Spatial variation of sediment sources and its implications: U-Pb detrital zircon analyses of the Mississippian Stanley Group in the Ouachita Mountains

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Abstract:

The collision between Laurentia and Gondwana during the Carboniferous created the Ouachita Orogeny and transformed the southern margin of North American Continent from a passive margin to an active margin. The Stanley Group are the first deep marine deposits in the foreland basin, known as the Ouachita Trough, that are indicative of the early stages of an encroaching continent. Although previous U-Pb studies have been performed in localized areas, no previous study has looked into detail at the spatial variations of sediments being deposited, and how sediment sources varied in different parts of the basin.

Nine samples in this study of the Stanley Group were collected within the Ouachita thrust belt in Arkansas and eastern Oklahoma. The samples were processed using U-Pb age dating (n=1093). Results of this study show that the samples can be put into two groups. The first group has major peaks at 545 Ma and 1057 Ma with a minor peak at 346 Ma, and correlates closely with age distributions from the Mayan Block. The second group has a major spike at 1057 Ma (Grenville) and 424 Ma (Appalachian), with minor peaks of 1496 Ma (Midcontinental Granite Rhyolite) and 1653 Ma (Yavapai Mazatzal), which correlates well with sediment being derived from Laurentia. This study showed that the primary sediment deposited in the southern and central part of the basin came from the south, from the Maya Block, and that the northern perimeter of the basin was likely derived from Laurentia.

Introduction:

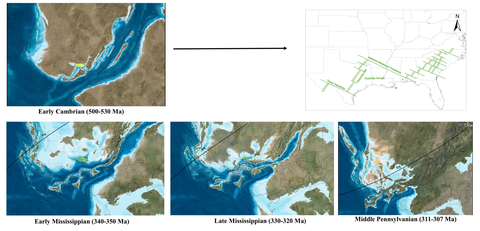
The collision of Laurentia and Gondwana during the Mississippian formed the Ouachita Mountains, as tectonic activity shifted from the Appalachians to southern Laurentia (Viele and Thomas, 1989). The mountain range spanned from Mississippi to northern Mexico. The Marathon Thrust and Fold Belt in west Texas and the Ouachita Mountains in Arkansas and Oklahoma are the only two exposures of this ancient orogenic belt (Keller and Cebull, 1973). Southern Laurentia changed from a passive margin to an active margin because of the collision (McGuire, 2016) which led to the sediments deposited in the Ouachita Trough being thrusted onto the southern portion of the North American craton.

Previous Provenance studies of the Stanley Group differ in the source of supplied sediments to the Ouachita Trough. Gleason (1995) proposed that sediments in the Stanley group were derived from subduction complexes to the south-southeast, which was composed of sediment from the Appalachian fold and thrust provenances. Totten (2000) suggest three sediment sources 1) a continental source 2) oceanic source, and 3) upper crustal source. Previous U-Pb detrital zircon studies of the Stanley Group agreed on the contribution of sediments from Laurentia but disagreed on the role of sediment potentially derived from Gondwana. McGuire (2016) identified a large population of zircon grains ranging from 1952-2094 Ma potentially derived from the Trans-Amazonian Province, and from 500-800 Ma coming from a Neoproterozoic source such as peri-Gondwanan terranes. Prines (2019) showed a large Paleozoic and Grenville contribution suggesting Laurentia as the primary source of sediment.

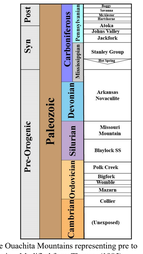
The distribution of sediments, and what landmass they originate from remain inconclusive. In this study, I present the sediment provenance of the Stanley Group. The results of this study will help identify that the Maya Block to the south of Laurentia is the primary source of sediment during the Late Mississippian.

Geological background:

Rodinia started to rift apart during the Precambrian to the late Precambrian-earliest Paleozoic at the Iapetan rifted margin in the present-day location of south-southeast United States. This rifting event created a passive margin along the southern portion of Laurentia (Thomas, 2011), which existed until the middle Paleozoic (Houseknecht et al., 1986). During the mid to late Cambrian, the rifting of the Rheic Ocean started to open and separated terranes from northern margin of Gondwana (Nance and Linnemann, 2008). The collision between Laurentia and Gondwana started during the Late Mississippian to the Early Pennsylvanian. The Stanley Group was deposited during the encroachment of Gondwana, transitioning the Ouachita Trough from a sediment starved basin into an area of rapid sediment accumulation. It is approximately 3,000m thick (Morris et al., 1989) and is comprised of mostly shales and turbidite deposits with thick sand bodies (Shaulis et al., 2012). Conflicting models support different landmasses present to the south of Laurentia before the collision.



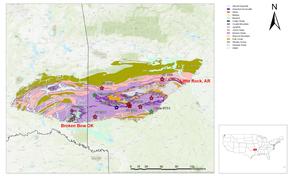
Paleogeography maps from @ Blakey (2013). TCU is an authorized user



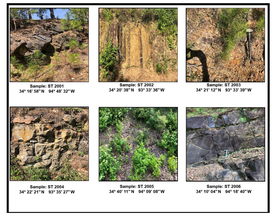
Strat column of the Ouachita Mountains representing pre to post orogenic deposits . Modified from Thomas (1985)

Sampling / Methods:

I collected nine samples from outcrops of the Stanley Group located within the Ouachita thrust belt in Arkansas and eastern Oklahoma. Samples were taken from thick sandstones associated with trubidite sequences. Traditional zircon extraction methods were used at the Department of Geological Sciences at Texas Christian University. The samples were crushed and grinded, put through water separation to remove the fine material, followed by a Frantz magnetic separator to remove magnetic material, and separated with LST heavy liquids to obtain grains with a density higher than 2.85 g/cm3. Individual samples were put into alcohol, and zircon grains were hand selected under a microscope. The selected zircon grains were put on a double-sided sticky tape on 1-inch epoxy resin mounts. Laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS) was performed at the Jackson School of Geosciences in Austin, TX. Zircon grains were randomly selected to prevent bias.

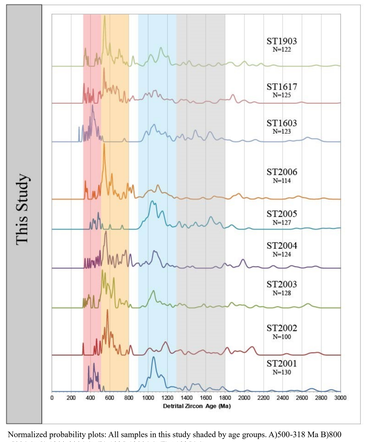


Locations of samples collected. Red Stars represent this study. Green stars represent study sites of Prines (2019). Blue stars represent study sites of Meguire (2017).

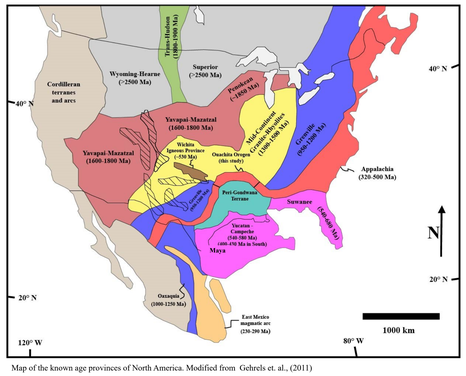


Images of 6 of the 9 samples used in this study showing classic turbidite deposits consisting of interbedded sandstone and shales. Samples 1603,1617, and 1903 were previously collected samples, and images were not taken.

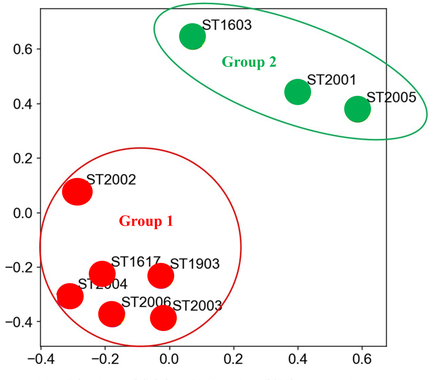
Results: Major source terranes include: A) Paleozoic (500-318 Ma), B) Neoproterozoic to Earliest Paleozoic (800-500 Ma), C) Mesoproterozoic to Early Neoproterozoic (1300-900 Ma), D) Late Paleoproterozoic-Early Mesoproterozoic (1825-1300 Ma), E) Archean (>1825 Ma),



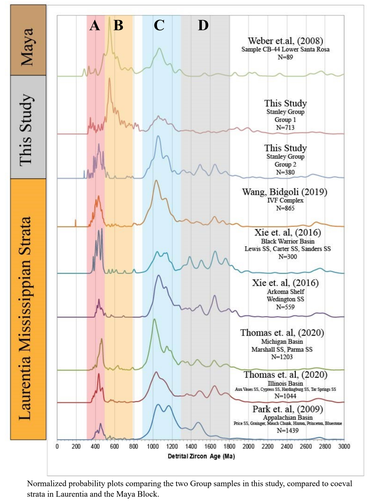
Normalized probability plots: All samples in this study shaded by age groups. A)500-318 Ma B)800 -500 Ma C) 1300-900 Ma D) 1825-1300 Ma E) >1825 Ma



Map of the known age provinces of North America. Modified from Gehrels et. al., (2011)



MDS analysis used to show similarity in samples. The samples are divided into two groups. Group 1 shows a strong Neoproterozoic signature (red circle). Group 2 lacks a similar Neoproterozoic signature (green circle).



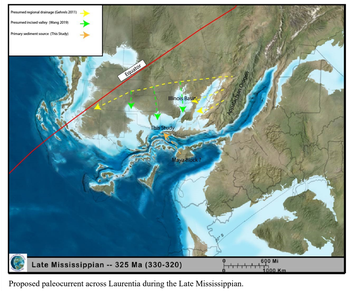
Normalized probability plots comparing the two Group samples in this study, compared to coeval strata in Laurentia and the Maya Block.

Interpretations:

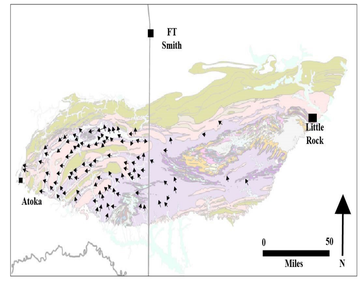
- Group one which consists of samples ST2002, ST1617, ST1903, ST2006, ST2003, and ST2004 all show a strong Neoproterozoic signature. This signature is not present in the other coeval strata across Laurentia. This age group correlates well with ages derived from Mayan Block, and suggest a southern source.
- Group two which consists of samples ST2001, ST2005, and ST1603 all have a strong Paleozoic, Mesoproterozoic to Early Neoproterozoic, and Late Paleoproterozoic-Early Mesoproterozoic signatures. These signatures are similar to the signatures from Wang et. al, (2019) suggesting they were likely recycled sediments from the Appalachians with possible additional sedimentation from the Illinois Basin.

Conclusions:

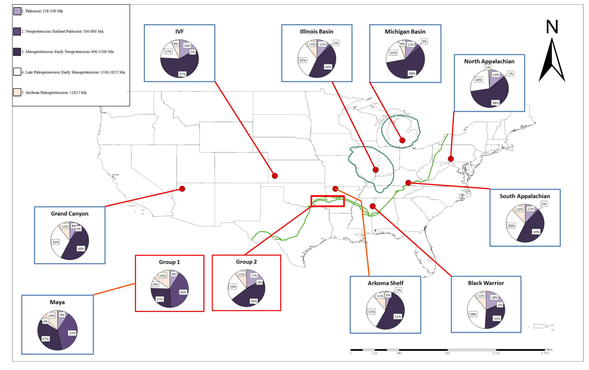
I conclude that the Ouachita Trough was filled with recycled sediments from Laurentia as well as sediments being derived from the Maya Block which is a peri-Gondwana terrane. Strong Neoproterozoic age signatures are contributing evidence that the Maya Block south of Laurentia is the most likely source of sediments in the Ouachita Trough during the deposition of the Stanley Group. Neoproterozoic aged terranes, such as the Suwanee, Avalonia, Carolina, and Wichita Igneous Province are not the likely source of these ages, as they are not found in any other coeval strata across Laurentia. This conclusion also aligns with paleocurrent data, from previous studies, that suggest a north to north west paleo flow of the Stanley Group.



Proposed paleocurrent across Laurentia during the Late Mississippian.



Paleocurrent indicators located within the Stanley Group. Modified from Morris (1974)



Map showing age populations divided in different studies areas, of Mississippian strata, across Laurentia, and the Maya Block. The lack of Neoproterozoic aged grains in the Black Warrior basin, and the Appalachian Basin are strong evidence that Laurentia could not be the source of grains ranging in age from 500-800 Ma.

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