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Emplacement and solidification process of off-axis large submarine lava field from the Oman Ophiolite

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Large submarine lava flows more than 100 m in thickness and a volume exceeding a few cubic kilometers are not uncommon volcanic constructs of mid-ocean ridges and Hawaiian volcanoes, yet details of the physical processes of emplacement of such large flows are poorly constrained because of their inaccesibilty under deep water and lack of direct observations. The V3 Volcanics of the Oman Ophiolite extruded at 90 Ma far off the paleospreading axis as thick lava flows with a minimum areal extent of >11 km by 1.5 km and the maximum thickness >270 m, yielding a minimum estimated volume of several cubic kilometers. The V3 flow was fed through a thick feeder dike in the SW of the flow field and buried off-axial fault-bounded basins with a thick sedimentary cover in ca. 40 days. The basic structure of the V3 flows consists of massive lava sandwiched between columnar jointed lava crusts, similar to that of subaerial flood basalt. The upper crust comprises piled up flow lobes forming dome-like structures with occasional inflation cracks, which are interpreted as welded aggregates of coalesced and inflated flow lobes. V3 flow is roughly divided into the Upper and the Lower flow by the presence of pillow lava with interstitial mudstone. Thickness of individual lobes varies from 2 to 20 m. The uppermost 35 m comprises at least eight welded flow lobes, averaging 3.4 m in thickness.

Low-T hydrothermal alteration and weathering slightly modified the bulk compositions as indicated by moderately albitized plagioclase, completely replaced olivine by clay minerals and partially replaced titanomagnetite and augite by titanite and actinolite, respectively. However, HFSEs and REEs show mutual positive correlations and relatively good correlations with some major elements besides LILEs and Pb, indicating that these elements were less mobile and preserve primary characteristics. V3 flow is hawaiitic-mugearitic dolerite and has intermediate characteristics between OIB and E-type MORB. TiO_2 shows a moderate increase with decreasing MgO from 8 to 5 wt%, and then decreases with the decrease in MgO down to 4 wt%, whereas Yb ranges from 2.12 to 4.56 ppm.

Whole-rock major and trace element variations through a stratigraphical transect at a distance of 8.7 km from the feeder dike indicate fractionation of augite, plagioclase and magnetite. By contrast, other V3 samples show highly scattered whole-rock compositions, suggesting internal mixing of variably differentiated magmas. Yb concentrations of the basal crust increase downflow to a distance of 4.5 km from the feeder dike, and then decrease further downflow with a spike at 7 km. Because the basal crust is the first lava that came to rest at that place, samples farther away from the feeder were extruded and emplaced later in the eruptive event. The downflow variations show extrusion of differentiated lava in the middle stage of the eruption and less differentiated lava in early and late stages.

Width/length ratio of groundmass plagioclase at 6 km from the feeder, where V3 flow is thickest, is higher in the Upper flow than in the Lower flow. Stratigraphic variations of Yb shows a decrease from the basal crust to a height of 26 m in the core, and then increase to a height of 83 m in the upper crust and decrease to the top of the Lower flow. The minimum Yb in the core is close to that of the latest lava shown by the basal crust. This can be reconciled with the model that the core is formed by the last intruded lava. On the contrary, the variation in Yb from the height of 83 m to the top of the Lower flow is correlatable to that of the basal crust at distances from 6 km to 8 km, suggesting that the upper crust consists of piled-up and welded lava lobes.

Keywords: Oman Ophiolite, V3, Large Lava Flow, emplacement process, chemical variation, geochemistry