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.
References Cited


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

Jerome A. Bellian*, Charlie Kerans**, and John Repetski***

*Whiting Oil and Gas Company
Denver

**Department of Geological Sciences
JSG, UT Austin

***United States Geological Survey
Reston, VA

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).
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...

Reservoir Characterization Research Laboratory
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 m$^2$ to several 10’s m$^2$

Total breccia area = 226,063 m$^2$
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 downward dropped 10’s of meters below stratigraphic equivalent.
Dolomitized Fusselman in Dolomitic Limestone

Dolomitized clast of Fusselman (V. decussata) at QB

Reservoir Characterization Research Laboratory
Predictable Vertical Breccia Succession
Breccia Matrix Conodonts

Conformable

No conodonts recovered

Pending analysis

Reservoir Characterization Research Laboratory
## Breccia Matrix Conodonts

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

• Western Boundary Fault (WBF) is Tertiary Laramide Uplift ~K/T

• Topography makes fault tracking extremely difficult.

• Breccias appear to cluster.
Structure Mapping for Dummies

Rotating the map to view another perspective.

WBF

190 m

Σ~1500-2000 m

Reservoir Characterization Research Laboratory
A plane normal to the WBF was created and all mapped breccia bodies were projected onto it.
• 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)

• 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(s)?
Major Tectonic Events

- Wyoming Province
  - >2.5 Ga
  - 1.8-1.9 Ga

- Superior Province
  - >2.5 Ga

- Magmatic Province
  - 1.35-1.5 Ga
  - Anorogenic

- Grenville Province
  - 1.8-1.6 Ga
  - 1.6-1.7 Ga

- V.H.
  - 1.38-1.25 Ga

- L.U.

- Sonora-Mojave Megashear

- Front
Rocky Basin
and Range
Colorado
after Monroe and Wicander, 1999; and Carciumaru and Ortega, 2008.

Laramide-Rio Grande

Laramide Compression

Basin and Range
Snake River Plain
Rocky Mountains

Colorado Plateau

Great Valley
Coastal Ranges

South Nevada

SA-A

0 200 400 mi
0 600 km
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?).
Alternative Model for Timing of Cave

1. Early Laramide Compression

Similar karst mechanism was documented by Woodcock et al. 2008) for the Dent Fault in NW England (also L. Paleoz).

(after Woodcock and Schubert 1994)
2. Uplift Provides Topography

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

(after Woodcock and Schubert 1994)
Alternative Model for Timing of Cave


Orientation of breccias along E. face, and Spacing of breccia bodies at ~1km

(after Woodcock and Schubert 1994)
Key Observations:

- 3-D mapping identified spatial relationships not documented in prior studies.
- Breccia clasts of dolomitized Montoya and Fussleman 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.
Acknowledgements

WHITING

For support to attend and present this material

Chevron

For support in preparation of the manuscript
Dr. Charles Kerans supported this research project with funds from JSG and RCRL Research Funds

*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.