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The origin of fluids and gases in the DFDP-2B borehole, New Zealand; insight from on-line mud gas monitoring

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The Deep Fault Drilling Project (DFDP) aims to improve our understanding of the Alpine Fault Zone, a tectonically active fault system in New Zealand known to rupture in large events, by deep scientific drilling. The borehole DFDP-2B approached the Alpine Fault at depth, reaching a final depth of 892 m. During drilling, gas was extracted from returning drilling mud and changes in the gas composition were tracked by mass spectrometry (N2, O_2, Ar, CO_2, CH4, He, and H2), gas chromatography (CH4, C2H6, C3H8, i/n-C4H10), and alpha-spectrometry for 222Rn. The rapid formation of mud wall cake seals the borehole from fluid inflow along the borehole; hence formation-derived gases enter mostly at the drill bit during drilling. Gas was sampled for offline analyses on noble gas and stable isotopes to complement the dataset. Apart from an atmospheric input, the gases in drilling mud derive from the pore space of rock, crushed at the drill bit, and from permeable layers intersected by the borehole. OLGA thus may provide information on fluid origins, flow rates and paths, fluid-rock interactions along these paths, and the permeability structure of the faulted rock mass.
The principle formation-derived gases found in drilling mud during drilling of DFDP-2 were CO_2 ($\leq$1.7 vol.-%), H2 (<2.5 vol.-%), and CH4 ($\leq$0.18 vol.-%), with minor contributions of He. Zones of enhanced gas concentrations and high radon activity are interpreted to reflect intervals of active fluid flow through highly fractured and faulted rock. Air-corrected 3He/4He values of samples from 236m (0.68 Ra), 610m (1.03 Ra) and 707m (0.63 Ra) show mantle helium contributions similar to those measured in hot springs along the Alpine Fault, e.g. Fox River (0.64 Ra), Copland (0.42 Ra), Lower Wanganui (0.81 Ra). CH4/C2H6 ($\sim$20) and δ13C of methane (-31.7 ‰ PDB) underpin a thermogenic origin of hydrocarbons at depths below 600m, while mixing with biogenic gas is indicated at shallower depth (δ13C of methane= -46.7 ‰ PDB), CH4/C2H6 >50 at 236 m). For a more comprehensive overview, compilation of the OLGA dataset with cuttings data and data from geophysical downhole logging is ongoing.