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Chemical Sealing of Microfractures by Anhydrite during Expulsion of Geopressured Fluids: An Example from the North Sea Central Graben

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We have examined both vertical and horizontal microfractures found in small cores taken from Cenozoic mudstones in the North Sea Central Graben using x-ray tomography, SEM, and petrographic analysis. These mudstones are situated in the transition zone between normal hydrostatic pressure and overpressure and may episodically rupture and expel fluids through the development of microfractures. The widths of the microfractures are, on average, 10 microns and if distributed over a larger distance could conduct a large volume of fluid over geologic time. Three general morphologies of microfractures were found. In one sample the microfractures imaged are subparallel and vertical while in other samples horizontal microfractures were imaged. Comparison of the samples containing the horizontal microfractures show a single, through-going microfracture in one sample and a blocky, disconnected fracture system in another sample. It is possible that some of the microfractures were induced during sampling, however, the presence of diagenetic anhydrite indicates that the microfractures formed in the subsurface (Figure 1). In addition, the microfractures have altered fracture margins (Figure 1). Higher Al/Si ratios have been determined for the North Sea samples based on qualitative EDS analyses suggesting that the fracture margins have undergone more complete alteration of smectite to illite. In some samples the anhydrite has completely sealed part of the microfractures thus destroying the ability of the microfractures to transmit fluids.

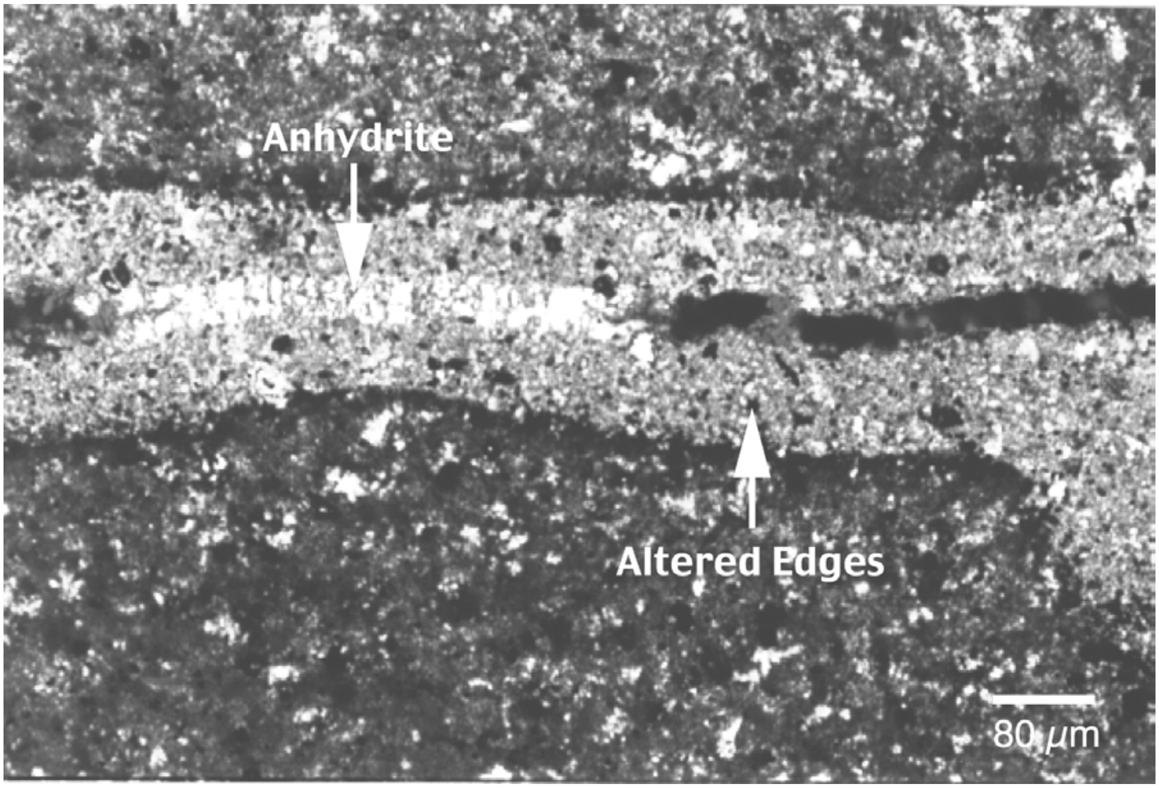

Figure 1. Petrographic photomicrograph of a microfacture in a North Sea sample under high magnification and polarized light. Microfracture has chemically altered edges and is filled/sealed with anhydrite.

Anhydrite, like calcite, has retrograde solubility (it is less soluble at high temperatures). At mid-ocean ridges, anhydrite is a pervasive diagenetic mineral formed by hydrothermal convection. Hot pore water moving upward through the oceanic crust mixes with seawater causing anhydrite to precipitate. A similar mixing of waters of different temperature and salinity may have occurred in the subsurface of the North Sea. Overpressures may episodically rupture sediments creating a microfracture network. Hot fluids from the geopressured zone move rapidly upward along the microfracture network. These hot fluids expulsed from the geopressured zone mix with seawater or similar composition waters in the overlying mudstones, precipitating anhydrite, which seals the microfracture network and ends upward fluid migration. This cycle of hydrofracture, upward fluid transport, fluid mixing, and chemical sealing may be repeated numerous times over geologic time. More complete alteration of smectite to illite along the edges of microfractures also is consistent with movement of fluids at temperatures greater than formation temperatures along the microfractures. If this hypothesis is correct, chemical sealing of microfractures by anhydrite should be found in other geopressured sedimentary basins such as the Gulf of Mexico.