

How concentration of porosity, crack shape, and crack wall asperity control the seismic structure of the upper oceanic crust

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Authors Fontana, E*, Department of Earth Sciences, Universit degli Studi di Milano, Milano, Italy
Gilbert, L A,

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Abstract

Surprisingly little is known about several important aspects of the architecture of oceanic crust, including controls on lithology, heterogeneity of hydrothermal alteration, and thickness of the lava section and sheeted dike complex and their influences on the seismic structure. Ophiolites provide useful analogs of ancient oceanic crust, with more exposure and access than deep-sea drill holes or submarine fracture zones. We examine the brittle structure of the lava, sheeted dikes, and lava-dike transition zone of the Troodos ophiolite (Cyprus) in the Lythrodontas area. The lava zone consists of pillow basalts; the transition zone consists of sheeted basaltic dikes cutting pillow lava through a large interval, and of hyaloclastic breccia; the sheeted dikes are composed of 12 m thick basaltic or dacitic dikes. Detailed sample measurements of P- and S-wave velocity, permeability, porosity, and structures, show that porosity decreases drastically, as does permeability from lava to sheeted dikes. Variation of P-wave velocity mainly depends on the porosity, as well as the shapes of the cracks or pores. To better understand the relationships among P-wave velocity, porosity, and crack shape and aspect ratio, we made laboratory measurements using synchrotron X-ray computed microtomography (micro-CT). Micro-CT images enhance the phase-contrast between primary (igneous) minerals and alteration minerals now filling the pores. Overall, quantitative data of the volume and shape of the pores (at the sample scale) allow us to evaluate the "empty" (effective) porosity as well as the paleo-porosity (pores now partially or completely filled with secondary minerals). We also quantify the asperity of crack walls. These measurements allow us to construct 3D structural patterns in the investigated ophiolite, which we use to examine the influence of cracks in the upper oceanic crust on seismic structure.

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