Carbonate Critical Zones

Planning for Research Coordination Workshop I

Lithology – the Overarching RCN Theme

Critical zones (CZs) are composed of a variety of minerals and their mineralogical contents and distributions impact all CZ processes. The variety of minerals can be simplified to a continuum between two end-member CZ compositions, one dominated by silicate and the other carbonate minerals. Carbonate and silicate minerals can be distributed within and across CZs, including: (1) varying proportions of silicate and carbonate minerals within individual stratigraphic horizons, (2) vertical stratification of carbonate-rich and silicate-rich strata, and (3) laterally discontinuous silicate-rich and carbonate-rich strata. In case 3, the direction of drainage, e.g., from silicate to carbonates or vice versa, could also affect critical zone processes.

The first Carbonate Critical Zone RCN workshop will be organized around discussions of various themes related to how varying carbonate content affects CZ processes. Themes listed below are suggestions that are designed to fertilize discussions; their alphabetic listing emphasizes none has priority over others. Additional themes and questions related to themes are expected be developed by workshop participants and will be included in future RCN workshops. Discussion will lead to Workshop outcomes, which could include a workshop report and other white papers, peer-reviewed papers, and the seeds for proposals for future work. These documents will take a retrospective perspective through identification of available data and syntheses of data as well as a forward looking perspective through building consensus on future research needs and how to best accomplish the research.

Discussion Themes

Architecture: Increased fractions of carbonate minerals increase the extent of congruent dissolution of critical zone minerals. Carbonate-dominated critical zones will display classic karst features, such as caves and sinkholes. Variations in architecture should affect transport of solutes through and export of solutes from critical zones.

Questions to consider: How does the relative amount of congruent versus incongruent dissolution alter critical zone architectures and processes?

Climate and land use change: Anthropogenic disturbances of critical zones include local impacts, for example from changing land use and infrastructure development, to global changes including expectations of rising temperatures and increased extreme weather events from climate change.

Questions to consider: What critical zone processes will be altered, and by what extent, as climate changes over the next decades? How will varying reaction rates of silicate and carbonate minerals respond to changing climate including global warming and shifts in precipitation patterns? What land use changes will bring the greatest changes to critical zone processes.

Ecology: Macro- and micro-biotic processes produce and consume CO_2, which is the principal, but not only, weathering agent in critical zones. Biotic processes also alter other acid production and redox conditions. Thus the depth within and distribution across critical zones of biological processes are important for dissolution reactions.

Questions to consider: How do interactions between biota and critical zone structure vary along lithological gradients? What processes control terrestrial vegetation and soil microbial community composition and structure? How does variation in biotic communities affect bio-reactive solute and gas fluxes, and bedrock dissolution through and from critical zones? How do the fluxes feedback to controls on the biotic processes? How do downstream aquatic communities respond to different geomorphic, hydrologic, and hydrochemical regimes along such lithological gradients?

Hydrology: The extent and distribution of congruent dissolution will alter water flow paths and rates through the critical zone. The flow rates, and distribution of flow paths, should alter water-rock interactions and dissolution. They should also alter exchange of water and gases between the land surface and subsurface.

Questions to consider: What impacts result from feedbacks between congruent dissolution, formation of preferential flow paths, and water delivery to and through the critical zone? How do water and solute flow paths, fluxes, and travel time distributions vary with the proportion of silicate and carbonate materials in the critical zone?

Ecosystem goods and services: Karst critical zones provide important ecosystem goods and services, including water supply (for domestic, agricultural, industrial, recreational and ecosystem uses), food security, habitats for endangered species, and carbon sequestration. Climate change, sea level rise, human water use, and point and non-point source pollution from urban, industrial and agricultural sources all threaten the provision of these services.

Questions to consider: What are these services and how do they vary across lithological gradients? What are the implications of changes in weathering, biogeochemical cycling and partitioning of hydrologic fluxes to the provision of these services? How does the provision of, and threats to, these services vary with the proportion of silicate and carbonate materials in the critical zone?

Time: Critical zone processes range across time scales from event (floods, fires, droughts) to intermediate (community assemblage and succession; responses to disturbance) to geologic (biological evolution, geomorphic changes). These distinct time scales and the rates of each process, dictate how critical zone characteristics will respond to the processes.

Questions to consider: How do rates of critical zone processes scale with varying amounts of carbonate and silicate contents of the critical zone? How do the varying time scales of processes interact; for example, how would increased fire rates alter community assemblages and succession?

Weathering: Weathering of critical zone minerals depends on the delivery rates of acids, local redox conditions, and variations in the dissolution rates for each mineral weathering reaction. Amount and rates of weathering control solute and some nutrient production, alterations of mineralogical composition, and thus physicochemical characteristics of the critical zone.

Questions to consider: What are relative contributions of various acids to weathering in critical zones (e.g., carbonic, sulfuric, nitric, organic). How do reaction mechanisms of each affect solute and gas cycling within the critical zone? How will contributions from each acid change in the future, for example, through addition of pollutants and acid rain? How do redox conditions vary across space and time in critical zones and what controls the variations?