

Reconstructing Surface and Subsurface Paleohydrology Using Evidence from Caves, Paleosprings, and Travertine in the Arbuckle Mountains, Southern Oklahoma, USA*

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Abstract

The Arbuckle Mountains are a complex geologic province, characterized by thick sequences of intensely folded and faulted carbonates, sandstones, and shales of the Late Cambrian through Pennsylvanian. Severely deformed structures of these mountains have played a significant role in the development of subterranean conduits and fluvial systems. The development of hypogenic cave systems occurred by ascending fluids and internal corrosion, beginning as early as the Late Pennsylvanian. Subsequent burial during the Permian helped preserve the fossil terrane with clues to its origin and fluid anisotropy. The mountains have been eroded steadily since the Cretaceous, but evidence of off-set speleothems suggests gradual uplift associated with the Laramide epeirogeny, which appear to have altered surface and subsurface flow-paths. Evidence of scallops on the walls of dry cave passages indicate various directions and velocity of subterranean fluids.

During the Pleistocene, massive deposits of travertine accumulated along several stream systems. Remnants of once large waterfalls are found on dry hillsides, providing evidence of paleochannels that may be traced back to paleosprings. Surface incision into caves has formed swallow holes that has left channels abandoned from upstream flows. Some streams also appear to follow unroofed cave passages for some extent. Reconstructing the flow-paths from field datasets is providing clearer insights to a dynamic hydrologic system, which is controlled by complex geologic structures. Models of these past fluid-flow events

provides clues to the occurrence of hypogene minerals, understanding the paleoclimates in which these systems formed, as well as predicting how these systems might evolve within various scenarios of our continually changing climate.

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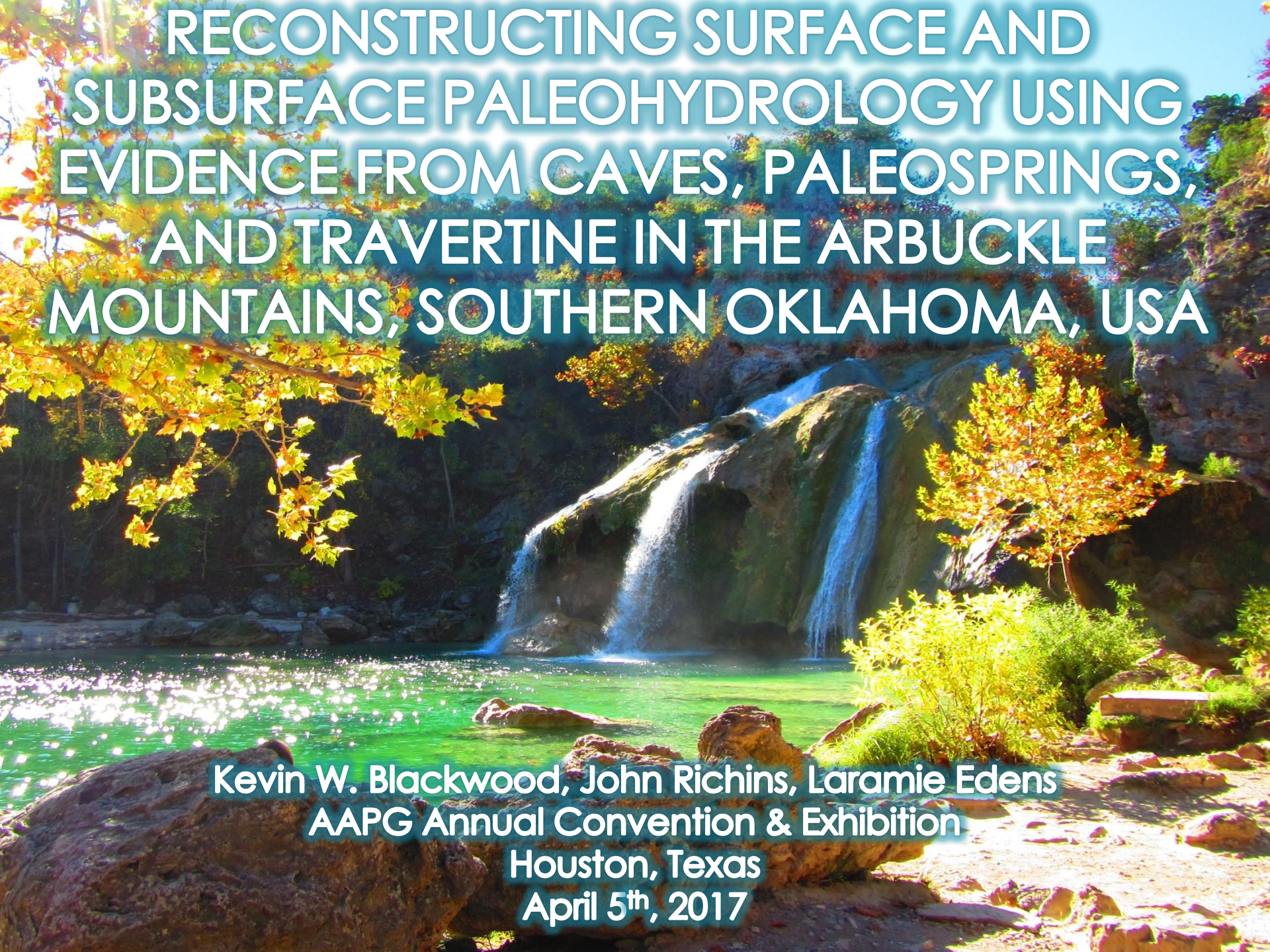
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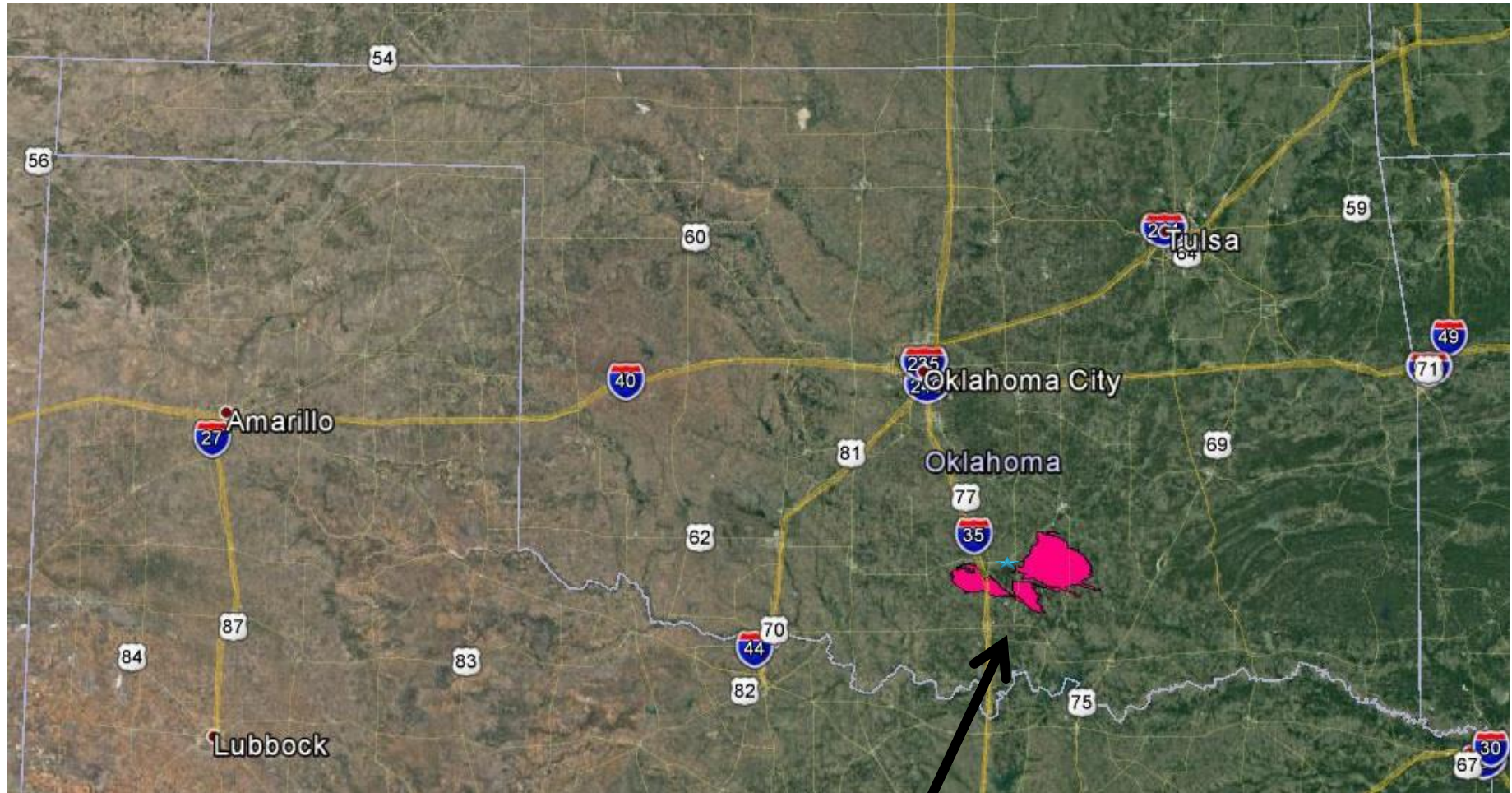
RECONSTRUCTING SURFACE AND SUBSURFACE PALEOHYDROLOGY USING EVIDENCE FROM CAVES, PALEOSPRINGS, AND TRAVERTINE IN THE ARBUCKLE MOUNTAINS, SOUTHERN OKLAHOMA, USA

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INTRODUCTION

- The Arbuckle Mountains are a complex geologic province, characterized by thick sequences of intensely folded and faulted carbonates, sandstones, and shales of the Late Cambrian through Pennsylvanian (Ham 1973).
- Severely deformed structures of these mountains have played a significant role in the development of subterranean conduits and fluvial systems. The development of hypogenic cave systems occurred by ascending fluids and internal corrosion, beginning as early as the Late Pennsylvanian. Subsequent burial during the Permian helped preserve the fossil terrane with clues to its origin and fluid anisotropy (Blackwood 2017).
- Presented here, is a summary of some of the highlights of the the paleo-hydrology of the Arbuckle Mountains. The objective of this study is to develop an animated model of the geological and geomorphological evolution of the Arbuckle Mountains for educational outreach.

ARBUCKLE MOUNTAINS



Arbuckle Mountains

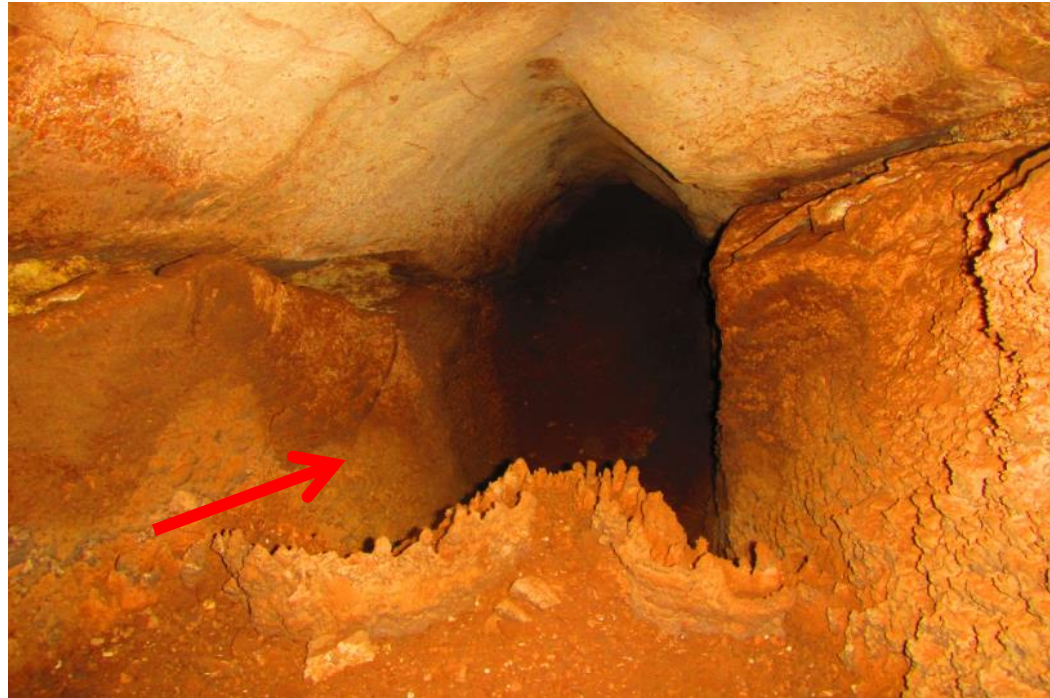
BACKGROUND

The Arbuckle Mountains have eroded steadily since the Cretaceous, but evidence of off-set speleothems suggests gradual uplift associated with the Laramide orogeny, which may have altered surface and subsurface flow-paths (Puckett et al. 2009)

- Evidence of scalloping on cave walls and paleo-waterfalls indicates direction of past-groundwater flow.
- Distribution of stygofauna (aquatic cave critters) may serve as evidence of present and/or paleo hydrologic connections.
- Remnants of once large waterfalls are found on dry hillsides, providing evidence of paleo-channels that may be traced back to paleo-springs.
- Surface incision into caves has formed swallow holes that has left channels abandoned from upstream flows. Some streams also appear to follow unroofed cave passages for some extent.

FLUID ANISOTROPY IN CAVES

Corroded travertine waterfall inside Temple Cave indicates direction of groundwater flow in the cave at an earlier time.



Scallops along a wall in a dry section of Wild Woman Cave indicate direction of flow.

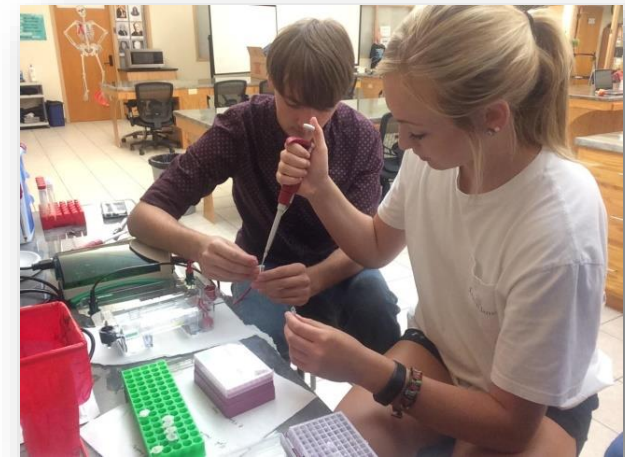


Note: The velocity can be crudely determined by dividing the length of the scallop (cm) by 300 to obtain V in cm/s (Curl 1974).

STYGOFAUNA AND HYDROGEOLOGY

- Stygofauna (such as the cave amphipod) are limited to effective mobility within the phreatic environment and may be used to study groundwater connections.
- Despite topographic and structural “barriers”, the endemic amphipod *Allocrangonyx sp.* (top 2 specimens) is found on all major geologic structures.
- Their widespread occurrence suggests two possibilities (pending genetic analysis):
 1. The groundwater systems remain hydrologically connected; that isolating mechanisms are not in place.
 2. Paleo-terrane allowed for effective migration, but erosion has removed pathways in the aquifers.

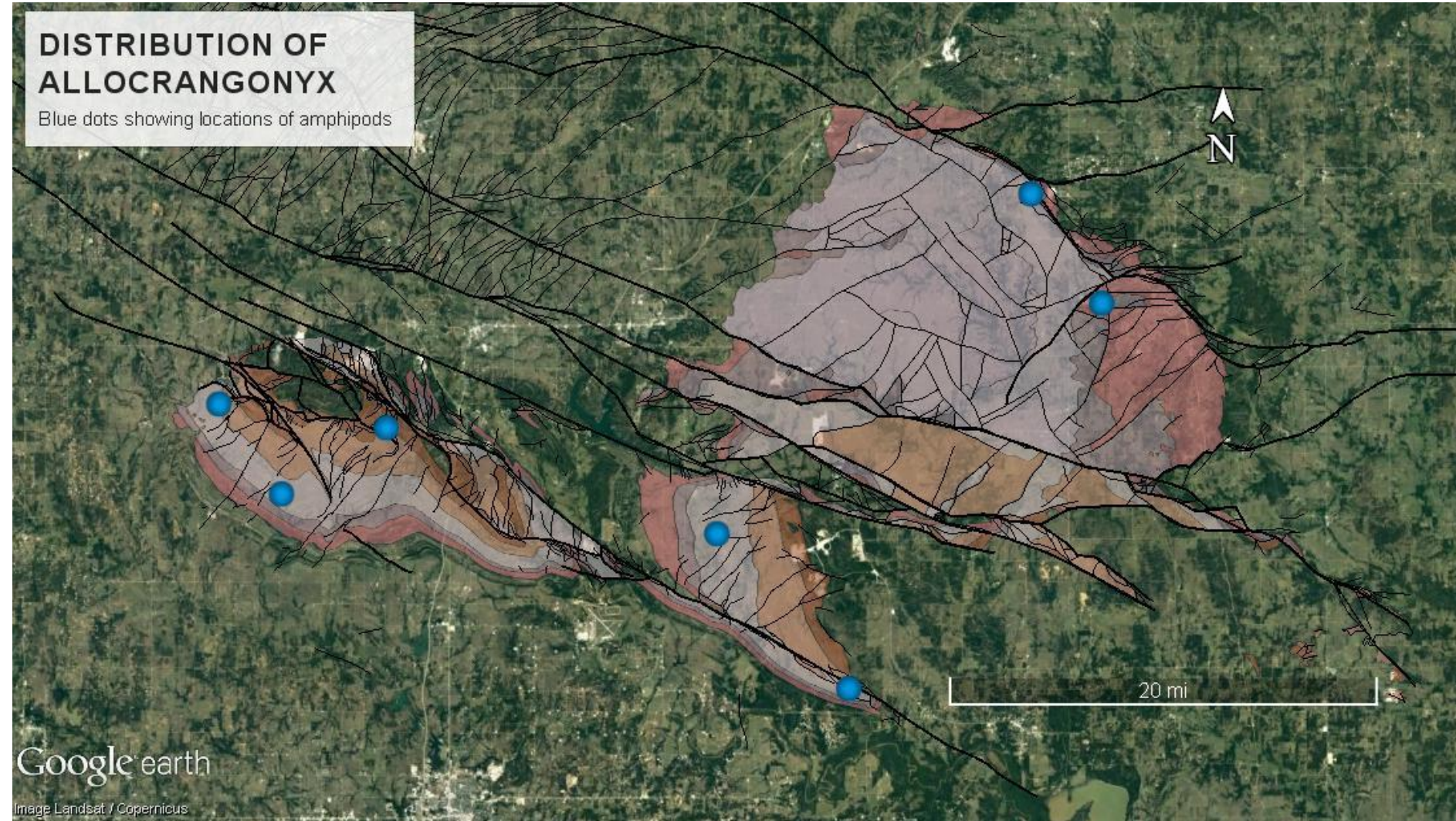
*NOTE: DNA work is currently being conducted on both the *Allocrangonyx* and *Bactrurus* amphipods.*



STYGOFAUNA AND HYDROGEOLOGY

DISTRIBUTION OF ALLOCRANGONYX

Blue dots showing locations of amphipods



Amphipods (*Allocrangonyx pellicidus*) are endemic to the Arbuckle Mountains and found in the groundwater of all three major geologic structures, across major faults, and in separate strata. If these are effective isolating mechanisms, colonization must rely on paleo-hydrologic groundwater connections. Analysis of genetic drift might be effective to test this hypothesis.

SURFACE TRAVERTINE DEPOSITS

- Surface travertine deposits are common throughout the Arbuckle Mountains, occurring where turbulence is greatest (waterfalls) because of the degassing of CO₂ from solution and supersaturation of dissolved CaCO₃. Deposition is further exacerbated by microbes, algae, & bryophytes which remove CO₂ and act as nuclei (Pentacost 2005).
- Deposition is minimal where deciduous tree foliage dominates the basin, probably due to lowering of water pH during autumn months.
- Surface travertine deposits provide many clues to past hydrological environments.
- Some travertine waterfalls appear to have accumulated over ancient beaver dams and fallen trees as evidence from log casts.
- Massive travertine terraces formed near the present sites of Turner Falls on Honey Creek, Prices Falls on Falls Creek, and below Viola Spring of a tributary of Delaware Creek (Emig 1917).

SURFACE TRAVERTINE DEPOSITS



HONEY CREEK & TURNER FALLS



- Massive travertine deposits accumulated at the site of Turner Falls.
- Clastic rhyolite is found at the base of the travertine deposit and at the top, but none has been found in between. This suggests that large floods were unavailable to mobilize the rhyolitic rocks for a very long period of time.
- The rhyolite found at the top suggests that flooding returned and the harder rhyolite pulverized the travertine to form Grotto Gorge above Turner Falls.



EIGHT MILE CREEK

EIGHT MILE CREEK

MEANDERING AND OXBOWS



Purple lines showing paleochannels of oxbows.

This stream used to be higher gradient with evidence of ancient travertine deposits, the sites of old waterfalls. Tilting of the Mid-Continent to the SE may have caused a gradient decrease on this NW flowing stream.

THE ROLE OF THE WASHITA RIVER

- The Washita River is the lowest point and the watershed of for many of these streams including Honey Creek and Falls Creek. The Washita River flows through a constriction known as Big Canyon.
- Rapid down-cutting may have occurred through the Woodford Shale and lowered the elevation of the river (Ham 1973).
- Evidence of paleo-stream substrates abandoned by valley deepening are visible above Honey Creek near Cedar Village (below right) and at Prices Falls on Falls Creek (Below left). Prices Falls may have descended directly into the Washita River prior to the breaching of the Woodford Shale, causing a gradient change and erosion of the ancient waterfall.



CAVES & PALEOKARST

- The Arbuckle aquifer is a karst aquifer and caves are widespread in many of the formations.
- Paleokarst is locally common on the north flank of the Arbuckle anticline where deformation is severe. Many of these paleokarst features were either not entirely buried, or have since been exhumed.
- Inspection of these paleokarst voids indicates that the morphologies are indicative of hypogene speleogenesis (Blackwood 2017).
- These represent ancient flowpaths wherein the groundwater movement and fluid geochemistry was different than at present.



FUTURE WORK & CONCLUDING REMARKS

- The data gathered from this study is being used to build an animated model of the geologic and geomorphologic evolution of the Arbuckle Mountains beginning in the Middle Cambrian.
- The animated model will be used for educational purposes and highlight major developments to the best of our understanding.
- The most notable results from this study is that lack of clastic rhyolite in the travertine terrace of the ancient waterfall at Turner Falls indicates that the discharge was not high enough to mobilize the rhyolite. This is probably most likely the result of low intensity rainfall and a lack of flooding events. The widening of the terrace could have been a contributing factor in diminished discharge per unit area relative to flow through the present gorge.
- The effects of the Laramide orogeny and tilting of the mid-continent may also be significant in the diminished gradient of the NW flowing Eight Mile Creek.
- The occurrence of beavers in the ancient stream ecosystems may be significant. Evidence of log casts is indicative of a wooded-frame in many of the waterfalls.

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QUESTIONS OR FEEDBACK?



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