Linking fluvial processes and elemental cycling within the Old Rifle, CO aquifer

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A successive series of biostimulation experiments within the Old Rifle, CO (USA) aquifer since 2002 have focused on biogeochemical pathways arising from organic carbon injection and its role in mediating the cycling of iron, manganese, sulfur, uranium, vanadium, arsenic, and selenium. While most have concentrated on reductive pathways and their impact on contaminant mobility, recent studies have begun to explore oxidative pathways and their impact on metals dynamics, carbon modification, and the long-term viability of reductive immobilization as a remedial strategy. Insights gained from such experiments have shed light on analogous natural biogeochemical pathways that mediate element cycling in the absence of exogenous carbon amendment. Within the aquifer, such pathways are often seasonal and correlate with excursions in groundwater elevation of 1-2m associated with increased discharge in the Colorado River during spring/summer snowmelt. Imbibition of oxygen bubbles within the capillary fringe associated with such excursions is inferred to be the primary contributor to seasonally oxic groundwater, with its impact on redox-mediated reactions exhibiting close correspondence to intentional introduction of oxidants.

Superimposed upon natural and artificial redox fluctuations are relic signatures of the depositional fabric of alluvial accumulation. Specifically, ferromanganese-encrusted cobbles accumulated as channel fill deposits serve as an effective vector for iron and manganese delivery during incipient accretion of the aquifer materials. Post-depositional redox processes and oxygen incursion associated with groundwater level fluctuations enable redistribution and mineralization of iron and manganese throughout the aquifer, with subsequent implications for carbon and metals transformations. Linking such pathways within the context of a ‘porous subsurface bioreactor’ constitues an ambitious yet tractable means for quantifying elemental fluxes at the floodplain and potentially larger scales.

Petrologic implications of magmatic underplating: Observations from the Athabasca granulite terrane

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The Chipman mafic dike swarm, Athabasca granulite terrane, Saskatchewan, CA, provides a field example of mafic magmatic intraplating in the deep continental crust. The Chipman dikes were emplaced at 1.0-1.2 GPa (35-40 km) at 1.9 Ga, possibly above a magmatic underplate. The dikes are dominated by Hbl and Pla with minor Cpx. Host rocks include the 3Ga Chipman tonalite and 2.6Ga Fehr and Stevenson granites. Several effects of underplating have been documented, including tonalite genesis, granite genesis and contamination, garnet growth, and crustal densification. Only limited melting was induced in the Chipman tonalite during underplating and intraplating. Instead, the mafic dikes themselves were partially melted to Grt + tonalite. Leucosomes occur in strain shadows associated with garnet. Where melting was extensive, individual leucosomes have coalesced and tonalite dikes and veins are common. Within the Fehr granite/gneiss, partial melting was extensive. Leucosome veins, pods, and pools apparently represent the products of several melting reactions, including hydrous modal melting and both biotite and hornblende dehydration melting. Granitic partial melt apparently accumulated in an early (S1) foliation and then was mobilized during formation of a “megacrenulation” into S2. This “pumping” mechanism provides one model for melt segregation in the deep crust. Subsequent Chipman dikes mingled and mixed with the new granitic magma producing a wide range of hybrid compositions. With increasing extent of granite melting, Chipman dikes are more irregular in geometry, apparently trapped by the granite mush. Magmas moving to higher levels probably evolve from mafic to contaminated intermediate and felsic compositions over time. Other granitoids in the region were apparently heated and deformed but not melted during dike emplacement and underplating. One common reaction involves Opx + Pla = Grt + Cpx. Extensive Grt production leads to increased density, up to 3.0 g/cm^3 even in felsic rocks and may play a role in stabilization and possibly delamination of lower continental crust. Based on the Athabasca example, underplating can initiate a number of positive and negative feedbacks that ultimately result in dramatic and probably irreversible changes in character, rheology, composition of the overlying crust.

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