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GEOLOGY OF MEDICINE LAKE VOLCANO, NORTHERN CALIFORNIA CASCADE RANGE

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ABSTRACT

Medicine Lake volcano (MLV) is located in an E-W extensional environment on the Modoc Plateau just east of the main arc of the Cascades. It consists mainly of mafic lavas, although drillhole data indicate that a larger volume of rhyolite is present than is indicated by surface mapping. The most recent eruption was rhyolitic and occurred about 900 years ago. At least seventeen eruptions have occurred since 12,000 years ago, or between 1 and 2 eruptions per century on average, although activity appears to be strongly episodic. The calculated eruptive rate is about 0.6 km^3 per thousand years during the entire history of the volcano. Drillhole data indicate that the plateau surface underlying the volcano has been downwarped by 0.5 km under the center of MLV. The volcano may be even larger than the estimated 600 km^3, already the largest volcano by volume in the Cascades.

INTRODUCTION

Medicine Lake volcano (MLV) is a Pleistocene and Holocene shield volcano located in the Cascade Range, east of the main arc and northeast of Mt. Shasta (see Figure 1 of Bacon, this volume). Lavas from MLV cover about 2000 km^2. They range in composition from basalt through rhyolite and include both tholeiitic and calc-alkaline types. Basalt and basaltic andesite dominate the lower flanks of MLV. Higher on the volcano, basaltic lavas are mostly absent, andesite dominates, and high-silica lavas are present, including the spectacular late Holocene rhyolites of Glass Mountain and Little Glass Mountain. Volume of the volcano is estimated at 600 km^3 (Donnelly-Nolan, 1988), larger than Mt. Shasta which is the largest of the Cascade stratocones. The highest point on the rim of MLV's caldera is 7913 feet. Lava flows reach elevations as low as 3360 feet although most lavas are found above 4100 feet, the approximate elevation of the surrounding Modoc Plateau. The low shield shape, central caldera, and dominance of mafic lavas are similar to Newberry Volcano of central Oregon, also located in an extensional tectonic environment east of the main Cascade arc.

RESULTS OF GEOLOGIC MAPPING

A preliminary version of the geologic map of MLV covers about 1800 km^2. Scale is 1:50,000. The map includes approximately 230 units and 350 vents. The youngest eruption occurred at Glass Mountain about 900 years ago. Wherever possible, individual lava flows were mapped. Some units include multiple flows from the same vent or from several closely spaced vents. Age spans of such units are thought to be short, not exceeding a few tens of years, based on paleomagnetic data (D.E. Champion, unpublished data). Only one widespread marker bed is present, an andesitic ash-flow tuff of late Pleistocene age, and even this is not present or not exposed on the south and northeast sides of the volcano. Potassium-argon age data are limited for MLV, but based on existing K-Ar and radiocarbon ages, stratigraphic relations and geomorphology, ages of the lavas at MLV were estimated and grouped into 5 time periods. Approximate percentages of the map area covered by lavas of the 5 periods are 0-12 ka, 15%; 12-25 ka, 17%; 25-120 ka, 40%; 120-700 ka, 23%; >700 ka, 5%. The 5% of lavas older than 700 ka may be pre-MLV in age. Most of these older lavas lie on the far west side of MLV and may be part of earlier centers that form a highland of volcanic vents connecting MLV with Mt. Shasta.

The most recent eruptive period, from 0-12 ka, included at least 17 eruptions ranging from basalt to rhyolite. The eruptions were widely scattered over the volcano. A compositional gap in erupted lavas occurs between 58 and 63% SiO_2. The eruptive activity was strongly episodic with 8 eruptions early in the period and 8 late in the period (Donnelly-Nolan et al., 1989). Eruptive volume amounted to about 7.5 km^3, yielding an average eruptive rate of about 0.6 km^3 per thousand years. Assuming that MLV began to erupt 1 million years ago, the overall average eruptive rate is the same.

Approximate percentages of map area by rock type are 55% basalt (47.2-52.9% SiO_2), 19% basaltic andesite (53.0-56.9%), 21% andesite (57.0-62.9%), 2% dacite (63.0-69.9%), and 3% rhyolite (>69.9%). Some lava flows are compositionally zoned, e.g. Glass Mountain, 64-74% SiO_2, the Callahan flow, 51-58%, the Giant Crater lava field, 48-53%, and Mammoth Crater lava, 48-55%.

Vent alignments are commonly oriented N-S or within 30° of north. Faults follow similar trends. Open ground cracks are present on the upper northwest flank of MLV associated with the Little Glass Mountain eruption (Fink and Pollard, 1983). The cracks trend about N 30° E, but the direction of opening is east-west, the same as the direction of crustal extension indicated by regional normal faults. Similar open ground cracks can be found on the lower north, east, and south flanks of the volcano, typically oriented in NNW to NNE directions.

The 7 x 12 km caldera contains Medicine Lake and may be a long-lived feature of the volcano. The present-day caldera rim apparently formed by voluminous eruptions of fluid andesite from ring fractures, as suggested by Anderson (1941). These eruptions took place in late Pleistocene time following

eruption of MLV's only ash-flow tuff and prior to at least one major glacial episode.

Many lava flows contain inclusions. Most are chilled mafic inclusions ranging from 48-63% SiO_2. Host lavas are always more silicic than these inclusions. Much scarcer are partially-melted granitic inclusions which are present in a variety of lava flows from basalt to rhyolite. Some lava flows contain both kinds of inclusions, e.g. Glass Mountain, Little Glass Mountain (Grove and Donnelly-Nolan, 1986), and Burnt Lava flow (Grove et al., 1988).

Geologic mapping of Lava Beds National Monument on the northeast flank of MLV, covering about 10% of the volcano, has been published at a scale of 1:24,000 (Donnelly-Nolan and Champion, 1987).

DRILLHOLE DATA

Drillcore from 8 holes on the upper flanks of MLV provide additional information about the distribution of lavas. The 8 holes are located on the north, south, and west sides of the volcano at drillsite elevations of 5600-6680 feet. None are located in the caldera. Available drillcore begin 350 to 600 feet below the surface. Five of the 8 holes are thought to go through the base of MLV lavas, based on entry into altered flows, sediments, and (or) hornblende-bearing porphyritic lavas unlike the typically poorly-porphyritic, olivine- and plagioclase-bearing lavas of MLV. Elevations at the base of the volcano vary from 2487 to 4600 feet. The drillhole with basal elevation at 4600 feet is located on the west side of the volcano where MLV overlaps a highland of volcanic vents that connect WSW to Mt. Shasta. Four of the 5 holes that penetrate through the volcano have basal elevations between 2487 and 3365 feet, and an additional hole bottoms at 3341 feet still within the edifice. Cross-sections constructed from the data indicate that under the center of the volcano regional strata of the Modoc Plateau have been downwarped by 0.5 km. Thus the volume of the volcano may be significantly greater than the previously estimated 600 km^3.

Of 16,394 feet of drillcore in MLV lavas, 5635 feet amounting to 34% by volume are rhyolitic, distributed among 5 of the 8 holes. The data indicate that a substantially greater volume of rhyolite is present than is indicated by the present surface distribution. The surface area of the volcano that lies above 5600 feet is about 450 km^2, of which about 50 km^2 is rhyolite, or only about 9% of the area. However, three of the rhyolite-bearing drillholes are located on the upper north flank above 6100 feet and within 6 km of each other. These 3 holes contain 4487 feet of rhyolite, or 78% of the total present in the drillcores, suggesting that a rhyolite dome complex was penetrated, similar to the set of silicic domes and flows present at Glass Mountain on the upper east flank. It is doubtful that more than 30% of the volume of MLV is rhyolitic. Drillholes sited below 5600 feet would be expected to encounter considerably less rhyolite because only 20% of the rhyolite that has been mapped on the surface of the volcano occurs in the 1500 km^2 of the volcano that is below 5600 feet. It is probable, however, that a larger percentage of rhyolite is present at MLV than is indicated by the surface mapping.

GEOTHERMAL IMPLICATIONS

MLV includes the Glass Mountain KGRA where several deep exploratory wells were drilled during the 1980's. Although temperature and fluid data are proprietary, continued interest in exploration suggests that a significant resource may be present. The greater volume of rhyolite found within the edifice as compared with surface outcrops supports the idea of substantial heat storage at shallow crustal levels. The primary heat source, however, is mafic magma intruded at shallow depths.

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