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Chemical bleaching: An indicator for fluid flow in sandstone deformation bands

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Iron is a sensitive indicator of fluid flow in Jurassic sandstones on the Colorado Plateau that have been variably bleached through interaction with reducing solutions. Deformation bands associated with monocline uplifts in the Navajo Sandstone display a variety of colors in comparison with the host rock color that indicate the timing of bleaching relative to deformation band formation. This diagenesis of deformation bands is a valuable record of fluid-rock interactions, transient permeability variations, fluid pathways, and timing of fluid movement. Color differences are a result of differential diagenetic development of clays, iron oxides, and cements between deformation bands and host rocks (Fig. 1) that reflect a multi-phase history of fluid-rock interactions. This research presents a new interpretation of how deformation bands are involved in reservoir compartmentalization and focusing fluid flow. We investigate the coupling between tectonic deformation and geochemical reactions during fluid flow transport.

White deformation bands in red sandstone indicate that deformation bands were likely permeable at an early dilatant stage in their development history. Field characteristics, petrography, bulk rock chemistry, and clay mineralogy show that the coloration differences in some deformation bands are not simply a matter of grain diminution. This research indicates that bleached deformation bands have experienced an episode of chemical reduction where fluids removed ferric (Fe^{3+}) iron and left the remaining reduced iron as pyrite and magnetite.

The hydrologic properties of deformation band structures may be partially quantified by estimating the pore volumes required to do the bleaching and removal of iron. Geochemical modeling and mass balance calculations show that as much as 10 kg of chemically reducing fluid per 100 grams of rock (1,500 pore volumes of fluid) are necessary to remove 0.1 wt % Fe (0.14 wt % Fe_2O_3) from a deformation band. These large pore volumes suggest that moving, hydrocarbon-solutions regionally bleached the sandstone white, and bleached deformation bands result where deformation bands provided fluid access to unbleached, red sandstone. Color and chemical composition are valuable indices to mechanical and hydrologic properties through regional structures of host rocks as well as small-scale deformation bands.

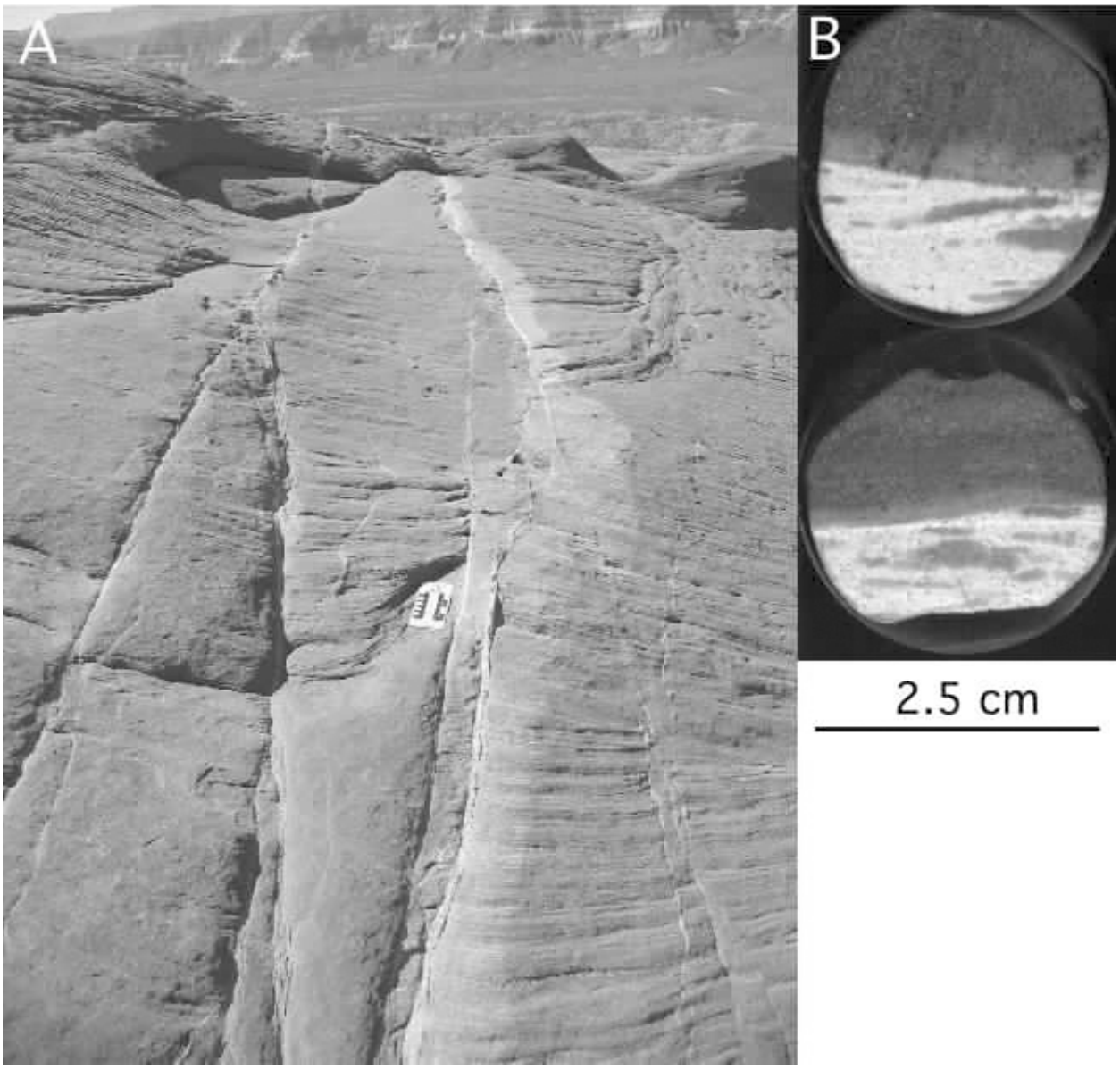

Fig. 1: Southern Utah examples of bleaching of deformation bands at the outcrop scale (A) in the Jurassic Entrada Sandstone of Grand Staircase-Escalante National Monument, and on the small scale (B) in the Jurassic Navajo Sandstone of Capitol Reef National Park. In the polished plugs (B), red host rock is in the upper half of the plugs, with bleached white deformation bands in lower half of the plugs. Note the thin, bleached selvage at the contact between the two parts right in the middle of the plugs.