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Peter Eichhubl[1], Peter D'Onfro[2], Atilla Aydin[3], John Waters[4], Martha Gerdes[5] (1) Stanford University, Stanford, CA (2) Conoco, Inc, Houston, TX (3) Shale Smear Project, Stanford University, Stanford, CA (4) Black Diamond Mines Regional Preserve, Antioch, CA (5) Chevron Petroleum Technology Company, San Ramon, CA

Deformation and Alteration of Shale in Fault Zones: An Example from the Black Diamond Mines, California

Entrainment of shale along faults or shale smear represents a significant mechanism providing fault seal in hydrocarbon reservoirs. This ongoing project is designed to assess fault sealing properties by shale smear as a function of the depositional, structural, and diagenetic evolution of petroliferous basins. In an underground coal mine near Antioch, California, an estuarine clastic sequence of alternating quartz arenite, laminated shaly sand, and organic-rich black shale is offset along a normal fault with about 9 m of dip slip. Whereas quartz arenite and laminated shaly sand are faulted, black shale is entrained into the fault by flow. Fragments of laminated shaly sand are incorporated into the shale smear by flow of over- and underlying shale layers causing boudinage, rotation, and flattening of sand lenses with increasing shale attenuation. Smeared shale is characterized by a well developed planar shale fabric as observed in SEM. Mercury intrusion experiments indicate a 5- to 50-fold increase in capillary entry pressure of deformed shale compared to shale outside the fault. Preliminary X-ray analyses appear to indicate an increase in kaolinite to smectite ratio in smeared shale. Such an increase would suggest that water-mineral reactions accompanied shale deformation, potentially affecting the petrophysical properties of smeared shale in addition to the mechanical reorientation of clay minerals. The sealing properties of smeared shale along faults may thus be controlled by the initial shale composition and by the pore water content, stress conditions, and extent of diagenetic alteration at the time of fault formation during the burial cycle.