Ichnology and Paleopedology in Mixed Carbonate and Siliciclastic Environments: A Study of the Lower Permian Halgaito Formation, South-Central Utah

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STATUS: Project expanding on previous work; fieldwork Summer 2013.
TIMING: Data being collected; results to be reported.
FUNDING: Seeking support

Purpose
Ichnofossils can provide detailed information about the depositional history of mixed carbonate and siliciclastic systems. Such systems are common in the geologic record, but few studies have focused on them. Invertebrate organisms react to changes in climate and depositional environmental settings, producing specific patterns in bioturbation that reflect specific biophysicochemical characteristics that can be used to interpret subenvironmental settings and changes in eustatic sea level in mixed carbonate and siliciclastic strata. These changes also impact the resultant bioturbation textures that modify the original horizontal and vertical effective porosity and permeability. **This study aims to better understand these complex systems through the integration of trace fossil, lithofacies, and pedofacies associations of the Lower Permian Halgaito Formation to (1) define and subdivide environments of deposition, (2) develop ichnopedofacies models to help predict vertical and lateral facies changes produced by changes in eustatic sea level, and (3) develop a sequence stratigraphic framework for continental and marine strata. Understanding the depositional history of mixed carbonate and siliciclastic systems will help reduce and constrain uncertainty by models for larger scale regional architecture, and for identifying targets for oil and gas production.**

Project Description
The Permian Halgaito Formation is part of the Pennsylvanian-Permian Cutler Group, and is primarily a ~1,500 m thick succession of alluvial deposits that thin westward, across southeast Utah from the Uncompahgre uplift and interfingers with marine carbonates in the west toward the San Rafael Swell (Baars, 1962; Cole et al., 1996; Montgomery et al., 1999). The Cutler Group is not subdivided in the southwest and grades toward the San Rafael Swell into the Lower and Upper Cutler groups. The Halgaito Formation is time-equivalent with the Lower Cutler Group and contains a succession of thinly interbedded siliciclastic and carbonate deposits (Figure 1) (Kunkle, 1958; Baars, 1962; Peterson and Hite, 1969). Donald Rasmussen is currently revising the stratigraphic nomenclature of the Cutler Group in a series of papers and maps; he will be working with us in the field on these units.

The Halgaito Formation is a thinly bedded mixed carbonate and siliciclastic unit located in southcentral Utah near Mexican Hat. The Halgaito Formation contains intercalated carbonate and siliciclastic deposits that represent shallow marine to coastal plain settings and record relatively rapid changes in sea level. Continental deposits include thick paleosol units associated with alluvial plain deposits. Marine carbonate deposits of the Halgaito Formation also show pedogenic overprinting, as well as modification due to penetrative soil formation.
Marine trace fossils are well studied and have been used in a variety of studies (e.g. Clifton and Thompson, 1978; Ekdale and Bromley, 1984). Marine organisms react to a variety of marine conditions (i.e. medium, nutrients content, salinity, turbidity, temperature and oxygen content) and particular suites of trace fossils can be used to interpret depositional environment (Ekdale and Bromley, 1984; Hasiotis, 2006). Such interpretations must be done cautiously, as many marine trace fossils can be found in multiple environments (Hasiotis, 2006) Trace fossils are common in continental settings (Hasiotis, 2006), and are created by organisms that are reacting to a different suite of environmental factors than organisms in a marine setting. This includes soil moisture and saturation, temperature, seasonality, and precipitation (Hasiotis, 2006; Hasiotis and Platt, 2012)

Figure 1: Photograph of the Halgaito Formation and younger Cedar Mesa Formation in outcrop taken near Mexican Hat, UT
This project will be accomplished through field research and lab investigations to characterize the ichnofossils located in both the carbonate and siliciclastic parts units within the Halgaito Formation. Fieldwork will consist of measuring several stratigraphic sections for vertical and lateral correlations. Sections will be logged spatially with GPS. Beds will be described sedimentologically and lithologically and assigned to lithofacies. Photographic mosaics will be constructed to illustrate the architecture graphically and photographs will be taken of all relevant small- and large-scale features. Paleosols will be trenched in order to examine morphology, remnant sedimentary structures, and ichnofossil assemblages, and will be classified using the U.S. Soil Taxonomic System. Grain-size fractionation will be estimated in the field using standard soil texture methods.

Laboratory work will use X-ray diffraction analysis (XRD) and thin-section descriptions. Clay content and mineralogy will be determined through XRD with samples taken from each trench or horizon. Thin sections will be used to further examine the sedimentary structures, as well as to identify microscale biologic features, such as borings. Thin-sections will be 24 by 46 mm in size and be impregnated with blue epoxy to increase the paleosol sample’s durability. Sodium cobaltinitrite staining will also be used to identify the relative abundance of potassium feldspars, a common clay-forming mineral in soils.

**Deliverables**

Ichnological and pedological studies in the mixed carbonate-siliciclastic strata of the Halgaito Formation are important as they provide: 1) important clues to interpreting EODs, as well as syndepositional and postdepositional conditions; 2) information on how bioreworking impacts and modifies the original depositional fabric and texture; 3) biomodified textures commonly have different porosity and permeability than the primary depositional matrix. This research will
provide 1) models of trace fossil, lithofacies, and pedofacies associations, 2) interpretations of changes in eustatic sea level, and 3) a sequence stratigraphic framework for local and regional architecture of the mixed carbonate and siliciclastic strata. This research will provide new conceptual models for the extent and significance of ichnology and paleopedology in the reconstruction of depositional environments and the modification of depositional porosity and permeability.

References