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Mineral Physics and SEM Study of KTB Rock Indicates Carbon Present in Cores Was Deposited During Fracturing

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The Kontinentales Tiefbohrprogramm (KTB) Project in Windischeschenbach, Germany, began drilling in September 1987 reaching an approximate depth of 9.1 km in October, 1994 in the Variscides: rocks that resulted from continent-continent collision about 400-300Ma. The region was later reworked by further collision, rifting, and graben formation, with associated magmatism and hydrothermal alteration, which produced a very heterogeneous, steeply dipping crust. The entire Vorbohrung was cored, and the Hauptbohrung was cored at 35 selected depth intervals. Core was thoroughly documented and characterized in the field, and quickly distributed to various teams of scientists for studies. Electrical conductivity measurements of the core from various depths showed that conductivity increased with pressure, unlike other rocks whose conductivity decreases with pressure as conductive pore fluids are expelled as porosity decreases. Originally, we attributed the increased conductivity to closure of cracks in the core that had opened upon exhumation from depth, allowing reconnection of the conductive ilmenite, which made up about 8 percent, and sometimes more, of the cores. However, extensive modeling subsequently showed that there had to be some other good conductor present as well. Consequently, scanning electron microscopy indicated that carbon was decorating the cleavage of amphiboles in the rocks and that this carbon was a strong contributor to the conductivity increase.

We then fractured standard rock cores with no carbon in them in two different high-pressure rigs at temperatures of ∼400 C—one series unjacketed in CO_2-CO atmospheres of ∼200 MPa and the other jacketed at hydrostatic pressures of ∼290 MPa and piston-loaded to failure with CO_2-CO pore pressure. Both series of experiments showed carbon deposition and increased conductivity of core remnants. We conclude that fracturing related to earthquakes likely produced carbon in KTB rocks. If deposition of carbon occurs during dilation as our measurements indicate, the increasing conductivity could be a precursor to seismogenic events.