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Evidence for fluids in crust and mantle of the outer rise offshore southern Chile from passive seismic monitoring

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Hydration of the crust and mantle at the outer rise has been proposed as a significant pathway for water into the subduction system. Anomalously low heat flow values in some outer rise regions indicate the presence of an active hydrothermal system, multi-channel seismic profiles have shown that large bending faults cross the Moho and penetrate the mantle, and Pn velocities measured on refraction profiles are reduced just seaward of the trench, consistent with partial hydration of the underlying mantle. Here, we present observations that suggest the presence of free fluids both within the crust and mantle of the Outer Rise of even very young plates, which lack the characteristic bulge due to their low elastic thickness, and where changes in seismic velocity are hard to see because of superposition with the plate-cooling signal. Specifically, we examine the micro-earthquake seismicity recorded by two temporary arrays of ocean bottom seismometers on the outer rise offshore southern Chile on young oceanic plate of age 14 Ma and 6 Ma, respectively. Approximately 10 events per day were recorded with each of the arrays.

The catalogue, which is complete for magnitudes above 1.2-1.5, is characterized by a high b value, i.e., a high ratio of small to large events, and the data set is remarkable in that a large proportion of the events form clusters whose members show a high degree of waveform similarity. The largest cluster thus identified consisted of 27 similar events (average inter-event correlation coefficient>0.8 for 9.5 s window), and waveform similarity persists far into the coda. Inter-event spacing is irregular, but very short waiting times of a few minutes are far more common than expected from

a Poisson distribution. Seismicity with these features (high b value, large number of similar events with short waiting times) is typical of swarm activity, which, based on empirical evidence and theoretical considerations, is generally thought to be driven by fluid pressure variations, where the fluid can be either water or melt. Because no pronounced bulge exists on the very young plate in the study region, it is unlikely that melt is accessible from decompression melting or opening of cracks. Likewise no pressure or temperature changes are imaginable, which could have initiated dehydration reactions. We thus infer the fluid to be derived from seawater, which enters the crust through hydrothermal circulation.

Most of the similar-earthquake clusters are within the crust, but some of them locate significantly below the Moho. If our interpretation is correct, this implies that water is present within the mantle. The deepest events within the array on the 6 Ma old plate occur when the temperature reaches 550-650°C, similar to the value observed for large intraplate earthquakes within the mantle, suggesting that the transition temperature for these fluid-mediated micro-earthquakes is similar or identical to that of large earthquakes.