Carbon Dioxide Groundwater Mixing and Mineralization Reactions with Reservoir Rocks at a Natural Analogue Site, Soda Springs, Idaho, USA

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Analogue sites are particularly relevant and useful to the study geologic carbon dioxide sequestration for a number of reasons, particularly because they offer the opportunity to examine a system that has operated on a time scale (centuries to eons) that laboratory and field experimentation (days to decades) cannot compare. One such example of a mafic rock CO2 analogue is the Soda Springs site located in Caribou County of Southeastern Idaho, USA. At this site, CO2 and formation fluids generated by the dissolution of Paleozoic carbonates at depth are migrating and reacting with a series of shallower thoelitic basalt flows that host a fresh water aquifer. We believe that the layered basalt flows are acting as a reactive barrier to the vertical migration of the deep CO2 charged fluids. However, in several cases the CO2 charged reservoir fluids make it to the surface and are expressed as either carbonated springs, or as cold-water geysers caused by wells that encounter the system at depth. Analysis of these sources of water shows a steady evolution of groundwater from unaffected by the basalt (deep wells) to more fully reacted (springs).

Data from this system makes a compelling argument for the ability of basalt flows to maintain containment for CCS applications. Our study has shown that CO2 charged fluids migrating upwards are being neutralized by mineral dissolution and precipitation within the basalt flows. These neutralization reactions have resulted in a specific chemical signature being imparted to the formation fluid that can be used to determine which minerals are dissolving and precipitating. Through and integrated study of this natural analogue site including field and laboratory experiments, the relative roles of mineral dissolution and precipitation and phase assemblage are being characterized for this basalt-hosted system.

The benefit of studying this natural analogue is that it has been active for many 1000's of years and depending on sample location and depth, the resulting fluid chemistry carries the chemical signature (tracer) indicative of the degree of reaction within the basalt formation. Additionally, the study of this system is helping define the appropriate laboratory scale experiments that will be needed to accomplish the larger objective of the project, understanding changes in aqueous geochemistry associated with progressing CO2-water-interactions.

Reconstructing the large-scale deep and intermediate ocean circulation in the North Atlantic during the LGM and last deglaciation

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The large-scale subsurface circulation of the ocean is an important component of the Earth's climate system, and contributes to the global and regional transport of heat and mass. More than two decades ago, geochemical analyses of deep-sea sediments in the Atlantic Ocean revealed that the distribution of water masses and their characteristics were significantly different at the LGM and other times in the past when compared to modern observations. Although some of the paleodata have been reproduced and shown to be robust, there has been continued debate about the implications of these results for the dynamics of the large-scale circulation and the consequences for the storage and transport of heat, freshwater, nutrients and carbon in the past. There is also no consensus on the variations in water mass and dynamics that occurred between the LGM and the establishment of the modern Atlantic circulation despite the development of time series and maps of more than a half dozen paleo proxies for various aspects of the circulation.

Here we present a discussion of new and previously published Pa/Th, $\delta^{13}C$, SS, εNd, $\Delta^{14}C$, Cd/Ca, B/Ca, Zn/Ca and other data. We consider which aspects of past circulation during the LGM and deglaciation are robustly established and which remain open to competing interpretations. These results combine to confirm that the Atlantic circulation was different both in terms of water masses and their fluxes. The LGM Atlantic was characterized by rapidly overturning intermediate waters, consisting of more than one water mass, most likely of northern origin, and southern-sourced deeper waters with a longer residence time in the basin. Early in the deglaciation, during the H1 iceberg discharge and ensuing stadial, the boundary between intermediate and deep water masses shoaled, although a shallower overturning cell persisted throughout. We seek to reconcile apparently conflicting new and existing proxy evidence regarding any substantial change in the rate of deep water production and residence time during H1. Shortly after 15 ka, nearly all proxies indicate a rejuvenation of deep overturning, followed by a reduction during the Younger Dryas event (12.7 – 11.5 ka), and the subsequent development of the modern Atlantic circulation in the Holocene.