyroxene dacite. An interval of erosion lasting 0.1 Ma followed stage I. During stage II, which lasted 0.1 Ma, thick flows of porphyritic augite-hypersthene silicic andesite, generally lacking interbedded pyroclastic material, were erupted. Volcanism then shifted to the north and east and became more silicic. Eruption of a minimum of 50 km^3 of rhyolitic magma at 0.35 Ma as air-fall tephra and ash flows initiated stage III. This eruption probably produced a collapse caldera now filled by a dacite domefield. The dacite domefield consists of two groups of rocks totaling on the order of $30\text{--}50 \text{ km}^3$. During the period from 0.25 to 0.2 Ma pyroxene-hornblende dacite magma produced a group of six domes and flows. Hornblende-biotite rhyodacite has been erupted as domes, lava flows and pyroclastic flows in at least ten episodes over the past 0.1 Ma. At least six times during the past 0.1 m.y. hybrid andesite totaling 10 km^3 and consisting of thoroughly mixed mafic and silicic magma has been erupted from the margins of the dacite domefield.

Porphyritic andesite and dacite with high Al_2O_3 , low TiO_2 , and medium K_2O contents and FeO/MgO ratios of 1.5–2.0 are the most abundant rock types in the LVC. Early mafic andesite, late rhyodacite, and hybrid andesite are subordinate in abundance. Rocks of the LVC resemble other calc-alkaline

volcanic rocks emplaced on a continental margin overlying sialic crust.

Harker variation diagrams of the major element chemistry of rocks from the LVC show smooth trends from 55-73 per cent SiO_2 . The overall evolution is from mafic to silicic. However the evolution is not strictly sequential (see fig). Sparse isotope data suggest that crustal interaction is not significant in the development of the silicic rocks. However, partial melting of young mafic crust may play a role in the origin of the silicic magmas at LVC. Smooth geochemical trends, increasing silica content with time, and isotope data all suggest the origin of LVC magmas by crystal fractionation of a mafic parent. The long time span of activity at LVC and the presence of a hydrothermal system imply the presence of an evolving magma chamber. However, the current conceptual model of the magmatic system of the LVC as outlined below is poorly constrained and somewhat speculative.

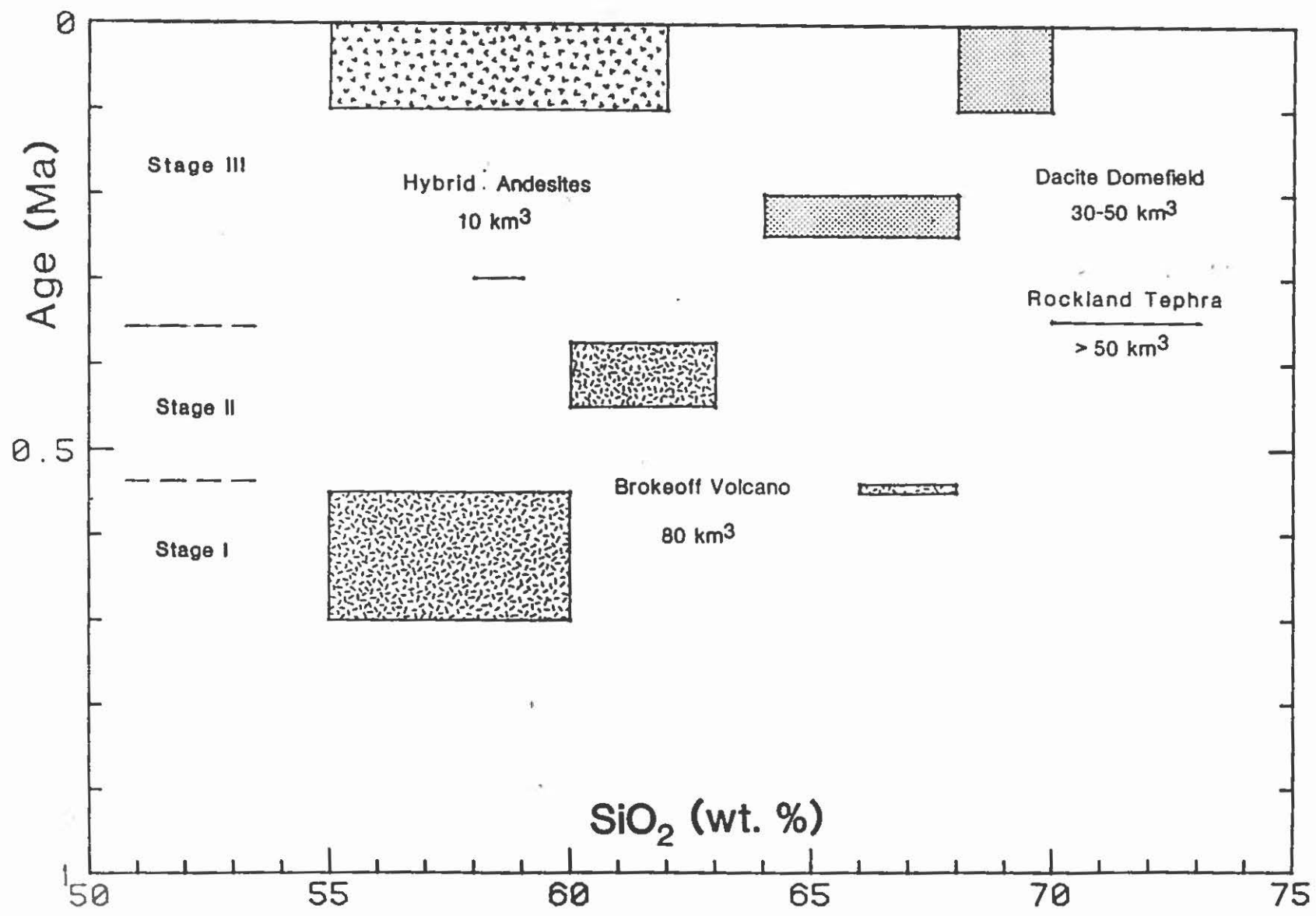
The Lassen volcanic center differs from other Cascade volcanoes by having a larger volume of silicic rocks. The stress regime in the southern Cascades is moderate east-west extension, which favors retention of mafic magma in the crust and development of zoned systems with large volumes of derivative silicic magma. Systematic geochemical variation of the rocks of the Lassen volcanic center and the mineralogic and geochemical homogeneity of the youngest rocks suggest derivation from a single source. The magma system of the Lassen volcanic center can be envisaged as an evolving pluton-sized body of magma in the middle crust (10-20 km depth). The pattern of young vents suggests that an 5-8 km diameter magma body underlies the northwestern corner of LVNP. The young volcanic vents and hydrothermal system may indicate the position of a cupola on the magma chamber, which may be as shallow as 6 km beneath Lassen Peak. The hybrid andesites are produced by mixing of mafic magma intruded into silicic magma and may indicate a sill-like projection of

the magma chamber beneath the central plateau of LVNP. Alternatively the hybrid andesites may be erupted by tapping the main chamber at depth.

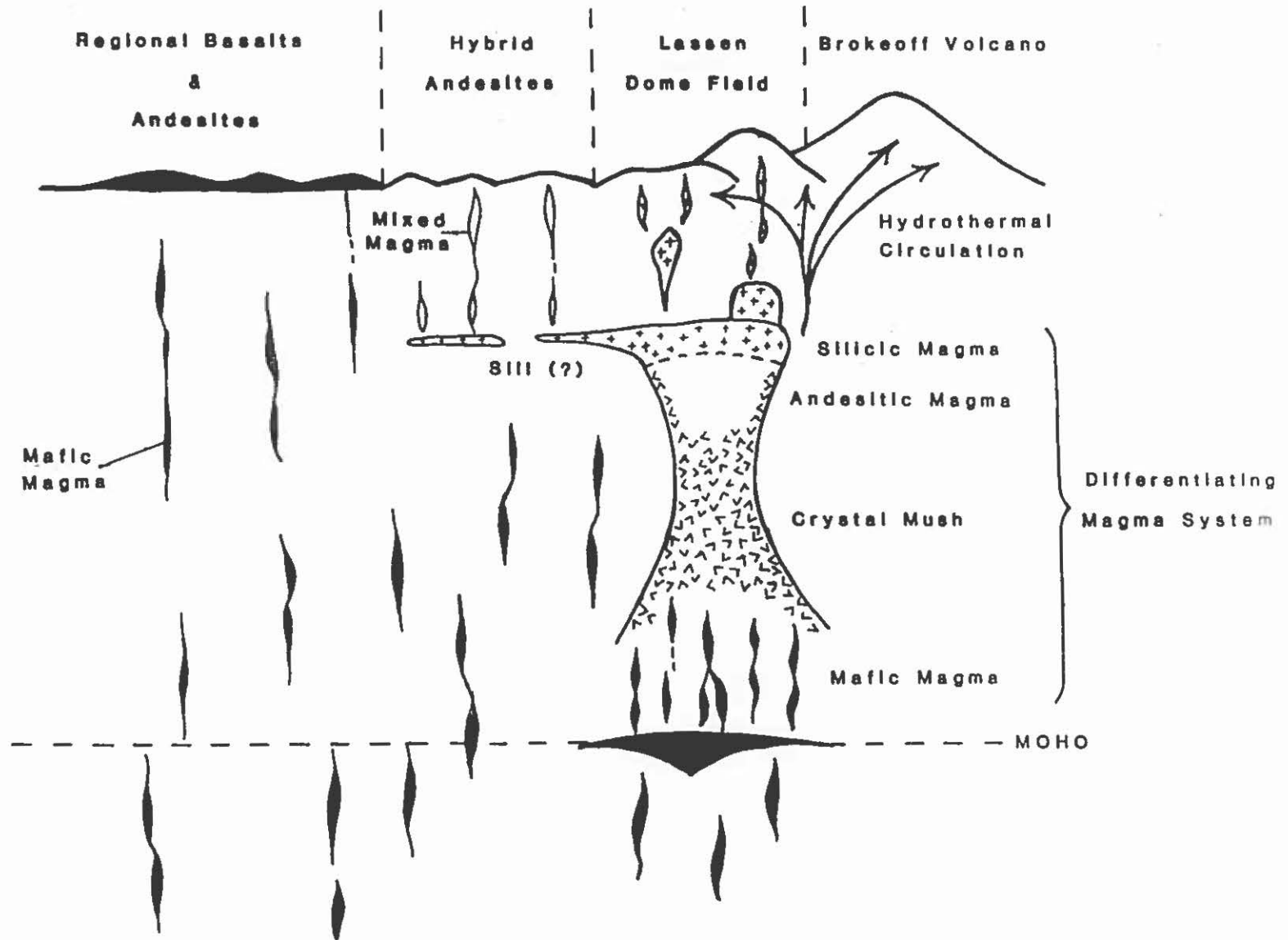
The upper portion of the chamber contains crystal-rich rhyodacite, and has varied little in composition over at least the last 50,000 years. The system is probably zoned to more mafic compositions at depth. Regional basalt provides heat and material input to maintain the system in the partially molten state. There is abundant evidence for the interaction of mafic and silicic magma. A small volatile-rich cap has periodically developed at the top of the magma chamber but is removed by venting before increasing to substantial volume. Assuming that the vertical extent of the magma chamber is 10 km results in volume estimates of 250-500 km³.

Despite the volcanologic and petrologic evidence of a magma system beneath the LVC, geophysical evidence for the presence of a magma chamber is lacking. A 25 km oval, -50 mgal gravity anomaly is centered on the dacite dome field and central plateau (hybrid andesites) of LVC. The gravity low is probably an expression of light volcanic rocks in the near surface and the presence of Quaternary plutonic rocks below the volcanic field.

Teleseismic and seismic refraction studies have failed to show the presence of a magma chamber beneath LVC. However the resolution of these studies is such that magma chambers smaller than 5 km in diameter could not be seen. A compilation of regional seismicity reveals an area lacking crustal earthquakes that corresponds to the gravity low. Future geophysical studies will have to be of higher resolution to detect the magmatic system of LVC.



Evolution of the Lassen Volcanic Center



Cartoon of the Magma System of the Lassen Volcanic Center