Evaluating the Upper Triassic Chinle Formation for Aggradational vs. Degradational Cycles using Detrital Zircon U-Pb Geochronology and Provenance, Southeastern Utah

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Abstract:

This study will examine the paleo-landscape context of the Shinarump Member of the Upper Triassic Chinle Formation, in southeast Utah, as part of a broader Ph.D effort to define and quantify Upper Triassic source-to-sink sediment routing and landscape evolution. The Chinle has been the subject of much research over the years, with recent stratigraphic and detrtial-zircon (DZ) U-Pb provenance studies interpreting the basal Chinle (the Shinarump and Temple Mountain Members) as residing within a succession of discrete paleovalley axes. DZ U-Pb age populations have both defined source terrains for different paleovalleys and produced significant numbers of syndepositional volcanogenic zircons from the active Western Cordillera magmatic arc that provide maximum depositional ages (MDAs). I hypothesize that, in contrast to a typical aggradational fluvial system, the Shinarump represents a series of downward-stepping terraces within degradational mixed bedrock-alluvial paleovalleys. This aggradational vs. degradational model will be tested using DZ U-Pb age populations, as follows: (a) if the Shinarump is the basal part of an aggradational valley-fill system, successively lower-elevation Shinarump deposits will produce successively older MDAs, (b) if the basal Chinle Shinarump represents a series of downward-stepping terraces that represent a long period of bedrock-valley incision, successively lower-elevation Shinarump deposits will produce successively younger DZ U-Pb maximum depositional ages. In addition to using DZ U-Pb provenance and geochronological data to test for degradational patterns, this work will contribute to the overall understanding of Chinle provenance, geochronology, and Upper Triassic paleogeography and sediment routing for the region as a whole.

Regional Context:

The Paleozoic Appalachian-Ouachita orogeny played a significant role in the development of the North American stratigraphic record. DZ U-Pb age populations derived from the Appalachian-Ouachita Cordillera are known from the Western US beginning in the Mississippian and thought to record transcontinental sediment dispersal. However, the actual transport routes during the Paleozoic are unclear, as deposits of a transcontinental river system have not been identified. Identification of such transcontinental fluvial systems are fundamental to understanding sediment routing from source terrains to distal depositional sinks, and the Upper Triassic Chinle likely represents the oldest preserved transcontinental fluvial system in the United States that can be linked directly to the Appalachian-Ouachita Cordillera.

The basal Chinle (e.g., Shinarump, Temple Mountain, and their stratigraphic equivalents) was previously described as a complex interfingered succession of strata (Witkind, 1956; Cooley, 1959; Phoenix, 1963; Davidson, 1967; Stewart et al., 1972). However, a number of recent studies have revised stratigraphic and sedimentological understanding, and used DZ U-Pb age populations to show that differences in the basal Chinle can in part be attributed to represent a succession of discrete paleovalley axes that have different source terrains (Blakey and Guiditosa, 1983, 1984; Kraus and Bown, 1986; Haney, 1987; Dubiel, 1987, 1992, 1994; Kraus and Middleton, 1987; Blakey, 1989; Demko et al., 1998). Recognition of discrete paleovalleys provides important stratigraphic and paleogeographic context for the Chinle Formation.

Methods:

Three DZ samples collected along-strike of the discrete paleovalleys yielded several MDAs with successively lower-elevation samples producing successively younger MDAs (Figure 1b). Eight more DZ samples will be collected from Shinarump sand bodies that rest on underlying Lower Triassic Moenkopi bedrock (Figure 1b). These samples will be systematically collected along-strike of the inferred trend of the discrete paleovalley axes (Figure 1a). They will then be prepared and analyzed by using LA-ICP-MS techniques to generate DZ U-Pb ages (Gehrels et al., 2008). The youngest population of DZ U-Pb ages identified from each sample will then be analyzed by the CA-TIMS method for improved precision and accuracy (Krogh, 1973; Mattinson, 2005). CA-TIMS will allow us to acquire refined DZ U-Pb ages that will be used to calculate MDAs for the basal Chinle Shinarump member along-strike of the discrete paleovalleys (Gehrels, 2012) (Figure 1a, b).

The aggradational vs. degradational model will be tested as follows: (a) if the Shinarump is part of an aggradational valley fill, successively higher-elevation Shinarump deposits will produce successively younger DZ U-Pb MDAs (Figure 2a), (b) if the basal Shinarump represents a series of downward-stepping terraces within a bedrock valley, successively lower-elevation Shinarump deposits will produce successively younger MDAs (Figure 2b).

Scientific Importance:

Clastic sedimentology has experienced a paradigm shift from a multi-decadal focus on facies models and sequence stratigraphy to a broader process-based emphasis on quantifying sediment routing and storage within entire source-to-sink systems and predicting properties of one part of the system from reconstructed properties of another. Much progress has been made quantifying properties of modern systems, including quantification of relationships between fluxes of sediment and properties of deposits within and between different parts of the system, from highland source terrains to deepwater sinks.

Demonstration of a degradational bedrock-valley would contribute to a new model for interpretation of ancient fluvial systems. More broadly, my research on the Chinle will leverage insights from modern systems, as well as advance the use of DZ U-Pb geochronology tools to reconstruct the nature and properties of sediment routing and paleogeography in ancient source-to-sink systems.

Figures:

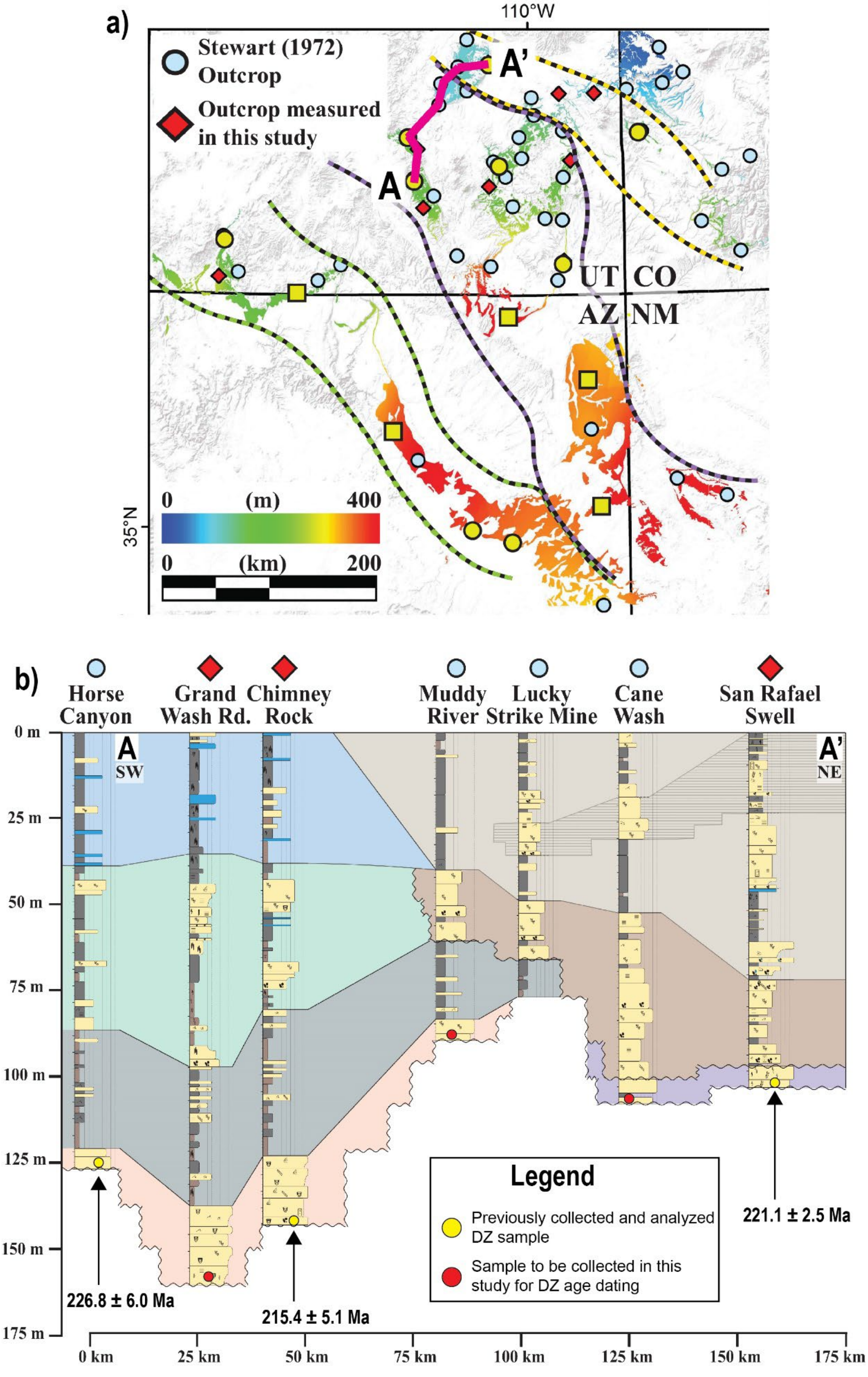

Figure 1 - a) Location of cross section and total Chinle Formation thickness map with paleovalley systems. All outcrops are bounded by Moenkopi strata (below) and Wingate strata (above).; b) Along-strike cross section A-A' with MDAs collected from the basal Chinle displayed.

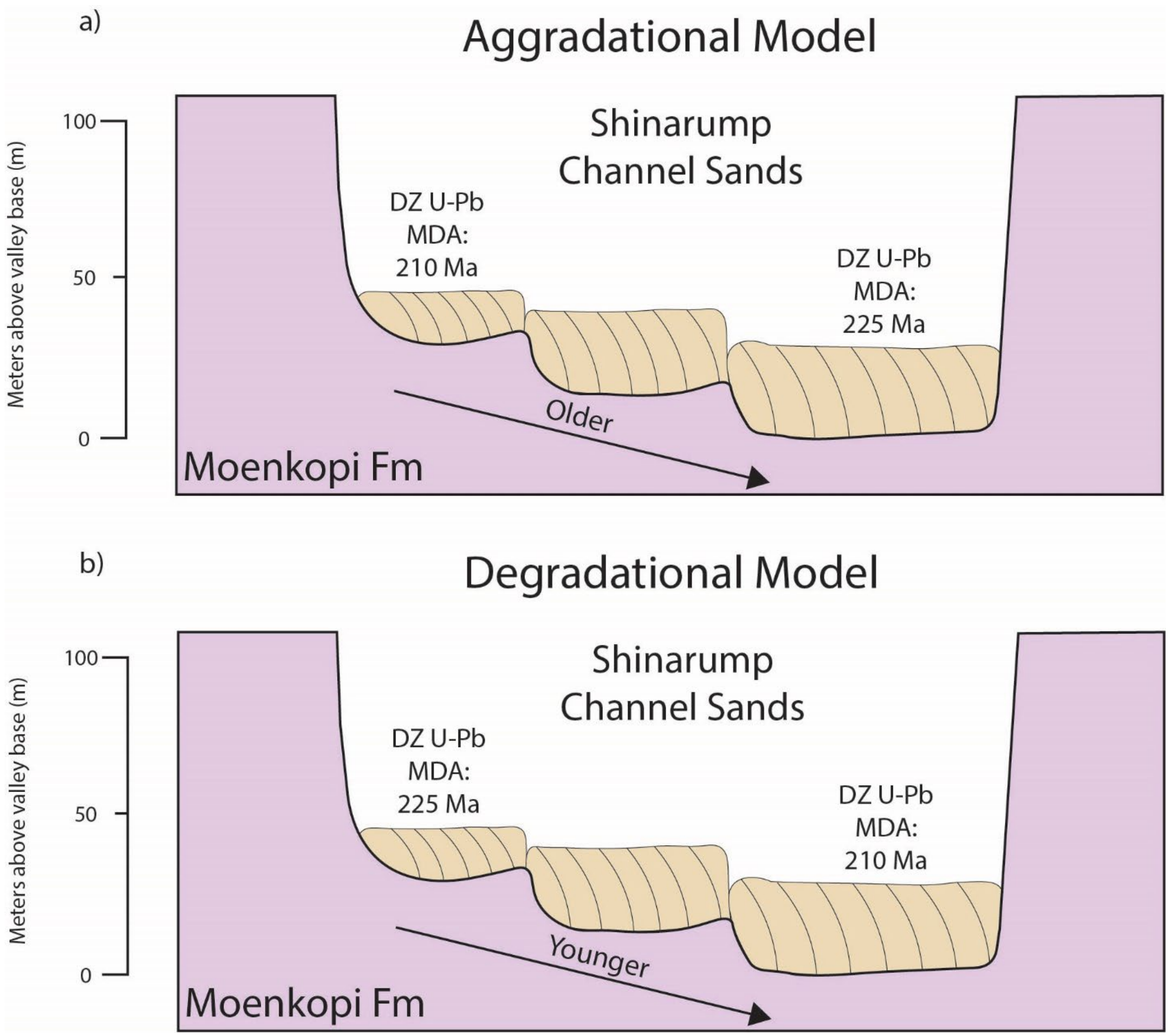

Figure 2 - a) Schematic interpretation of cross-sectional architecture resulting from aggradational cycles during basal Chinle deposition; b) Schematic interpretation of cross-sectional architecture resulting from degradational cycles during basal Chinle deposition.

Budget:

Item	Cost	Have	Need
Detrital Zircon Analysis: $1,060/sample	8 samples = $8,480	$6,500	$2,000

Timeline:

Spring 2022	Conduct two weeks of field work, collecting additional samples and measuring detailed stratigraphic sections in the inferred Chinle paleovalleys (Fig. 1a). Create thin sections of the basal Chinle at each stratigraphic section measured.
Summer 2022	Prepare samples for LA-ICP-MS and CA-TIMS dating techniques (e.g., extracting and annealing detrital zircon grains). Conduct point count analysis on thin sections.
Fall 2022	Conduct detrital zircon U-Pb analysis using LA-ICP-MS techniques at the Arizona LaserChron Center; Identify youngest age populations yielded from analysis. Conduct additional U-Pb analyses, focusing on youngest grain populations using CA-TIMS techniques at the University of Kansas TIMS Laboratory. Present initial data at 2022 GSA Annual conference.
Winter 2022/2023	Model U-Pb results. Present research at AGU. Begin writing manuscript.
Spring 2023	Finalize manuscript and submit for publication.

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