Mineralogy and geochemistry of a potential CO_2 sequestration reservoir and seal system, Illinois Basin, USA

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Increasing atmospheric CO_2 concentrations have resulted in numerous studies into methodolgies for sequestering antropogenic CO_2 in the subsurface. Demonstrations of geologic CO_2 sequestration in the Illinois Basin are targeted at the basal Cambrian Mount Simon Sandstone as the potenital reservoir and the overlying Eau Claire Formation as the primary seal. Characterizing the mineralogy and geochemistry of these formations is an essential step towards predicting how these units will perform as a storage reservoir and seal respectively. Ongoing investigations are focused on characterizing the mineralogical and geochemical composition of these formations utilizing core analysis, microscopy, x-ray diffraction, reflectance spectroscopy, stable isotope geochemsitry and major and trace element whole rock geochemical analysis. Minerals identified in the Mount Simon Sandstone include monocyrstalline and polycrystalline quartz, k-feldspar, illite, kaolinite, goethite, hematite, and calcite with minor zircon, muscovite, and biotite. The amount and spatial context of the mineral phases vary with depth and across the basin. Some of the minerals, such as k-feldspar and the iron oxides, occur as overgrowths and grain coatings, putting them directly in contact with pore-fluids. Principle mineral phases identified in the Eau Claire Formation include: quartz, k-feldspar, plagioclase feldspar, illite, glauconite, dolomite, ankerite, calcite, chlorite, pyrite, goethite, and hematite. The suite of minerals identified in both of these units includes both detrital grains and multiple generations of authigenic precipitates that suggest a burial history that has included multiple episodes of fluid-rock interactions. Detailed analysis of the geochemistry of specific mineral phases (e.g., stable isotopes, trace elements, etc.) can be used to determine the nature of the fluids that have interacted with these rocks in the past. These analyses help to constrain the role of fluids in the evolution of these formations, the current reactivity of the minerals present, and the potential changes that could occur with the introduction of CO_2 into the pore fluids.

Impacts and feedbacks: Are the PETM and Eocene hyperthermals relevant to future global change?

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After more than two decades of study, significant uncertainty remains regarding the causes and mechanisms underlying Early Paleogene transient “hyperthermal” climate events such as the Paleocene-Eocene thermal maximum and Eocene Thermal Maximum-2. Despite a lack of consensus on key details such as the trigger for these events and sources of carbon to the ocean and atmosphere, these events are frequently invoked as being among the paleoclimate case studies most relevant to understanding our climate future. Given all the uncertainty, it’s fair to ask whether our current level of understanding of these events really has relevance to the study of the anthropogenic climate era.

I will make the case that by focusing on the impacts and feedbacks associated with Eocene hyperthermal events researchers have been able to demonstrate several key patterns that are of relevance to informing and testing models of future anthropogenic climate change. The foundation for this inference is the unequivocal result, supported most strongly by records of widespread deep-sea carbonate dissolution, that the PETM and other hyperthermals are distinguished first and foremost by the massive addition of CO_2 to the exogenic carbon cycle. Despite uncertainties regarding the source and amount of this CO_2, we can view the subsequent sequence of events for any hyperthermal as a realization of CO_2-driven global change.

Important impacts and feedbacks associated with hyperthermals have been identified in at least four different systems. First, observations have largely supported existing models for the centennial-to-millennial-scale dynamics of the carbon cycle in response to massive CO_2 release. Second, estimates of pCO_2 change have been used to suggest high equilibrium climate sensitivity relative to most IPCC models. Third, there is increasing evidence for continental-scale water cycle change that is broadly consistent with the predictions of global climate models. Fourth, to the degree it has been studied these events have been demonstrated to have widespread, if not always deleterious, impacts on the biota. Although many details remain to be resolved, our current state of knowledge of Early Paleogene hyperthermals enables tests, and should support refinement, of models for anthropogenic global change.