Implications of the stratigraphic results of the Colorado Plateau Coring Project (CPCP): salt vs. plate tectonics vs. eustasy in the Late Triassic Chinle Formation

Olsen, P.E.
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Olsen, P.E.[1], Parker, W.[2], Kürschner, W.[3], Huber, P.[4] , Geissman, J.[5]

1 LDEO of Columbia University, Palisades, NY, 10968 USA. polsen@ldeo.columbia.edu; 2 Petrified Forest National Park, Petrified Forest, AZ, 86028 USA; 3 University of Oslo, 0316 Oslo, Norway; 4 Geoscience Books, PO Box 1036, Faribault, MN 55021 USA; 5 University of Texas at Dallas, Richardson, TX, 75080 USA.

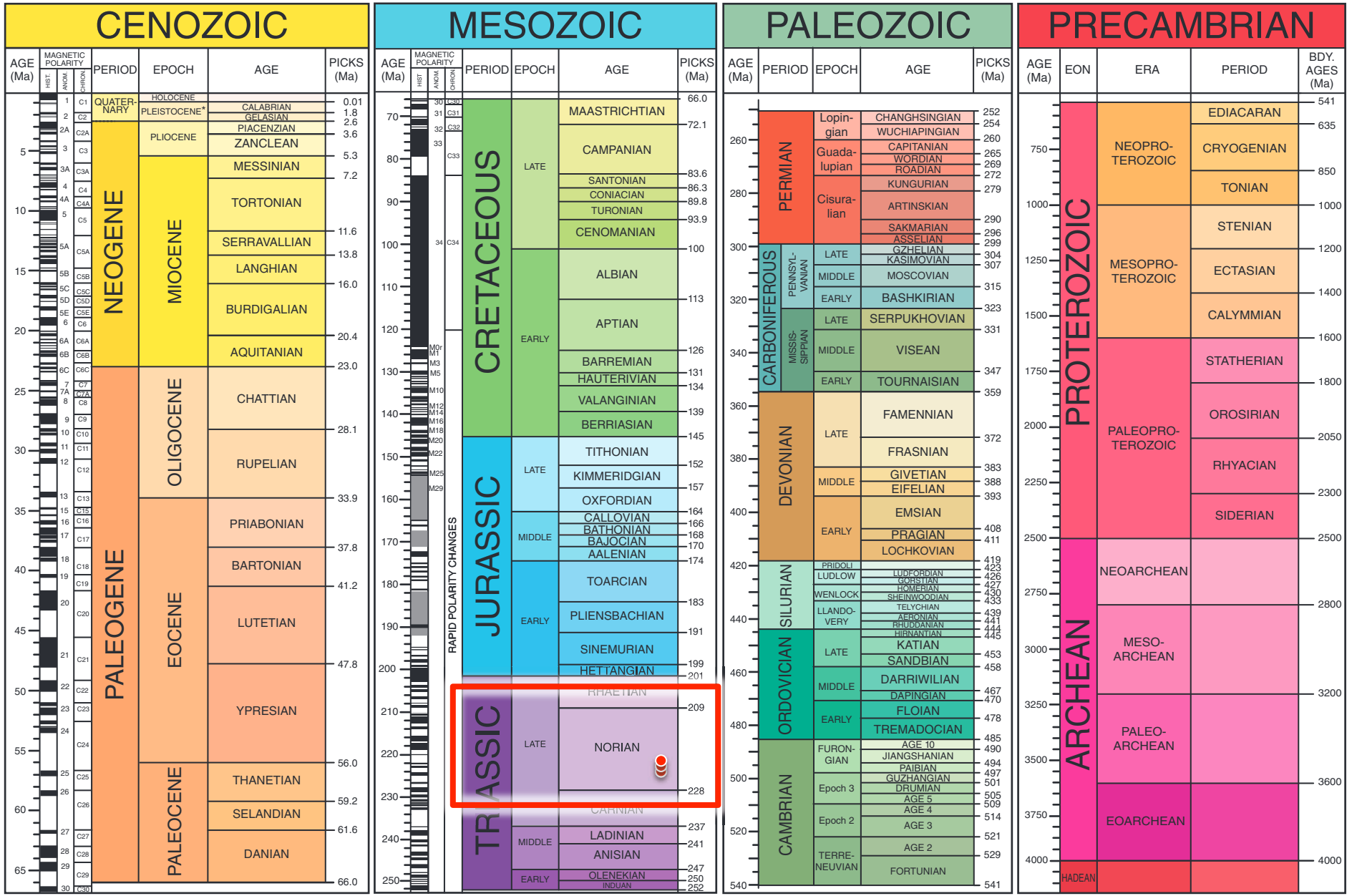
Understanding of the basic tectonic framework for the deposition of the highly fossiliferous continental Chinle Formation (Fm) of the western US is poorly understood; it is far from clear if the setting was a back arc basin [1], a passive margin [c.f., 2], or something else. In addition, the role of eustasy in driving basin-wide sequences, unconformities, and hiatuses [e.g., 3] is contentious. Analysis of cores from Phase 1 of the CPCP in Petrified Forest National Park, AZ, USA (PFNP) integrated with new field studies suggest that the major control was halokenesis of Paleozoic salt, not tectonics or eustasy. Core 1A spans 520 m of the lower Owl Rock Member of the Chinle Fm to the formation base (L Triassic), as well as all of the Moenkopi Fm (E - M Triassic), with TD in the Permian. While the overall stratigraphy of the major units encountered in the core correspond well to those based on local outcrops [e.g., 4], a major facies complex present in southern part of the PFNP, which we call the "Monitor Butte facies" (MBF) is completely lacking, along with its associated palynologically- and macro-plant-productive levels. Our field studies suggest that MBF is associated with very rapid deposition in localized basins associated with syndepositional tilting and well-developed to profound local, angular unconformities, and extreme development of multi-colored mottled strata (MS), all related to basins produced by salt withdrawal. Halokenesis-related unconformities and basins are well documented in the Chinle Fm in Utah [5] overlying the Paleozoic Paradox Basin, and we argue such features are widespead. In the Fort Wingate NM, USA area, steeply dipping to vertical Chinle strata with recumbent-folded MBF with a major plant locality [USGS 10060: 6] are overlain by a profound angular unconformity by virtually flat, black, lacustrine strata of the "Ciniza Lake Beds" (CLB) [7]. Adjacent undeformed facies include very thick MS. The overlying CLB are consistent with a slightly later and longer wavelength overlying sag. Both facies and geometry are similar to the salt withdrawal basins of Utah [5]. Such features are present not only elsewhere in New Mexico and Arizona, but also in the Dockum Group of Texas (with important plant localities [e.g., 8]), and fossil-fish-bearing lacustrine strata at Lisbon Valley, UT and Dolores Canyon, CO [9] may be in CLB-type sags. Lateral restriction of MBF as seen PFNP and core 1A, at Fort Wingate, as well as the unconformities and lacustrine strata reported elsewhere were not proximally a result of plate tectonic or eustatic processes but rather salt tectonics, which may be the most important control onlocal facies development other than climatic context for these Triassic strata in the western US. Phase 1 of the CPCP is funded by NSF (SG&P/IF), and ICDP. This is a contribution to UNESCO-IUGS IGCP Project 632.

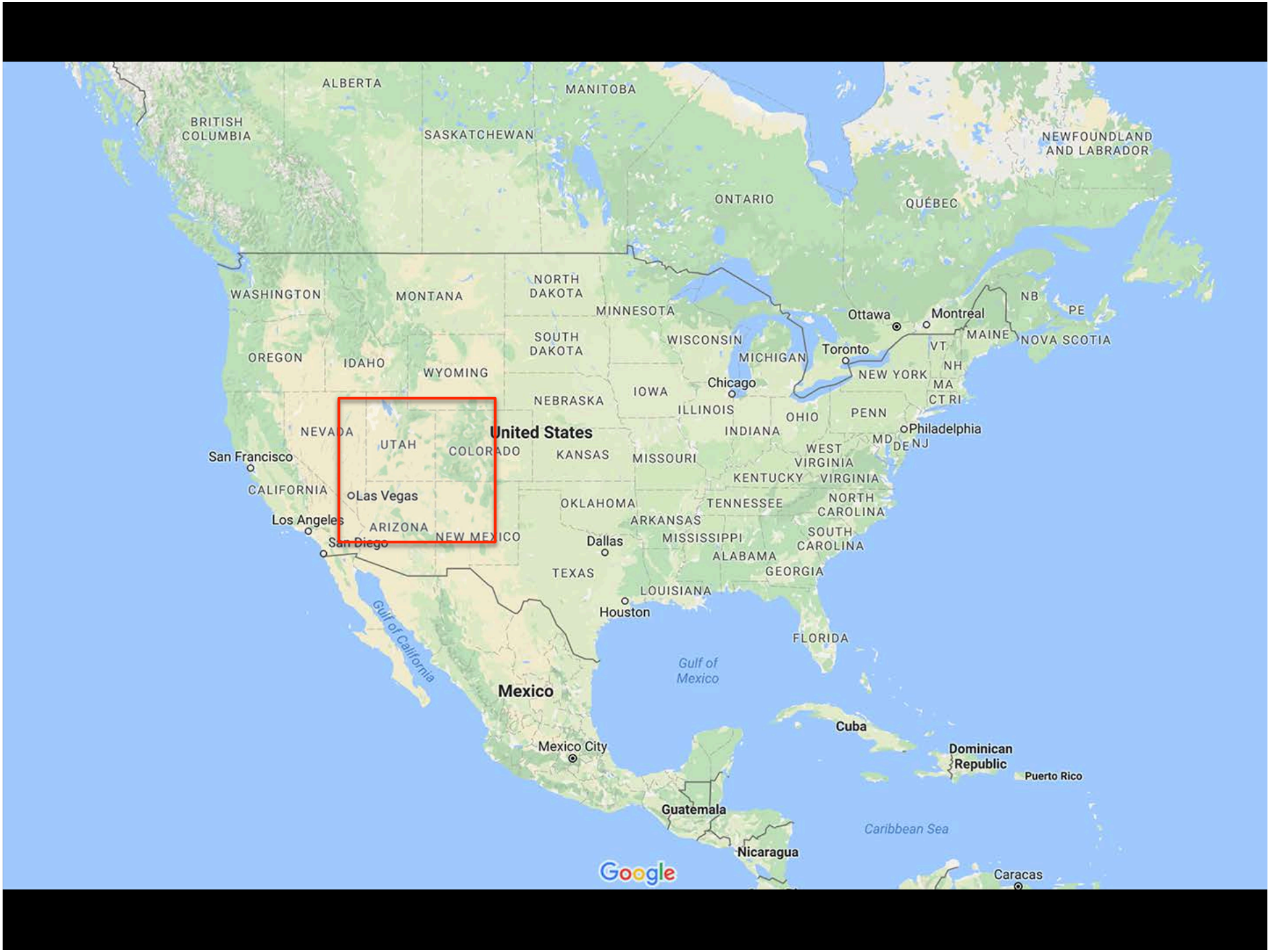
References: [1] Dickinson W R (2006) Geosphere 2(7):353-368; [2] Sigloch K and Mihalynuk M G (2013) Nature 496:50-57; [3] Lucas S J and Marzolf J E (1985) In: Mesozoic Paleogeography of the Western United States II, SEMP:375-388; [4] Parker W G, and Martz, J W (2011), Earth Env Sci Trans Roy Soc Edinburgh 101:231–260; [5] Matthews W J et al (2007) AAPG Bull 91(10):1367-1403; [6] Ash S R (1970) USGS Prof Paper 613-D:D1-D52; [7] Ash S R (1978) Brigham Young University, Geology Studies 25 (1978): 1-14; [8] Cornet B (1986) Evolutionary Theory 7:231-309;[9] Schaeffer B. (1967) Bull AMNH 135(6):289-342.

Basic concept is that the Triassic and possibly Jurassic continental sequences of the Western United states are basically a passive margin sequence in which both reported tectonic and eustatic elements are actually due to underlying Paleozoic salt tectonics.

1. Colorado Plateau Coring Project (CPCP).
2. What we were thinking we would get.
3. What we got.
4. Missing “Monitor Butte” facies
5. Lacustrine facies of Paradox Basin salt tectonics
6. Supposed sequence eustatic sequence boundaries in Chinle are salt related unconformities
7. Is there any tectonics or eustacy effects in the Western US Triassic?

GSA GEOLOGIC TIME SCALE v. 4.0

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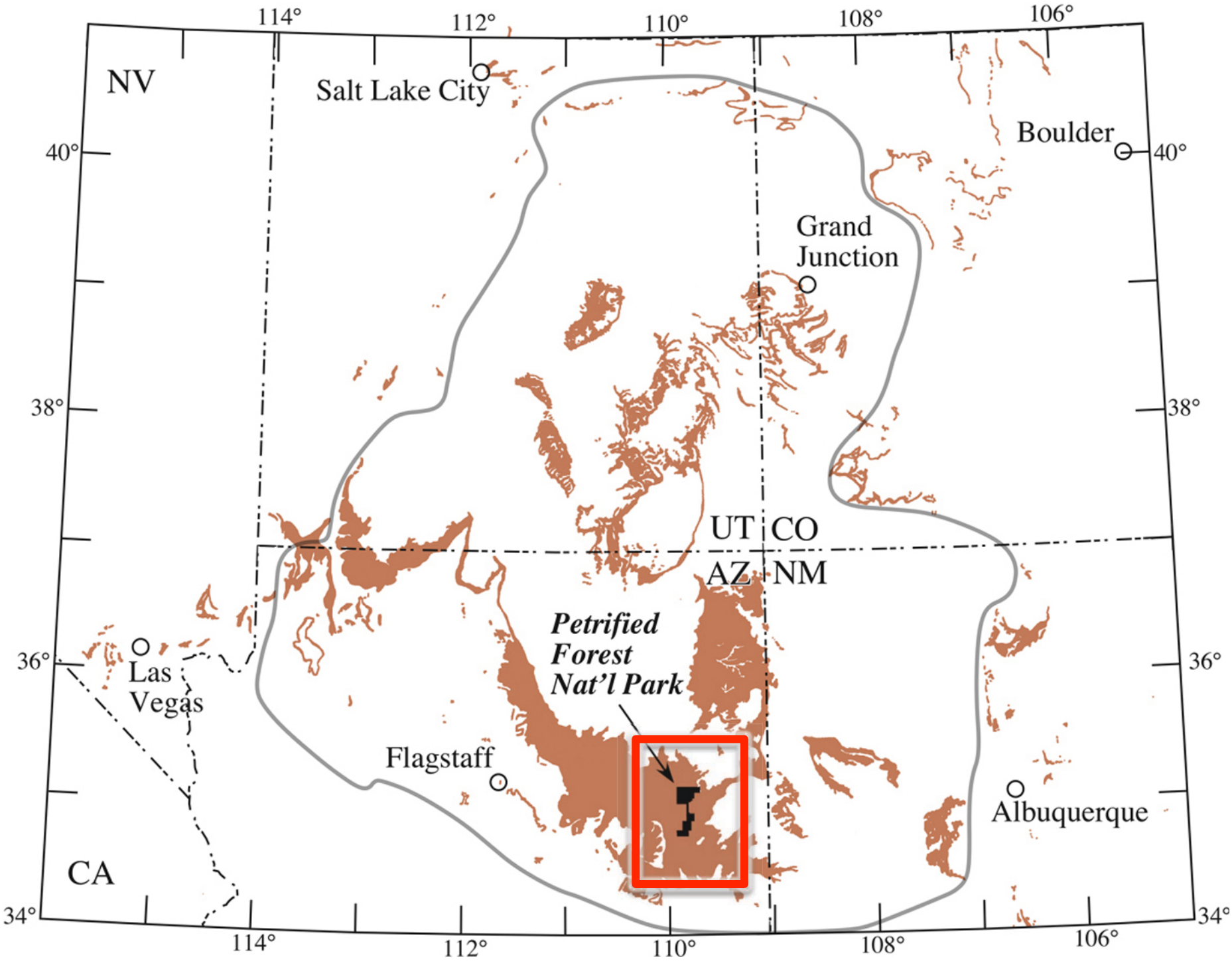
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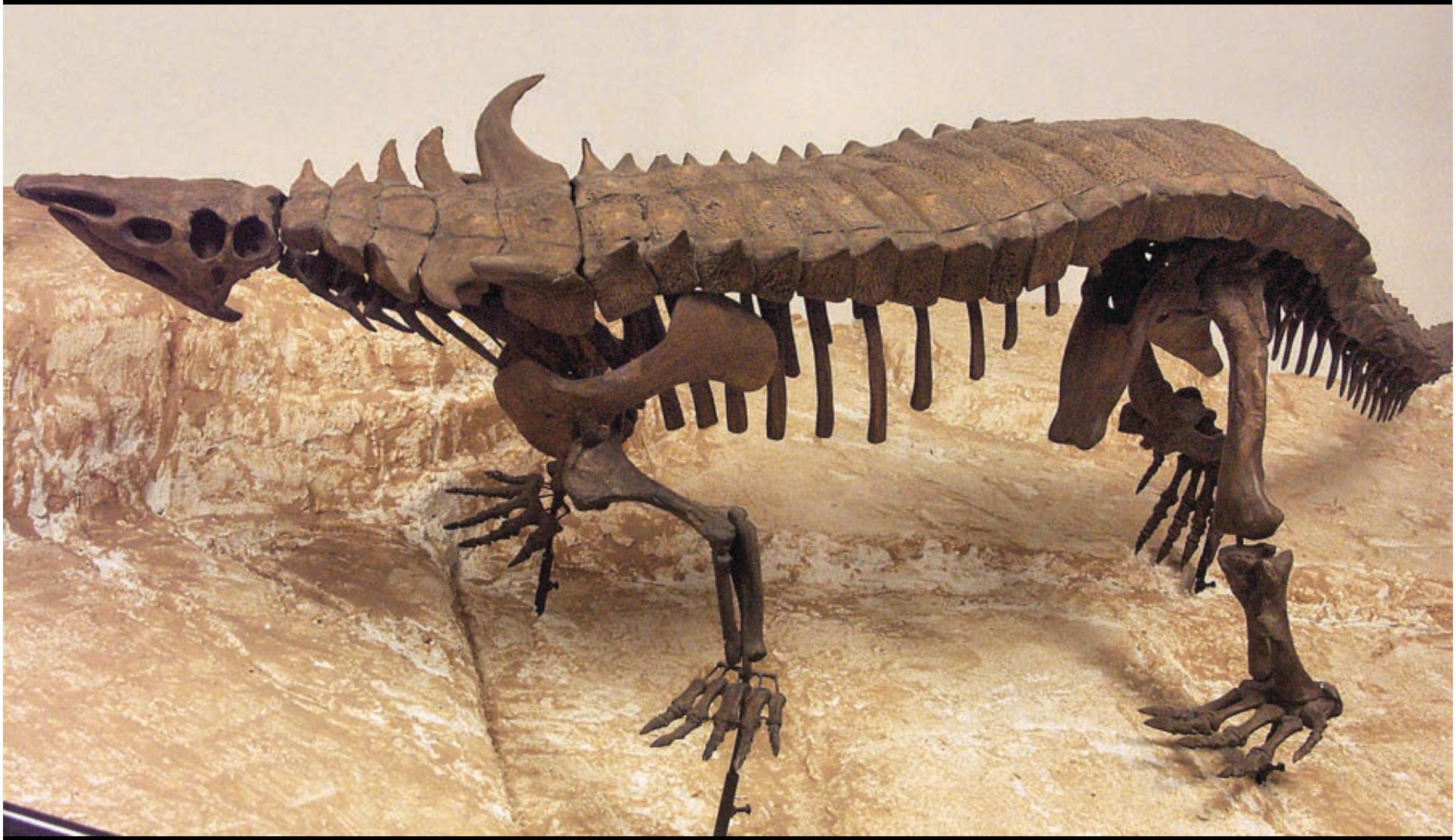
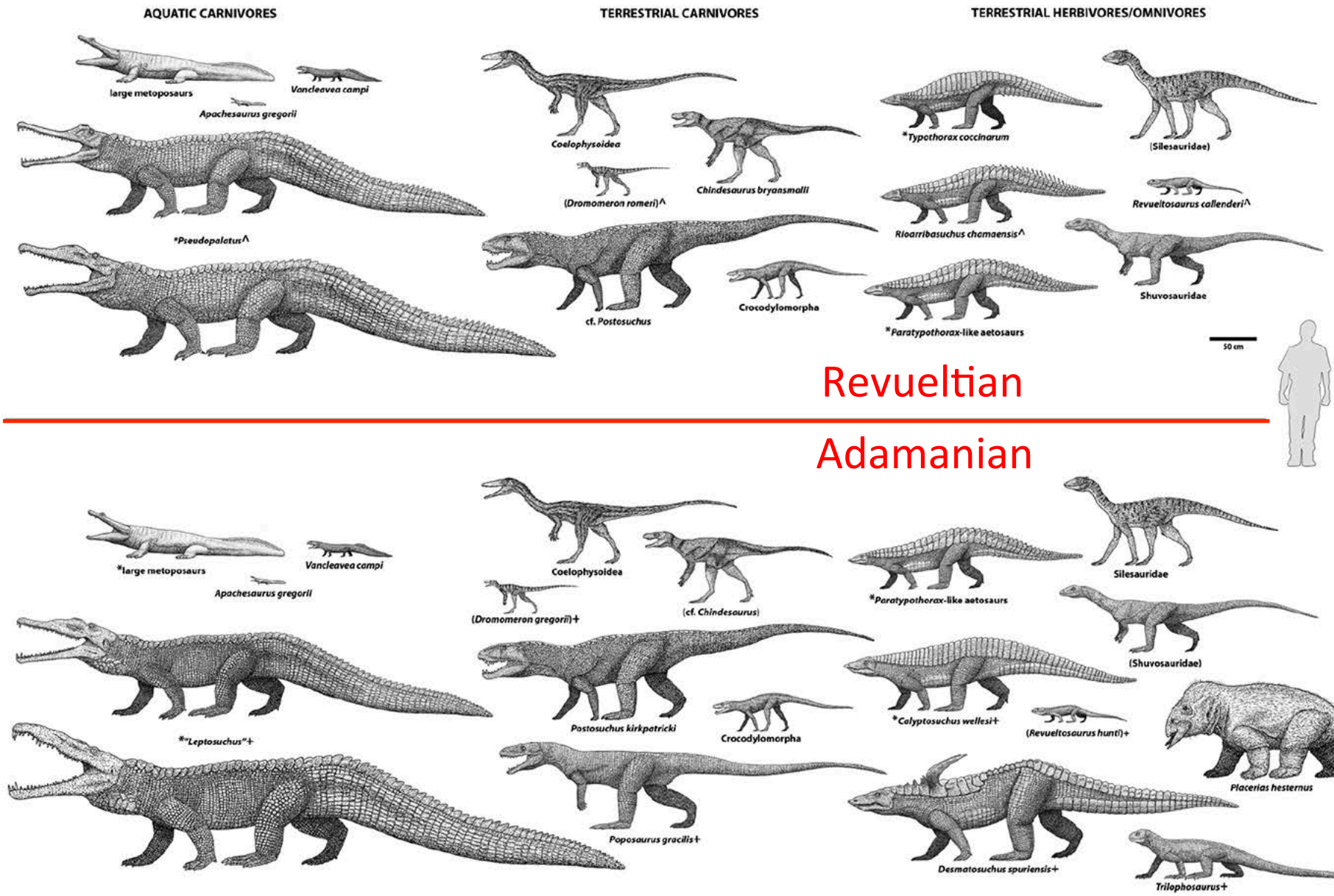
Sonsela and Blue Mesa members of the Chinle Formation

Desmatosuchus





Parker and Martz, 11

Parker and Martz, 11

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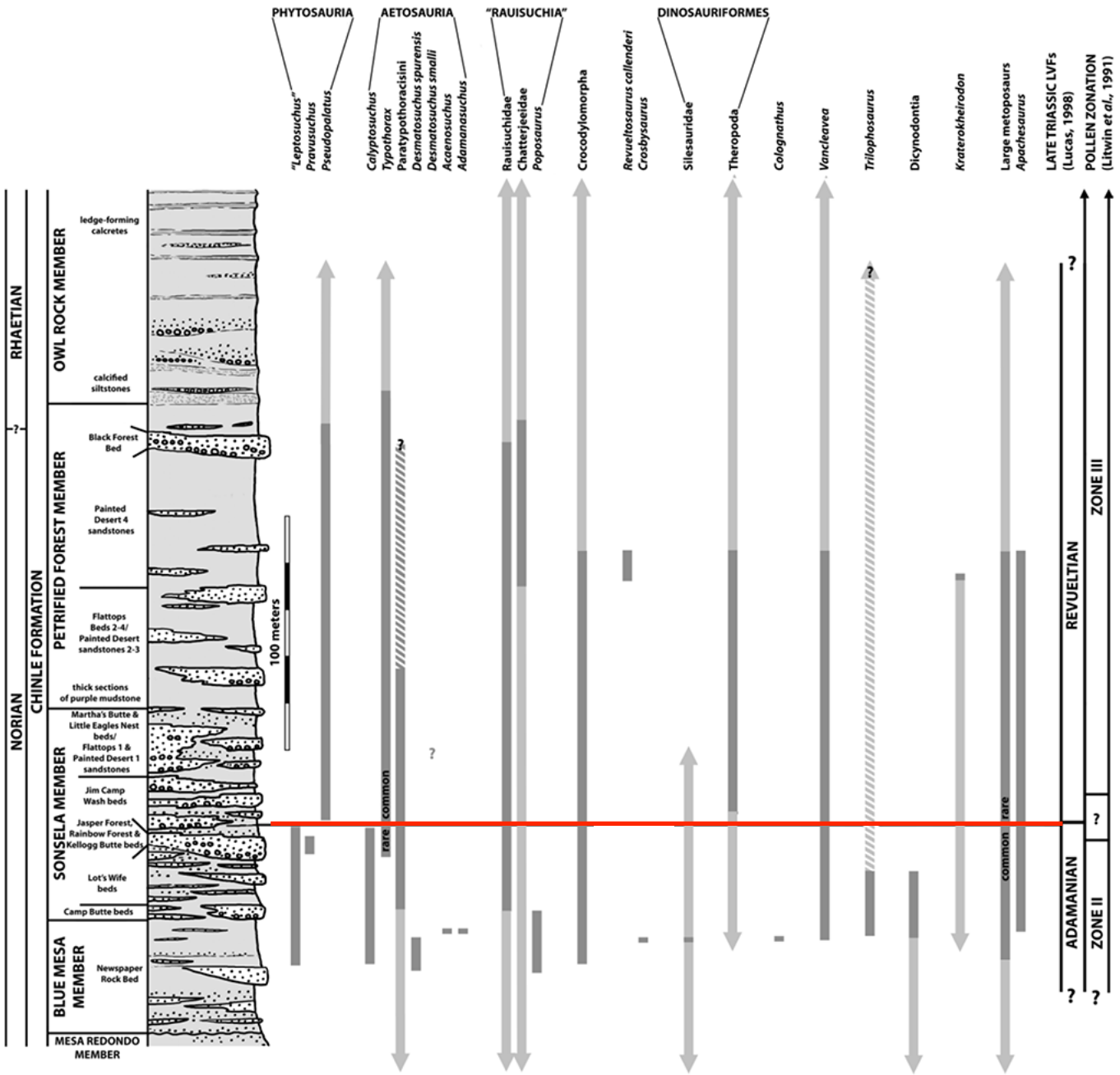
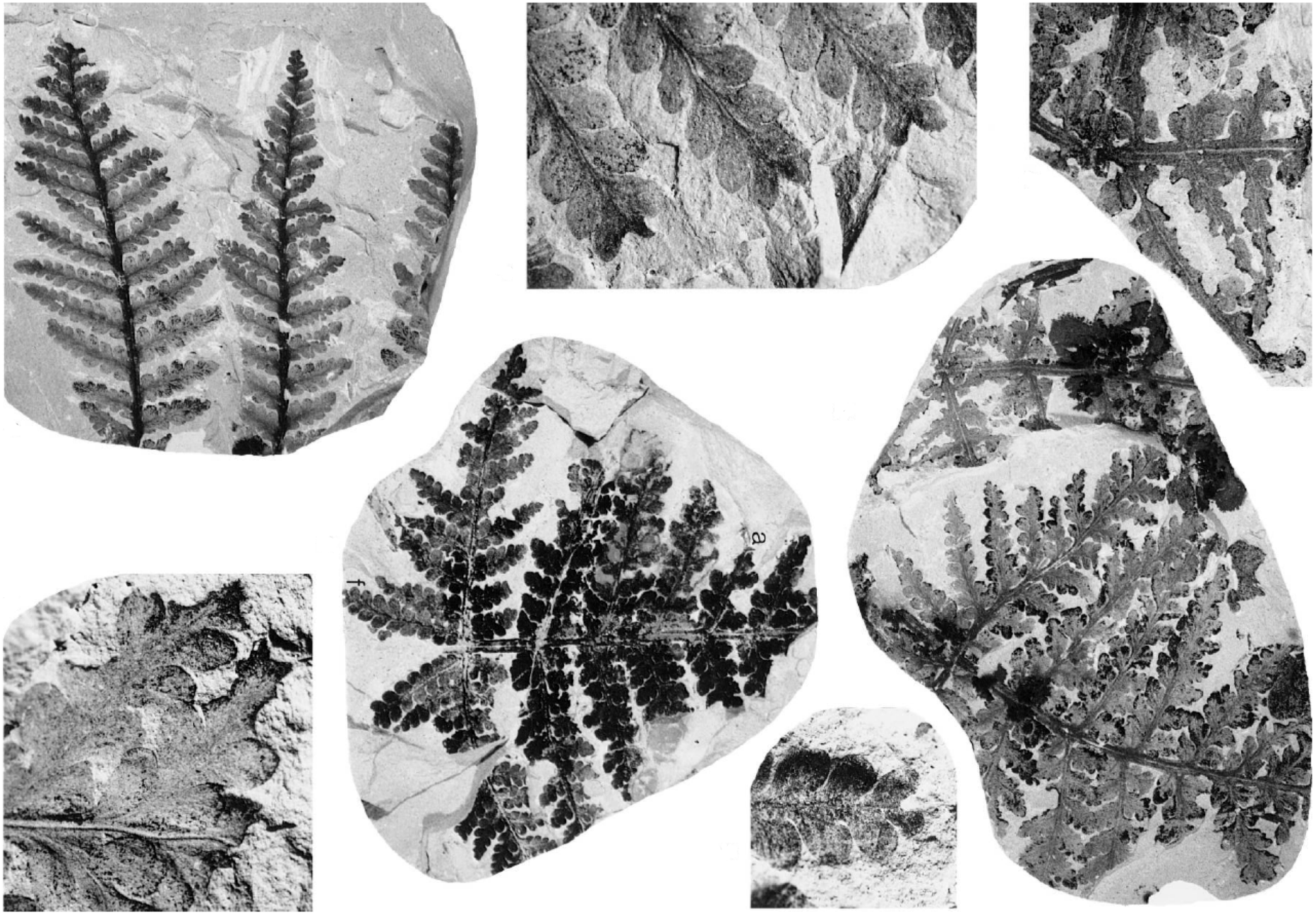
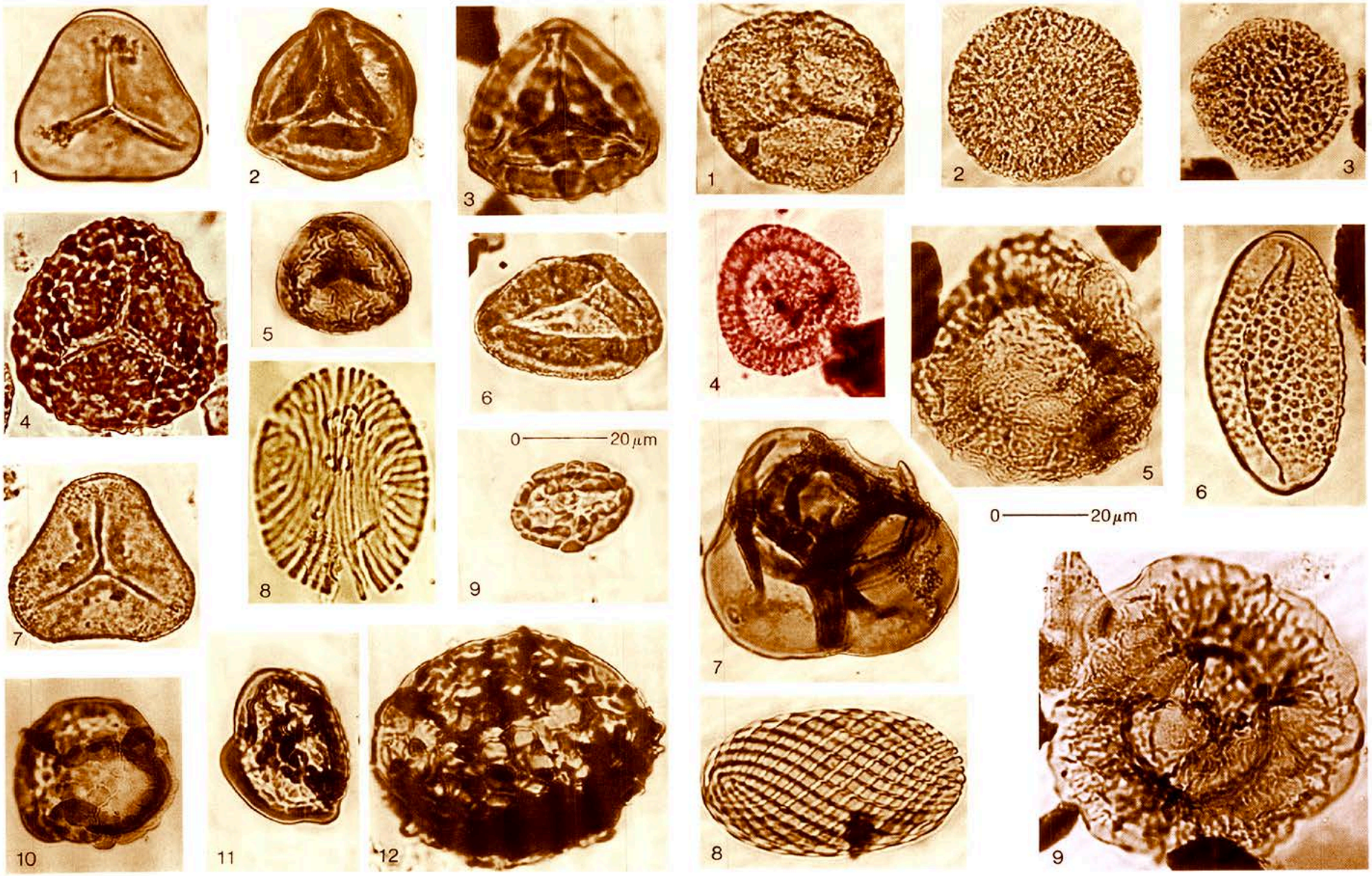


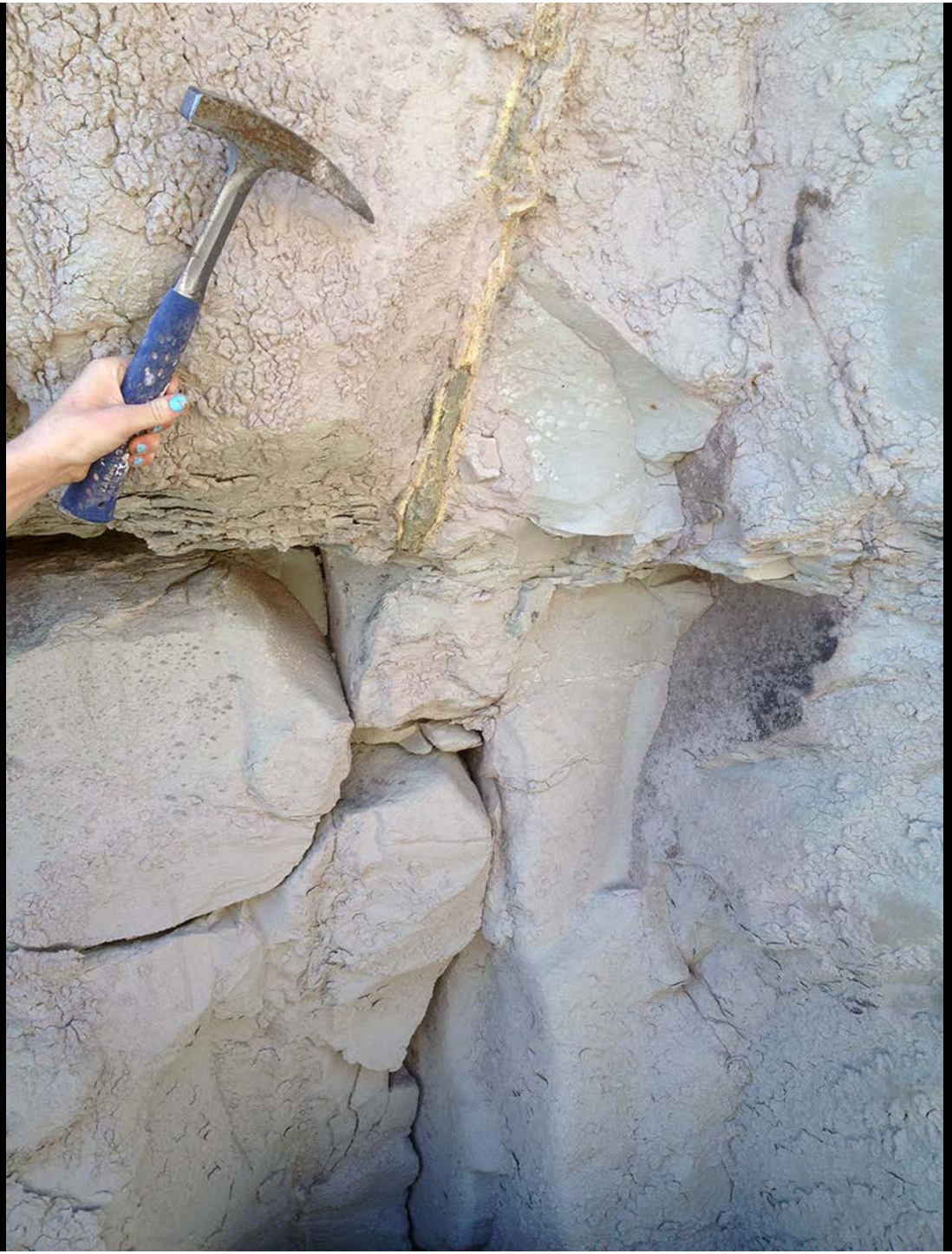


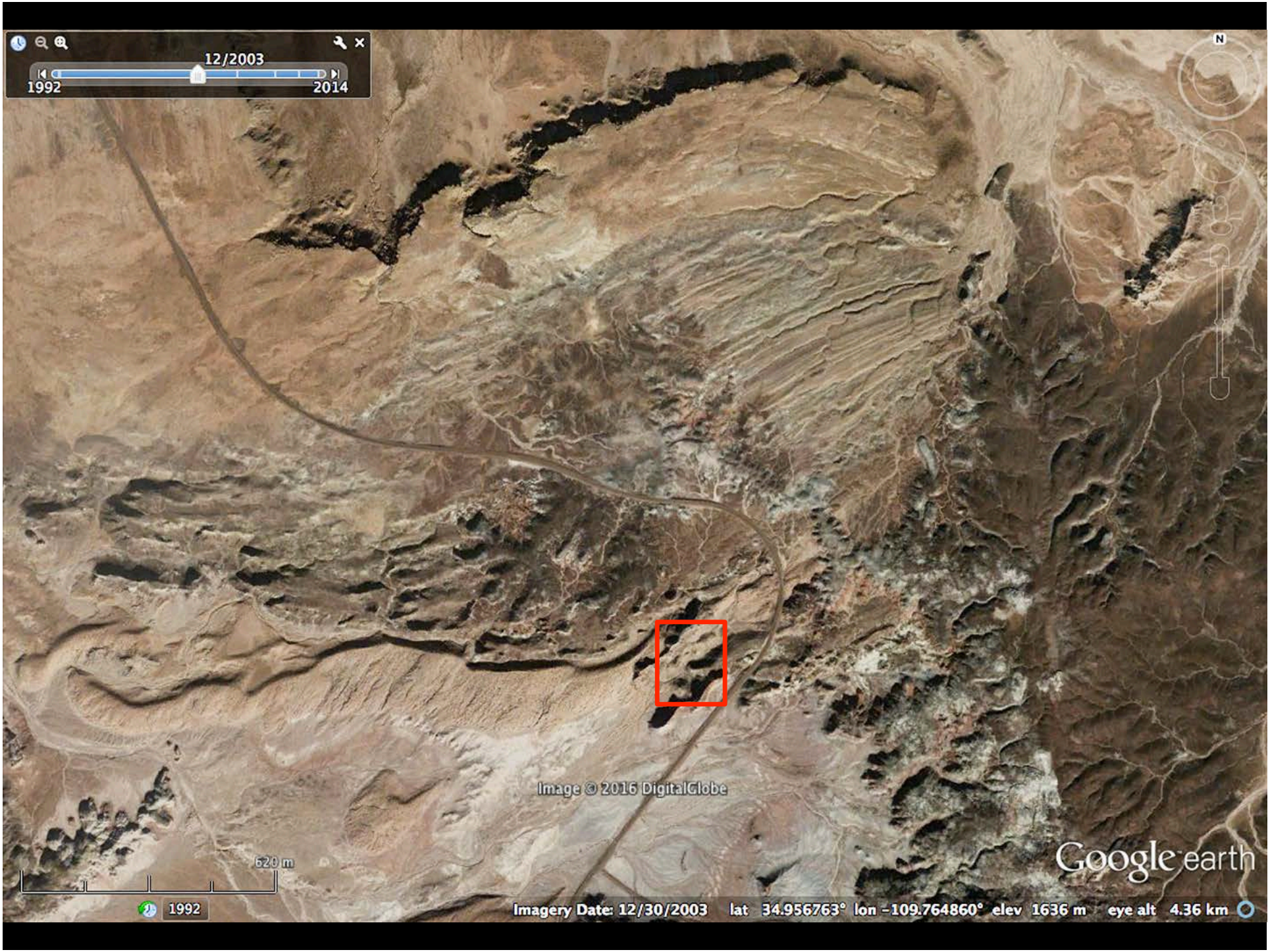
Sphenopteris

Ash, 1999



Litwin et al., 1991

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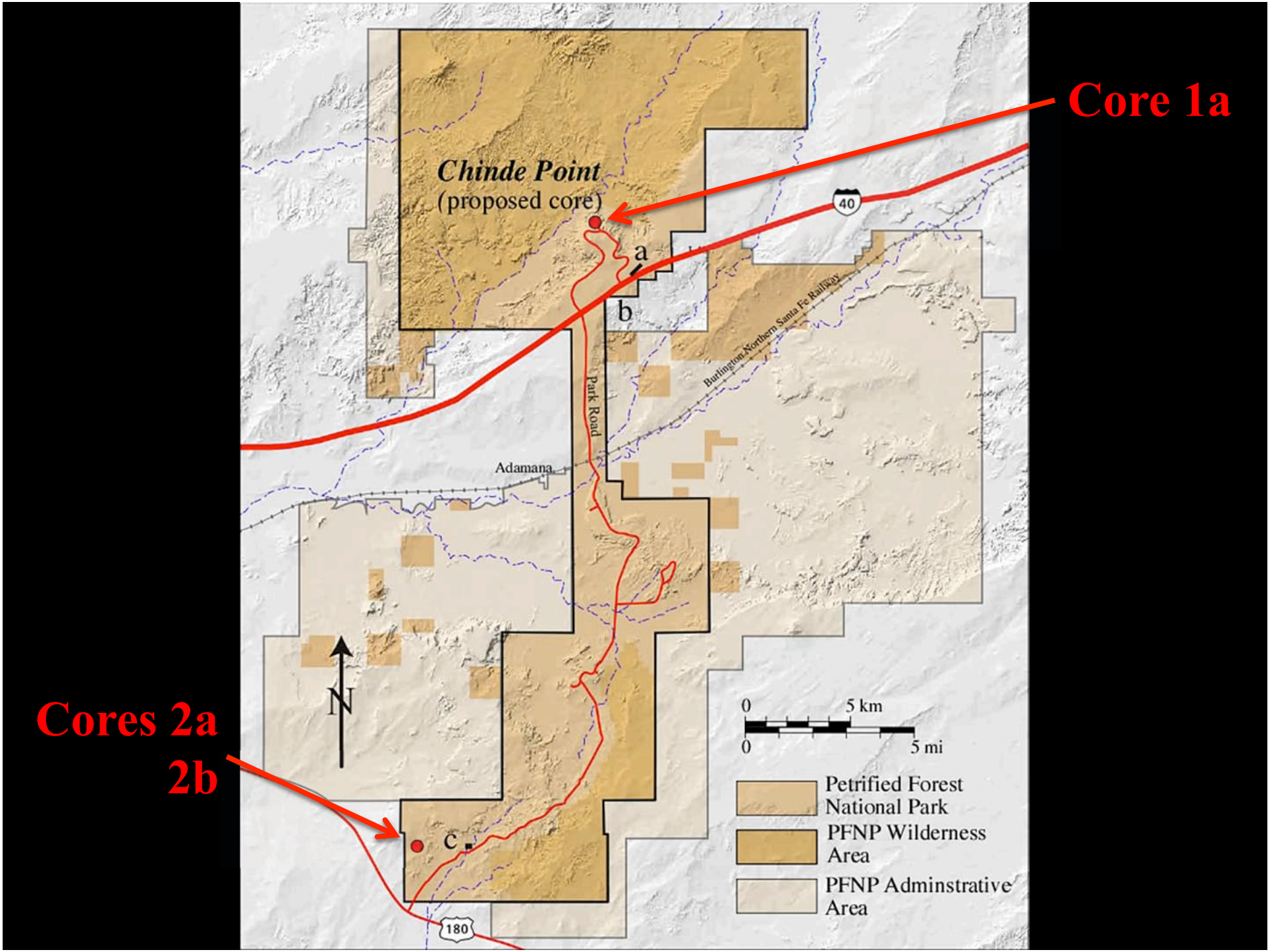
Imagery Date: 12/30/2003 lat 34.956763° lon -109.764860° elev 1636 m eye alt 4.36 km


Core 1a
Chinde Point
(proposed core)
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b
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Cores 2a
2b
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Petrified Forest
National Park
PFNP Wilderness
Area
PFNP Adminstrative
Area

CPCP : Phase I, Petrified Forest Core

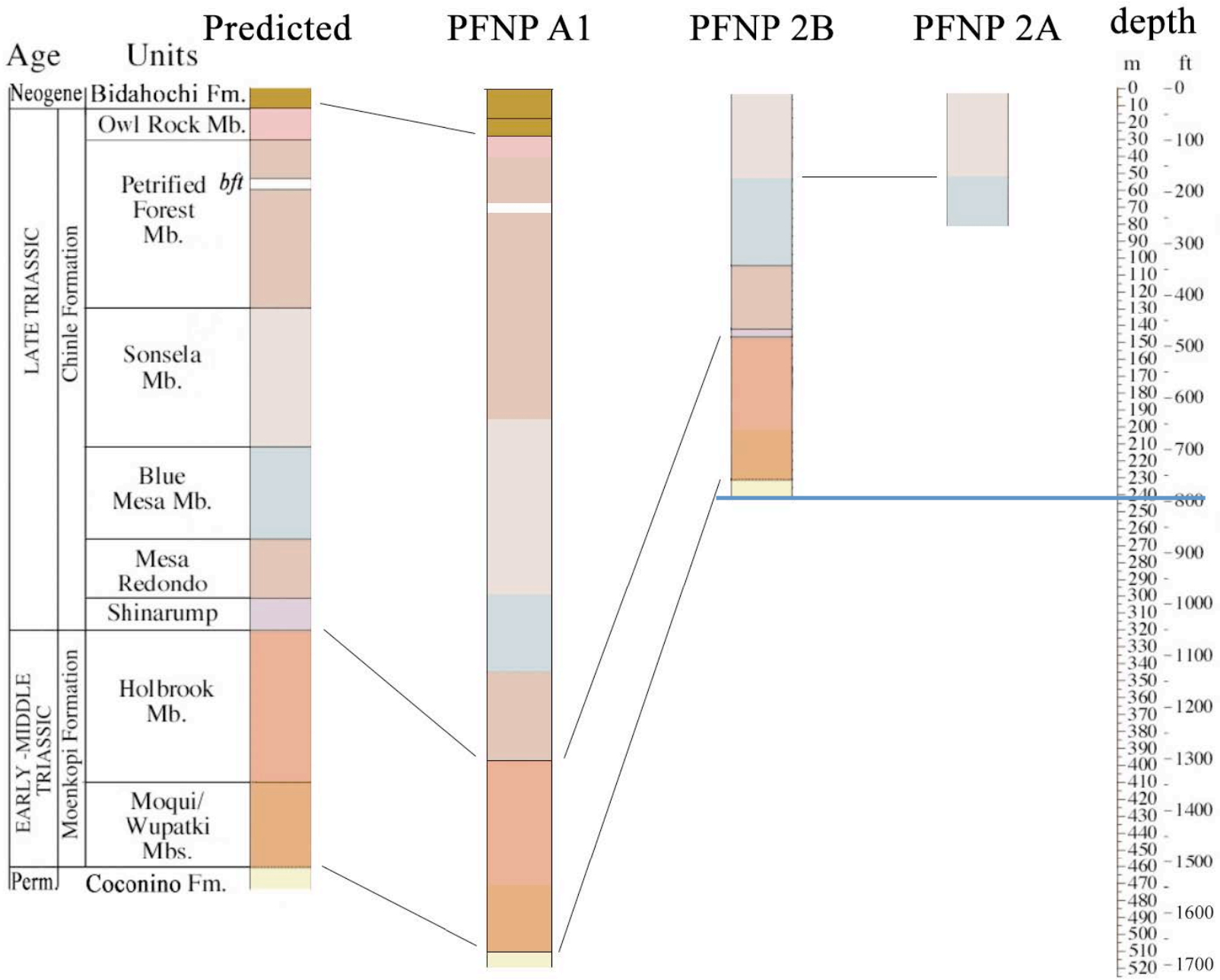
Chinde Point, Petrified Forest National Park

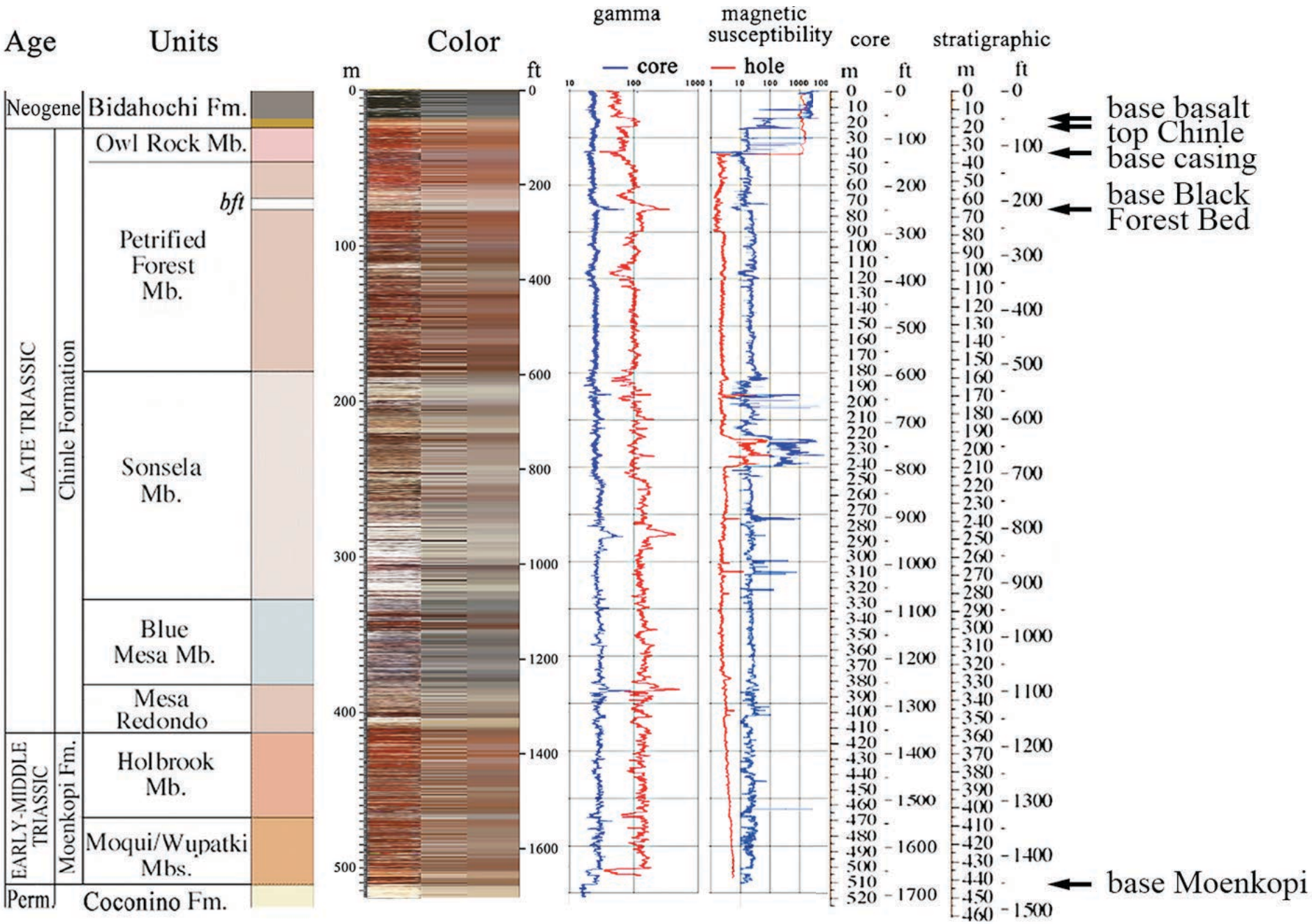
Site 1 - Chinde Point

Site 2 – West "Bone Yard"

Petrified Forest National Park Cores

(angled 30° from vertical)

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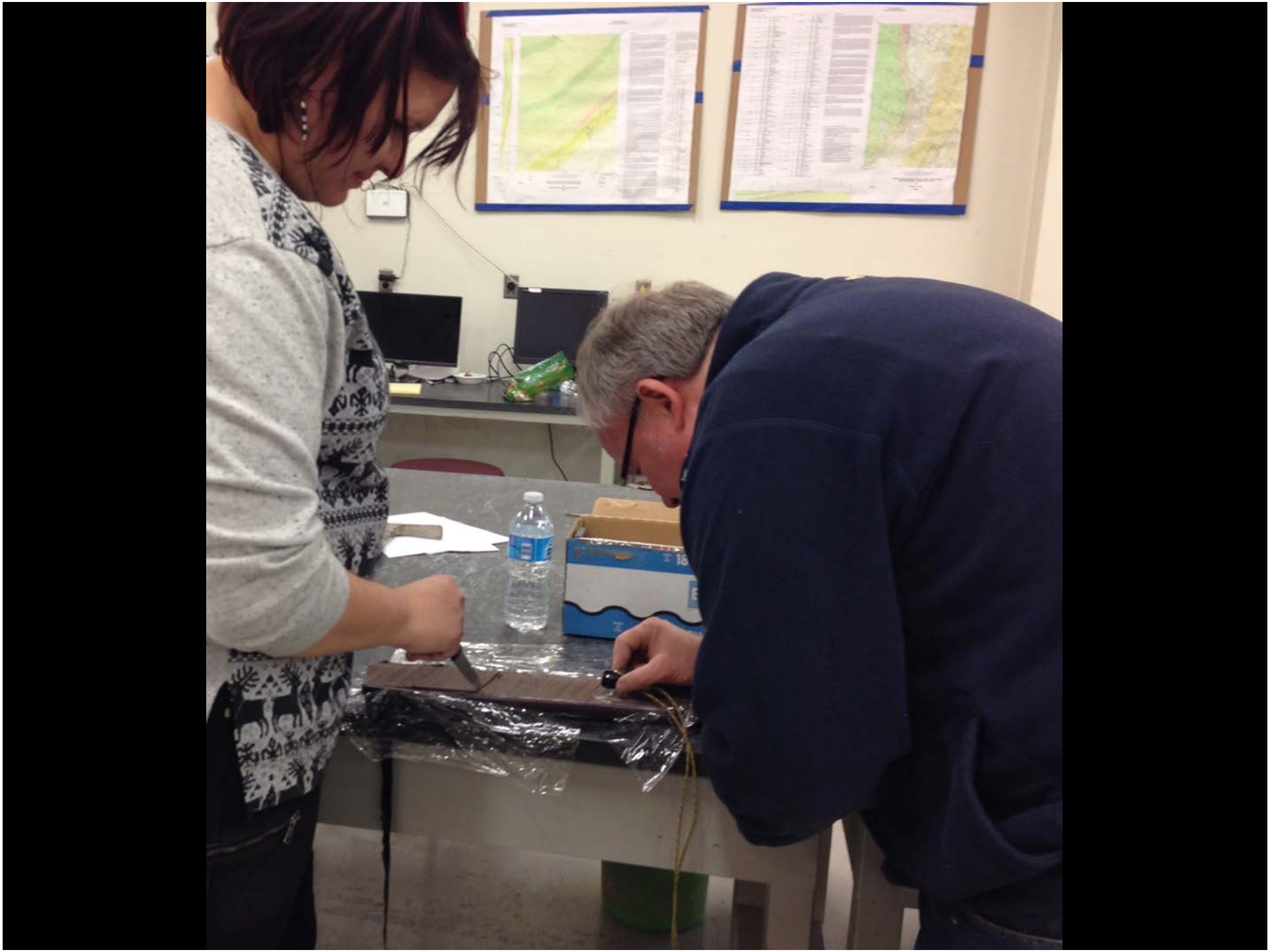
LATE TRIASSIC
Chinle Formation
Owl Rock Mb.
bft
Petrified Forest Mb.
Sonsela Mb.
Blue Mesa Mb.
Mesa Redondo
EARLY-MIDDLE TRIASSIC
Moenkopi Fm.
Holbrook Mb.
Moqui/Wupatki Mbs.
Perm.
Coconino Fm.
base basalt
top Chinle
base casing
base Black Forest Bed
base Moenkopi

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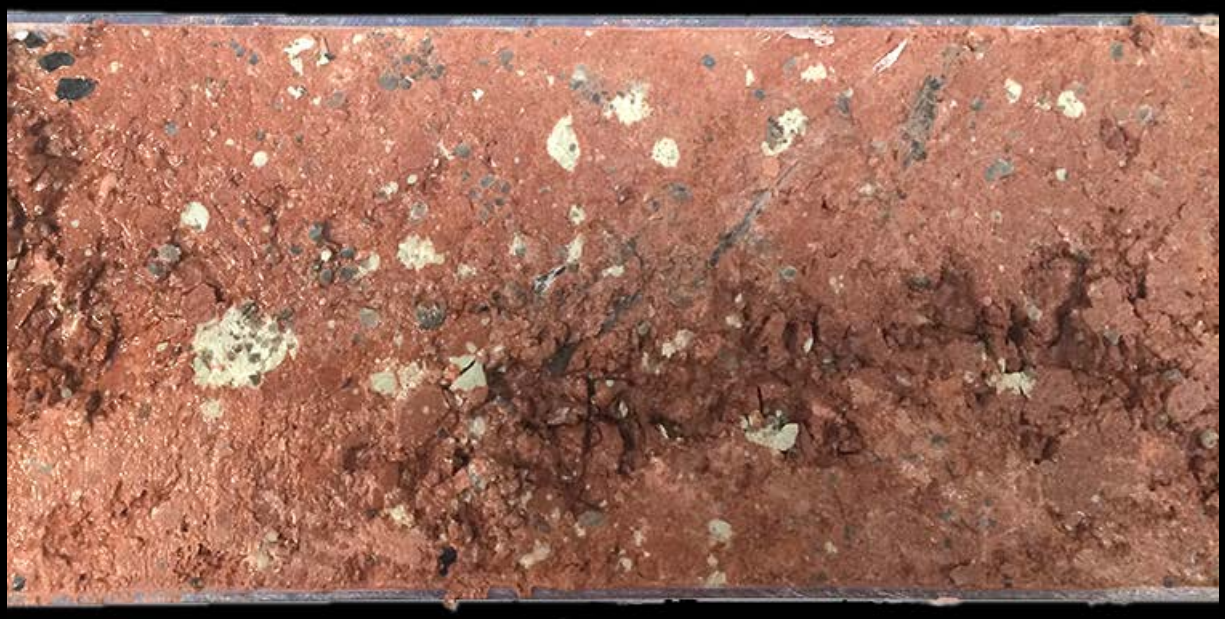
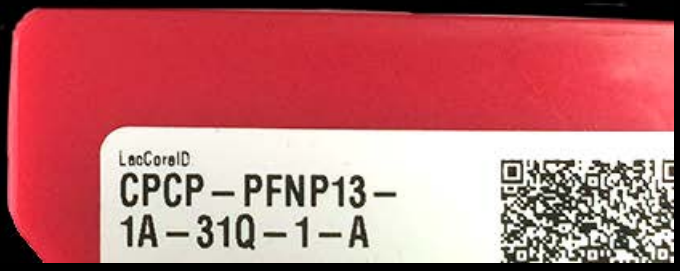
High Resolution X-ray CT Facility

An NSF-Supported Multi-User Facility

The University of Texas at Austin, Department of Geological Sciences

Owl Rock Mb. Cores

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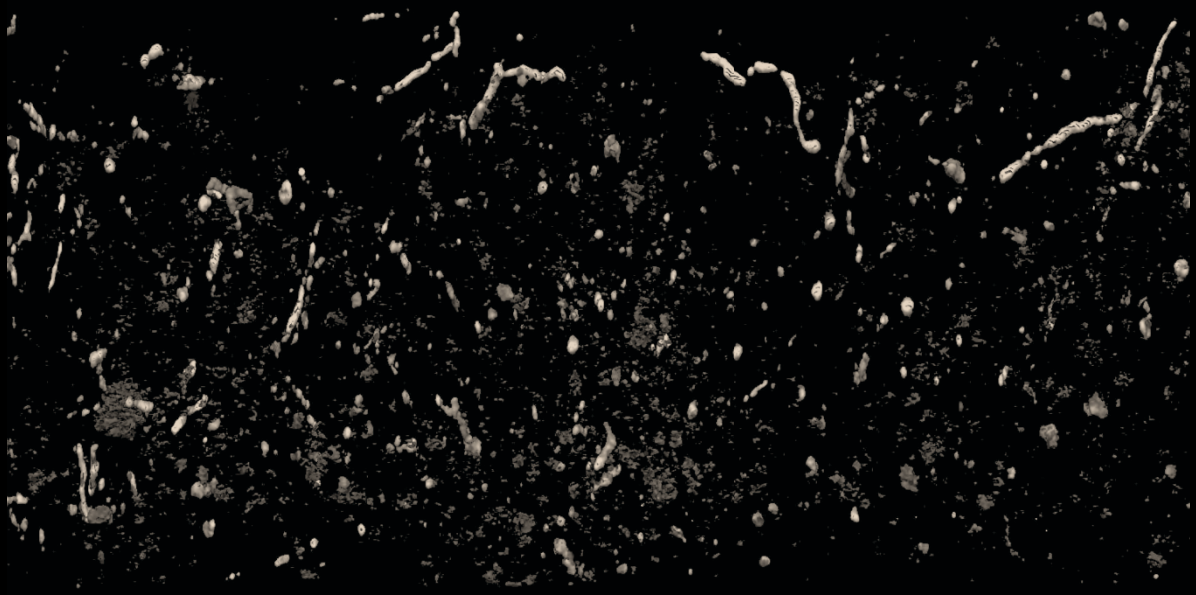

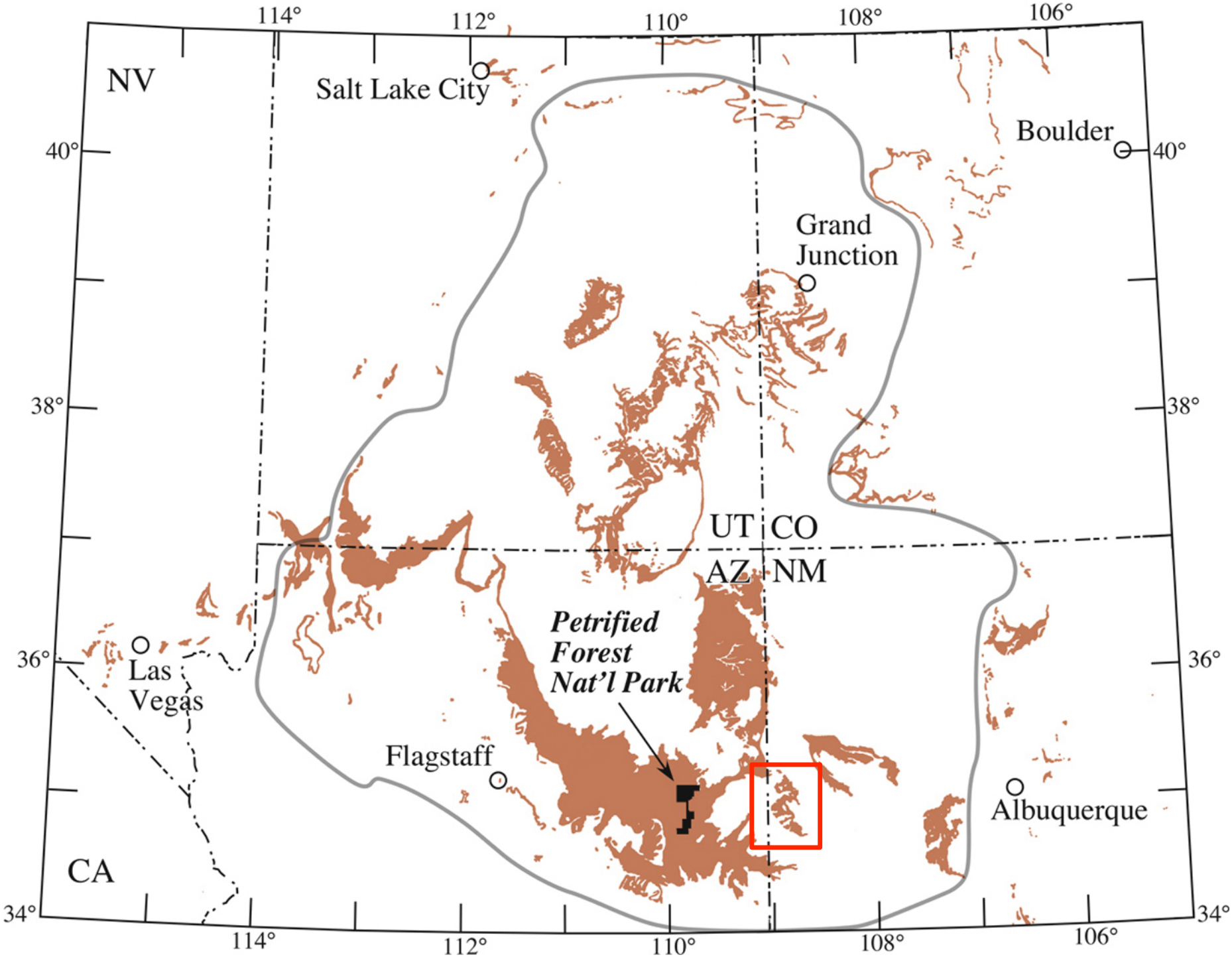
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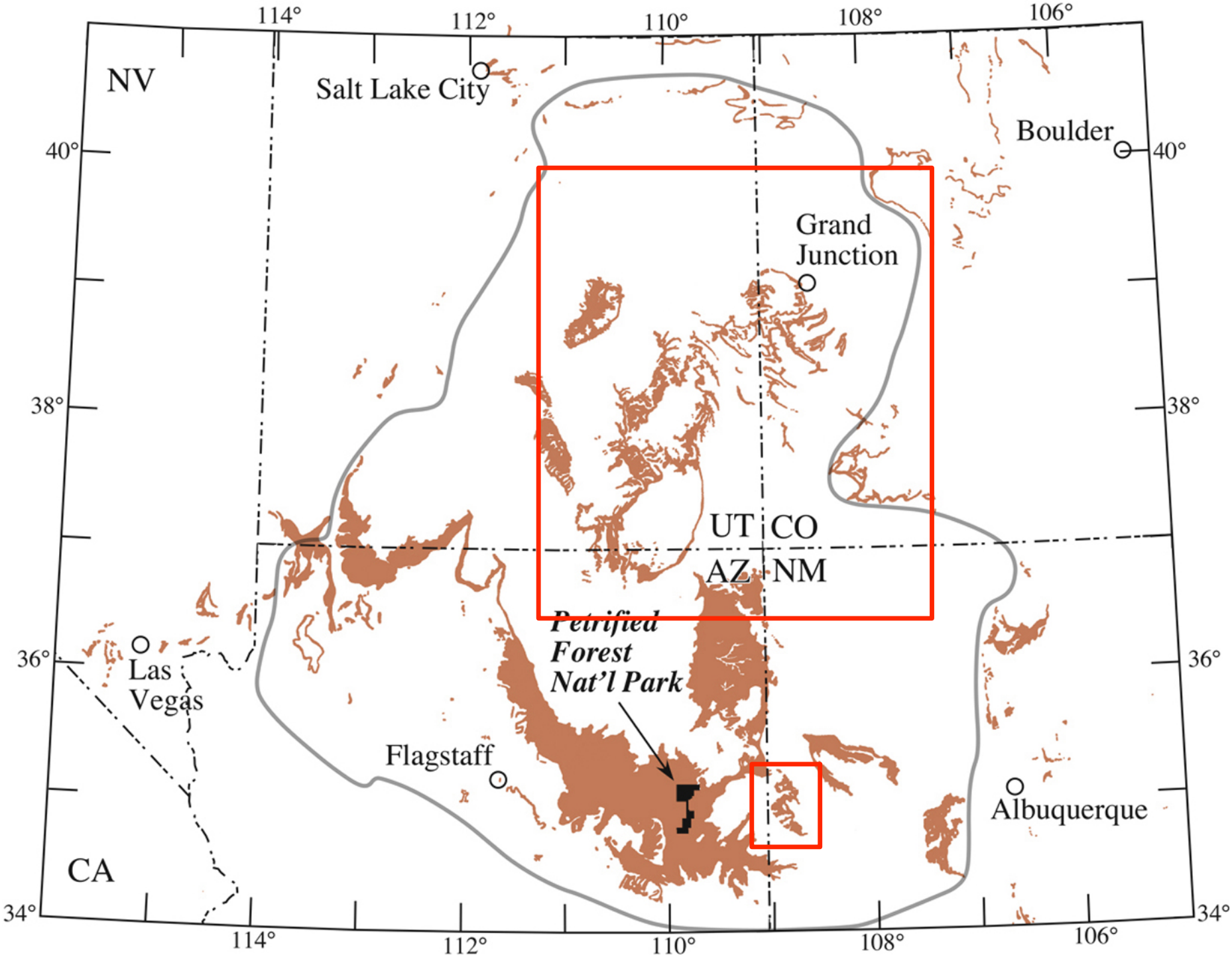
Recumbant fold in Montior Butte facies - Rt. 400 near Fort Wingate. NM

Recumbant fold in Montior Butte facies - Rt. 400 near Fort Wingate. NM

Profound unconformity within Chinle with overlying Ciniza Lake Bed

Profound unconformity within Chinle with overlying Ciniza Lake Bed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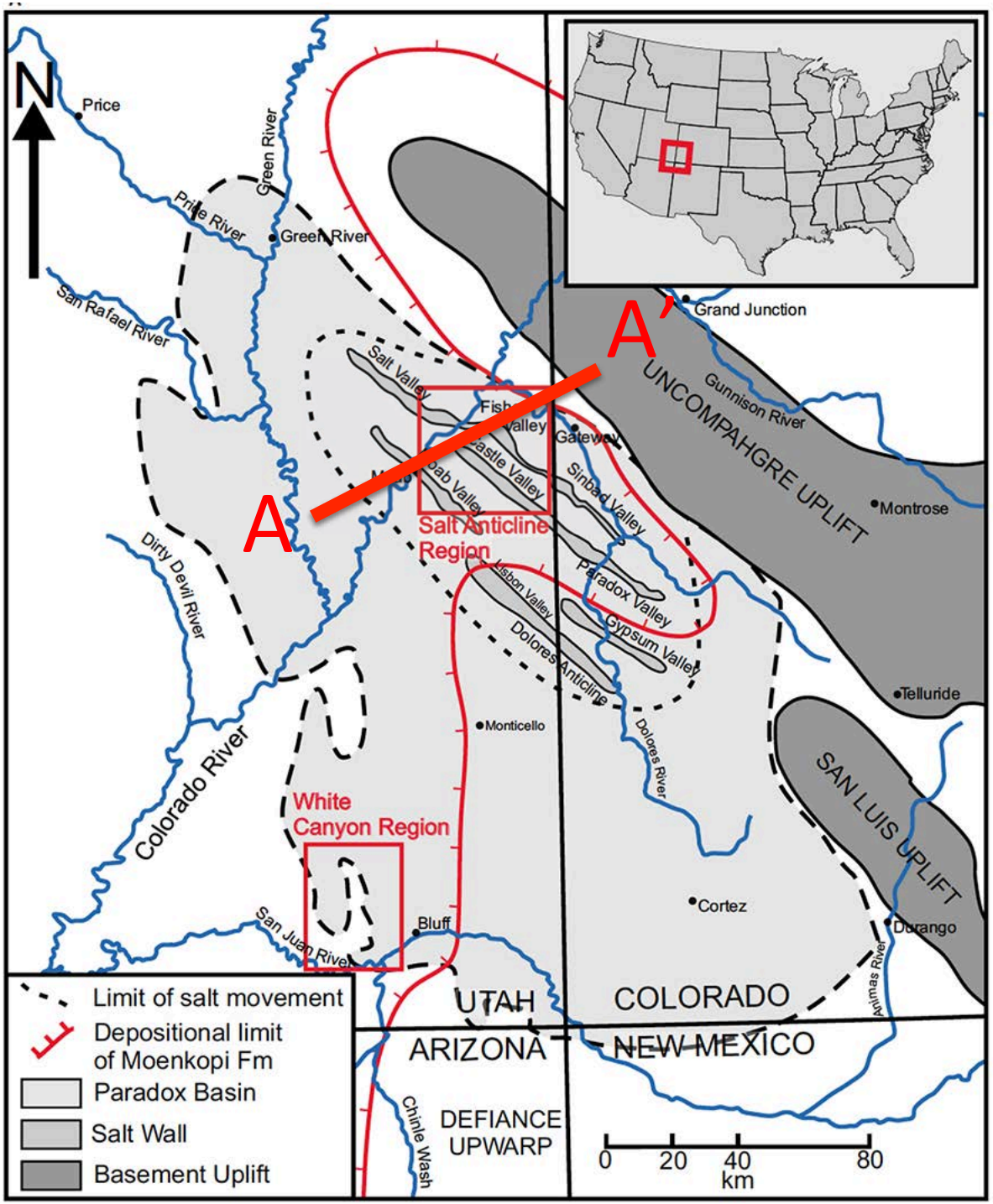
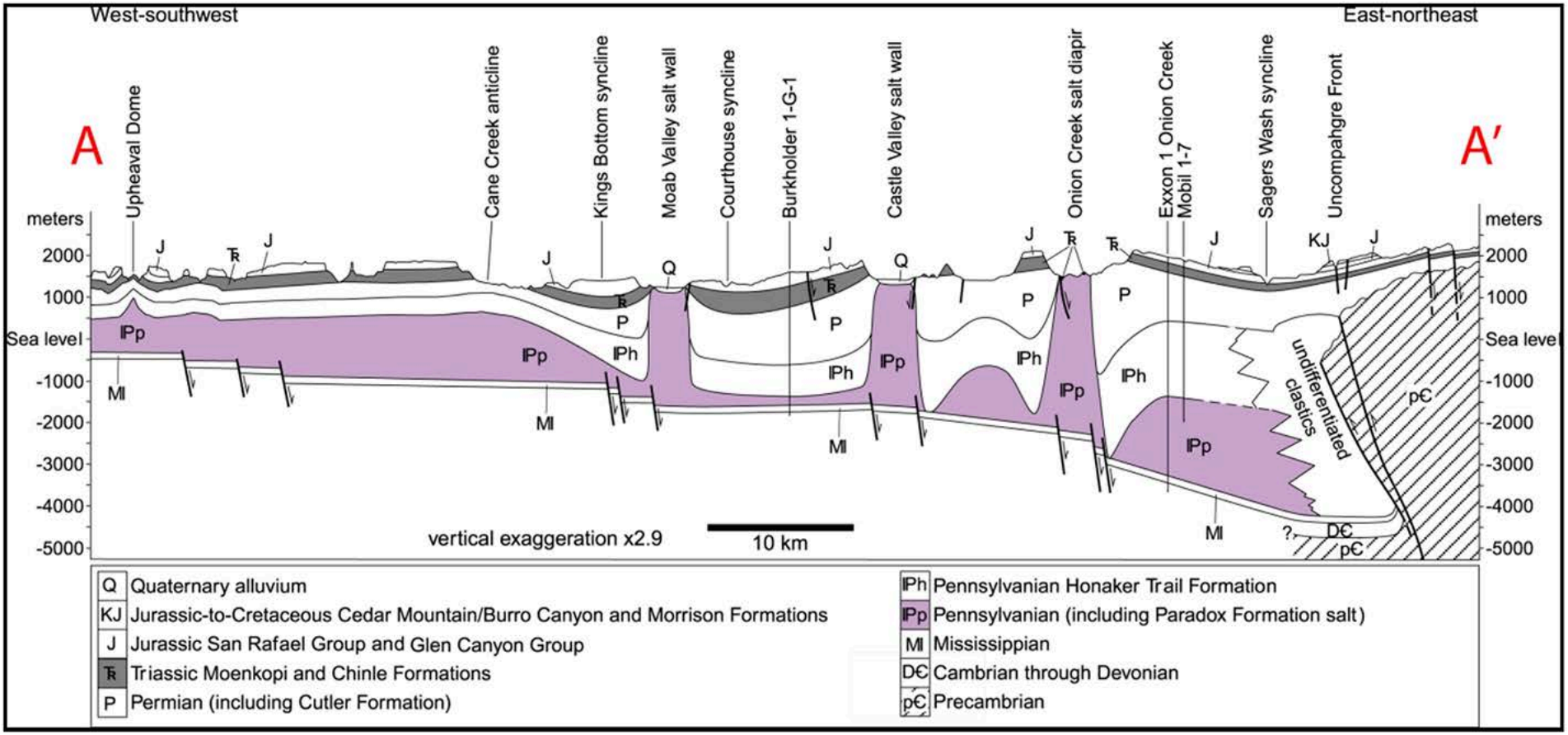
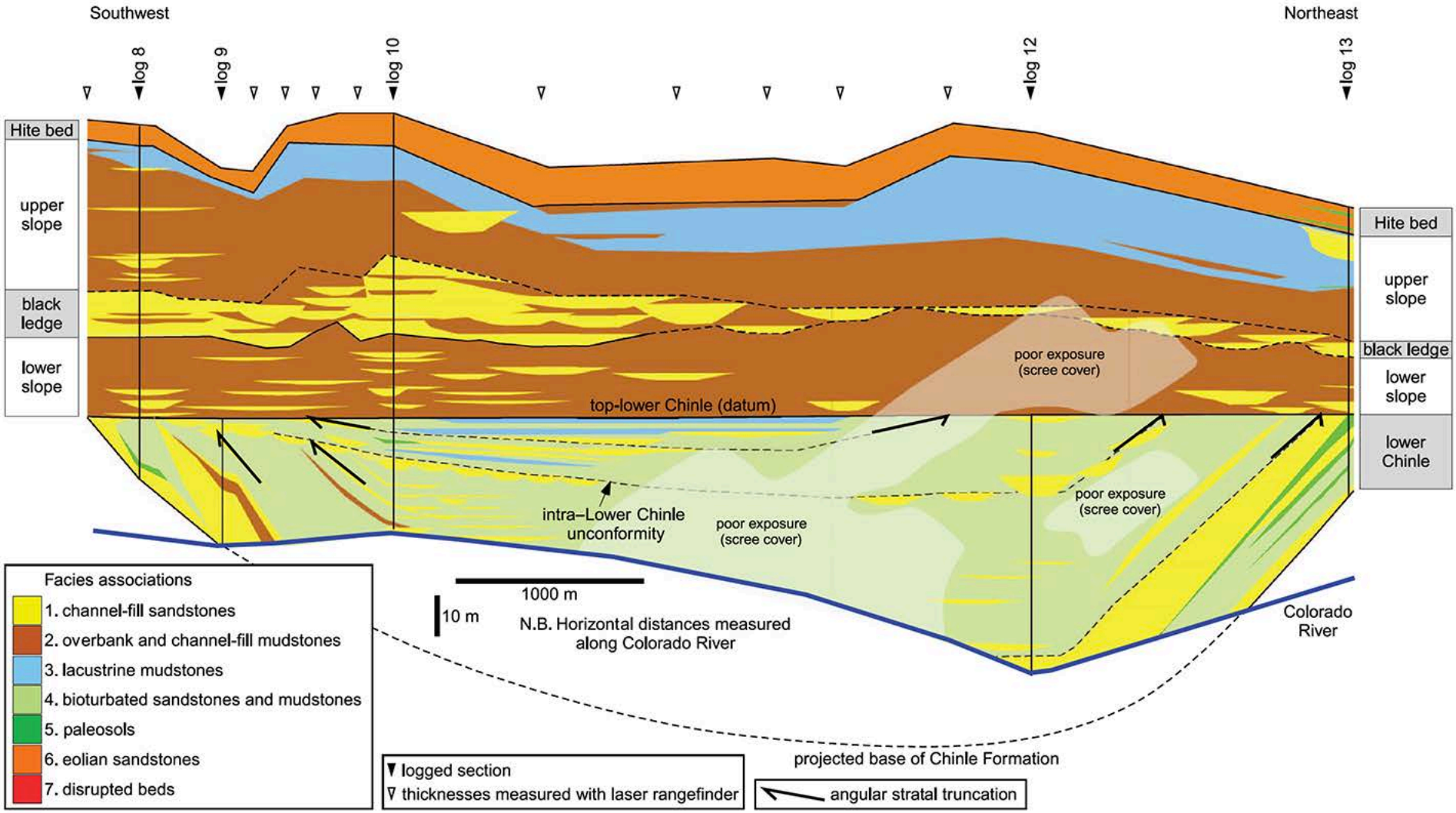


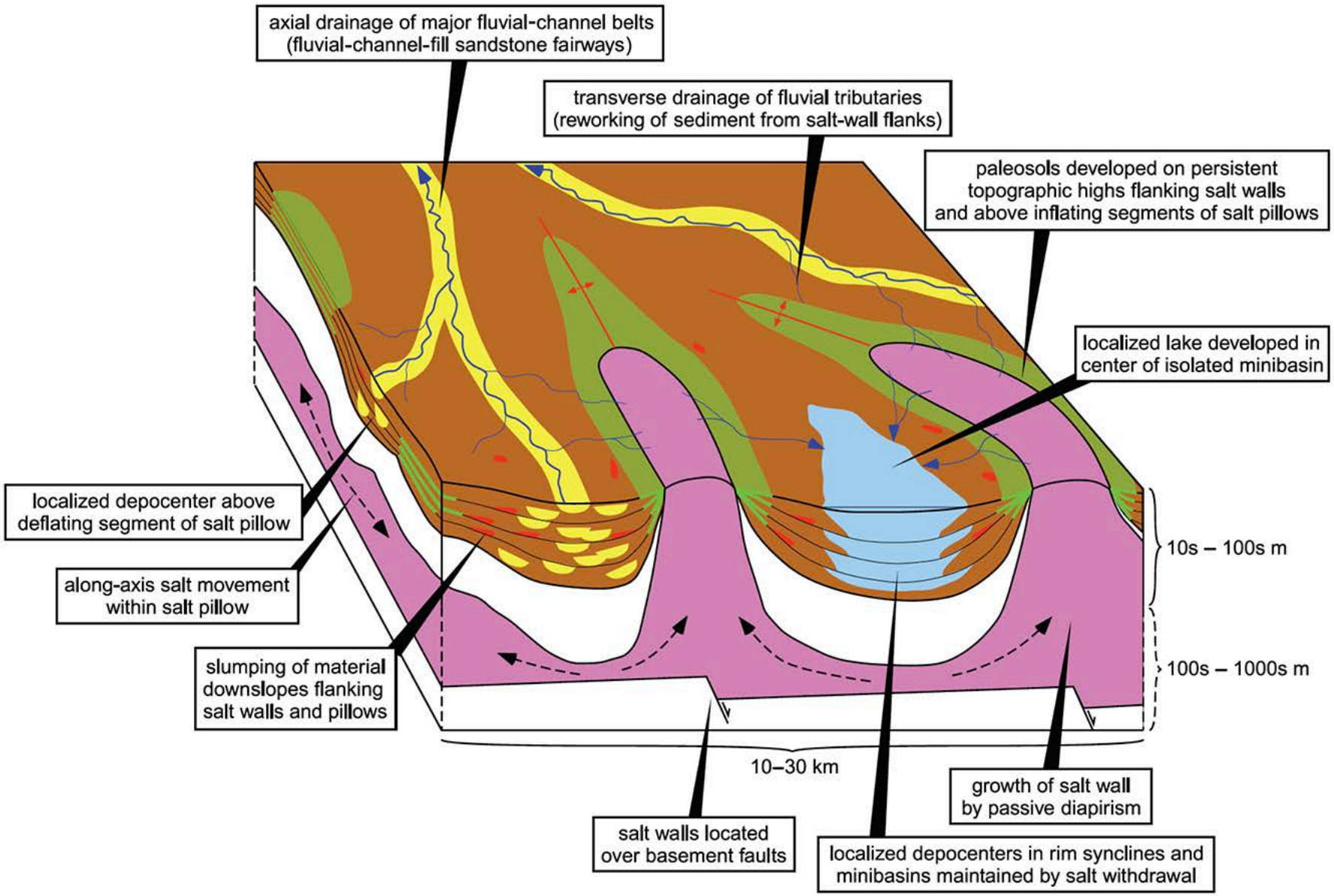
BANHAM & MOUNTNEY, 2013



Foster, 2015, after Trudgill (2004) and Mathews et al. (2007).



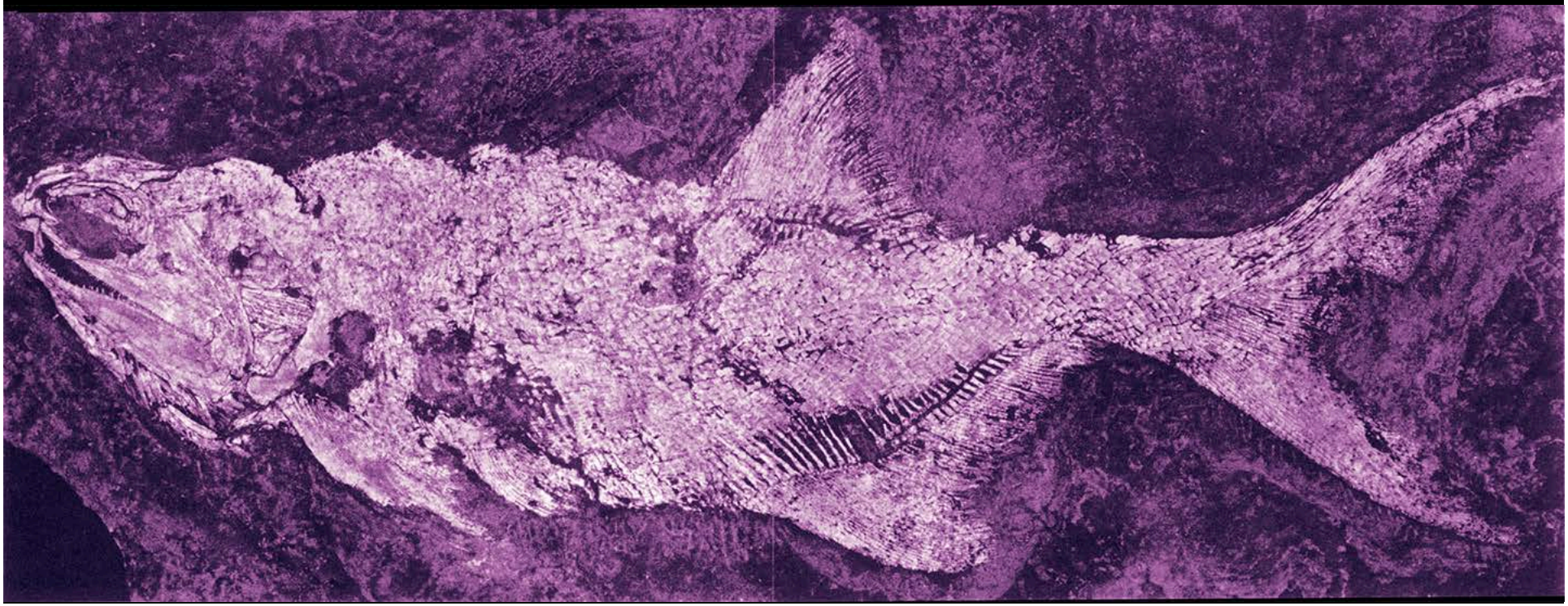
Matthews et al., 2007

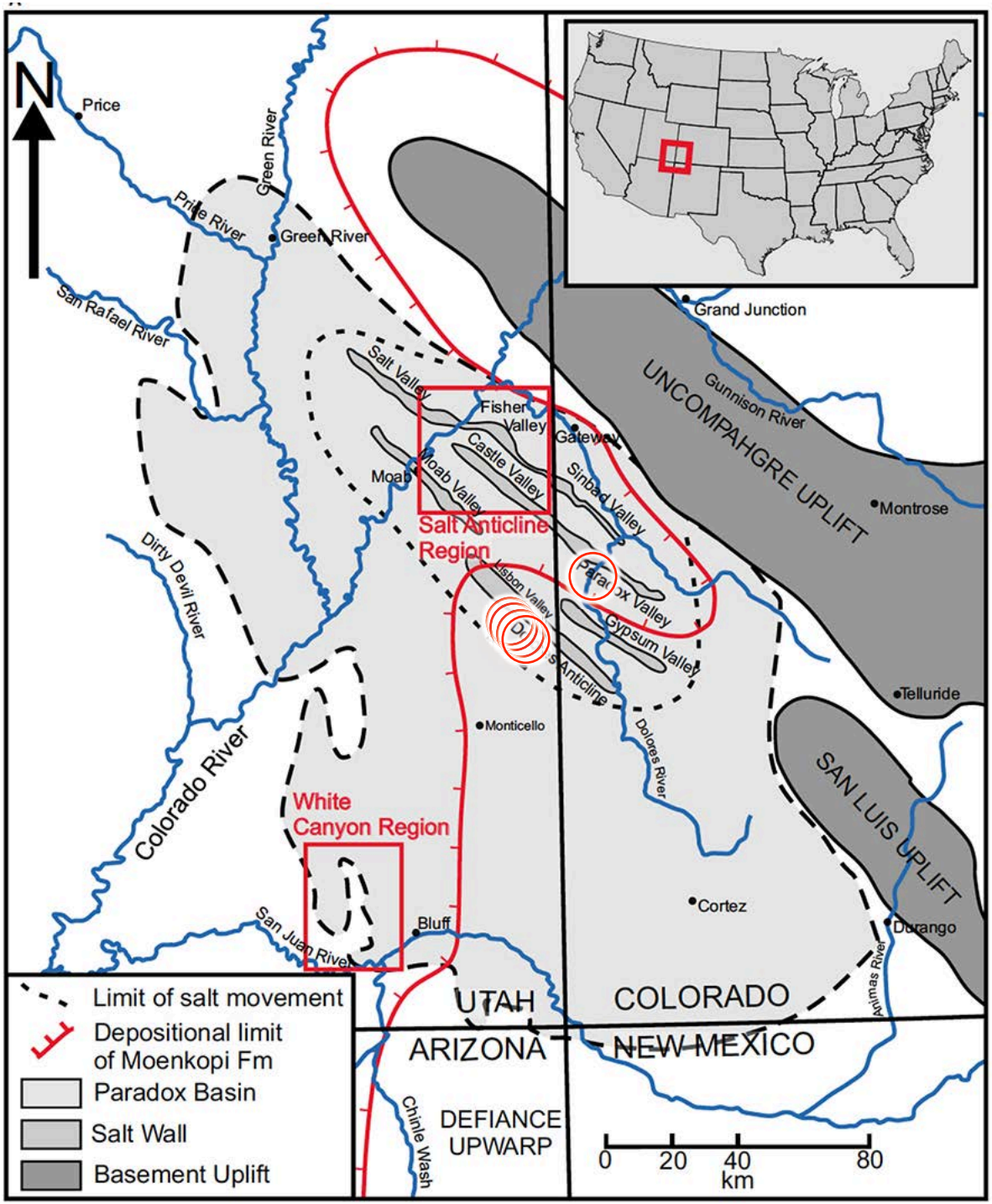


Matthews et al., 2007

S. Gibson: https://biodiversity.ku.edu/node/1431

Schaeffer, 1967





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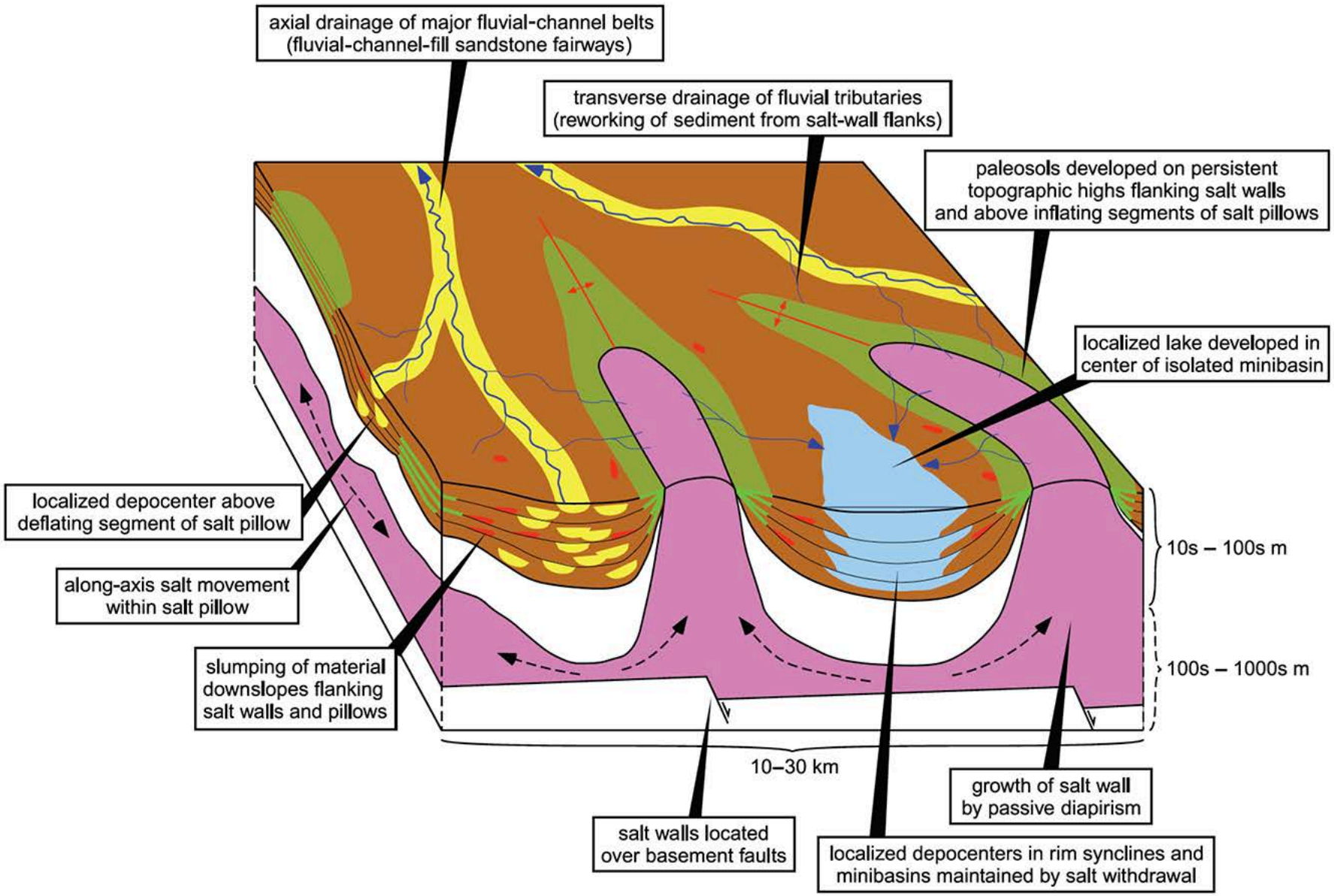
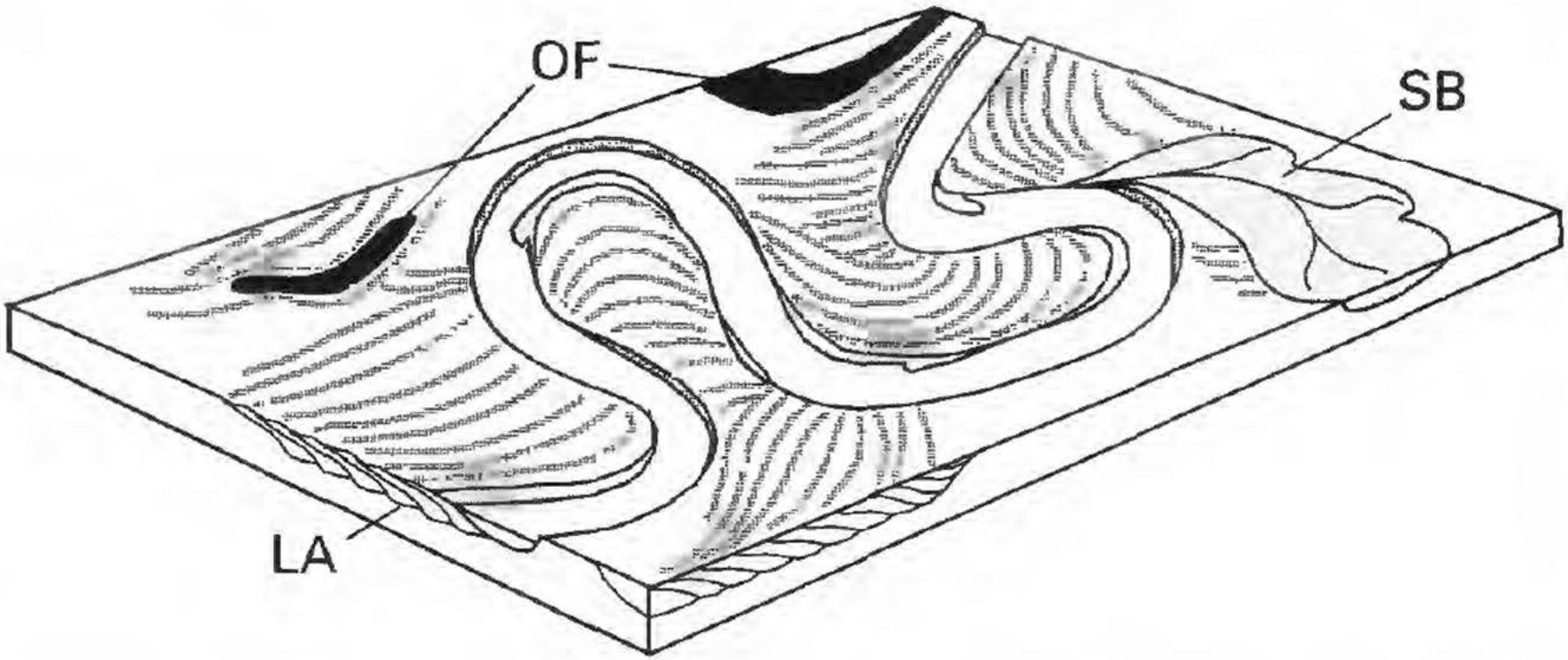
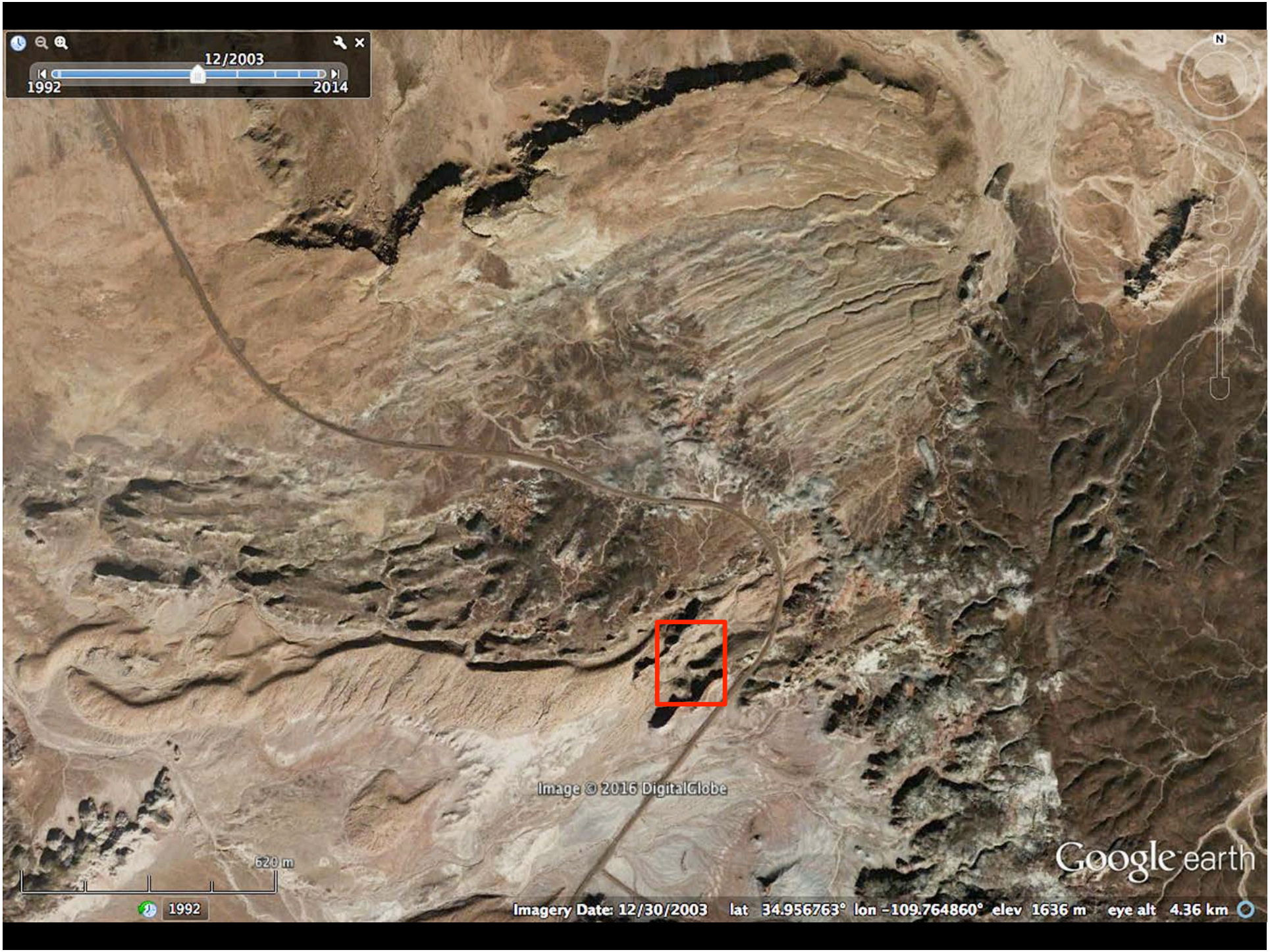


Matthews et al., 2007



Hazel, 1994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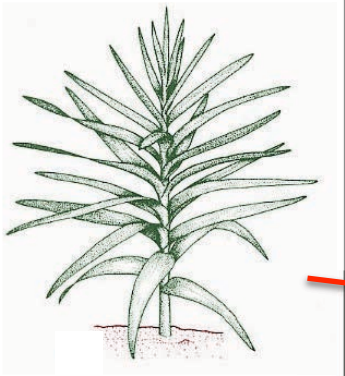
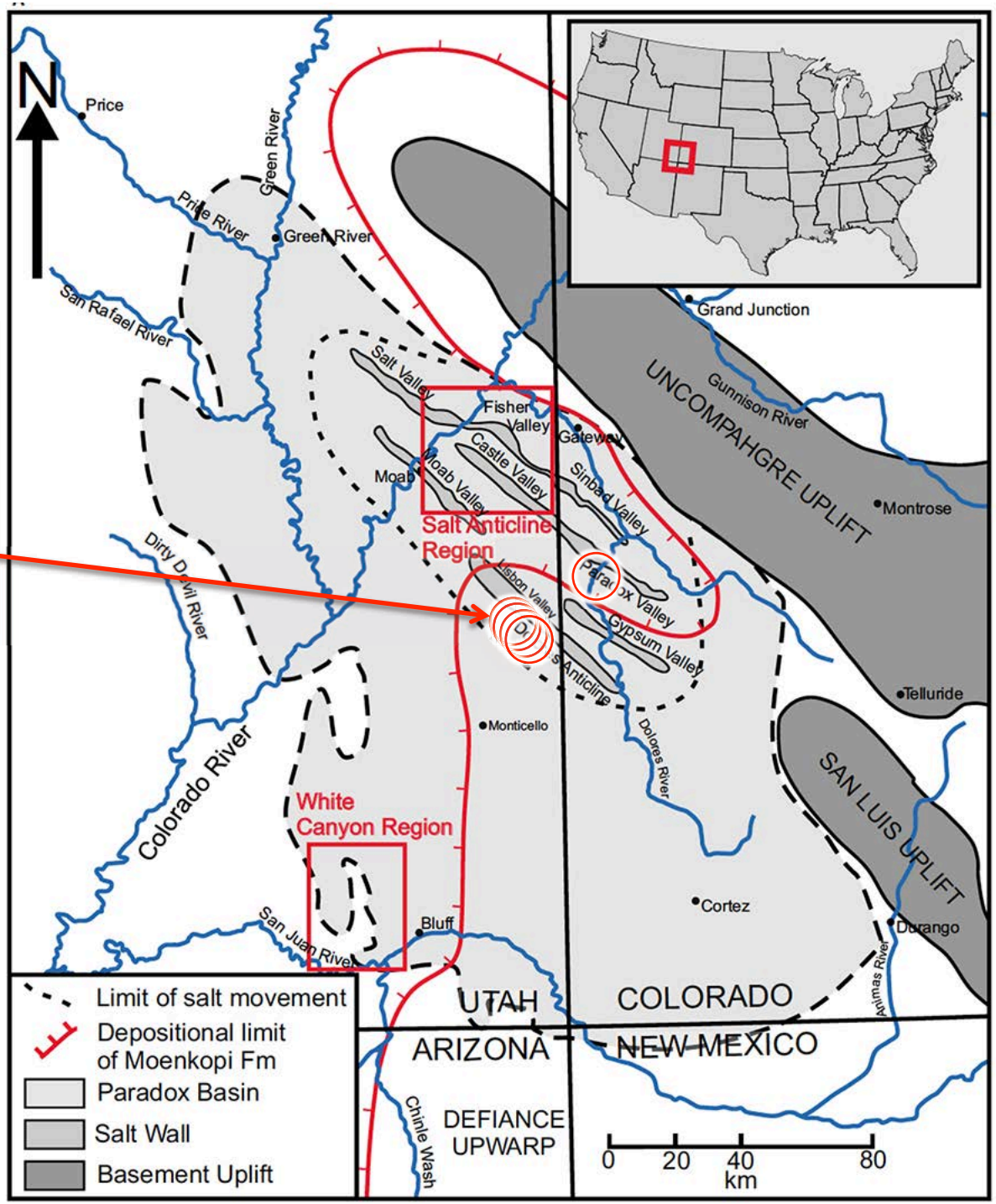
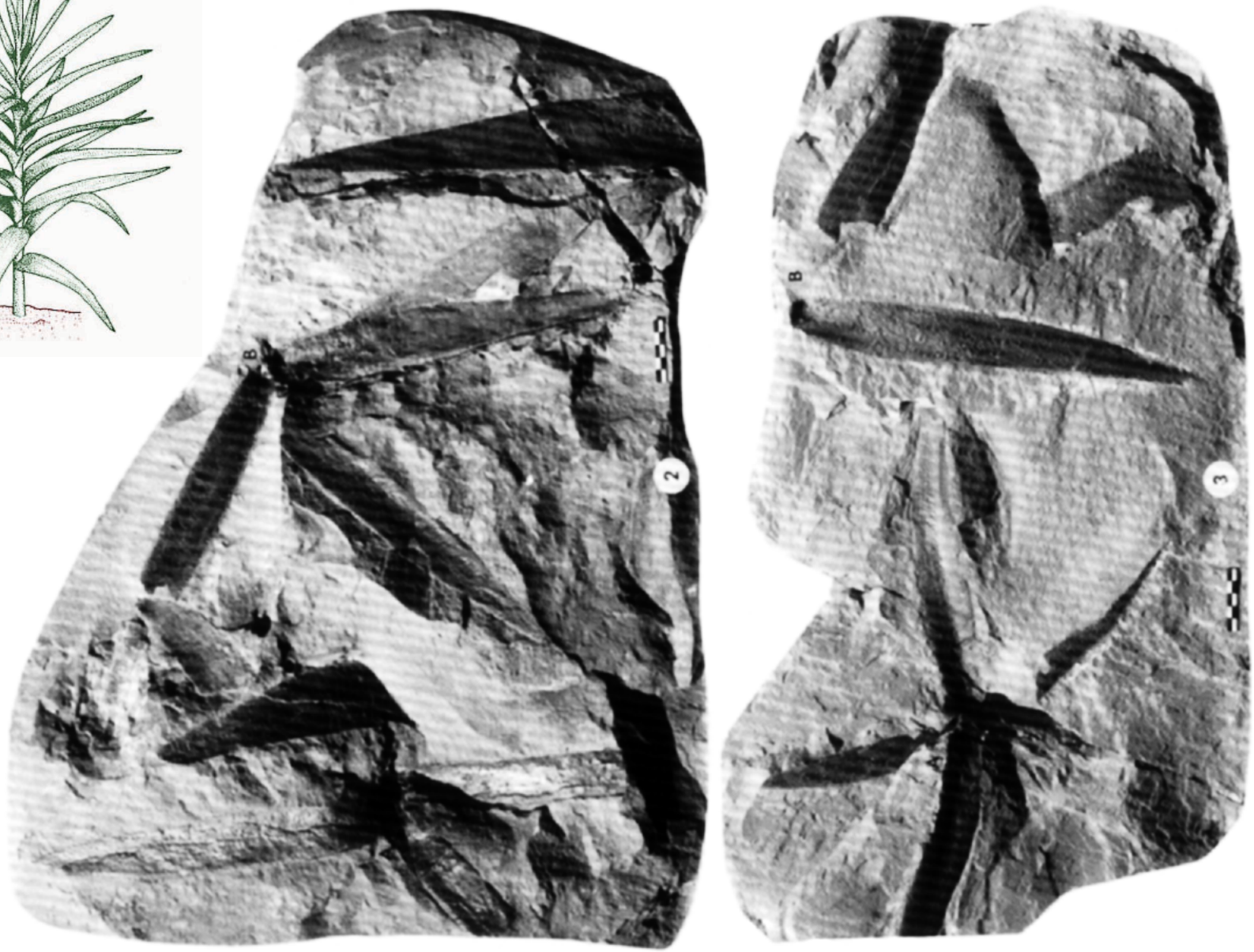


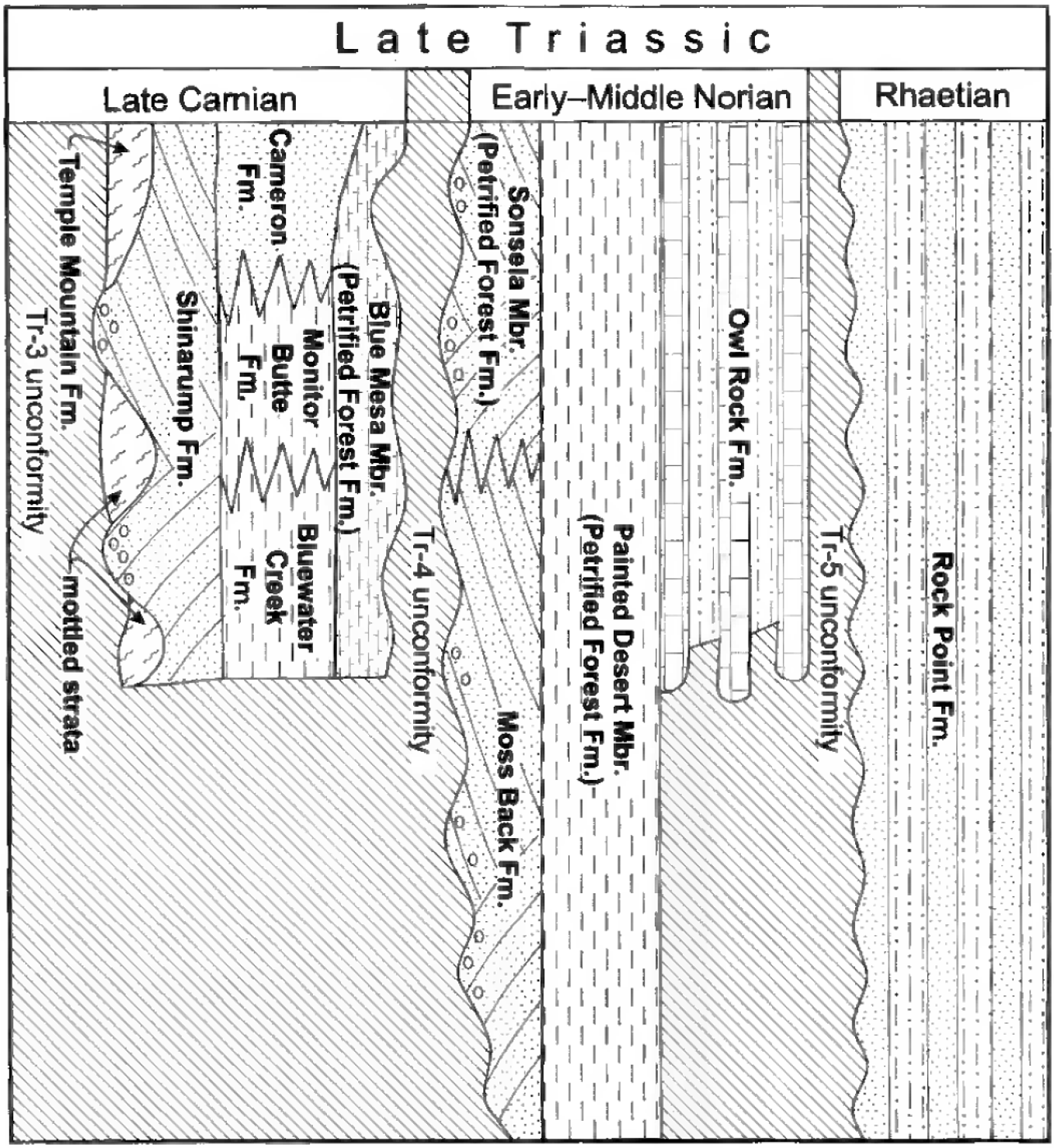


BANHAM & MOUNTNEY, 2013

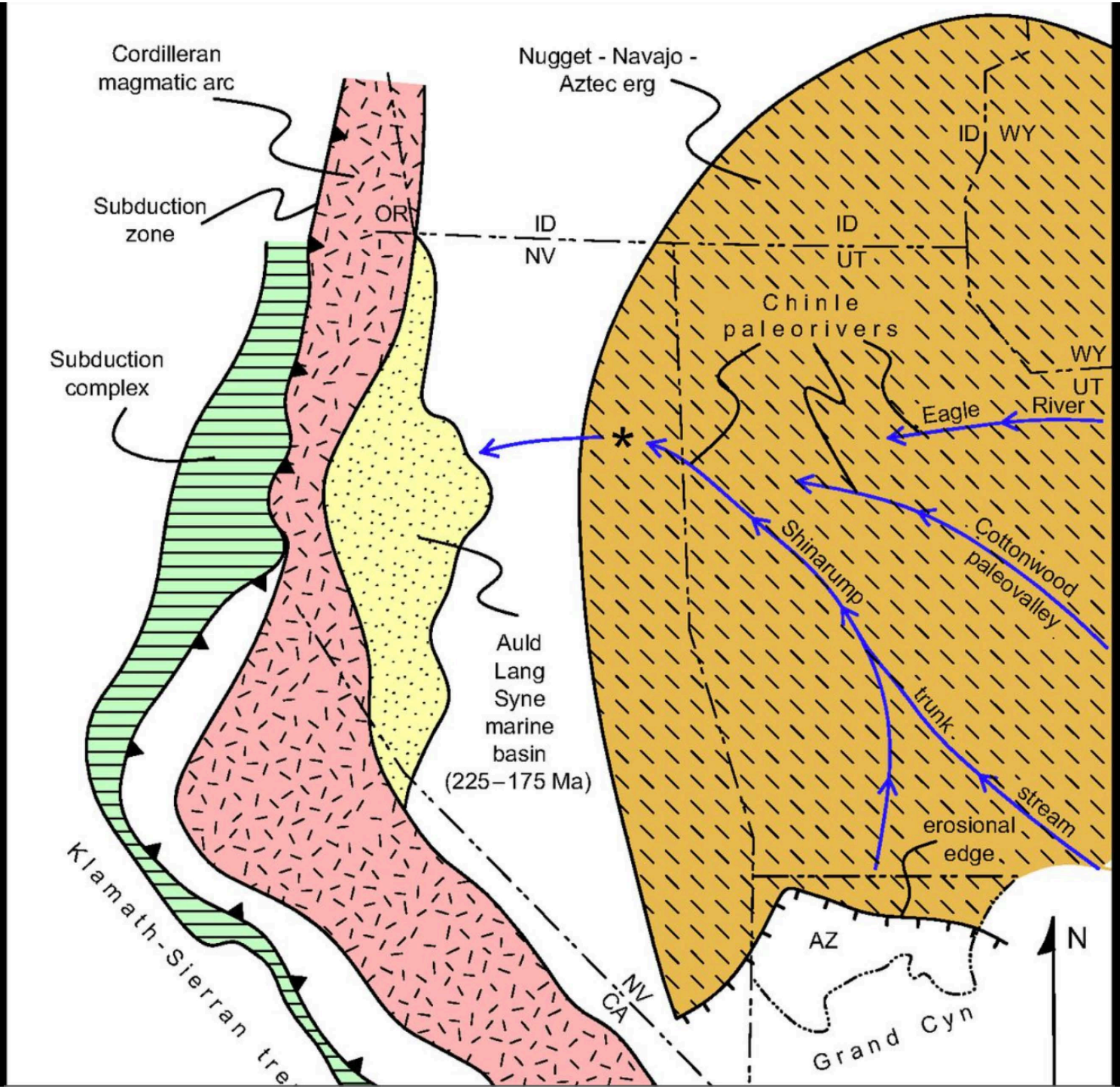


Ash, 1987

LUCAS ET AL., 1997

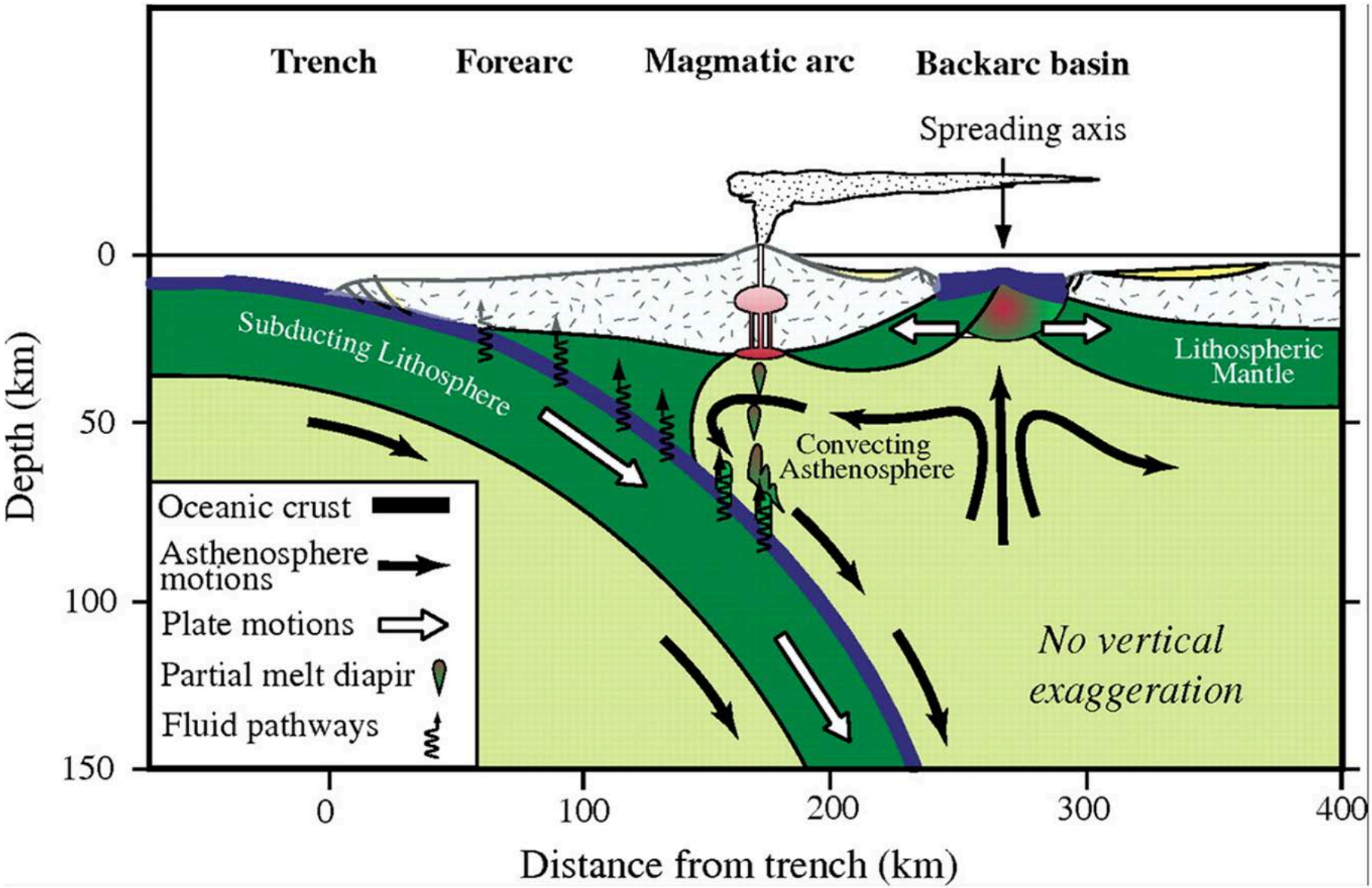


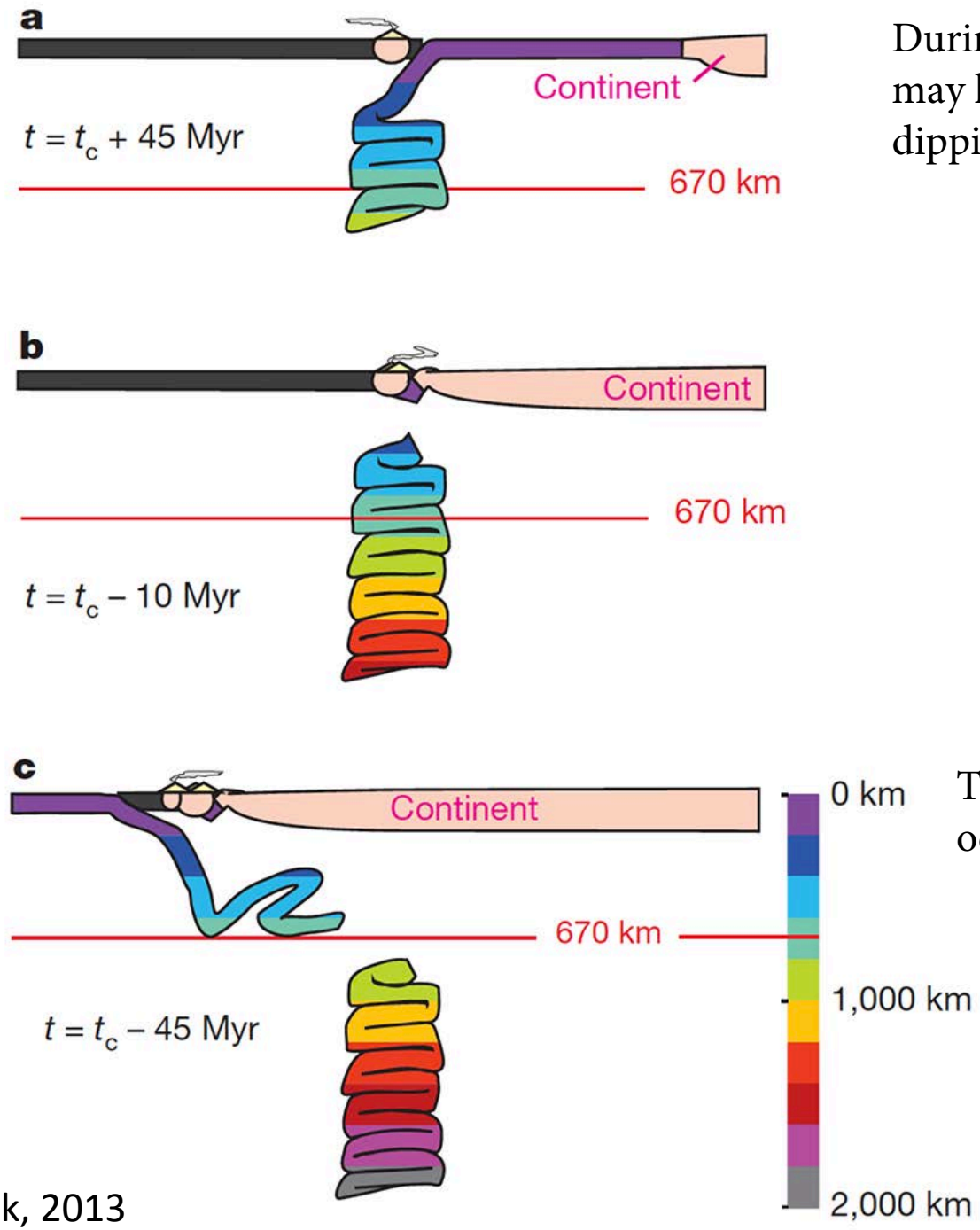
Adamanian | Reveultian



Dickinson, 2013

Standard model of back arc basin does not resemble Chinle basin.



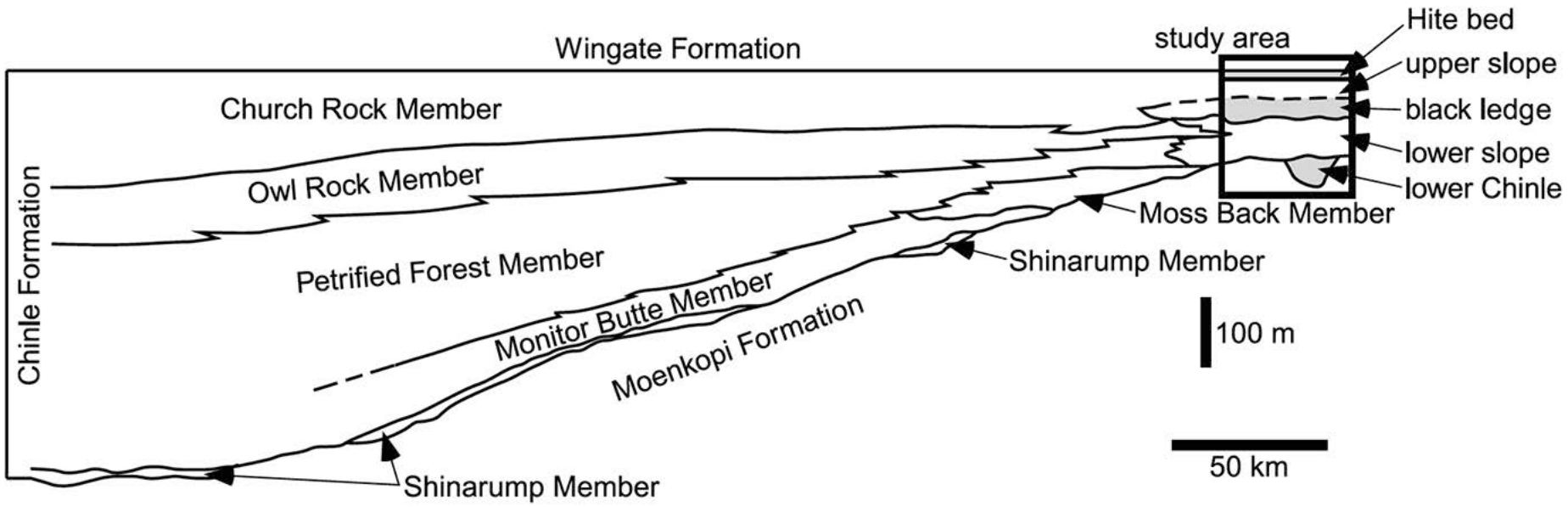


During Chinle time there may have had a western-dipping suduction zone

The western subduction occured later

Sigloch & Mihalynuk, 2013

Southwest Northeast



Matthews et al. , 2007 after Blakey and Gubitosa, 1984 and Hazel, 1994;

Thanks to:

G. Gehrels, R., D. Kent, R. Mundil, G. Bachmann, R. Molina-Garza, J. Sha, M. Schaller, J. Whiteside, N. Zacharova, C. Rasmussen, N. Giessler, V. Baryani, C. Miller, H. Buhedma, W. Parker