Transcontinental vs. Local Sediment Dispersal: Evidence from Late Mississippian to Early Pennsylvanian Strata of the Ardmore Basin, OK

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Abstract:

Beginning in the Late Mississippian to Early Pennsylvanian, southern Laurentia experienced a major tectonic regime change. Progressive closure of the Rheic Ocean and collision between Laurentia and Gondwana along the Ouachita-Marathon fold and thrust belt drove deformation and subsidence within a series of basins along the southern Laurentian margin. Few provenance studies in the Ardmore Basin have been conducted and are mainly based on facies distribution, and heavy mineral and petrographic analyses. There are two opposing ideas regarding regional sediment deposition: 1.) a transcontinental system with headwaters from the Appalachian Orogen region and minor inputs from uplifts associated with the Ouachita Orogen, and 2.) a dominant transport from a southern source, likely accreted Gondwanan terranes. I have proposed a detailed U-Pb detrital zircon geochronology study to document the provenance of major upper Mississippian (Chesterian) to lower Pennsylvanian (Atokan) sandstones in the Ardmore Basin. I hypothesize that due to increased regional tectonic activity to the east and south, the Ardmore Basin experienced a major source shift from the Late Mississippian to Early Pennsylvanian with sediment transitioning from mature sand, mainly derived from Laurentia, to less mature sediments likely sourced from the Appalachian and Ouachita Orogens and local uplifts. Results of this study will provide critical evidence to help address debate between previously proposed transcontinental vs. locally-derived sediment dispersal models, and contribute to the understanding of paleogeography during the collision of Laurentia and Gondwana.

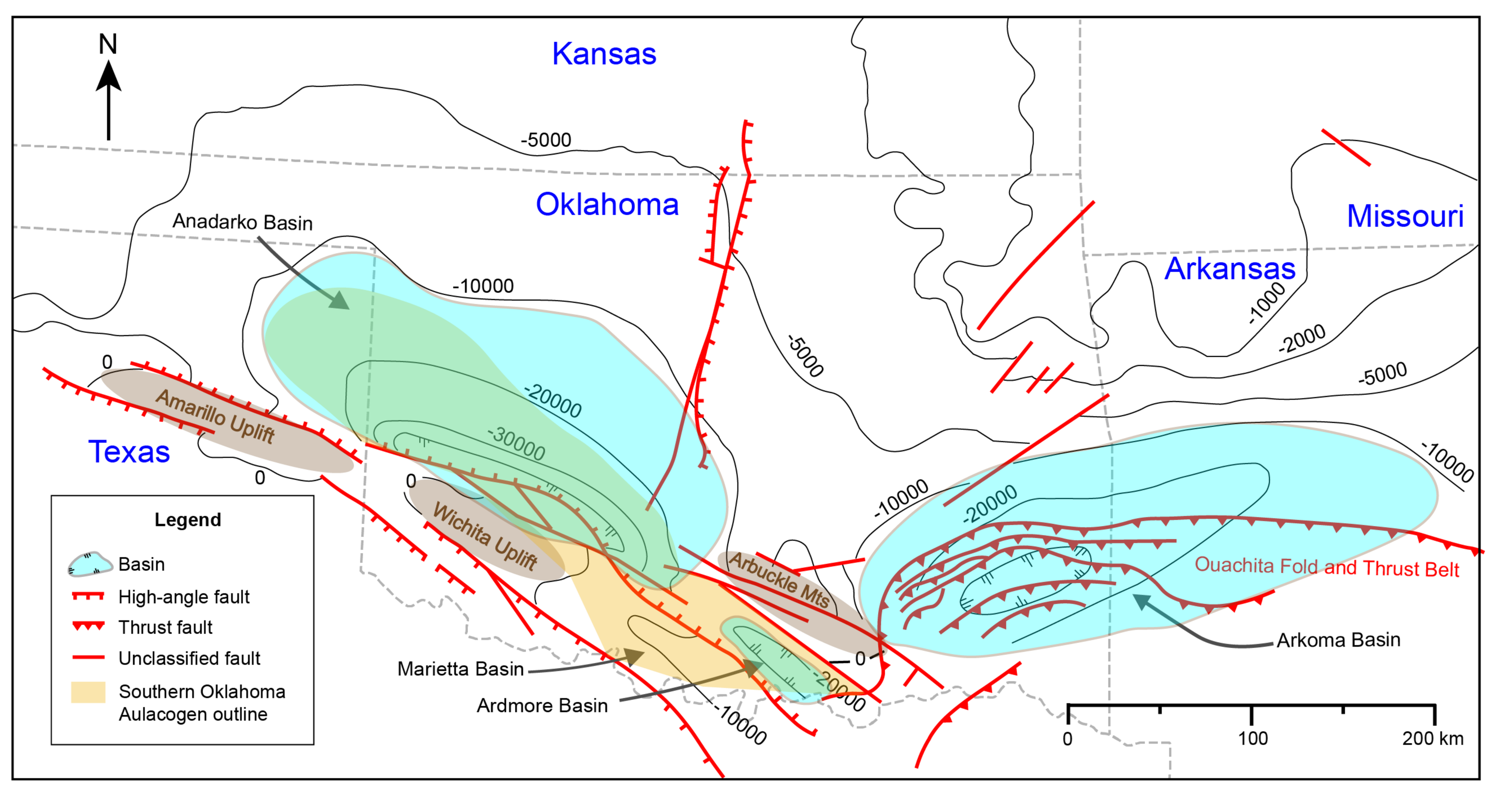

Figure 1: Basement structure map of the midcontinent, after Rascoe and Adler (1983) and Wang et al. (2019). Contours are in feet.

Geologic Background:

Rifting of the supercontinent Rodinia formed a broad passive margin along eastern and southern Laurentia during the Neoproterozoic-Cambrian (Miall et al., 2008). Opening of the Iapetus Ocean during this continental breakup was preceded and accompanied by intraplate magmatism at many sites along the eastern margin of the Laurentian craton. A prominent example lies within a major rift zone in southern Oklahoma and adjacent parts of Texas which contains an extensive Early Cambrian, mostly bimodal igneous assemblage. Following the halt of extensional tectonics and magmatism, the southern Oklahoma rift zone experienced thermal subsidence during marine transgression throughout the region (Hanson et al., 2013, Ham et al., 1964). The southern margin of Laurentia developed shallow-water carbonates and siliciclastics from the Middle Ordovician through Early Mississippian (Miall and Hsue, 2008). After extensive sedimentation, Laurentian subduction, caused by the collision with Gondwana, closed the Rheic Ocean and resulted in the Alleghenian-Ouachita-Marathon Orogenies and subsidence of various foreland basins during the late Paleozoic (Miall and Hsue, 2008; Thomas, 2006).

The Ardmore Basin is one of the several structural basins influenced by the continental collision. It is situated in south-central Oklahoma (Figures 1 and 2) and part of the southern Oklahoma rift, termed by many as the Southern Oklahoma Aulacogen (SOA). The NW-SE-trending structural feature measures ~480 km in length by ~80 km in width and extends through southwest Oklahoma and adjacent parts of Texas. Development of the SOA can be divided into three stages: a rifting, subsiding and deformation stage. The deformation stage during the Late Mississippian and Pennsylvanian, is marked by development uplifts and basins within the aulacogen–the Criner and Wichita Uplifts and Ardmore, Marietta and Anadarko Basins, along with accumulation of thick clastic sedimentary sequences (Ham et al., 1964; Johnson et al., 1989).

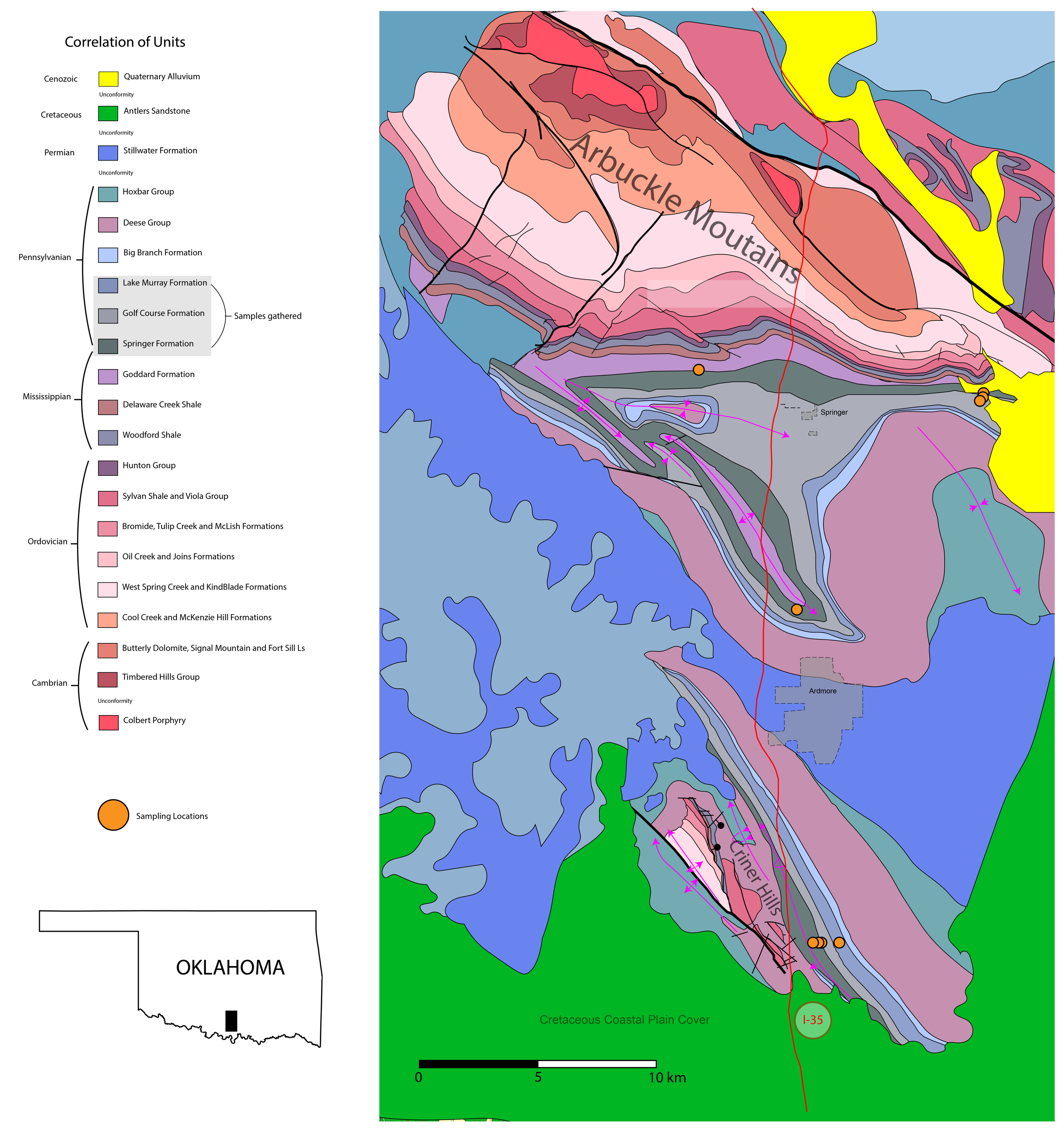

Figure 2: Geologic map of south-central Oklahoma, after Stanley and Chang (2012).

Sediment dispersal models:

A commonly cited sediment dispersal model of the late Paleozoic system within Alleghenian-Ouachita Orogen suggests a long-distance transport along the foreland that progressively closed during the collision of Laurentia and Gondwana. This widely accepted model essentially represents a transcontinental drainage system with headwaters in the Appalachians and minor inputs from the Ouachita orogeny (Alsalem et al., 2017; Gehrels et al., 2011; Graham et al., 1975; Lawton et al., 2021; Waite et al., 2020). However, Thomas et al. (2020) recently proposed an alternative interpretation of the region's paleogeography which suggests that sediment fill for the Marathon and Fort Worth Basins and areas of the Arkoma Basin was derived from accreted Gondwanan terranes south of Laurentia.

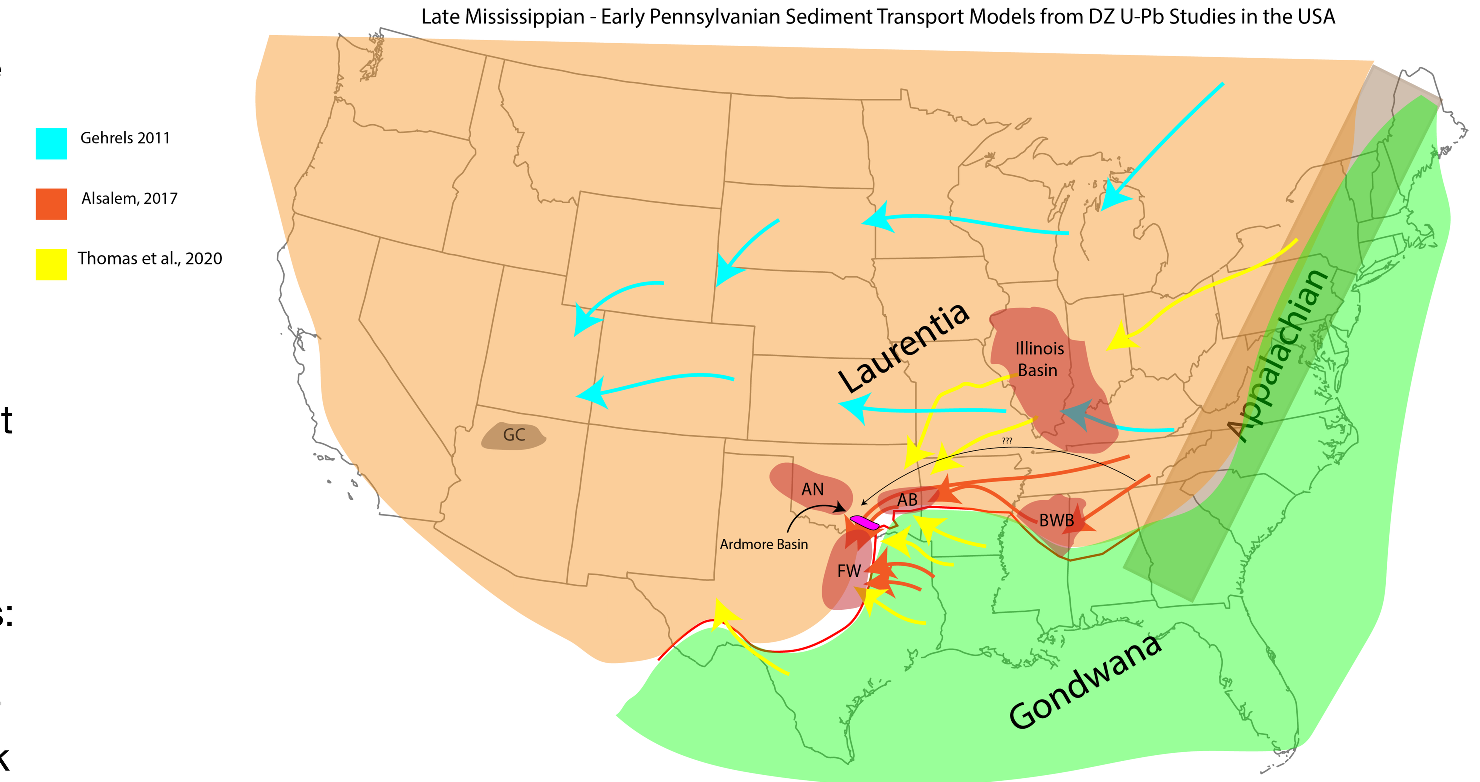

Figure 3: Sediment transport pathways discussed in DZ studies in the southern Mid-continent

Methods/field work:

Sampling locations for this study were chosen based on outcrop accessibility with the goal of acquiring multiple samples per sandstone member of Chesterian-Atokan age. Published field guides were used to locate outcrop sites. Nine sandstone samples of Chesterian, Morrowan and Atokan ages were collected from roadcuts and local exposures. Pictures from sampling sites below.

Detrital zircon grains have been extracted from samples using standard separation methods in the following order: crushing of whole-rock samples with a hammer, grinding with a disc mill, silt removal with the Wilfley table, magnetic susceptibility separation using a Frantz-LB-1 Magnetic Separator, and heavy-liquids density separation. Final zircon grains were sent to UT Austin for analyses at the UTChron Laboratory using the newly developed core-rim U-Pb zircon dating technique.

Zircon grains were placed on a double-sided tape and randomly chosen for analysis using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) to obtain U-Pb ages. Analyses was completed using a Thermo Element2 ICP-MS with an attached laser ablation system, a PhotonMachine Analyte G.2 excimer laser. A 30 µm laser spot was used to ablate ~16 µm holes on the flat, tape-mounted zircon and provide a depth profile of each analyzed grain. Lab analysis was completed March 2022.

Results and future work:

A total of 1135 concordant detrital zircon U-Pb ages were acquired for this study. Zircon grain ages range from 3688 Ma to 345.6 Ma and include signatures for all major provinces from the North American basement. They include Archean and Paleoproterozoic (> ~1825 Ma), late Paleoproterozoic (~1825-1600 Ma), early Mesoproterozoic (~1600-1300 Ma), middle to late Mesoproterozoic (~1300-920 Ma), Neoproterozoic to early Paleozoic (~790-510 Ma) and middle Paleozoic (~490-275 Ma). All samples display a similar age distribution with a few major and many subtle differences (Figure 4).

Age signatures of basement provinces in North America and published detrital zircon ages from other basins will be compiled and compared with data from this study to identify source regions for sediments in the Ardmore Basin. Results will provide new evidence for previously proposed sediment dispersal models in this time frame in the southern Midcontinent and help better understand the influence of regional vs. local sediment dispersal networks on the Ardmore Basin. My research efforts will not only help paint a clearer picture of the late Paleozoic setting in southern Oklahoma, but also constrain and improve dispersal models for surrounding basins such as the Anadarko, Fort Worth and Arkoma Basins, and provide insights to understanding the Alleghenian-Ouachita-Marathon Orogenies and their control on sedimentation along adjacent basins.

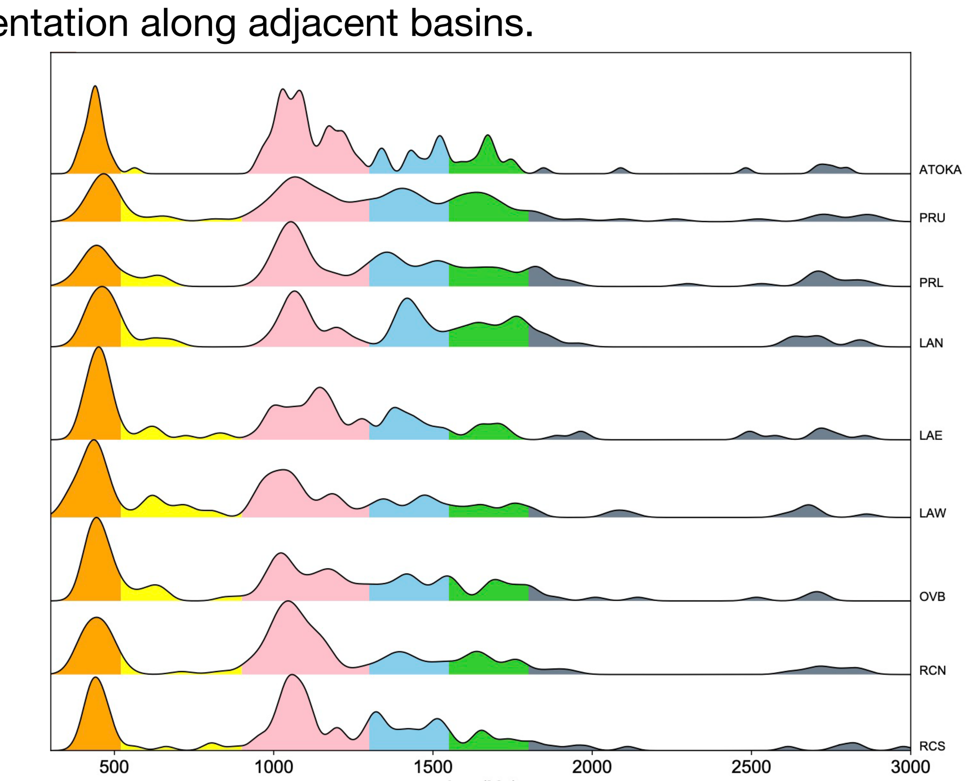

Figure 4: Kernel Density Estimation plot of detrital zircon ages of the Late Mississippian-Early Pennsylvanian sandstones from this study

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