Baharat Banjade is a Ph.D. student in the Department of Geosciences in the University of Tulsa. He has two master degrees: one from Bowling Green State University (Ohio) and another from Tribhuvan University (Nepal). Baharat has received several other grants in support of his research and we are pleased to be one of them. Dr. Dennis Kerr is his advisor.

Rheic Ocean closure recorded in the deepwater Atoka Formation through Sandstone and Mudrock Provenance Studies

Problems to be addressed:

Despite decades of study and proposed contradictory plate tectonic models, the tectonostratigraphic evolution of Ouachita Trough is not well understood along the southern margin of Laurentia. Three hypothetical plate tectonic models are proposed: (1) oceanic lithosphere subduction beneath southern part of Laurentia; (2) oceanic lithosphere subduction beneath northern part of Gondwana continental crust; and (3) oceanic lithosphere subduction involving island arc complex with or without peri-Gondwana terranes (Morris 1974; Thomas, 1989; Briggs and Roeder, 1975). Sediments from these three tectonic settings are expected to show differences in mineralogical and chemical composition, and detrital zircon geochronology contributions. Research will be conducted through the integration of physical sedimentology for depositional environment and paleocurrent direction, and provenance analysis, which will include petrography, bulk rock geochemistry, detrital zircon geochemistry and geochronology.

Regional context of the area:

Tectonostratigraphic evolution of the Ouachita Trough is the result of the closure of the Rheic Ocean, which separated Laurassia from Gondwana for much of the Paleozoic Era. The closure of the Rheic Ocean resulted in the assembly of a major portion of Pangea and created Marathon-Ouachita-Alleghanian-Variscan orogen (Nance et al., 2010). The southern bounding block of the Rheic Ocean that collided with the eastern margin of North America (Alleghanian orogeny) is interpreted as peri-Gondwana terranes. However, in the southern margin (Ouachita-Marathon), the identity and subduction style is unknown or at least poorly understood because of a thick Mesozoic and Tertiary sedimentary cover of the Gulf Coastal Plain. Study of the mid-Carboniferous Atoka Formation, deepwater turbiditic sandstones and mudstones, in the Ouachita Trough will shed light on the tectonic character of the closure event because Atoka records the final stages of Rheic Ocean closure that in turn was followed by orogenic suturing (Ouachita fold-thrust belt).

This research considers Atoka Formation in two areas of the Ouachita Mountain. One area is the frontal zone, which is in between Choctaw and Windingstair thrust faults, and another area is to the south and includes Boktukola syncline, which is in the hanging wall of Octavia thrust fault, and Athens Plateau, which is in the hanging wall of the Boktukola thrust fault extension eastward to Arkansas**.** Dr. Kerr (research advisor) and his students have been studying frontal zone exposure of deepwater Atoka with respect to depositional processes and detail stratigraphy (Harris, 2001; Haveman, 2003; Kerr, 2003, 2005), detrital zircon geochronology for provenance analysis (Sharrah

2006) and mudrock chemo provenance (Postelwait, in progress). The proposed research is focused on the southernmost Atokan exposures.

This research will help to evaluate or limit the possible plate tectonic configuration between southern Laurentia and Gondwana during the closure of Rheic Ocean, which is a major Earth history event. Recording age of terranes converging on southern Laurentia will complement the study of Sharrah (2006), who found the dominance of Grenville-age zircons, with some zircons of 600-800Ma, 520- 550 Ma, 340- 520 Ma, and interpreted the influence of both the Laurentia and Gondwana terranes. In addition, detrital zircon geochronology will add to the database of North America detrital ages by Dickinson and Gehrels (2010) and Dickinson et al. (2012) to understand zircon sources for younger North American dispersal systems.

Suitability of the Project to GCSSEPM:
The identity of the southern landmass, which collided with the North America during Paleozoic to form the Ouachita Trough, is unclear because of the thick cover of the Mesozoic and Tertiary sedimentary sequences of the Gulf Coastal Plain. This research will help to identify the southern colliding landmass which eventually will help to understand the Gulf Coastal Geology by recognizing the basement continent and Paleozoic geology. This will help the deep subsurface exploration of prospects in the pre-Gulf opening basins. In addition, chemo provenance of mudrock and zircon age dating are the two research methods for this project. This research will give one example of the analysis of mudrock geochemistry and its relation with the provenance, which will have broader applications to understanding shale gas resources.

Research Method:
Physical sedimentology and provenance indicators recorded in the Atoka Formation of the Ouachita Mountain will be studied by both field and lab methods. Field work includes two areas of the Ouachita fold-thrust belt: the frontal zone of Ouachita (northern part of Ouachita, which was proximal to Laurentia), and the southern fold-thrust belt with exposures in the Boktukola Mountains and the Athens Plateau areas (distal to Laurentia and proximal to any Gondwana terranes). Stratigraphic sections will be measured with description of sandstones and mudrocks including texture, sedimentary structures, paleocurrent indicators, and biogenic structure types and abundances. These data will be used to define lithofacies to construct larger-scale deepwater depositional systems. Paleocurrent directional information will be put in lithofacies context so that accurate paleodispersal patterns from depositional sites back to source terranes can be reconstructed.

Lab work will include thin-section study, and analysis of geochemical elements and heavy mineral separates to determine mineralogical and chemical composition. Geochemical analysis includes bulk rock geochemistry for major and minor elements of, XRD for clay mineralogy, and SEM microanalysis for heavy mineral geochemistry. Paleo-redox condition from redox sensitive elements will be studied to recognize the enrichment of trace elements, which may be either from provenance or from depositional environment condition. Study of zircon will be given importance because it is highly durable and records age of the contributing provenance. This research will use detrital zircon of Atoka sandstones, from southern fold-thrust belt, for its trace element geochemistry and U-Pb geochronology.

Integration of thin-section petrography, major and trace element geochemistry, detrital zircon geochronology, and physical sedimentology is expected to give a reliable estimation of the proximity and type of provenance terranes, subduction type, and basin evolution through time for the Ouachita Trough. Each proposed plate tectonic models will yield different results. Model 1 will have the composition of continental island arc, with Laurentia craton interior sediments and dominance of Grenville age zircons. Models 2 and 3 will show the contribution from Gondwana basement age detrital zircons, and model 3 will show oceanic island arc mineral and mudrock geochemical composition and younger age detrital zircons.

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