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The small-scale permeability structure of the San Andreas Fault at SAFOD deduced from drill mud gas data

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The San Andreas Fault Observatory at Depth (SAFOD) is a component of the U.S. research initiative EarthScope and supported by the ICDP (International Continental Drilling Program). It consists of two wells, from which the SAFOD main hole (MH) traverses the San Andreas Fault (SAF) between approx. 3100–3450m bore hole depth. In 2007, three side tracks were drilled out of the MH, including the holes D (3137m-3262m), E (2952m-3182m) and G (3125m-3356m). These holes are almost parallel to the MH and penetrate the SAF nearly orthogonal. The holes D and G intersect two active moving tracks of the SAF, identified by casing deformation in the MH at 3194m and 3301m depth. During all drilling phases of SAFOD, gas was continuously extracted from drill mud and analyzed in real-time for its composition. Off-line gas samples were investigated in the laboratory for selected isotopes. MH and all sidetracks show enhanced concentrations of hydrocarbons between approx. 3150-3190m and also below 3310m (if reached), but distinctly lower contents of hydrocarbons in the section enclosed by both active moving tracks at 3194m and 3301m (inner section, IS). Moreover the molcular, but not the isotopic composition in the IS is clearly different from above and below, suggesting hampered fluid flow orthogonal to the fault direction. Helium isotopes also imply that the permeability at and around 3194m and 3301m is low. Wiersberg and Erzinger (2007) report relatively constant R_a values on the Pacific Plate (0.354$\pm$0.021 R_a at 3051m) but increasing contribution of mantle-derived helium below 3196m on the North American Plate with maximum air-corrected R_a values at 3903m depth (0.938$\pm$0.097 R_a). This observation suggests that the SAF is not the principal conduit for mantle-derived fluids, however, only one sample from their study derives from the IS (0.46$\pm$0.26 R_a at 3196m). R_a values of $\leq$0.85 were found in two samples from hole D in 3203m and 3262m depth, indicating somewhat enhanced flow of mantle-derived fluids in the IS. In contrast, very low R_a values were observed outside of this interval at 3147m (0.26$\pm$0.12 R_a) and 3312m (0.22$\pm$0.12 R_a). The considerable variations in R_a values on short spatial scale imply that the SAF consists of strata with different permeability parallel to fault, from which low-permeable rocks hamper the fluid flow orthogonal to the fault (Wiersberg and Erzinger, 2008). It is, however, not clear weather the elevated R_a values found in 2007 in the IS reflect temporal variation in the fluid flow, i.e. recharging of the fault with fluids from the mantle after e.g. the earthquake from 09/28/2004.

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