A Cenomanian-Age Deep Continental Shelf Record of Cyclical Anoxia, Gulf of Mexico, South Texas*

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Abstract

While many Cretaceous paleoceanographic reconstructions have focused on global-scale oceanic anoxia events (OAEs) like that which occurred at the Cenomanian-Turonian Boundary (CTB), we focus on defining paleoceanographic changes that occurred prior to the CTB interval. Specifically, we present a chemostratigraphic record of mixed carbonate-siliciclastic sedimentation from what is interpreted to be a deep-shelf succession preserved in a drill core from Bee County, South Texas (Shell Oil Co., J.A. Leppard #1). This succession unconformably overlies Albian strata and is believed to predate most of the Eagle Ford-age deposition of South Texas. Biostratigraphic constraints define the ~140-foot thick succession as mostly lower Cenomanian, with approximately 30 feet of middle-upper Cenomanian, unconformably overlain by ~20 feet of Campanian strata. A suite of 105 total organic carbon (TOC) values range from 1% to 6% in the Cenomanian strata, and from ~0.5% to 3.5% in the Campanian strata.

A chemostratigraphic record for the drill core was generated using a suite of 830 major and trace element analyses obtained at an average sample spacing of two inches. Stratigraphic changes in the major element composition are generally reflective of bulk mineralogical changes, largely interpretable in the context of changing facies. Lower Cenomanian strata are dominantly calcitic (60+/−12% CaCO₃), middle and upper Cenomanian strata are less calcitic (42+/−12% CaCO₃), and Campanian strata are slightly higher than those of the lower Cenomanian (62+/−7% CaCO₃). Whereas the bulk major element geochemistry dominantly reflects changes in a simple two-component (calcite and clay mineral) depositional system, trace element signatures reveal exceptionally large, cyclical variations throughout the lower Cenomanian interval. The dominant signatures of anoxia/euxinia are best defined by vanadium and molybdenum (Mo). Eight stratigraphically distinct episodes of lower Cenomanian-age anoxia are defined by Mo enrichment factors (EF-Mo) higher than 100; and furthermore, several of the enriched intervals are defined by multiple peaks, indicating an oceanographic process that generates a pattern of redox-driven cyclicity in the sediments. It is hypothesized that the cyclicity is a manifestation of the paleo-oxygen minimum zone (OMZ) impinging on the deep shelf. However, the RSTE pattern could represent a very high-resolution record of the Middle Cenomanian Event (MCE).
Selected Reference


Website

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Bruker Elemental—for continued interaction on instrumental advances
Considerations

- Many studies of the Cenomanian have focused on the Cenomanian-Turonian Boundary and Ocean Anoxia Event #2 (OAE2).

- Less effort has been placed on understanding OAE2 precursors or the overall post-Albian conditions leading up to OAE2.

- We describe and interpret a chemostratigraphic record of pre-OAE2 paleoceanographic conditions from South Texas that may ultimately shed light on the evolution of the oceans toward OAE2-like conditions.

- We’ll also make some general comments about chemostratigraphy because of its burgeoning (but often unchecked) use.
### Upper Cretaceous Stratigraphic Column

<table>
<thead>
<tr>
<th>SERIES/STAGE</th>
<th>Lozier Canyon, TX</th>
<th>Comstock, TX</th>
<th>Big Bend, TX</th>
<th>Central TX Subsurface</th>
<th>South TX Subsurface</th>
<th>Biozones</th>
<th>AGE MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Cretaceous</td>
<td>Donovan &amp; Staerker 2010</td>
<td>Lock et al 2010</td>
<td>Cooper &amp; Cooper 2009</td>
<td>Sprinkle Big House Pflugerville Burditt</td>
<td>AUSTIN</td>
<td>18</td>
<td>parca</td>
</tr>
<tr>
<td>Coniacian</td>
<td>AUSTIN</td>
<td>AUSTIN</td>
<td>AGUJA</td>
<td>Dessau</td>
<td>AUSTIN</td>
<td>17</td>
<td>obscura</td>
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<tr>
<td>Campanian</td>
<td>L</td>
<td>L</td>
<td>PEN</td>
<td>Jonah</td>
<td>16</td>
<td>cayeuxii</td>
<td></td>
</tr>
<tr>
<td>Cenomanian</td>
<td>L</td>
<td>L</td>
<td>San Vicente</td>
<td>Vinson</td>
<td>15</td>
<td>anthophora</td>
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<tr>
<td>Turonian</td>
<td>L</td>
<td>M</td>
<td>BOQUILLAS</td>
<td>Atco</td>
<td>14</td>
<td>decussata</td>
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<tr>
<td>Coniacian</td>
<td>E</td>
<td>M</td>
<td>Upper</td>
<td>South Bosque</td>
<td>13</td>
<td>furcata</td>
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<tr>
<td>Santonian</td>
<td>E</td>
<td>M</td>
<td>Middle</td>
<td>Boudin</td>
<td>12</td>
<td>eximius</td>
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<tr>
<td>Cenomanian</td>
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<td>E</td>
<td>Lower</td>
<td>Waller</td>
<td>11</td>
<td>gartneri</td>
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<tr>
<td>Albian</td>
<td>E</td>
<td>E</td>
<td></td>
<td>Pepper</td>
<td>10</td>
<td>decorata</td>
<td></td>
</tr>
<tr>
<td>L. Cret</td>
<td>E</td>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Biozones
- 18: parca
- 17: obscura
- 16: cayeuxii
- 15: anthophora
- 14: decussata
- 13: furcata
- 12: eximius
- 11: gartneri
- 10: decorata

### AGE MA
- 83.5 Ma
- 85.8 Ma
- 88.6 Ma
- 93.6 Ma
- 99.6 Ma
Core Background

- Shell Oil Co. J.A. Leppard #1
- NW Bee County, South Texas
- \(\sim\)140 feet long; Depth: 13670 to 13530 ft
- Biostratigraphy based on nanofossil identification (Jim Pospichal, Bugware, Inc.)
- Lithostratigraphy based on observations made on slabbed face and thin sections
- 830 samples analyzed for bulk elemental geochemistry, TOC, \(\delta^{13}C\)-TOC. Chemostratigraphy based on methods and calibrations outlined in:
  
Core Location: Proximal to Stuart City Margin
Eagle Ford Carbonate Sediment Types

**Dominant**
- Planktonic flora/fauna
  - Globigerinid foraminifera
  - Nanoplankton (coccoliths)

**Subsidiary**
- Benthic fauna
  - Inoceramid pelecypods
  - Echinoids
- Nektonic/plantonic flora/fauna
  - Cephalopods
  - Calcispheres (dinoflagellates ?)
Typical Eagle Ford Facies and Variability

Calcereous Foram-Nanoplankton Mudrock-Lime Packstone

Calcereous Nanoplankton Mudrock
Quantitative Method of Obtaining Major/Trace Element Geochemistry
Major Element Calibration
A “Check” on Accuracy

- Why don’t all of the points fall ON the line?
- Why would we ever get points that fall significantly BELOW the line?
- Why would they fall significantly above the line?
- What is another quick “check” that one can make to evaluate accuracy?
Leppard Core Chemostratigraphy

Not a lot of quartz
Lower Campanian (CC20 and CC21)
Middle-Upper Cenomanian (CC10) and upper half of CC9
Lower Cenomanian (CC9)
Leppard Core Chemostratigraphy
Utilization of Mo for Evaluating Euxinia/Renewal Time
Environment for Mo Enrichment

A) Upwelling zone (unrestricted)
- Offshore current
- Continuous aqueous TM resupply
- O₂ minimum zone
- Upwelling

B) Silled basin (weak restriction)
- Pycnocline
- Limited aqueous TM depletion

C) Silled basin (strong restriction)
- Pycnocline
- Shallow sill
- Rare deepwater renewal
- Strong aqueous TM depletion

\[ TM_{\text{sed}} \equiv \text{redox} \]
No hydrographic effect

\[ TM_{\text{sed}} \equiv \text{resupply} \]
Redox control is 2°
Zoom in on Lower Cenomanian
Paleogeographic reconstruction of early Cenomanian (100 Ma; Blakey (2013); [http://cpgeosystems.com/nam.html](http://cpgeosystems.com/nam.html)). The approximate location of the drill core is indicated with the red dot. Note, the Western Interior Seaway (WIS) was open to the Arctic Ocean, but was not yet linked with the Gulf of Mexico.
Impingement of Oxygen Minimum Zone (OMZ) onto Outer, Deeper Shelf

- Occurrence, expansion, and contraction of the OMZ along the outer shelf could create the trace element and TOC signatures observed.
- The overall rhythmic (cyclical) pattern of redox changes may suggest the influence of a forcing mechanism that also tends to be cyclical (i.e., orbital forcing).
On a broader scale, the Leppard record provides a stronger understanding of conditions just before(?) the opening of the WIS. Sea level was lower, and then rose during the WIS establishment—this would have triggered “true” Eagle Ford deposition inboard of the Leppard site (behind the Stuart City Margin).
CONCLUDING COMMENTS

- Tremendous effort focused on characterizing the OAE-2 at the Cenomanian-Turonian Boundary (CTB)

- Much less effort toward resolving pre-OAE2 episodes or events during Cenomanian (some work on “Middle Cenomanian Event”)

- Based on core biostratigraphy, we do not believe the Leppard record preserves the OAE2, and it is unclear how much of the Middle-Late Cenomanian is preserved

- The redox variability (e.g., Mo, V) may reflect impingement of the OMZ upon the outer shelf.

- The Leppard is unique in that it is an older record of Eagle Ford lithofacies and redox variability
Extra Slides
Calcite - Clay - Quartz Ternary
Dominant *Lower* Eagle Ford Carbonate Facies

Calcareous Nanoplankton Mudrock

Subsurface

Calcareous Foram-Nanoplankton Mudrock-Lime Packstone
Eagle Ford - Austin Facies

**Austin**
- Proximal, cyclic, burrowed to laminated foram-nanoplankton, limestone

**Upper Eagle Ford**
- Medial, cyclic, laminated to burrowed, foram-nanoplankton, mudrock to limestone

**Lower Eagle Ford**
- Distal, laminated to massive nanoplankton-foram calcareous mudrock
Geochemical Model for Sample Mineralogy

Si → SiO₂ → Quartz

Si → KAl₂(SiO₃AlC₁₀)(OH)₂ → Illite

Al → FeS₂ → Pyrite

Fe → Carbonates: siderite, ankerite, dolomite

Ca → CaCO₃ → Calcite

Ca → CaSO₄·2(H₂O) → Gypsum

Ca → Mg, Mn

Ca → Phosphates: apatite, francolite, vivianite

Ti → ALWAYS detrital, regardless of origin
High Resolution Facies Definition from Geochemistry

Foram-nanoplankton packstone
Calcereous nanoplankton mudrock

Stuart City Margin, Maverick Basin