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Project Title: Mixed carbonate-siliciclastic sediment gravity flows: Depositional processes in the Mississippian Fort Payne Formation, Tennessee

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Importance of the Work

Located in central Tennessee and southern Kentucky, oil and gas production in the Mississippian Fort Payne Formation began in the middle 1800s and continues to present day. According to the Tennessee Department of Environment and Conservation (TDEC), more than 2,440 wells have targeted the Fort Payne interval since 1969. The general play style is stratigraphic and characterized by facies changes between carbonate bioherms and siliciclastic siltstones and shales. The primary purpose of this project is to: (a) define sedimentological processes operating during deposition of the Fort Payne Formation, and (b) characterize resulting geometries. Application of these results will impact petroleum exploration in mixed carbonate-siliciclastic systems, particularly in calciclastic slope environments.

Research Hypotheses

We posit that deposition in the study area (TN and KY) was dominated by carbonate-laden sediment gravity flows (SGFs), similar to those classically defined for siliciclastic deepwater systems, e.g. turbidite sequences and debris flow deposits. If so, it follows that carbonate allochems observed in the Fort Payne are detritus transported down the slope in submarine channels, and alternating layers of siliciclastic and carbonate mudstones record periods of increased SGF activity and quiescence, respectively. At the stratigraphic scale, we expect that architectures in the Fort Payne should be predictably organized, both in a vertical stratigraphic order and from axis to margin within individual channels. Results from sedimentological inquiry and stratigraphic inquiry may be combined to demonstrate that the Fort Payne is a calciclastic slope system with a variety of sedimentary bodies, a conclusion that will drive future petroleum exploration strategies.

Methods and Significant Results

Our work is divided into two concurrent study objectives: (1) sedimentological characterization of mixed carbonate-clastic architectures in the Fort Payne Formation; and (2) prediction of geometries in the Fort Payne using wireline log signatures. To accomplish both goals, our research team identified a series of outcrops in northern Tennessee and southern Kentucky where thick intervals of the Fort Payne are exposed and stratigraphic associations are clear, i.e. contacts with the underlying Maury Shale and Chattanooga Shale are mappable. Field work in the first year focused on measuring stratigraphic sections and identifying sedimentological facies in the mixed lithology system. One significant result of this effort was the description of seven lithofacies in the Fort Payne and linkage of these facies to sedimentological processes operating during deposition (part of study objective 1, above). In general, we were able to conclude that deposition in the mixed carbonate-siliciclastic system recorded both turbulent and laminar flow styles, and carbonate fragments such as crinoid stalks and skeletal debris were transported some distance down the continental slope.

The second project objective focused on characterizing geometries of sedimentary bodies in the Fort Payne and linking those shapes to wireline log signatures to aid in subsurface interpretation. To accomplish this goal, the team identified archetypal sedimentary body styles in outcrop: (a) submarine channels; (b) overbanks (levees); (c) lobes; and (d) carbonate-siliciclastic mounds. While most of these are fairly common in siliciclastic systems, the mounds of the Fort Payne are particularly interesting because they record a mix of skeletal debris in a clastic mudstone matrix, a result that impacts porosity and permeability in reservoirs adjacent to these features. To characterize what each geometry may look like in the subsurface, we acquired a handheld gamma ray spectrometer/scintillometer, the Gamma Surveyor II (GMS II). The instrument measures total dose rate as well as assays of potassium (%), uranium (ppm) and thorium (ppm). Our most recent field work incorporates the GMS II, and we have determined how these values change within submarine channels and carbonate-siliciclastic mounds (Figure 1, next page).

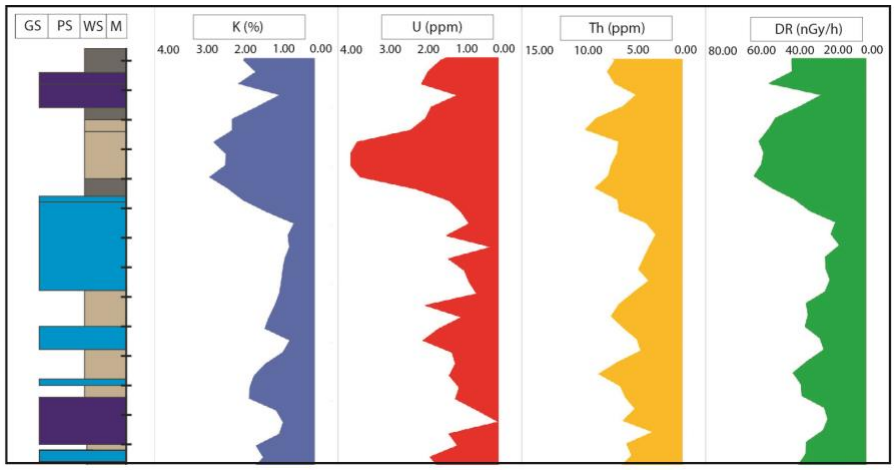

Figure 1. *Spectral gamma ray results from lithofacies in a channel within the Fort Payne Formation. Relative abundances of radioactive elements K (%), U (ppm) and Th (ppm) increase in interbedded siliciclastic-carbonate mudstones and decrease in fossiliferous carbonate grainstones. These results can be calibrated with regional wireline logs and may be used as a proxy for porosity and permeability.*

Continuing Work

With respect to sedimentological study, petrographic analysis of the Fort Payne lithofacies is ongoing. Recrystallization is evident in outcrop and hand sample, which suggests diagenetic effects have overprinted at least some primary sedimentary structures. Of the 40 samples collected for thin section analysis, approximately half were processed using techniques aimed at understanding the diagenetic overprint, e.g. calcite and dual carbonate stains. We anticipate that petrographic work during the fall of 2018 will shed light on the nature of diagenesis in the Fort Payne outcrops.

Finally, field investigations of Fort Payne geometries using the handheld spectrometer/scintillometer focused on collecting data from within the four types of sedimentary bodies. As a result, we now have more than 250 individual data points, or more than 1,000 individual assay measurements of K (%), U (ppm), and Th (ppm). We anticipate that these data can be used to characterize each sedimentary body type, although some bodies may be more challenging to characterize because siliciclastic and carbonate beds are thinner (cm-scale) and likely below instrument resolution. With the completion of outcrop gamma ray analysis, we will extend our results to signatures observed in subsurface wireline logs in Tennessee and Kentucky.

Research Team and Dissemination of Research

To date, this funding has supported ten research projects for undergraduate students at Tennessee Tech University (TTU). Building on progress made in Year 1, students Z. Watson, G. Winkle, and H. Blaylock used the handheld gamma ray scintillometer to measure responses in the lowermost Fort Payne Formation at the contact with the underlying Chattanooga Shale. Their results were accepted for presentation at the 2018 Southeastern Geological Society of America meeting in Knoxville, TN. Watson and Winkle are now graduated and employed with K. S. Ware & Associates in Tennessee and Excellence Logging in Oklahoma, respectively. Students A. Allen, J. Gentry, and G. Miller joined the project during the spring of 2018 and completed several weeks of field work during June, July, and August 2018. Together, they measured more than 125 data points in various sedimentary bodies of the Fort Payne Formation; they also began a systematic analysis of where sedimentary bodies occur in local outcrops, e.g. channel outcrops versus carbonate mound outcrops. An abstract summarizing these results has been accepted for presentation at the 2018 Annual Geological Society of America meeting in Indianapolis, Indiana. In addition to regional and national meetings, all students participating in the research have presented their findings on campus at the TTU Undergraduate Student Research Day. Of the ten students who have worked on projects in the Fort Payne Formation, six have received senior thesis credit for their research, a required component of the geoscience curriculum at TTU. A final publication is in preparation for the Journal of Sedimentary Research or an SEPM Special Volume.

Additional Support

To aid with conference travel costs, six participating students have been awarded travel grants from the TTU Undergraduate Research and Creative Activity (UReCA!) program. Additionally, one student received an On to the Future Award from the Geological Society of America to offset costs to attend the annual conference.