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Genesis and evolution of the upper oceanic crust (ODP-IODP site 1256, East Pacific Rise): inferences from structure and composition of late magmatic veins in a lava pond

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A complete intact "in situ" section of upper oceanic crust, from extrusive lavas, through dikes into gabbros has been recently drilled for the first time in a 15 Ma old crust that formed at the East Pacific Rise with a full spreading rate of >200 mm/yr. The study area is ODP-IODP Site 1256 (6°44.2N, 91°56.1W, Pacific Ocean). Holes 1256C and 1256D have been drilled into the basaltic basement during ODP Leg 206, IODP Expeditions 309 and 312. Hole 1256D has been deepened to a depth of ca. 1500 meters below seafloor (mbsf). The upper section of the igneous basement consists of thin (<3m) basaltic sheet flows separated by chilled margins, and massive basaltic flows (>3m). The massive flows include a ponded lava flow, located near the top of both Hole 1256C and 1256D, where it has a thickness of 32m and 74m, respectively.

The lava pond is interpreted as a thick lava flow delivered either on-axis or off-axis and accumulated in a topographic depression. Although very close (ca. 30m), the two holes record different structural patterns of the lava pond, probably related to different steps of the lava flow emplacement.

In the lava pond, both igneous (magmatic foliation, flow-related folds, late-magmatic veins) and post-magmatic (joints, veins, shear veins, and microfaults) structures were recognized. Late magmatic veins (LMVs), which were identified as primary features typical of the lava pond, are the main goal of this work. Mm-thick LMVs are mainly clustered in the middle (290-300 mbsf in hole 1256C and 282-297 mbsf in hole 1256D) and bottom (312-313 mbsf in hole 1256C and 311-328 mbsf in hole 1256D) parts of the lava pond. Structural measurements on cores suggest that they are mostly gently dipping structures, but we also observed sub-vertical LMVs. At the bottom of the lava pond in hole 1256C, late magmatic veins are often arranged in en echelon arrays and sigmoidal pull aparts, suggesting a syn/post-magmatic shear component.

Thin-section observations show that basalt including LMVs consists of plagioclase, clinopyroxene, ilmenite, and spinel. LMVs cutting basalt are filled with quartz, quartz + plagioclase intergrowth showing a granophyric texture, clinopyroxene, ilmenite, spinel, and apatite. Rarely we observed pyrite crystals at the LMV core that cut plagioclase + quartz intergrowth. Quartz + plagioclase intergrowth (with apatite) are also present in the basalt as mm-size interstitial domains or rimming plagioclase (IDs = intergrowth domains). Rare samples display IDs with interstitial K-feldspar growing around plagioclase. LMVs often show sharp contacts with basalt. Plagioclase or pyroxene crystals of the basalt may be fragmented at the contact with LMVs (brittle rheology of basalt). Differently, IDs commonly corrode plagioclase crystals, without fragmentation (ductile rheology).

The composition of basalt plagioclase ranges from Ab37 to Ab62, with a main concentration around Ab50. On the contrary, plagioclase in the LMVs intergrowth as well as that in the mm-sized IDs are Na-rich (Ab64-Ab98). Mineral analyses also highlight homogeneous clinopyroxene, spinel and ilmenite, without variations in the LMVs and IDs. Clinopyroxene usually shows a Ca-poor core (mainly augite or pigeonite) and a diopsidic rim. Opaque minerals often exhibit ilmenite-ulvospinel lamellae intergrowths.

EDS mapping of IDs and LMVs cutting basalt supports the previous observations. LMVs and IDs have higher Si, Na and lower Al, Ca values than basalt. This distribution is only due to albitic plagioclase concentration in LMVs and IDs. K has low and homogeneous concentrations: rarely IDs are characterized by interstitial K enrichment (K-feldspar). Incompatible (Zr, Rb, Sr, Ba), hydrothermal elements (Cu, Cl), and F are undetectable or absent. We infer that LMVs and IDs likely crystallized from a pure Si-Al-Na-(Ca) melt. K, rarely noticed in the IDs, may be related to late magmatic fluids differentiation or to subsequent hydrothermal fluids.

Core description, microstructural observations, mineral compositions and EDS mapping of the studied samples

suggest that:

- the middle and bottom parts of the lava pond has been affected by Si-Na rich late magmatic melts, without chemical interactions between host rock and melt;
- IDs may represent the diffused reservoir of late magmatic felsic material;
- LMVs could be the migration channels for Si-Al-Na-(Ca) melt through the basalt mush during the late stages of crystallization;
- late magmatic material rapidly cooled producing granophyric textures in veins and interstitial patches.