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Emplacement mechanism of Salahi sheet flows in the Oman Ophiolite

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The Salahi Volcanics, erupted at the obduction stage of the Oman ophiolite, comprises 3 sheet flows associated with pillow and pahoehoe flows. The lowest flow has the largest extension >12 km and 100 m in thickness. It consists of columnar jointed upper and lower crusts and massive cores. The crust contains some finely jointed layers and lenses, which are finer grained than above and below, indicating a complex cooling history of the crust. In contrast, the core lacks fine columnar joints and shows a typical doleritic texture. We interprete that the crust was formed by coalescence of overlapped flow lobes, while the core was fomred by endogenous growth as the sheet inflated.

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. Flow-lobe coalescence and inflation are also known from submarine sheet flows from mid-ocean ridges and submarine extensions of Hawaiian rift zones. The Salahi Volcanics (V3) of the Oman Ophiolite has an extensive sheet flow of alkali basalt attaining 12 km and as thick as 100 m. We propose that this unusually thick sheet flow was formed by complex flow-lobe coalescence and inflation of subaqueous lava lobes extruded at low supply rates of lava.

V3 mainly consists of 3 sheet flows separated by red shale beds associated with pillow and pahoehoe flows. An alkali dolerite dyke >30 m in thickness to the southern end of V3 distribution is assumed to be the source of V3 lavas, intruding into the Alley Volcanics (V2) beneath V3. Wrinkles on the chilled margin of the dolerite dyke indicate intrusive directions to the northeast-obliquely upward. V3 lavas unconformably overlie V2 lavas, both of which are bounded by thick red shale. Red shale also occurs as interflow sediments, associated with pillows. Ropy wrinkles are commonly observed on the top and bottom of the sheets, indicating north to north-westerly flow directions.

Sheet flows occasionally grade into pillows and pahoehoe lobes both laterally and downward. Pillows and pahoehoe lobes directly broke out from the base or peripherals of sheet flows are observed. Red shale fills interstices between pillows and fractures along the cooling joints in the base of sheet flows. Because pillows are formed on slopes >10 degrees, the above occurrence indicates that the slowly advancing lava formed pillows as it flowed down into a depression filled with unconsolidated mud. When the depression was filled with the pillows, the lava form changed into flattened, lobate pahoehoe lobes, flowing onto the pillowed field. The lobes were coalesced and inflated to a thicker sheet flow. The underlying pillows are mingled with and heated water-saturated mud, which eventually rose into fractures along the cooling joints of the overlying sheet flow.

The lowest sheet flow (SF-1) has the largest extension and thickness among the three flows. It has columnar jointed upper and lower crusts, and massive cores, among which the upper crust is thickest. Such joint structures also develop in subaerial flood basalts, but are more complex in the Salahi SF-1. Most part of SF-1 has only one core between the upper and lower crusts, while in places double cores are present separated by a columnar jointed layer, or no core appears in other places. The core lacks dendritic clinopyroxene, showing a typical doleritic texture. In contrast, the crust contains thin and elongated clinopyroxene, suggestive of crystallization under a large degree of supercooling. It contains some finely jointed layers and lenses, which are finer grained than above and below, indicating a complex cooling history of the crust. The roof of the sheet develops domed structures several metres to a few hundred metres across. Finely jointed zones beneath such domed roofs sometimes continue into and thin out within the crust below the neighbouring roof. Such finely jointed layers and lenses are most plausibly seal zones of coalesced flow lobes.

Hyaloclastite veins and lenses are found along vertical joints in the lower part of the upper crust. Repeated fragmentation of chilled margins along the joints indicates that molten lava was in contact with water, which entered through deep cracks into the upper crust.

All these observations led us to conclude that the crusts were formed by coalescence of partially overlapped or stacked flow lobes, while the core developed endogenously as the sheet inflated. Meanwhile inflation cracks opened and penetrated deep into the crust.