

Digital Outcrop Model of Stratigraphy and Breccias of the Southern Franklin Mountains, El Paso, Texas*

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Abstract

This article reviews and synthesizes lithostratigraphy, biostratigraphy, chronostratigraphy, and breccia types of the southwestern part of the Great American Carbonate Bank in the southern Franklin Mountains (SFM), El Paso, Texas. Primary stratigraphic units of focus are the Lower Ordovician El Paso and Upper Ordovician Montoya Groups. These groups preserve breccias formed by collapse of a paleocave system. Precambrian and Silurian units are discussed in the context of breccia clast composition and relative timing of breccia emplacement. Specific attention is paid to the juxtaposition of the top-Sauk second-order supersequence unconformity between the El Paso and Montoya Groups and its relationship to breccias above and below it. The unconformity represents a 10-m.y.-exposure event that separates Upper and Lower Ordovician carbonates.

The breccias of the southern Franklin Mountains were previously described as the result of collapsed paleocaves that formed during subaerial exposure related to the Sauk-Tippecanoe unconformity. A new approach in this work uses traditional field mapping combined with high-resolution (< 1 m point spacing) airborne lidar data over 24 km² to map breccia and relevant stratal surfaces. Airborne lidar data were used to create a Digital Outcrop Model of the southern Franklin Mountains from which a detailed (1:2000 scale) geological map was created. The geological map includes formation, fault, and breccia contacts. The Digital Outcrop Model was used to interpret 3-D spatial relationships of breccia bodies with respect to the current understanding of the tectonic and stratigraphic evolution of the southern Franklin Mountains. The data presented here are used to discuss potential stratigraphic, temporal, and tectonic controls on the formation of caves within the study area that eventually collapsed to form the breccias currently exposed in outcrop.

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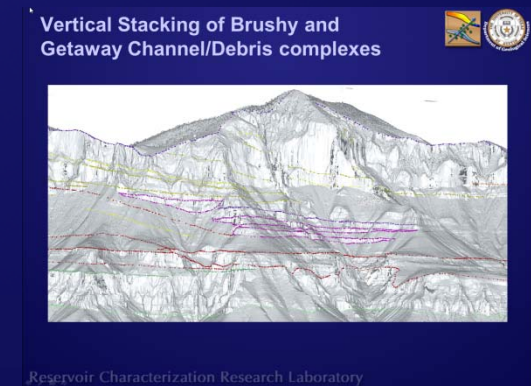
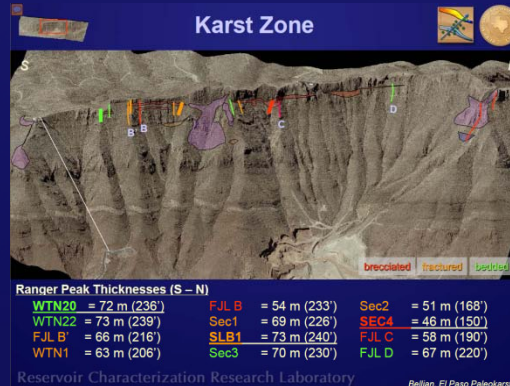
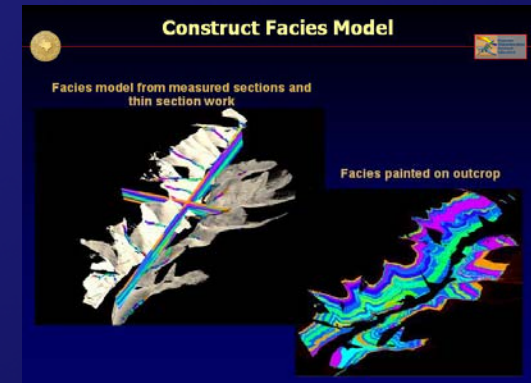
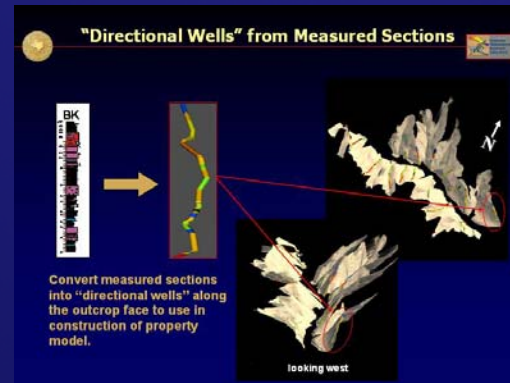
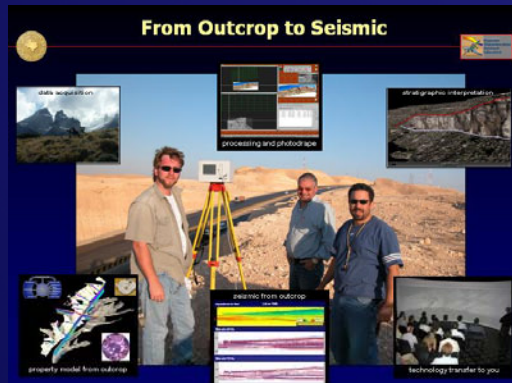
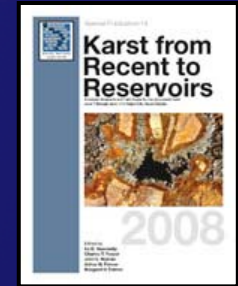
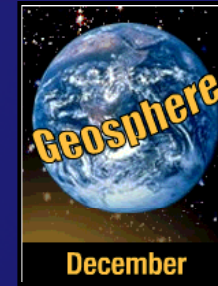
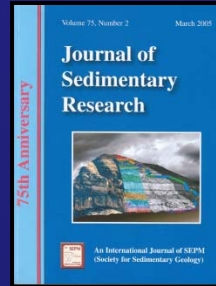
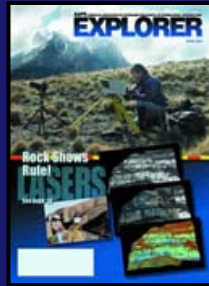
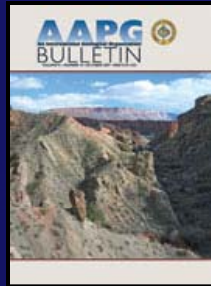
May 21, 2013

Talk Objectives

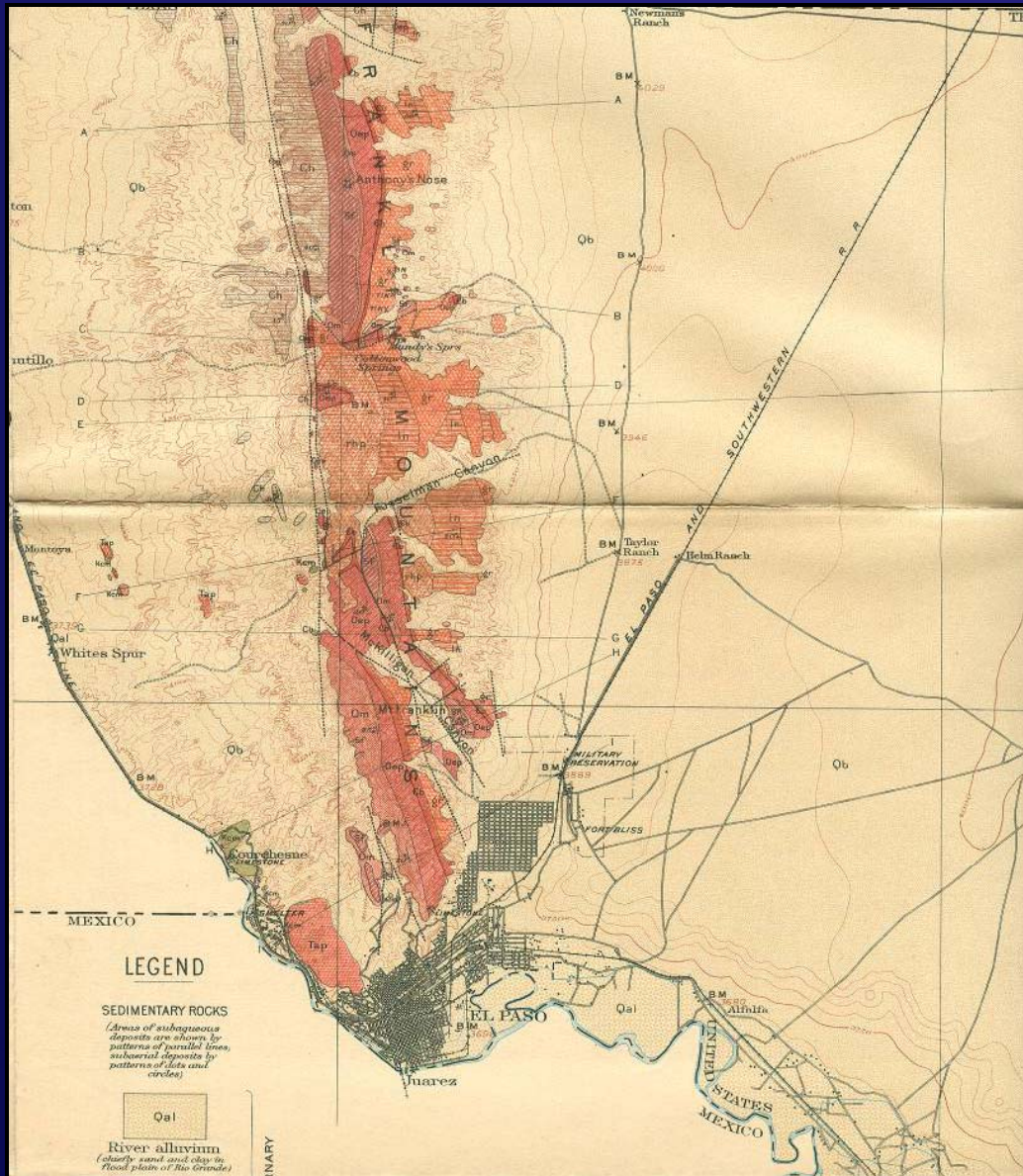


- **Brief Review of Digital Mapping**
- **Overview of Southern Franklin Mountains Stratigraphy and Brecciated intervals**
- **Present observations from field and remote-sensing mapping**
- **Discuss revised model for timing of breccia emplacement(s).**

Digital Outcrop Modeling Dozen 2001-2013



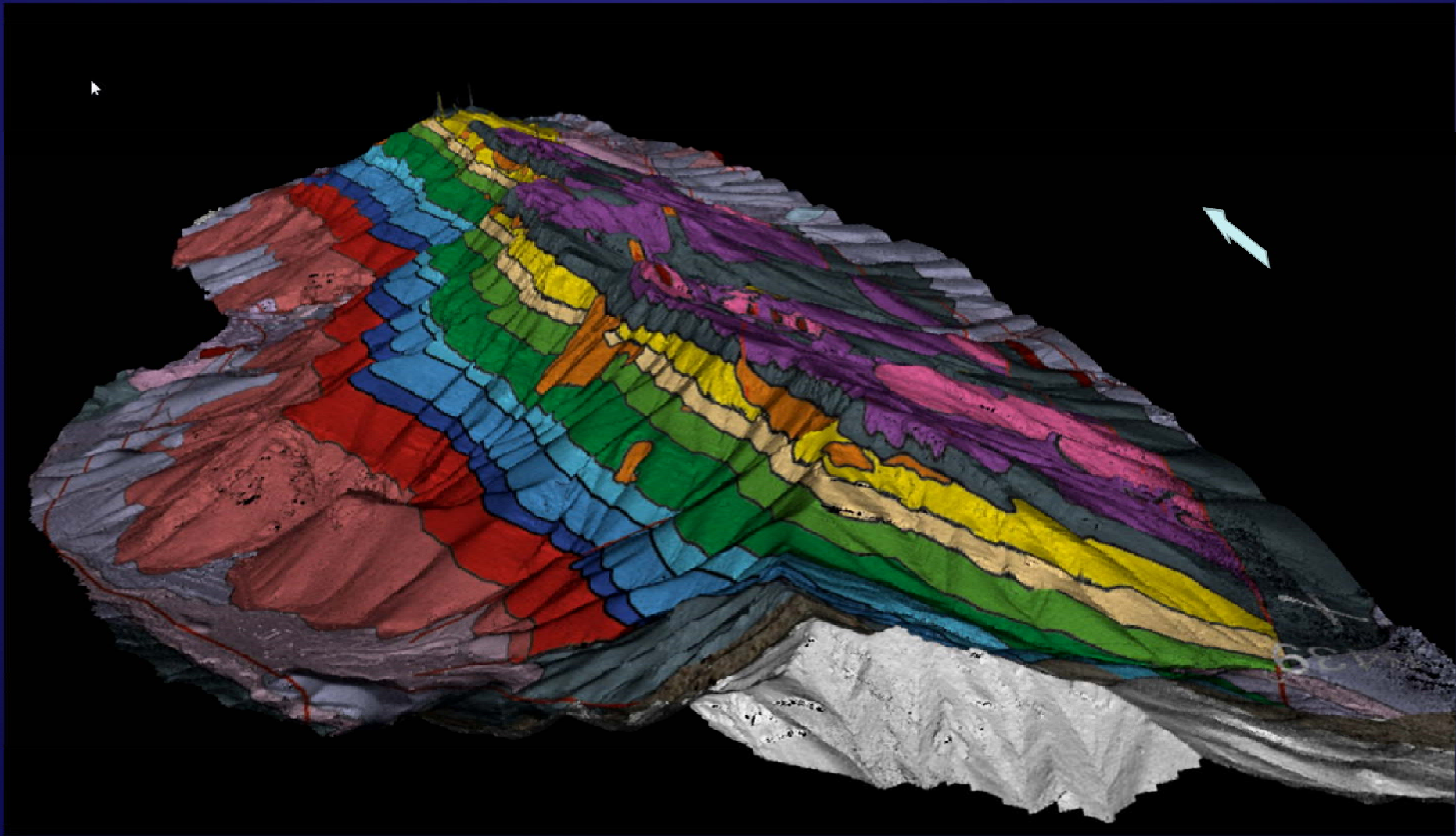
It's taken us about 100 years to go from this...

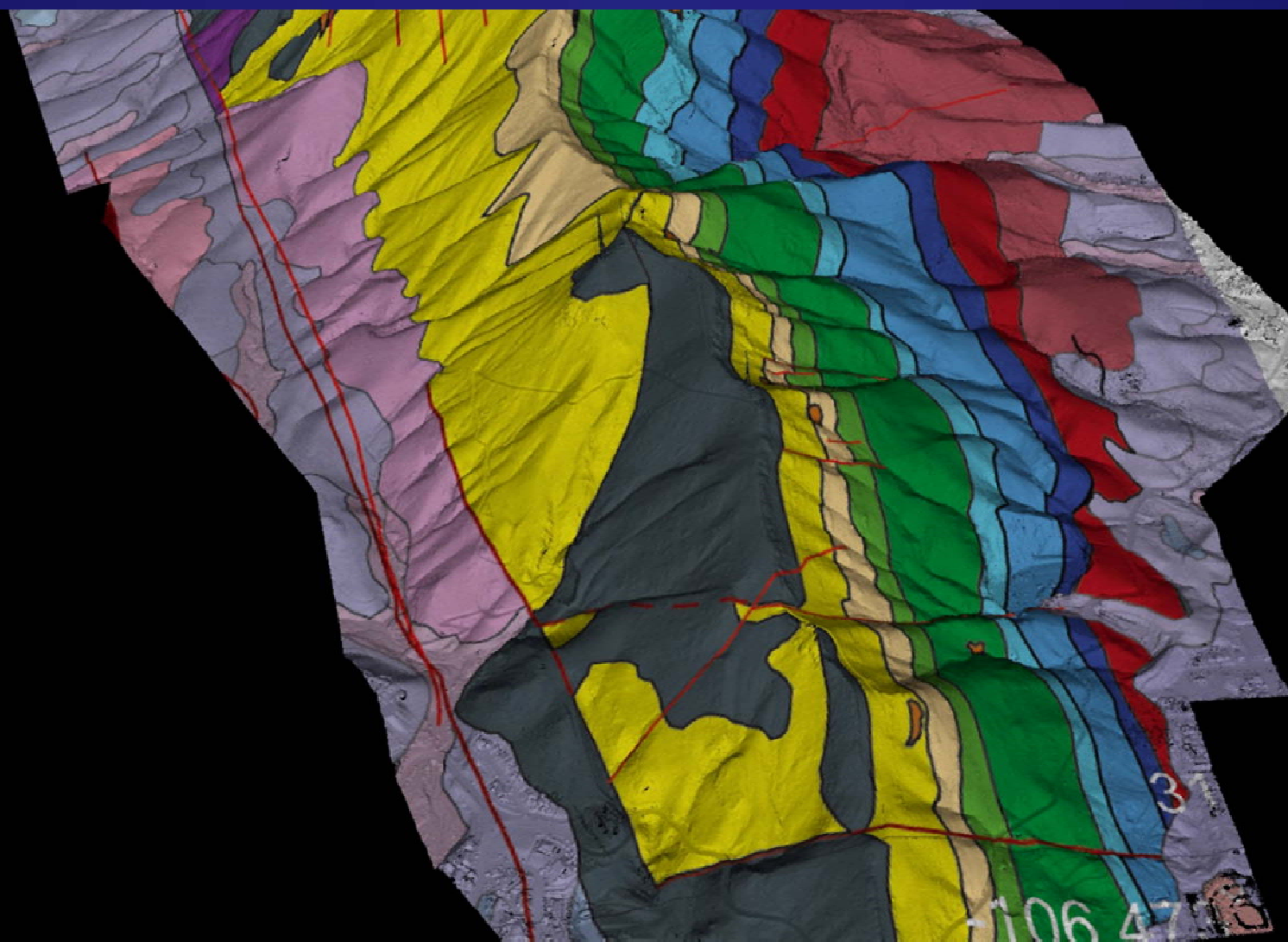


El Paso Group first described by Richardson in 1904 and later expanded in 1909.

Geologic Atlas of the United States, Folio 166 El Paso, Texas

To this...



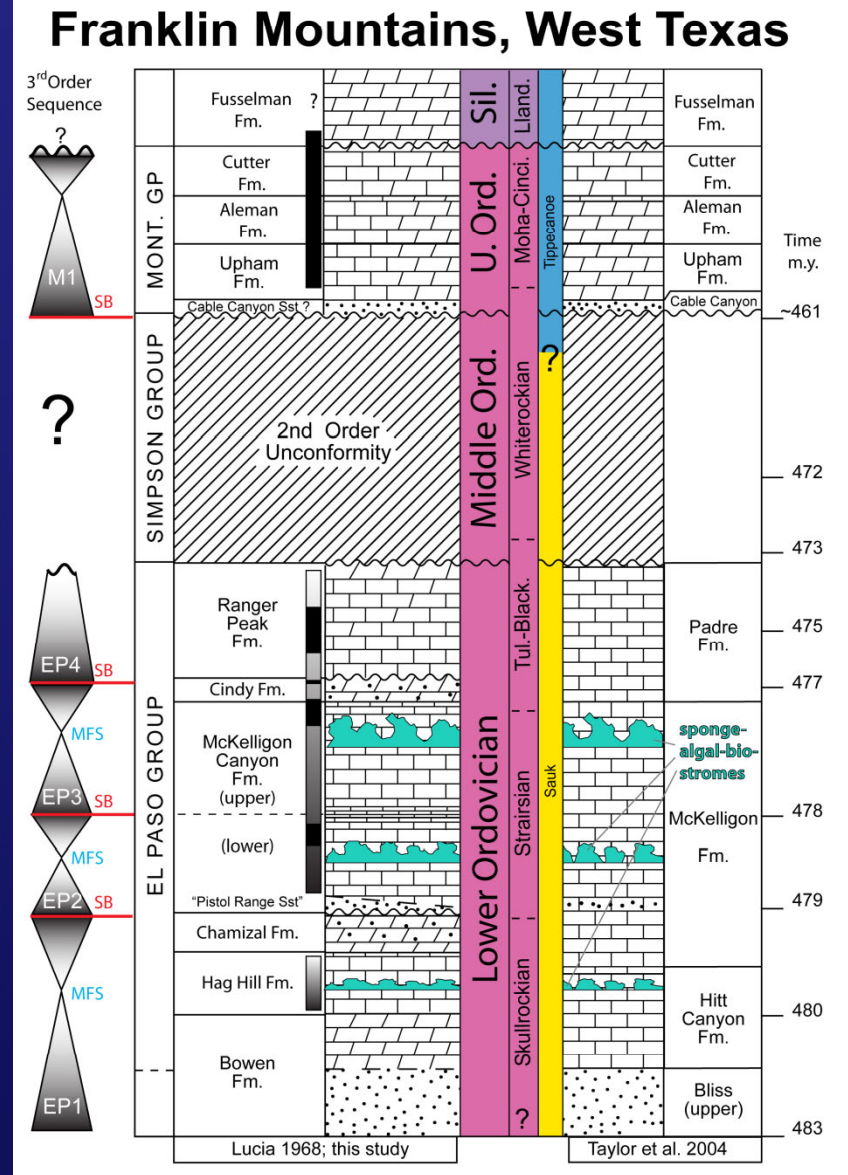


The Franklin Mountains Stratigraphy



The El Paso and Montoya Groups

- Richardson, G.B., 1904 and 1909
- Nelson, L.A., 1940
- Cloud, P.E. and Barnes, V.E. 1948
- Lucia, F.J., 1968
- LeMone, D.V., 1968
- Lucia, F.J., 1971*
- Harbour, R.L., 1972
- Kerans and Lucia, 1989
- Goldhammer et al. 1993
- Lucia, F.J., 1995*
- Bellian, J.A. 2009*

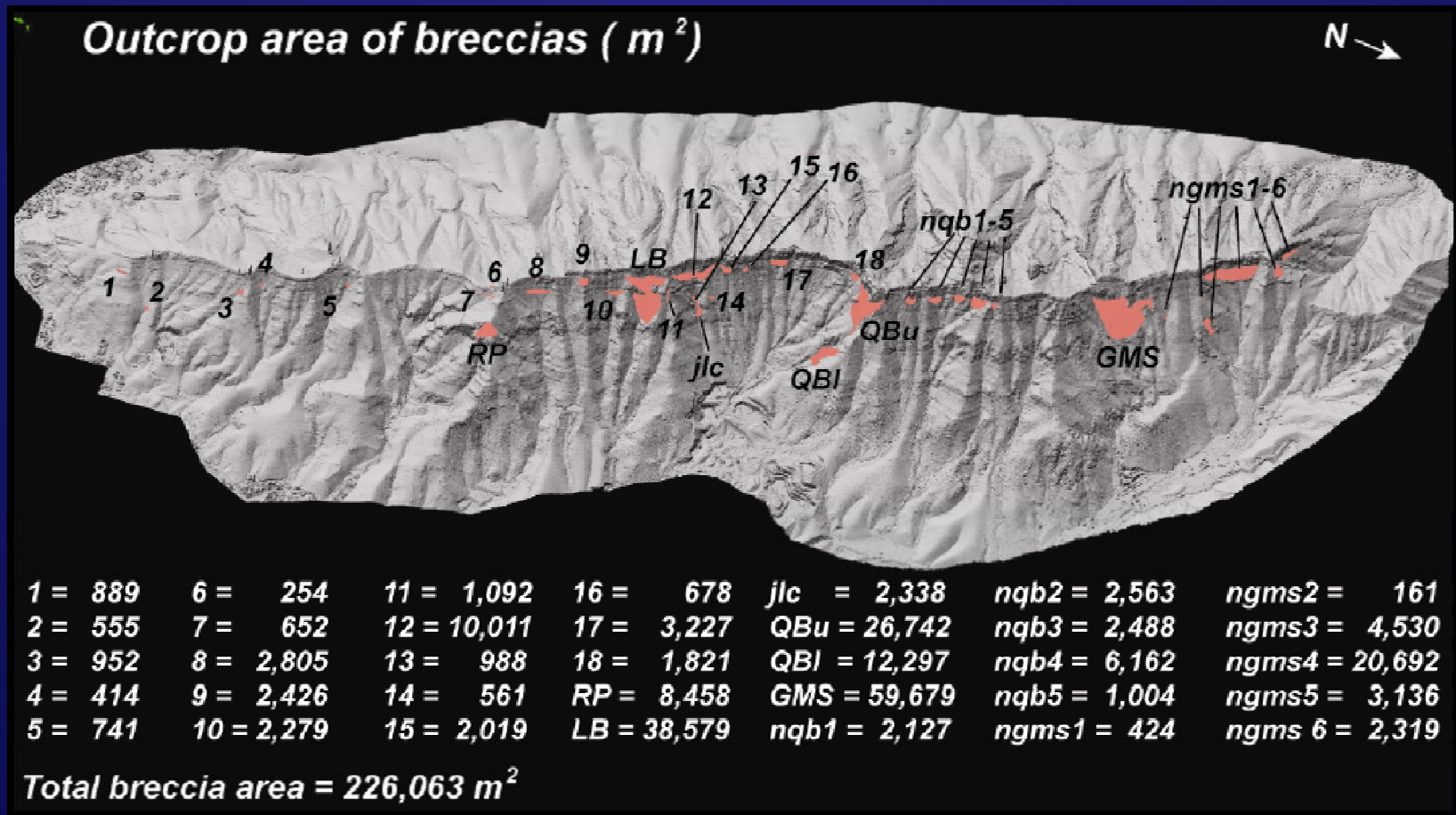


Key Questions (after Lucia 2012)



- **Did caverns (caves) exist?**
- **What is the age compared to the surrounding strata?**
- **What is the relationship to surrounding structure?**
- **What is the age of collapse?**

Over 40 Breccia Bodies Mapped



Sizes ranges from a few hundred m² to several 10's m²

Key Questions (after Lucia 2012)



- **Did caverns (caves) exist?**
 - **Without Question.**
- **What is the age compared to the surrounding strata?**
 - **Displaced (identifiable) strata.**
 - **Conodonts and macrofaunal paleontology**
- **What is the relationship to surrounding structure?**
- **What is the age of collapse?**

Downward Displaced Strata



**Upper
McKelligon
Canyon FM
slabs are down-
dropped 10's of
meters below
stratigraphic
equivalent.**

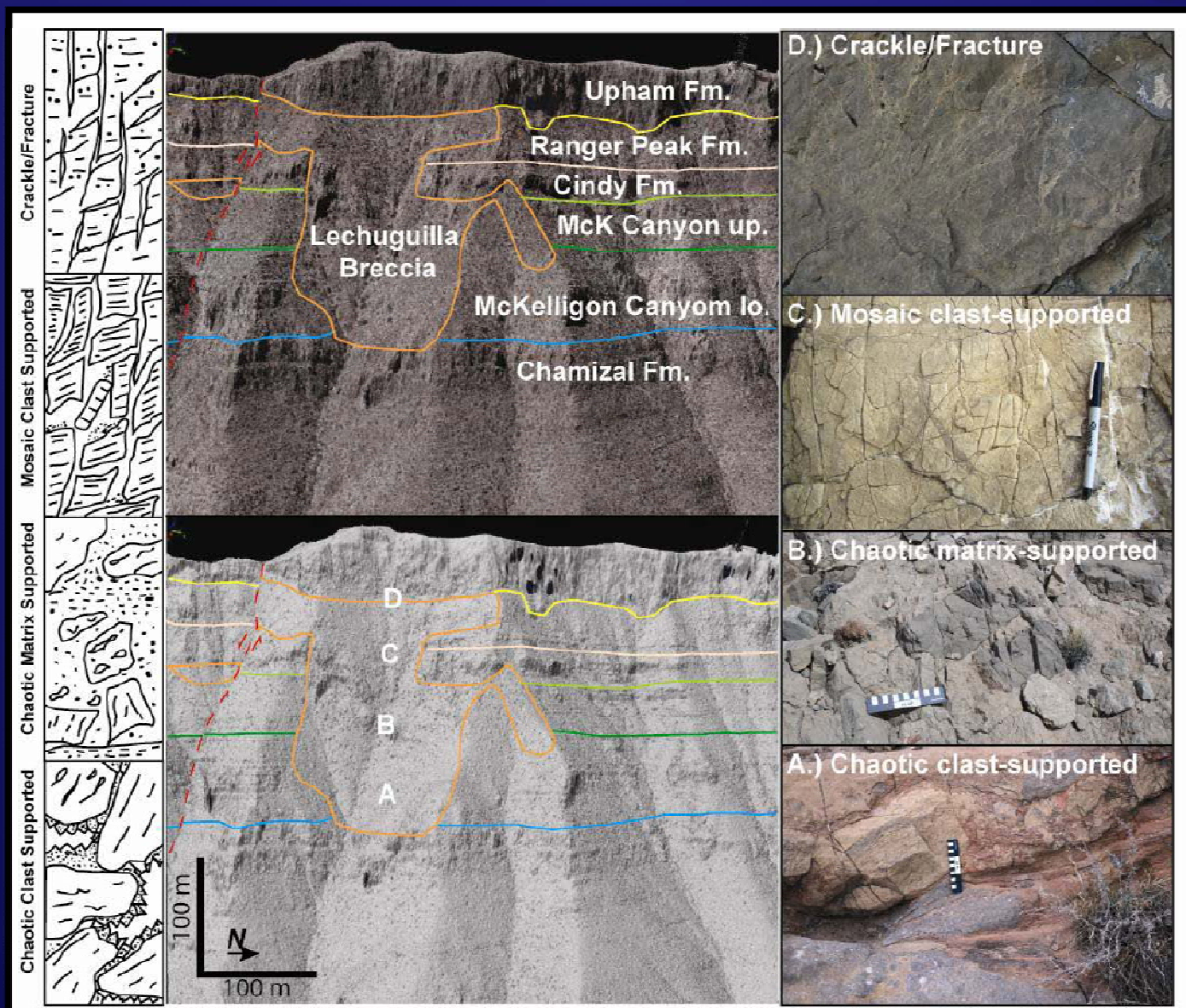
QBub

Dolomitized Fusselman in Dolomitic Limestone

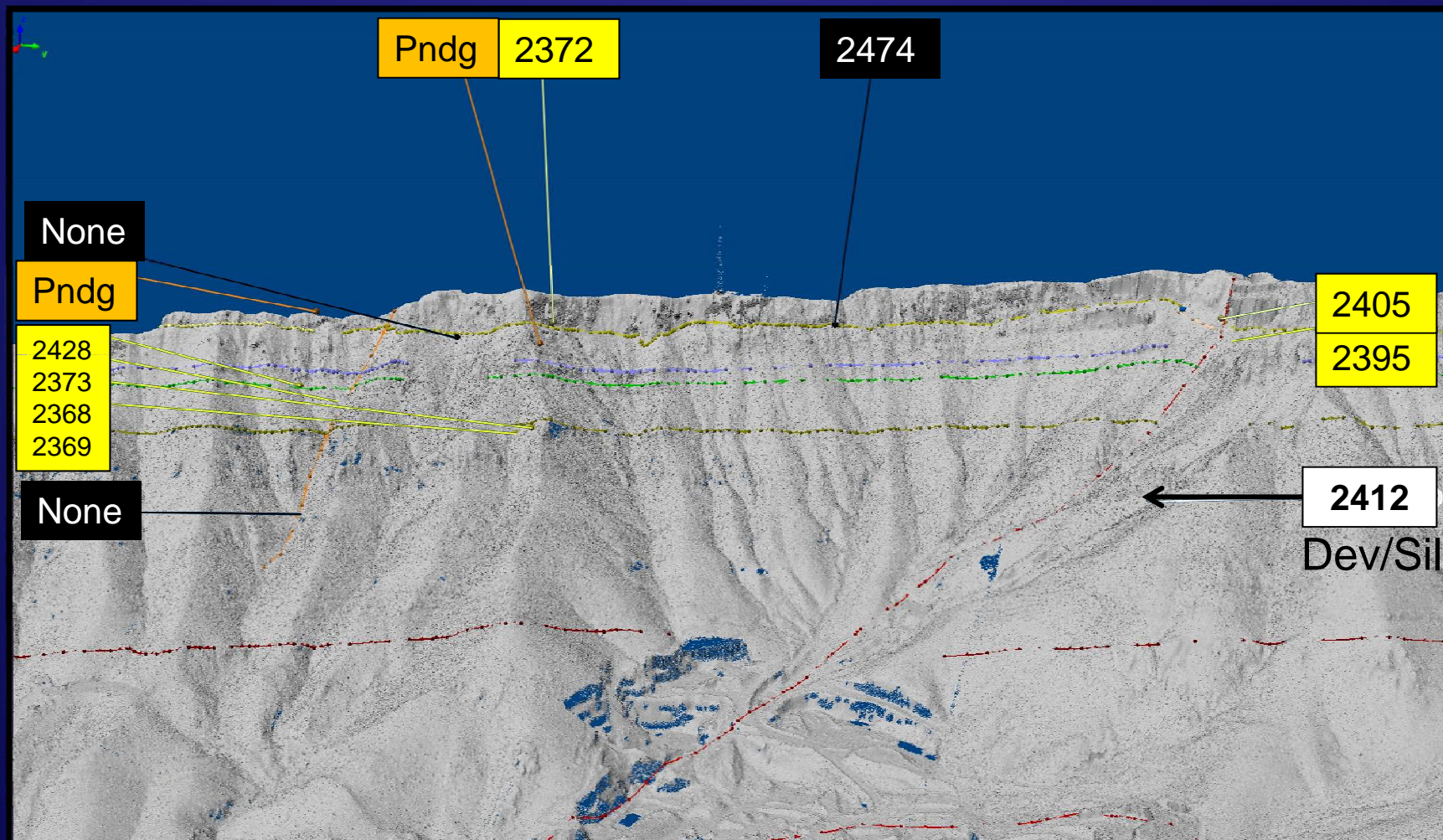


Dolomitized clast of Fusselman (*V. decussata*) at QB

Predictable Vertical Breccia Succession



Breccia Matrix Conodonts



Conformable

No conodonts recovered

Pending analysis

Breccia Matrix Conodonts

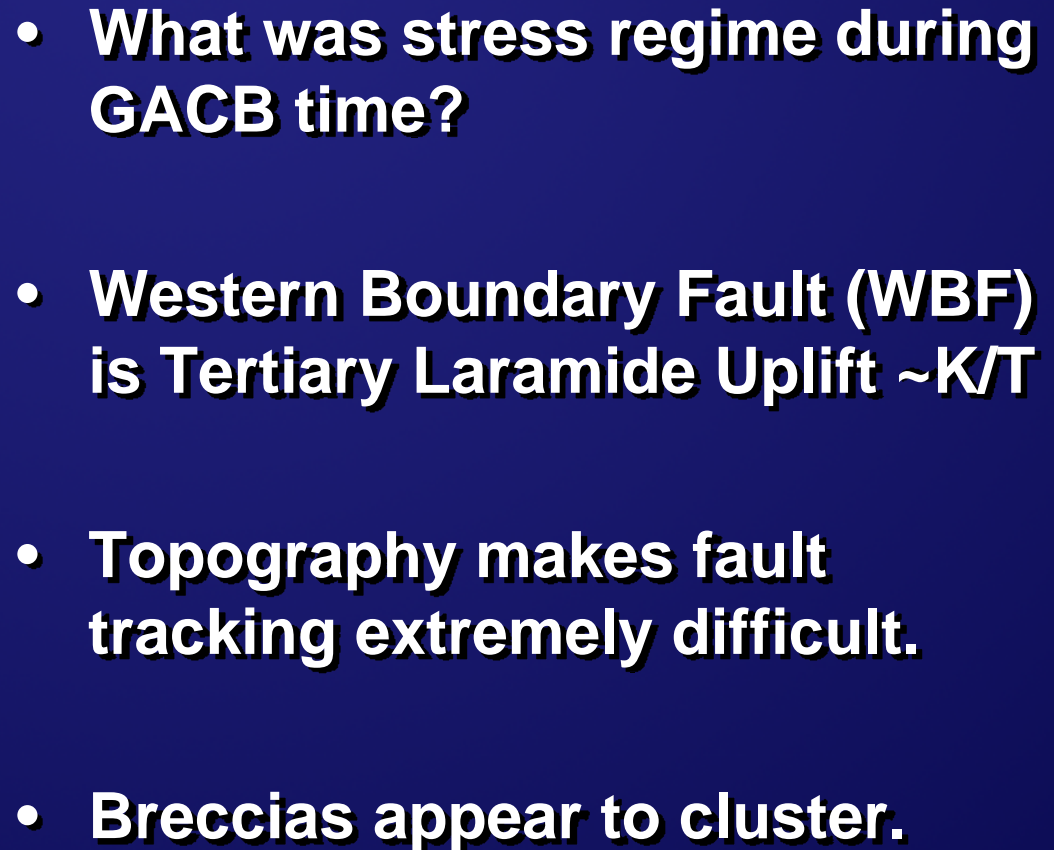


<u>Sample No.</u>	<u>East</u>	<u>Northing</u>	<u>Elev (m)</u>	<u>Fm Equivalent</u>	<u>Most likely conodont zone</u>
<u>2368</u>	359448	3520725	1640	Cz-RP	<i>Acodus deltatus</i> – <i>Oneotodus costatus</i> Zone through <i>Reutterodus andinus</i> Zone
<u>2369</u>	359437	3520695	1624	UMcK-RP	<i>Oepikodus communis</i> Zone or <i>Reutterodus andinus</i> Zone
<u>2372</u>	359222	3520676	1737	RP	<i>Reutterodus andinus</i> Zone
<u>2373</u>	359409	3520391	1638	HH-RP	Anywhere from the Low Diversity Interval through the <i>Reutterodus andinus</i> Zone
<u>2395</u>	359015	3521700	1738	UMcK-RP	<i>Oepikodus communis</i> or <i>Reutterodus andinus</i> Zone
<u>2405</u>	358977	3521677	1761	RP	<i>Reutterodus andinus</i> Zone
<u>2412</u>	359330	3521624	1580	L.Dev (?) & McK-RP	Lower Devonian/Upper Silurian and <i>Oepikodus communis</i> – <i>Reutterodus andinus</i> Zone
<u>2428</u>	359412	3520330	1658	McK-RP	<i>Acodus deltatus</i> – <i>Oneotodus costatus</i> to <i>Reutterodus andinus</i> Zone

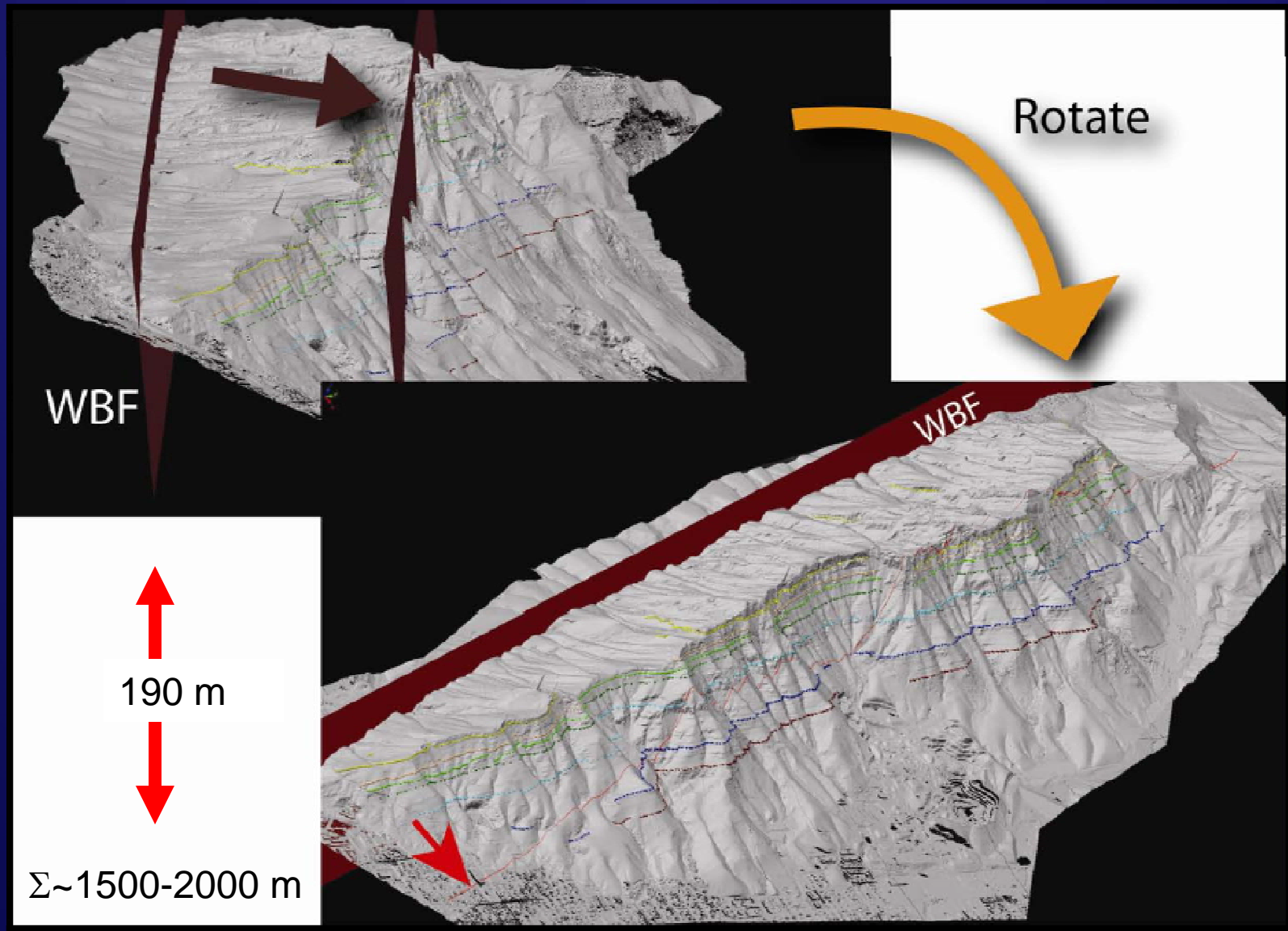
Key Questions (after Lucia 2012)



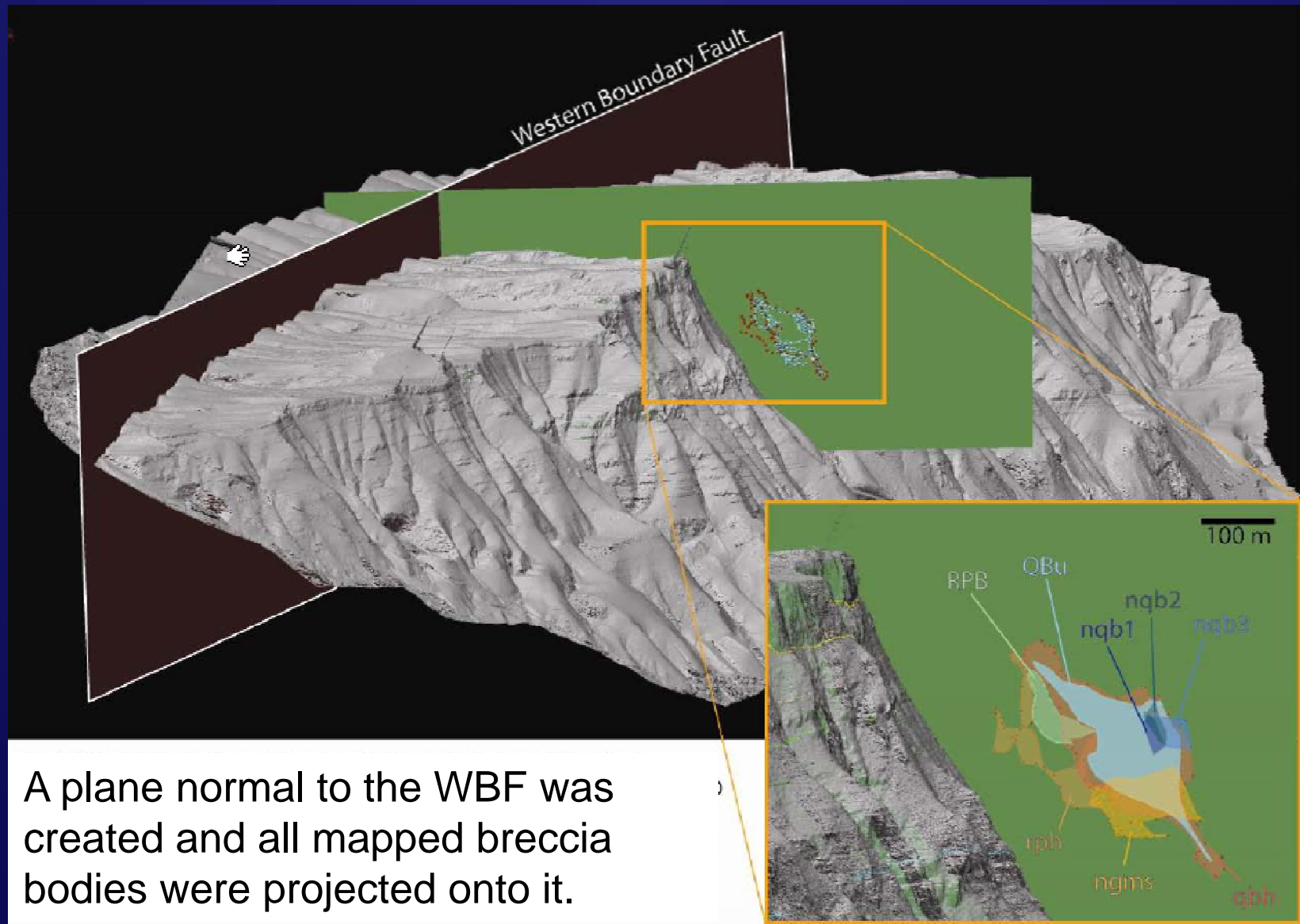
- **Did caverns (caves) exist?**
 - **Without Question.**
- **What is the age compared to the surrounding strata?**
 - **Displaced (identifiable) strata.**
- **What is the relationship to surrounding structure?**
 - **Faults and fractures- field and lidar mapping**
- **What is the age of collapse?**



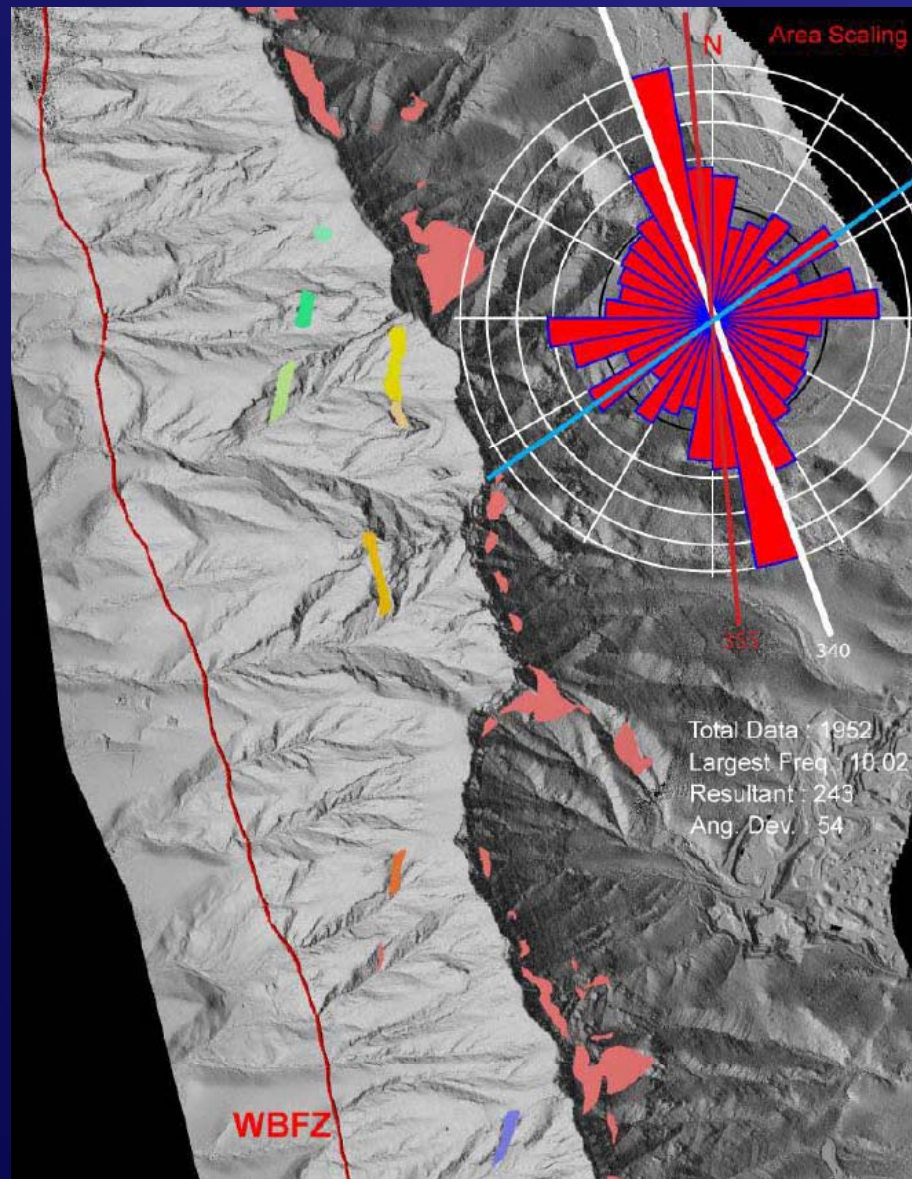
Structure Mapping for Dummies



WBF Projection to East Wall + Normal Plane



Breccia Proxy for Fracture Orientation



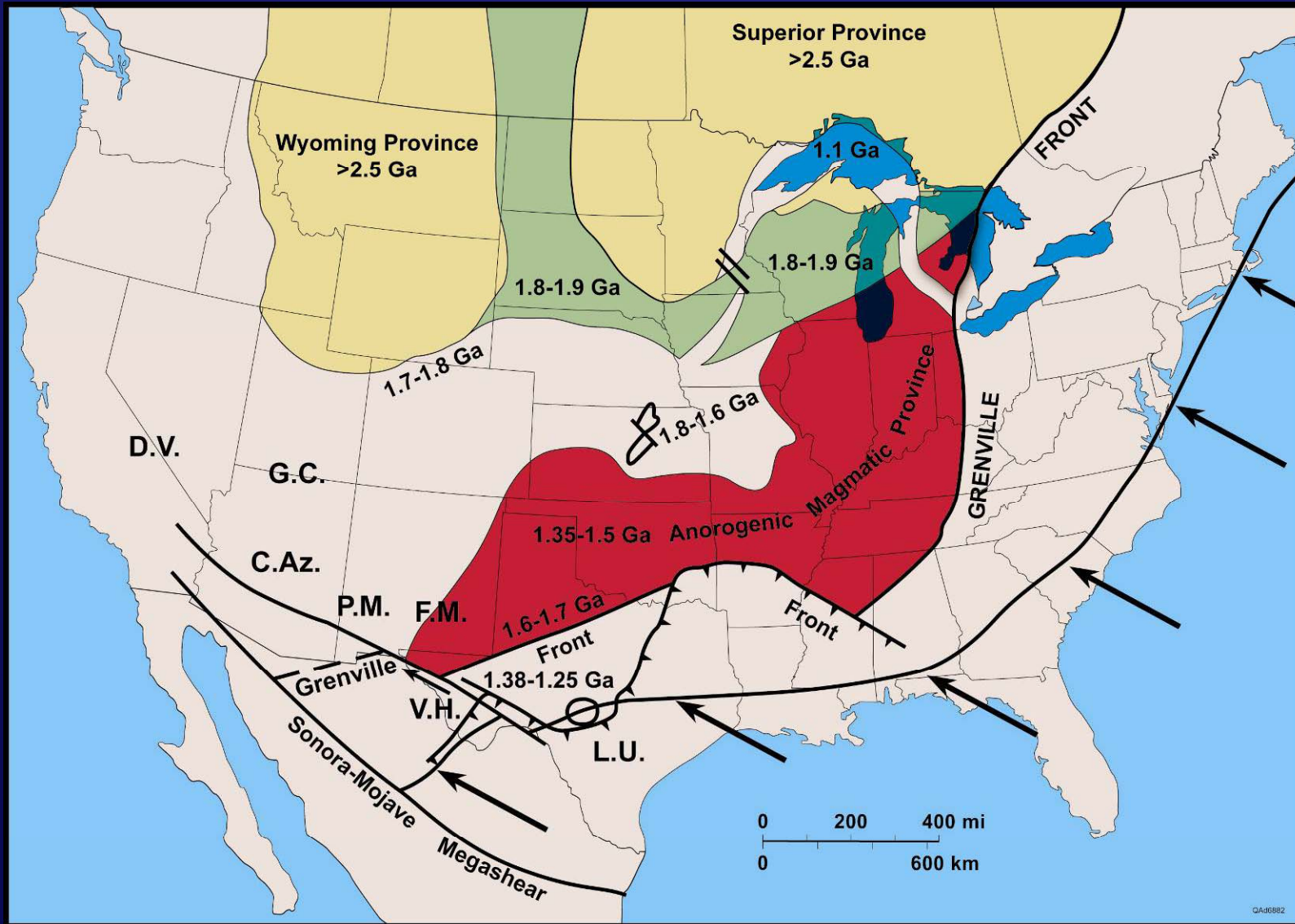
- Without question there is scatter in these data; however, the correlation to breccia body outcrop orientation and the WBF are compelling.
- The bimodal (trimodal?) nature of these fractures may tell us more about at least one phase of cave formation.

Key Questions (after Lucia 2012)

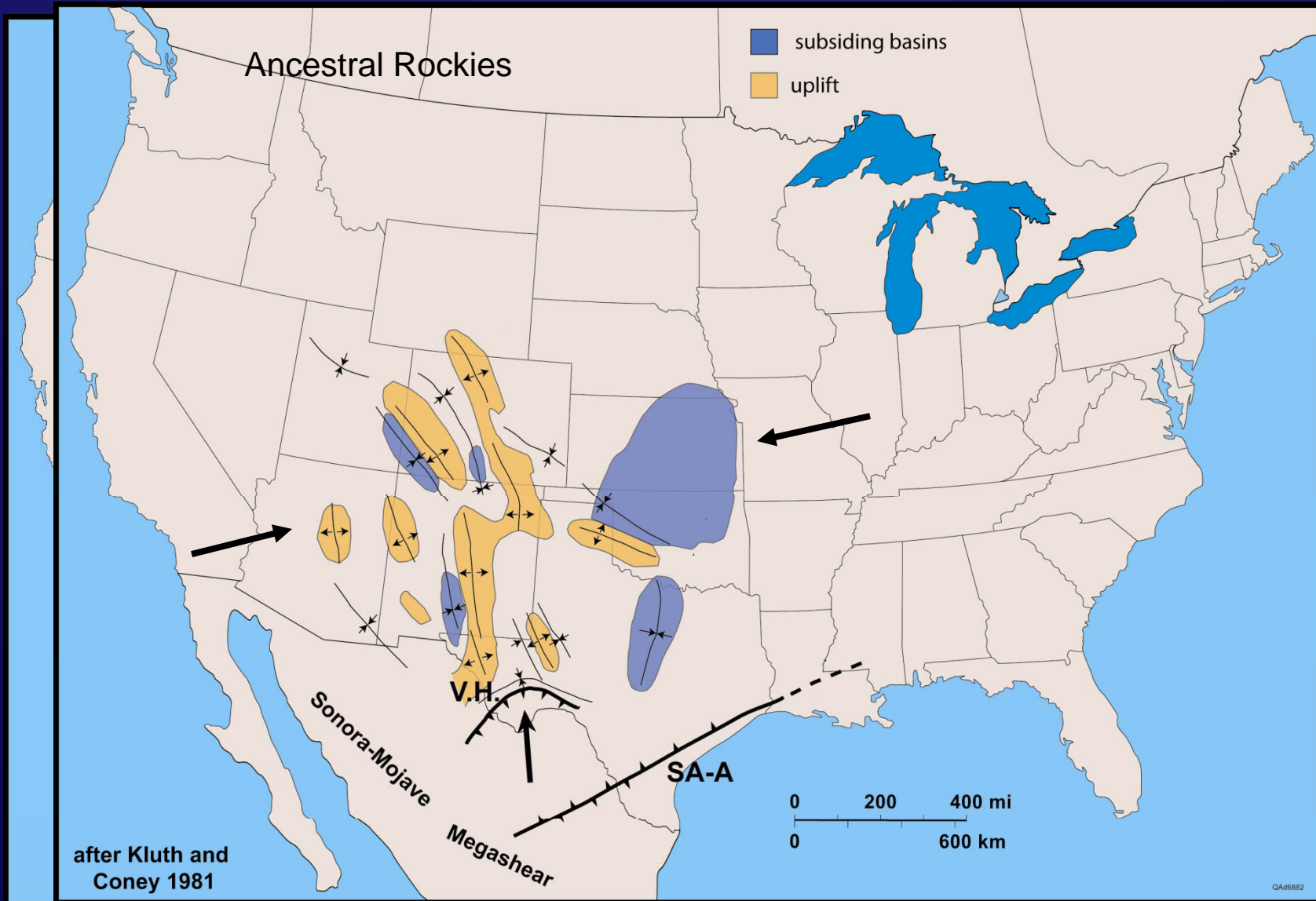


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- **What is the relationship to surrounding structure?**
 - **Faults and fractures- field and lidar mapping**
- **What is the age of collapse(s)?**

Major Tectonic Events

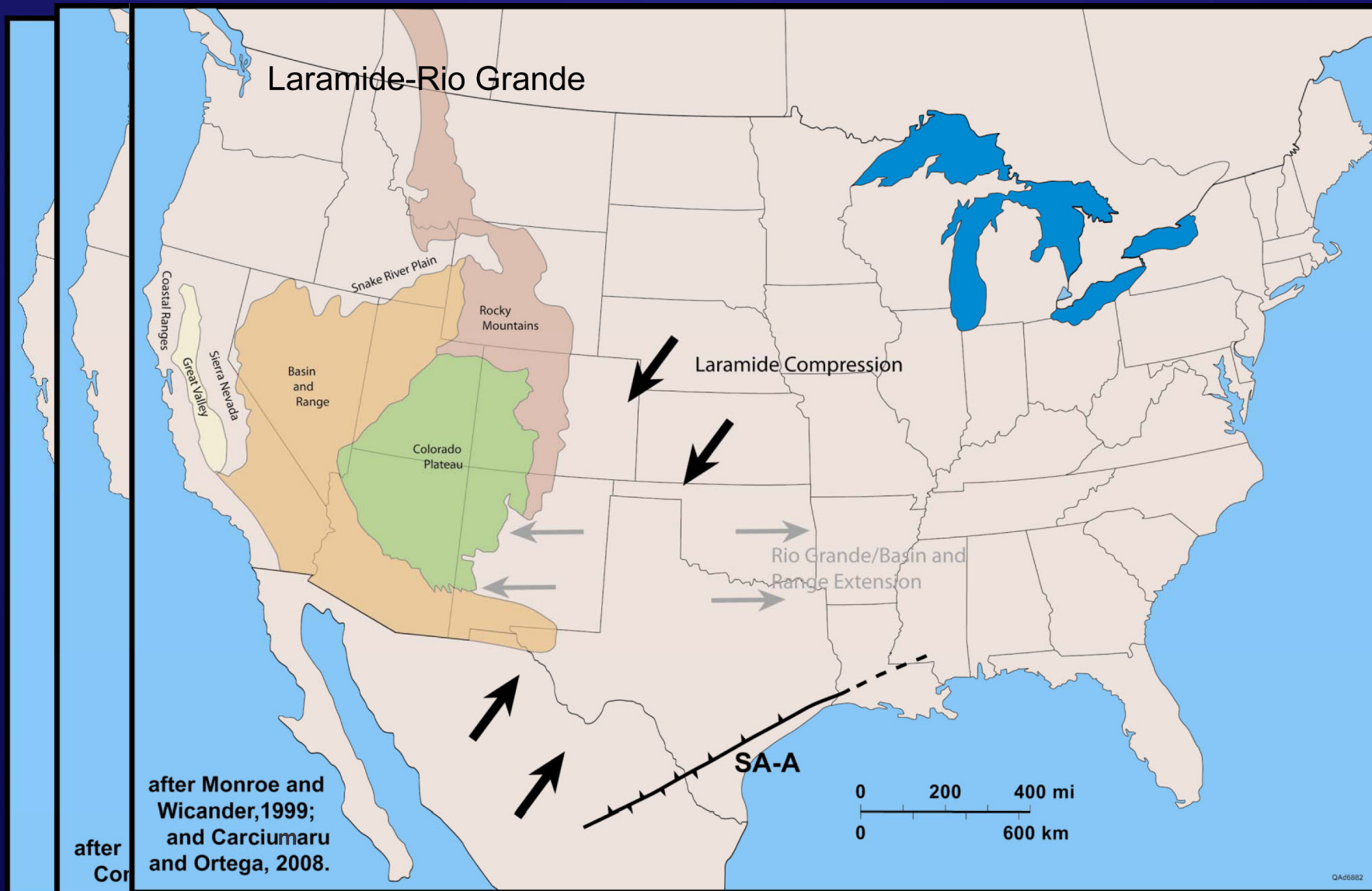


Major Tectonic Events



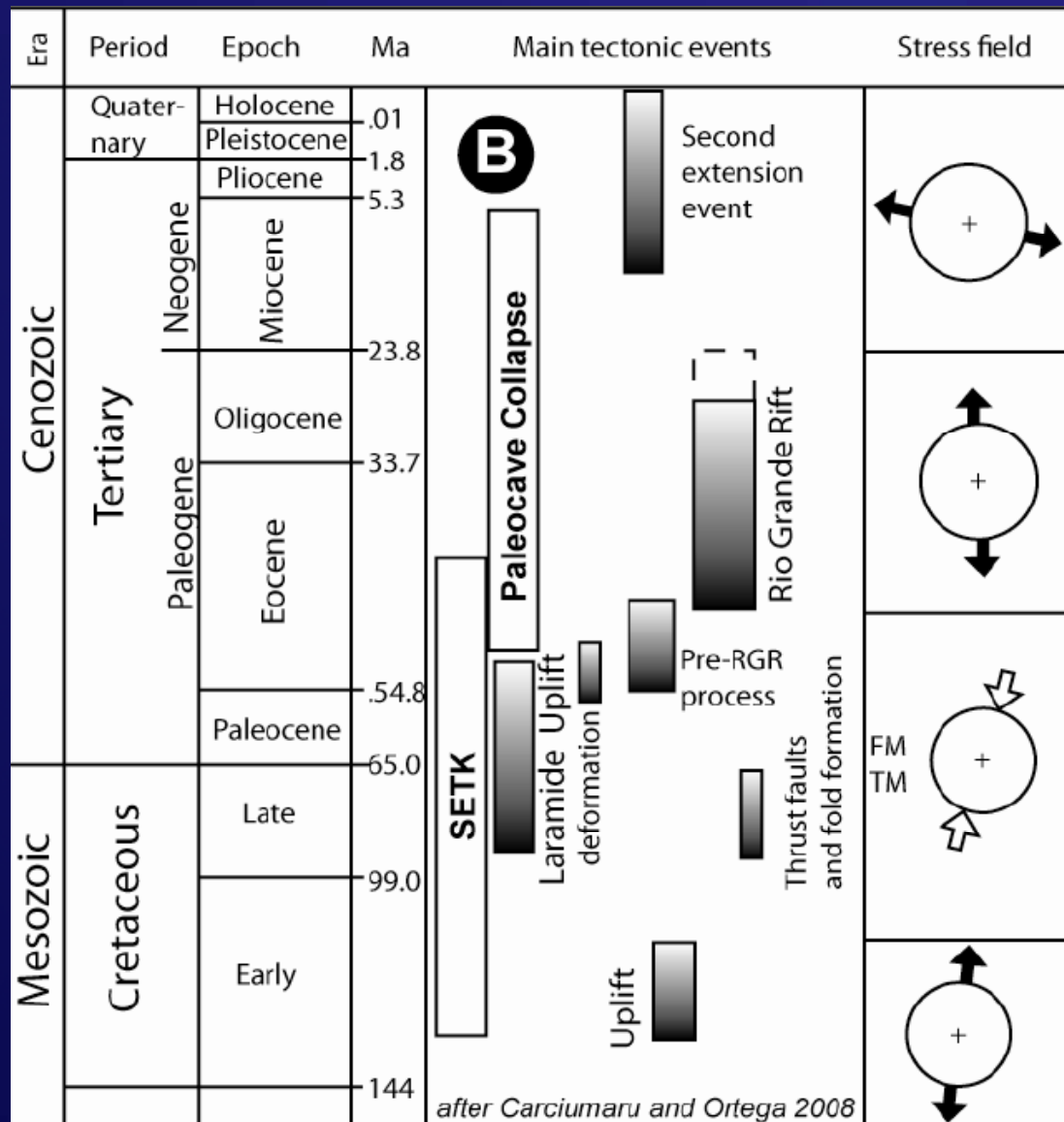
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Major Tectonic Events

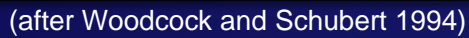


QA6682

Regional Structure Mapping



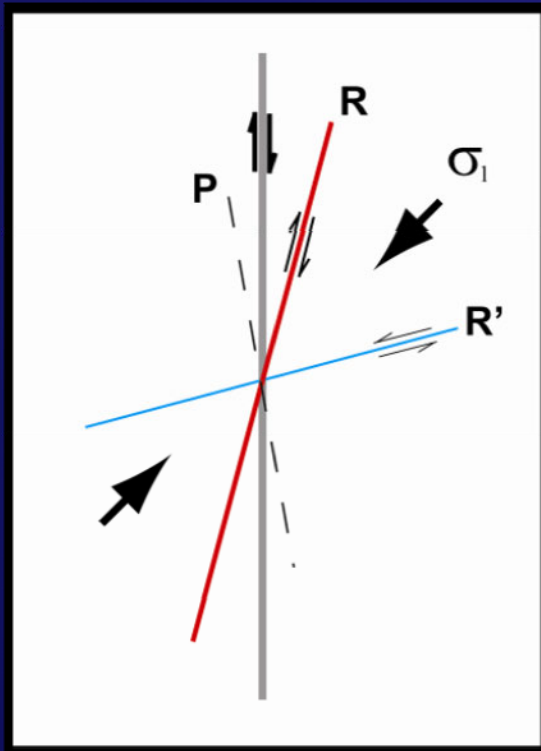
Timing of stress field alignment to WBF and breccia alignment indicates a possible link to Laramide and Rio Grande Rift tectonic brecciation (all or some phase?).



1. Early Laramide Compression

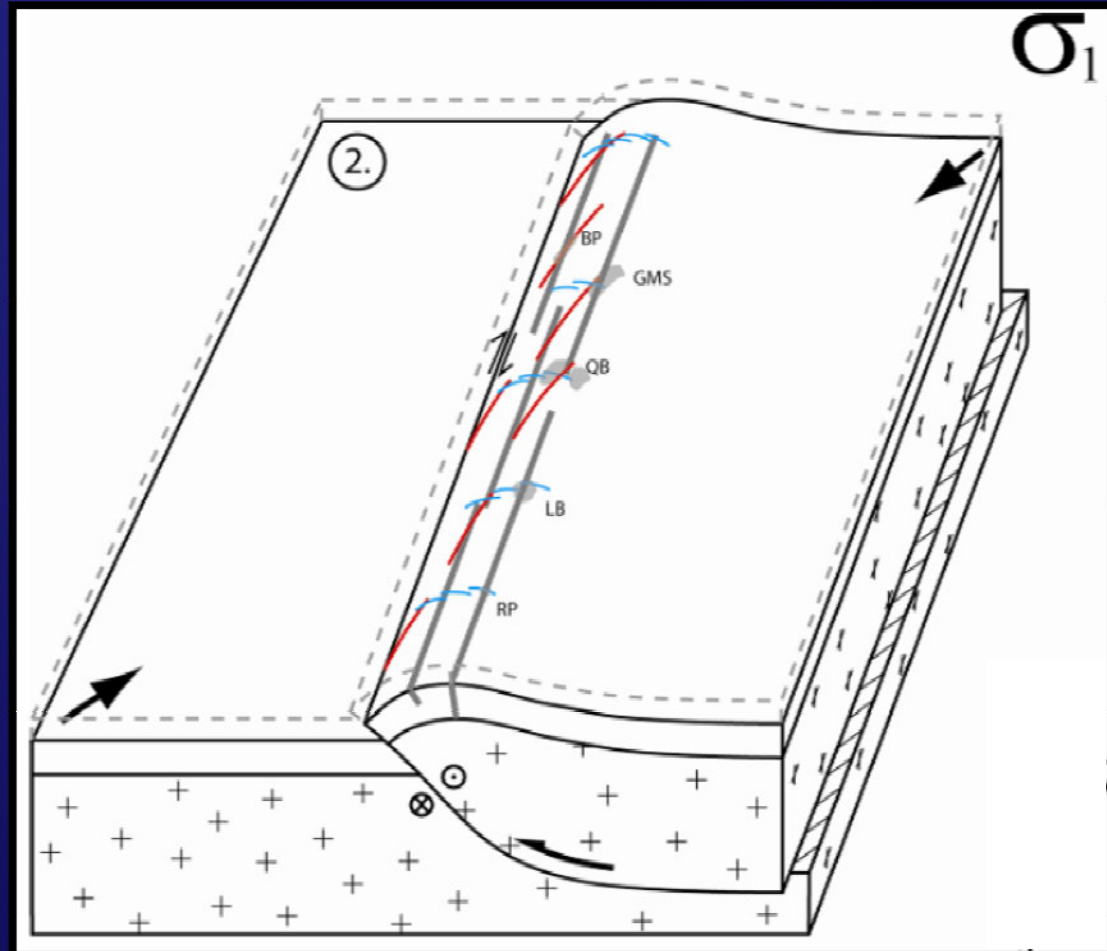


Alternative Model for Timing of Cave

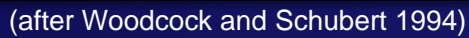


(after Woodcock and Schubert 1994)

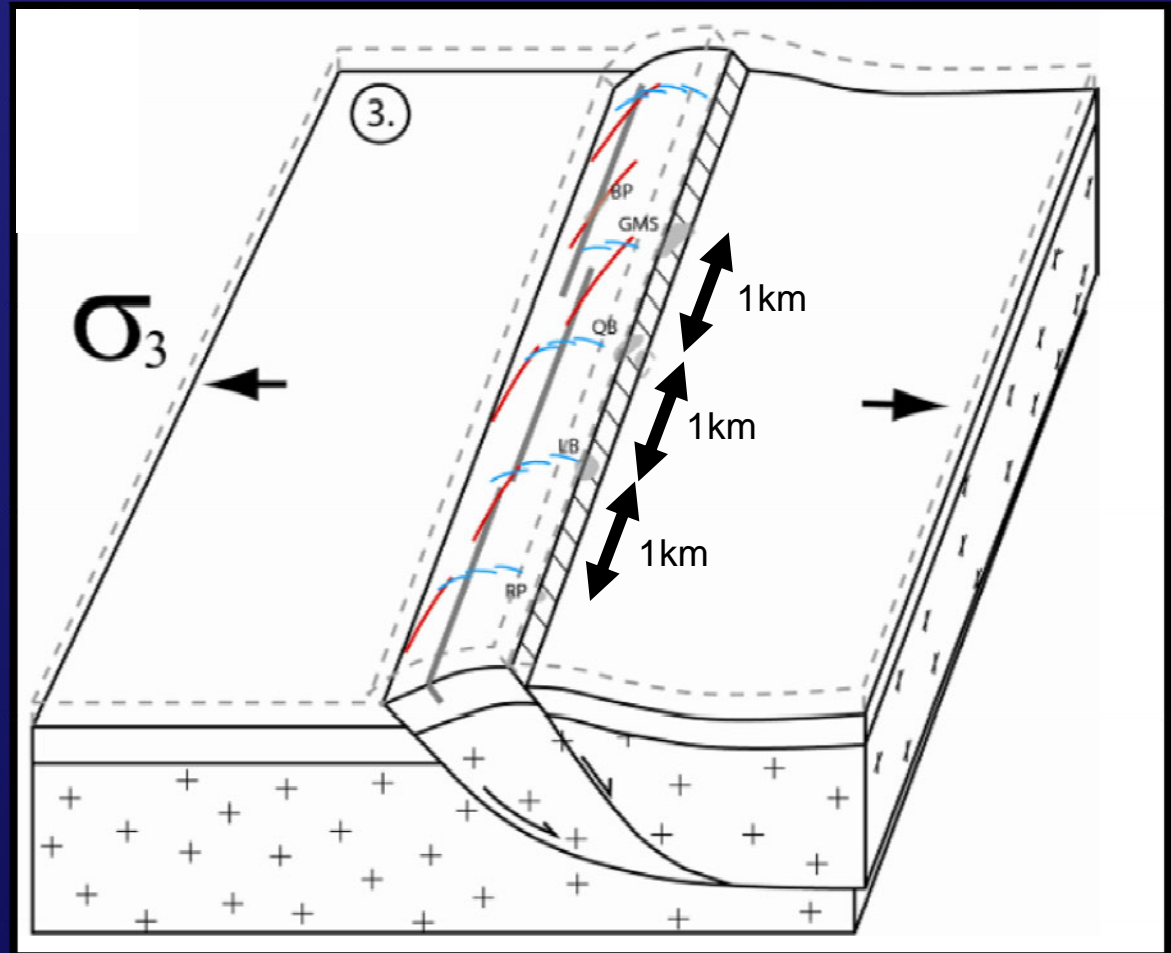
2. Uplift Provides Topography



Topographic enhanced hydraulic gradient to provide head to drive undersaturated fluids downward.



3. Basin and Range/Rio Grande ext.



Key Observations:



- 3-D mapping identified spatial relationships not documented in prior studies.
- Breccia clasts of dolomitized Montoya and Fusselman differ from matrix material and other clasts in breccias.
- No Middle or Upper Ordovician macrofauna or conodonts in the matrix.
- Dolomitization of Montoya and Fusselman has been proposed as Late Paleozoic (Lucia 1995).
- Lower Paleozoic was a time of relatively quiet “drift” passive margin setting in the El Paso Region (Goldhammer et al. 1993).
- Burial history in SFM (Repetski 1984) is deeper from burial history of Central Texas (Kupecz and Land 1991).

Key Observations:



- Breccia outcrop orientations and fractures/faults closely align to a Riedel Shear model under NE-SW compression.
- This region is “transitional-thick/thin skin deformation zone” and is Laramide (Carciumaru and Ortega 2008).
- Breccias cluster along a plane parallel to the Laramide Main Boundary Fault.
- Spacing of breccias (1 km) to height of El Paso Group (700 m) satisfies mechanical unit to fracture spacing ratio (Narr and Suppe 1991).
- Karst systems reactivate periodically and can overprint and canabalize (Loucks 1999).

Conclusions



- Possible Cretaceous/Tertiary age for the entire paleocave system may be valid. This would help explain required stress field to initiate through-going fractures and help explain alignment of breccias for a solution-enhanced tectonic karst system to have evolved.
- Alternatively, a far more extensive “cave life” or significant reactivation of previous karst systems may be associated with Laramide deformation.
- In depth geochemical and possibly high-resolution paleomagnetic analyses may help shed more light (or more questions!) on this topic.

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For support in preparation of the manuscript

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RCRL is a BEG Industrial Associate Program. Dr. Charles Kerans and Dr. Bob Loucks are current Principal Investigators. Jerry Lucia and Charlie Kerans started this group in 1987 and it has run continuously and successfully ever since.