Inflation structures of subaqueous lava flows in Oman Ophiolite

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Under subaerial conditions, inflation and coalescence of flow lobes are common to fluidal basaltic lava emplaced on a gentle slope to a flat field. We have identified evidence of inflation and coalescence of subaqueous flow lobes from effusive rocks at every stage of the evolution of Oman Ophiolite. V1 and V2 lavas contain abundant inflated pahoehoe lobes among pillow lava. Large flow-lobe tumuli are formed by coalescence of pahoehoe lobes, forming banding of lenticular crystalline cores within fine-grained coalesced chilled margins. Thick sheet flows are major constituents of V3, developing upper columnar jointed crust, massive core and lower columnar jointed crust, which is very similar to subaerial flood basalt.

Coalescence and inflation of flow lobes are common to fluidal basaltic lava emplaced on a gentle slope and a flat field, which are fundamental mechanisms to form vast sheet-like lava flows. High water pressure under deep sea favours quiet extrusion of lava flows rather than violent explosions. Therefore, flow-lobe coalescence and inflation are also expected to deep-sea environments. We can deduce the rate of lava supply and the period of lava extrusion by examining such inflation-related structures. We present evidence of flow-lobe coalescence and inflation of subaqueous lava flows from the lower (V1), middle (V2) and upper (V3) effusives of the Oman Ophiolite, correlated to the spreading, subduction and obduction stages, respectively.

We found many pahoehoe lobes among the effusives of V1 and V2, which were previously misidentified as pillow lava. These pahoehoe lobes have significantly lower height/width ratios (< 0.2) than pillows (0.8-1.0), and accompany partially hollow lobes with empty upper half. Such occurrence is very similar to proximal facies of lava flows on the conical lava cones from the south rift zone of Loihi Seamount, Hawaii. The width of Omani flow lobes is 1-2 m for pillows and < 3.5 m for pahoehoe lava. Ratio of height/length is 0.4 (< 0.8 maximum), which is similar to that for tholeiite pillows in Loihi Seamount, alkali basalt pillows from Ohkuzure coast, Shizuoka, boninite pillows from the Bonin Islands, while the lengths and heights are within the same range as Ohkuzure alkali basalt. Estimated supply rates of lava for V1 pahoehoe lobes are 0.02-0.2 cubic m/min, which are plotted on the extension of those for pahoehoe lobes from Loihi and subaerial tumuli from Kilauea.

Clusters of subaqueous tumuli were found from V2 lavas along Wadi Salahi, among which the largest one is 250 m by 140 m across and 20 m high. Upper 7.5 m is composed of stacked and coalesced pahoehoe lobes, underlain by the doleritic core. The coalesced crust consists of coarse lenses of basalt closely stacked in a matrix of fine basalt, which were cores and coalesced margins of pahoehoe lobes, respectively. Lava injected into the tumuli during inflation cooled slowly to form the doleritic core.

V3 mainly consists of at least 3 sheet flows with a maximum thickness > 100 m and lateral extension > 12 km. An alkali dolerite dyke > 30m thick to the southern end of V3 distribution is assumed to be the source of V3 lavas, comprising a NE-SW-trending vertical ridge. V3 lavas unconformably overlie V2 lavas, both of which are bounded by thick red shale. Red shale also occurs as interflow sediments. Sheet flows occasionally grade into pillows both laterally and downward. Pillows directly broke out from the base of sheet flows are observed, mingling with red shale underneath. The upper surfaces of sheet flows are undulating with wavelengths of several to tens of meters. Ropy wrinkles are commonly observed on the top and bottom of the sheets, indicating north to northwesterly flow directions.

A sheet flow can be divided into upper columnar jointed crust, massive core and lower columnar jointed crust, which look like those of the Columbia River Basalts. The lowermost flow in the north of V3 outcrops has volcaniclastic veins and lenses along vertical joints in the lower part of the upper crust. Repeated fragmentation of chilled margins along the joints produced hyaloclastite. Subhorizontal columnar joints are developed normal to and within ca. 5 m from the fractured joints. This indicates that molten lava was in contact with water entering through inflation cracks.

Low extrusion rates are indicated by the existence of pillows grading into sheet flows, and ropy wrinkles on the top and bottom surfaces of the sheets. Coalescence and inflation of the sheets are suggested by the undulating upper surfaces similar to the hummocks of inflated subaerial sheet flows in Hawaii, and fractured joints deep into the upper crust.