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Photograph of the Month

Photograph of the month: Fracture with crack-seal texture and porosity, depth 6274 m, Wyoming

Open fractures deep in the Earth profoundly influence migration of fluids and other deep-seated processes. Yet, such fractures are challenging to sample, and their attributes remain poorly known. This SEM-cathodoluminescence (CL) image mosaic shows a partly open vertical fracture in plan view cored from a depth of 6274 m in Cretaceous Frontier Formation sandstone. It is from the Big Horn 3 well in Madden field, north-central Wyoming. The multistranded fracture trace is aligned with the long dimension of the image. CL reveals textural evidence about how the fracture widened through time and the processes that preserve and destroy fracture pore space at these depths.

Shades of green mark epoxy filling fracture pore space. The rounded blue and red features are quartz grains surrounded by quartz cement having similar colors and cut by quartz-filled fracture segments that mark crack-seal texture. Black features are feldspar grains surrounded by black albite cement. In the center of the image fractures cutting feldspar grains are mostly open, except where they are adjacent to quartz grains. There, idiomorphic quartz crystals grew laterally into fracture pore space across feldspar from adjacent quartz-filled fractures. For this picture, color was created from gray-scale CL sources by superposing images captured using red, green, and blue filters. Differences in brightness across the image are an artifact.

The continuous quartz deposits that span the fracture near the center of the image result where quartz nucleates readily on a quartz substrate. Experiments show that quartz grows rapidly at first, but rates slow dramatically once large, idiomorphic crystal faces develop (Lander et al., 2008). Rapid growth from opposite fracture walls traps fluid-inclusion assemblages along medial lines like those visible on the right side of the image; temperature and composition information from fluid inclusions provides evidence of timing and fracture opening rate (Becker et al., 2010). Fluid inclusions from this fracture suggest opening at 140–220 °C. Where cement fails to bridge the fracture after an opening increment, local sealing is less likely because slow quartz-crystal growth on idiomorphic quartz is inefficient at destroying fracture pore space. Slow albite growth localizes fracture porosity in feldspar grains, even where fractures are narrow. Although cement textures like these are common in fractures recovered with deep core (Laubach et al., 2004) identical structures can be found in some outcrops (Laubach and Ward, 2006) providing accessible samples of deep-basin open fractures.

Papers in the structural diagenesis theme section in this volume describe other examples of interacting mechanical and chemical processes in deep-basin settings.

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