A Geologic History of Brown Mountain, Oregon

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Introduction

Brown Mt. is a 7311-foot volcanic cone in the Mt. McLoughlin area in the Southern Cascades of Oregon. The Mt. McLoughlin fault zone trends WNW across the area much as the Brothers fault zone trends across the Newberry Volcano.(Lawrence, 1976) Brown Mt. itself appears relatively fresh and unweathered, with slopes towards the top of 35 degrees. It lacks any but the most basic geologic mapping, so the first objective of this collaborative regional study was to produce a field map that could be fitted together with those of the other participants to form a map of the whole area. The second objective in the field was to take observations concerning the blocky lava flows making up the mountain, to determine how they flowed, where they originated, and their age in relation to other events in the area. In the lab, an effort was made to determine the origin and evolution through time, if any, of the magma supplying Brown Mt.

Fieldwork:

Four rock units are found within the eight square miles of the study area. The youngest and most important is the Brown Mountain Andesite. The next youngest is an olivine phyric basalt from Mt. McLoughlin. Next to oldest is a clinopyroxene-plagioclase-phyric andesite, from a peak just to the northeast of the area of the study. Oldest of all is a two-pyroxene andesite from Rye Spring, found only in one small area in NE1/4 NE1/4 sect31 T36S R05E.

Stratigraphically, Brown Mt is the youngest material in the area covered by the 8 participants in the project. Field evidence was found to indicate glaciation after the last volcanic activity on the mountain, and also some earlier. I therefore conclude that Brown Mountain was last active during the last glaciation, but dead well before the end of it. The mountain consists of stacked blocky flows, with very little evidence of pyroclastic activity - a small amount of ash within 50m of the summit comprises all the pyroclastics visible.

In hand specimen, the lavas of Brown mountain are virtually identical, though samples from the bottoms of flows, where exposed, show platy material containing small clusters of plagioclase crystals; not often observed in the surfaces of flows. Vesicularity, of course, varies from top to bottom of flows. The presence of solid, platy material at the bottoms of flows answers the question of whether these blocky lava flows had a liquid core, or were simply composed of blocks throughout. Clearly such blocky lava flows resulted from fluid bearing along blocks of rubble. The rubbly zone is at least 3 m deep wherever measurable. The blocks show further signs of near-surface fluid turbulence in the patterns of vesicularity and oxidation, (see figure 1) which show swirls and pockets of lava in different states.

An effort was made to quantify the sorting of the blocks, in order to support qualitative observation that the distribution of blocks was not entirely chaotic, whether by size or by type of block. To quantify sorting by size 400 boulders from 4 different slopes were measured across their intermediate axes, and the results shown in figure 2. This statistical survey, however small, supports the observation that size is not random, but has some degree of sorting, and varies also with steepness of slope. Steeper slopes show both larger average boulder size and lesser numbers of boulders of any given size. In comparison with the true disorder found in the areas of glacial moraine, the flows demonstrate a fair bit of order. It seems, therefore, that flow was sufficiently rapid to sort out blocks, though not to do so well.

Ordered structures of regular blocks connected beneath the surface were also observed. These form the walls of fissures and ridges, surprisingly smooth-sided in the surrounding roughness. These features generally trend at an angle to flow, and do not appear to be either levees or pressure ridges as are found in aa flows. They form two general types of features: fissures and ridges. Fissures appear in the midst of a flow and have rough columnar jointing visible in the walls, perpendicular to the horizon. These columns show decreasing vesicularity away from the surface, indicating that they were exposed after the mass had congealed. 'Ridges' have smooth sides, even into the valleys separating them, and show regular cracks that can be seen to represent the tops of primitive columns where the surface has broken away to allow a cross-section view. Both features range from 5-20 m in length, and up to 3 or 4 m high. They usually occur not as isolated phenomena, but in groups or fields of ridges and fissures. Furthermore, they only appear near the base of the mountain, in areas of low slope, near the distal ends of the flows. They may be related to increasing ground resistance as the pressure driving the flow forward diminishes relative to the drag of the ground on the underside of the flow on lower slopes.

Thin Section Analysis:

Study of thin sections shows an andesite with little variation through the entire set of samples. An average sample of Brown Mountain Andesite runs about 50-65% plagioclase in the andesine range. Other mineral phases are orthopyroxene and opaques. All slides contain to a varying degree an opaque or dark groundmass below the limit of definition of a microscope. Some of this seems to be glass, but most is probably oxidized material. Plagioclase is occasionally visible as microcrysts.

Many of the phenocrysts of plagioclase form cruxiform clusters that include orthopyroxene. Many of these orthopyroxene crystals are euhedral where not in contact with plagioclase, and become raggedly anhedral where they touch. The plagioclase does not show this effect, and generally envelops the orthopyroxene. Thus it would appear that the orthopyroxene nucleated first, with the plagioclase growing around it, preventing further growth and possibly partially resorbing the earlier phase.

Many of the plagioclase crystals show concentric zonation, particularly the blockier, squarer crystals. This demonstrates some variation in the melt with time, very possibly simply a variation in pressure affecting what composition of plagioclase is on the liquidus at a given depth, as magma rises. There is also the possibility of the chemistry of the melt changing to produce the different zones, but there are no other signs of this.

Many of the thin sections show a more or less trachytic texture, though this is by no means universal. This is most common among samples with moderate vesicularity. Vesicles do not show stretching in the direction of trachytic texture, nor do they show a dictytaxitic texture. Vesicles are usually irregular in form, truncating crystals that would extend into them with ragged boundaries, curved to fit the curve of the limit of the vesicle elsewhere. Thus it appears that structure caused by flow in terms of alignment of plagioclase grains must have taken place in a magma sufficiently fluid to allow them to retain an approximately spherical shape while aligning nearby plagioclase. There is no sign of a hardened boundary wall to the vesicle which might have allowed them to retain their shape in a very viscous fluid. I therefore conclude that the vesicular blocks, at least, cooled quickly, from a fluid sufficiently non-viscous to flow at the surface and not cause explosive pyroclastic events.

Chemistry:

Chemically, the Brown Mountain lavas are remarkably uniform across a single flow, as well as vertically through the pile. Major element chemistry shows them as true andesites, with a chemical signature of continental volcanic arcs: a perfect calk-alkaline andesite, in the silicic, medium-potassic range, unremarkable in every way, as figure 3 shows. A spider diagram of the trace elements (figure 4) shows two distinct populations in terms of rubidium content, and a sharp spike in the strontium content. The rubidium data are particularly interesting because all of the low-Rb group are stratigraphically older than the high-Rb group. Among the rare earth elements (REE's) La values range from 12-15 ppm, Ce from 19-26 ppm, Yb from 0.1-1.0 ppm.

The high Sr content is undoubtedly due to the very high plagioclase content of these samples, with the strontium replacing calcium. This may also indicate a crustal component to the melt, since Sr is not abundant in crustal rocks. However, the mere presence of the Sr anomaly provides no mechanism for its addition, whether by mixing, assimilation, or original melting of crustal material. The two populations of Rb, however, may indicate mixing with a magma contaminated by lower continental crustal rocks. The Rb gap between the youngest flows and those lying directly underneath them indicates a relatively sudden change, or else a period of inactivity inconsistent with the small difference in erosion between the two groups. It therefore seems likely that some form of sudden contamination was responsible. Magma mixing is a possibility - perhaps the addition of fresher magma with a small amount of lower crustal component. There is insufficient data to be certain, however, since if lower crustal contamination is responsible, this dual trend would extend to Th, Nb and Ta, none of which data are available.(Wilson, p.19) This cannot be an effect of fractionation of the earlier magma, being too sudden and requiring the addition of Rb. Finally, Yb values and La values indicate a magma source with little or no garnet present, or the heavier REE's like Yb would be relatively depleted - below 5ppm or so. The lack of significant enrichment in the LREE's like lanthanum indicates that there was little orthopyroxene or Ca-rich orthopyroxene in the source, and no significant fractional crystallization of those phases. Given that these rare earth elements are no more abundant on average in Brown Mt andesite than in basalts. (Wilson, 1989, P. 18, Swanson & Wright, 1981)we can assume that olivine fractionation also played little role in the formation of the magma. It seems that the Brown Mountain andesite may have had an untroubled passage to the surface, possibly a swift one allowing little time for fractional crystallization, possibly with some mixing with another batch of magma.

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References:
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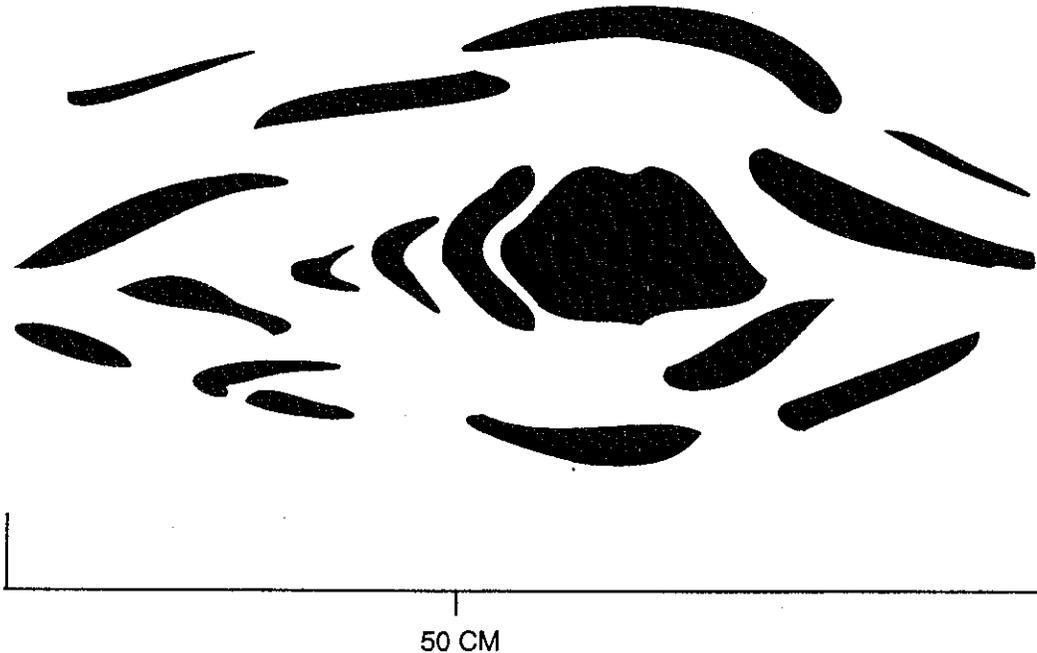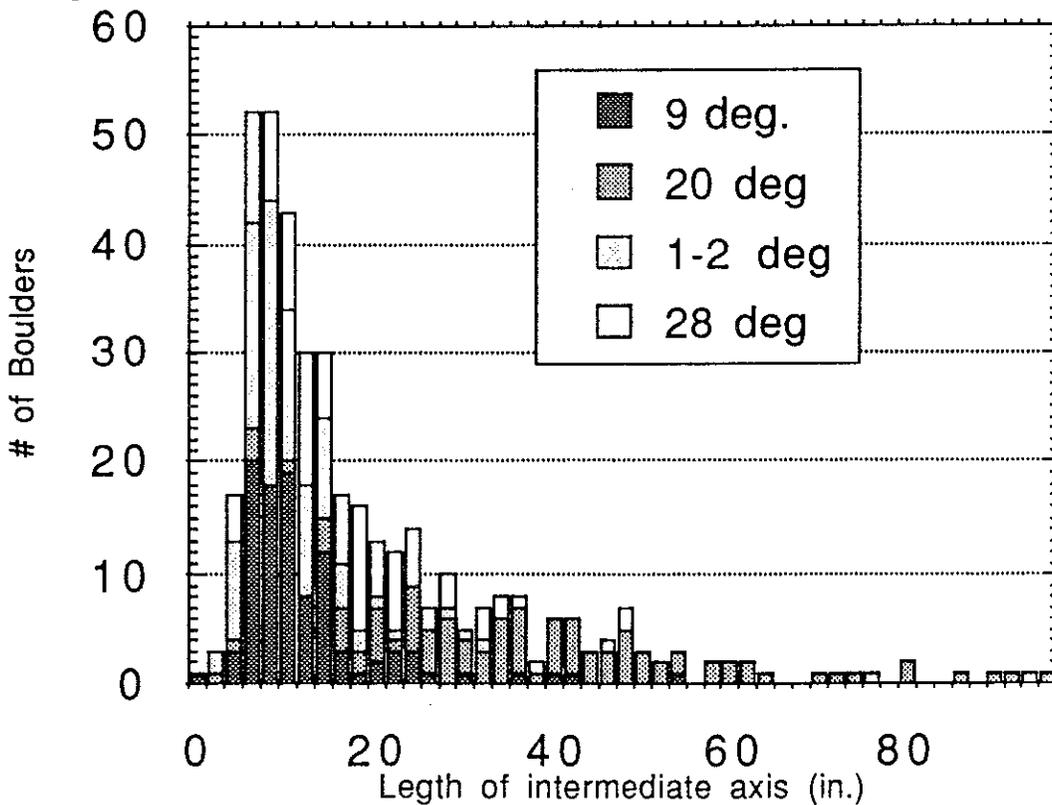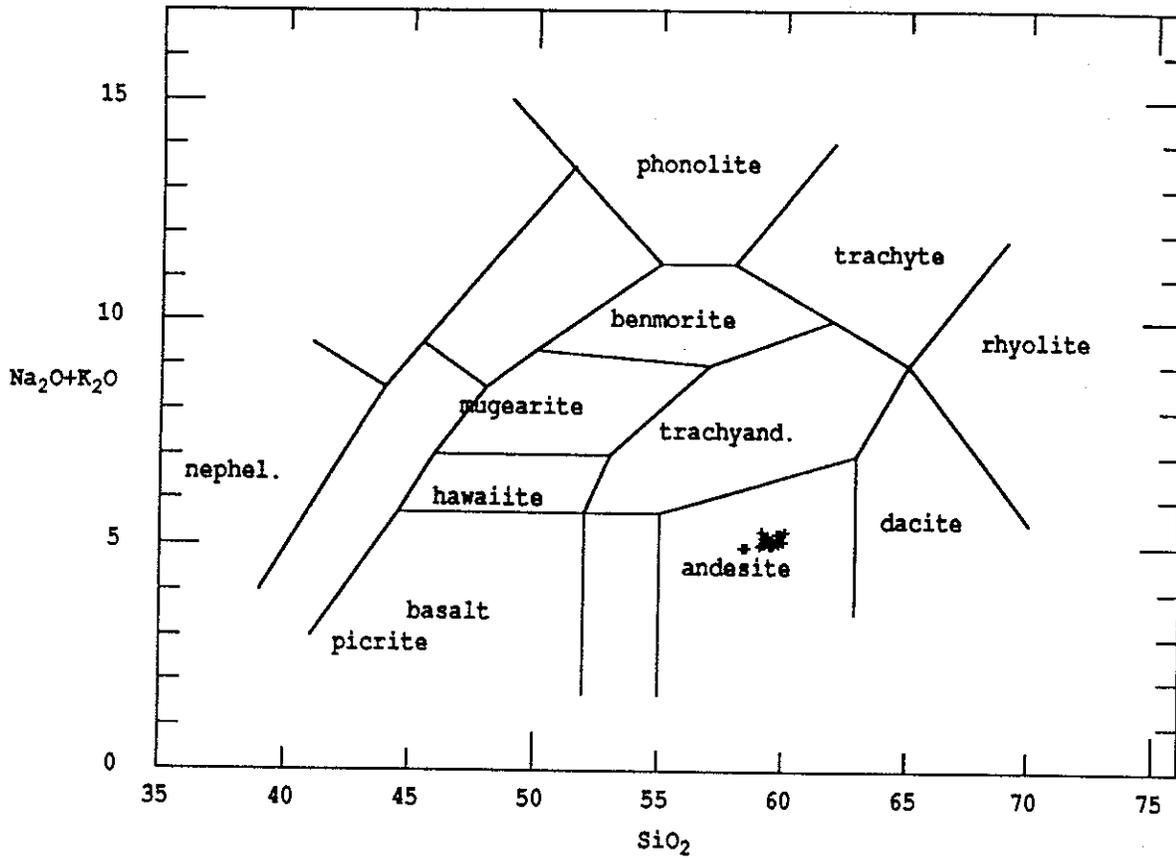Wilson, Margaret. 1989, Igneous Petrogenesis; Unwin Hyman, Boston.

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Figure 1: sketch of patterns of dark, massive material within a lighter, more
vesicular block demonstrating the mixing of different magma phases in the fluid

Figure 2: Distribution of boulders on Brown Mt. by degree of slope.

Figure 3: LeBas classification diagram for the Brown Mountain andesites - a true calk-alkali andesite.

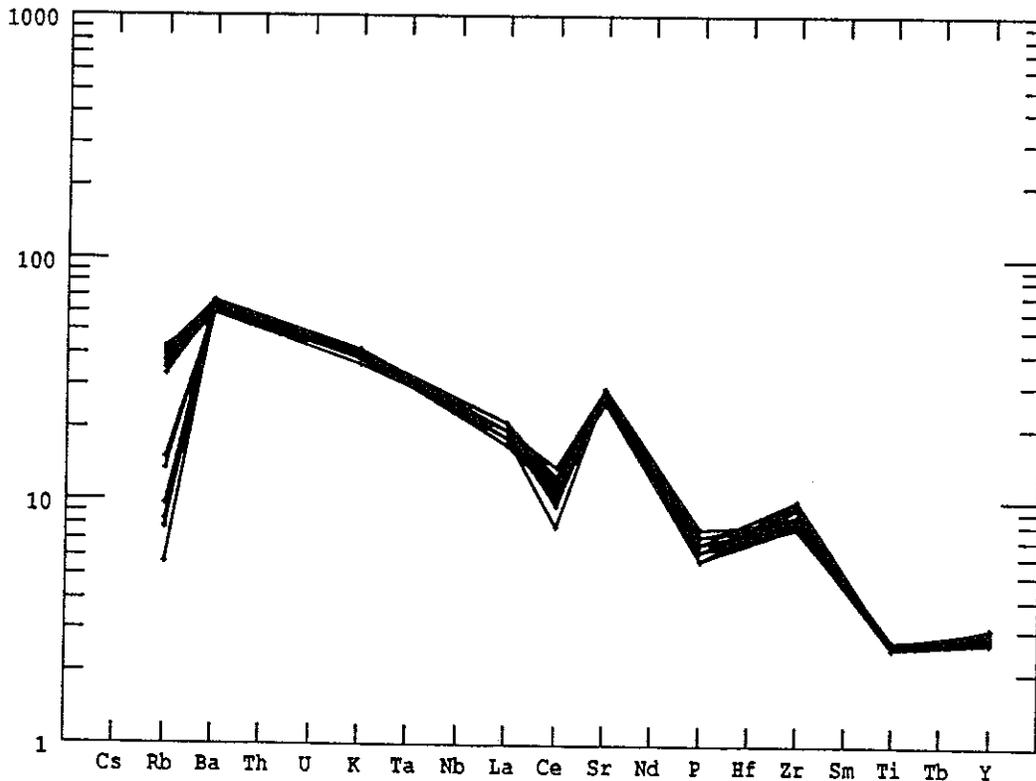Rock/Primordial Mantle   Wood, D.A. et al., 1979

Figure 4: Spider diagram showing two populations defined by Rb content, and a consistent Sr high.