

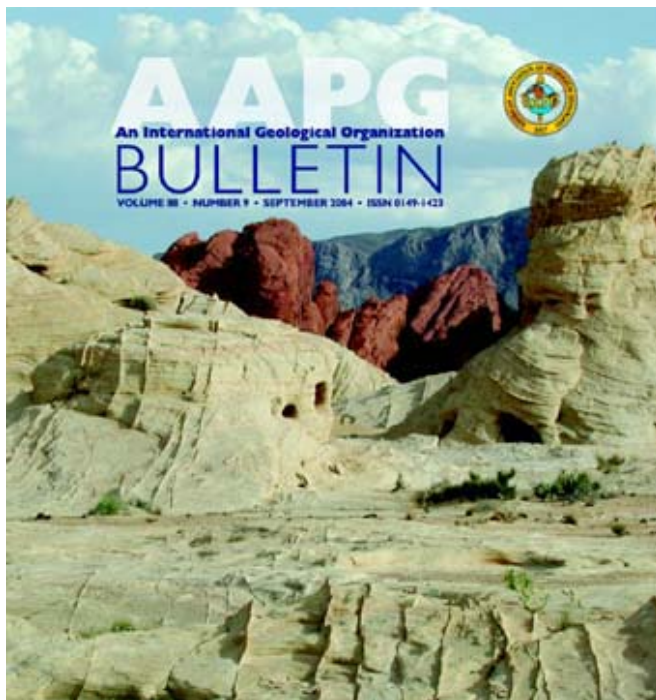
Structural Heterogeneities and Paleo-Fluid Flow in an Analogue Sandstone Reservoir

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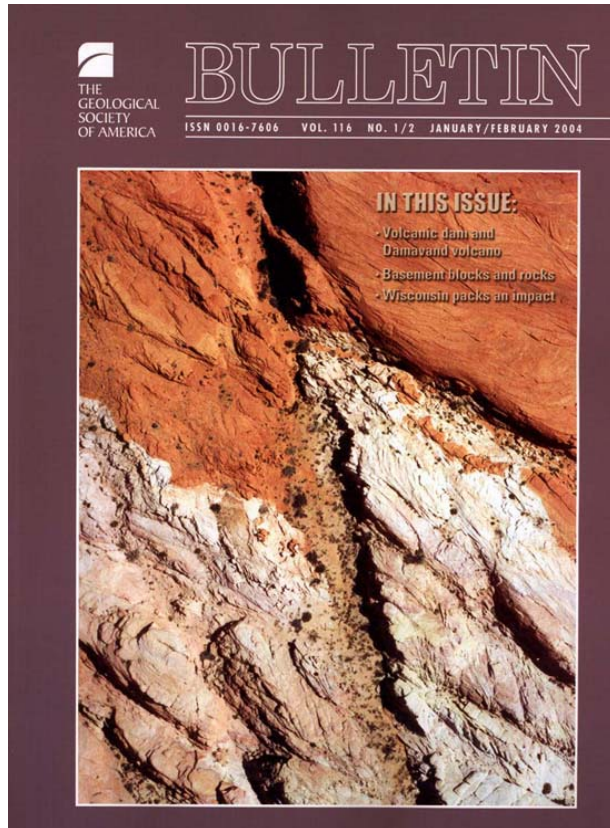
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Description: This integrated project is designed to develop conceptual and mechanical models for the evolution of structural heterogeneities in sandstone and to assess their effects on fluid flow in an analog groundwater and hydrocarbon reservoir. Such structural discontinuities include joints, sheared joints, deformation bands of shear and compaction types, and slip surfaces. They typically occur isolated in sets, or compose fault zones that evolve over time with increasing complexity. These structures can substantially impede or enhance fluid flow through an otherwise porous and permeable rock. At Valley of Fire State Park, Nevada, we study their distribution within the Jurassic Aztec Sandstone and measure their geometric and hydraulic properties to serve as input parameters for numerical fluid flow and mechanical models.

The petrographic and compositional analysis of diagenetic zones and field maps of their patterns (Eichhubl et al., 2004) revealed that the rock attained its red color by hematite coating of the grains during or immediately following the deposition. The white, yellow, and orange alteration bands are related to goethite and are associated with the bleaching and partial iron remobilization first by reducing hydrocarbon-related brines under deep burial conditions and second by meteoric fluids under vadose conditions. The earlier paleo-fluid flow is correlated with the emplacement of Cretaceous Sevier thrusts; the later is largely synchronous with Tertiary strike-slip faulting.



Structural field investigations and numerical modeling address the processes of deformation band formation. We currently focus on compactive deformation bands (Sternlof et al., 2004, figure 1-left) that exhibit predominantly band-normal compaction. Based on measurements of band width variations with band length, bands' porosity reduction, and boundary element modeling of band propagation, we find that compactive deformation bands can be modeled as brittle "anti-cracks". Grain rearrangement and porosity reduction in the wake of a propagating tip and secondary clay mineral infiltration resulted in the relatively impermeable feature. The anti-crack model predicts systematic patterns of elastic interaction among adjacent deformation bands that are consistent with patterns in outcrop.



The process of fault development by shearing of joint zones in sandstone is well displayed in Valley of Fire (Myers and Aydin, 2004; Flodin and Aydin, 2004). For example, the photograph in figure 2 (on the left side) shows a left-lateral strike-slip fault offsetting the boundary between the red and white sandstones by 22 meters. We map, analyze, and measure the petrophysical properties of the fundamental elements making up such fault zones with increasing complexity. We develop an improved upscaling methodology using numerical fluid flow models and the geometry and permeability of the component structures of the faults (Flodin et al., 2004, Jourde et al., 2002). Subsequently, upscaled fault permeabilities for sections of faults with various slip values are used to establish a slip-permeability transformer (Flodin et al., 2001). This relationship can then be used to represent similar faults in petroleum reservoirs and aquifers. Future efforts will be directed to stochastic/mechanical characterizations of such a fault system to facilitate a better interface with reservoir

simulators.

Selected Publications:

Eichhubl, P., Taylor, W. L., Pollard, D. D., and Aydin, A., 2004, Paleo-fluid flow and deformation in the Aztec Sandstone at the Valley Of Fire Nevada-Evidence for the coupling of hydrogeological, diagenetic, and tectonic processes. *Geological Society of America Bulletin*, v. 116, p. 1120-1136.

Flodin, E. A. and Aydin, A., 2004, Evolution of a strike-slip fault network, Valley of Fire, southern Nevada. *Geological Society of America Bulletin*, v. 116, no. 1/2, p. 42-59, DOI 10.1130/B25282.1.

Flodin, E., Aydin, A., Durlofsky, L. J., and Yeten, B., 2001, Representation of Fault Zone Permeability in Reservoir Flow Models, *SPE paper# 71617*, p. 1-10.

Flodin, E. A., Durlofsky, L. J. and Aydin, A., 2004, Upscaled models of flow and transport in faulted sandstone: Boundary condition effects and explicit fracture modeling. *Petroleum Geoscience*, v. 10, n. 2, p. 173-181.

Jourde, H., Flodin, E., Aydin, A., Durlofsky, L., and Wen, X. H., 2002, Computing Permeability of Fault zones in Aeolian Sandstone From Outcrop Measurements. *American Association of Petroleum Geologists Bulletin*, v. 86, No. 7, p. 1187-1200.

Myers, R., and Aydin, A., 2004, The evolution of faults formed by shearing across joint zones in sandstone. *Journal of Structural Geology*, v.26, no.5, p.947-966.

Sternlof, K., Chapin, J., Pollard, D.D. and Durlofsky, L.J. 2004, Effective permeability in sandstone containing deformation band arrays: *American Association of Petroleum Geologists Bulletin*, v. 88.

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