

Compelling Evidence from Eastern Mexico for a Late Paleocene/Early Eocene Isolation, Drawdown and Refill of the Gulf of Mexico*

Stephen P. Cossey¹, Don Van Nieuwenhuise², Joe Davis³, Josh H. Rosenfeld⁴, and James Pindell⁵

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¹Cossey and Associates Inc., Durango, Colorado, United States (cosseygeo@aol.com)

²University of Houston, Houston, Texas, United States

³Digital Prospectors, Dallas Texas United States

⁴Yax Balam Inc., Houston, Texas, United States

⁵Tectonic Analysis Ltd, Dunciton, United Kingdom

Abstract

Outcrops of the Paleocene/Eocene Chicontepec Formation in eastern Mexico have provided a unique opportunity to study exposed time equivalent sections of the deepwater Gulf of Mexico's Wilcox Formation. A 2012 study established a stratigraphic framework in the Tampico-Misantla Basin (TMB) and identified sequence boundaries that could not be correlated globally. Fieldwork in 2008 had also established a network of paleo-canyons in the basin associated with a particular "54 Ma" sequence boundary. At that time, a Paleocene turbidite basin fed from the northwest was incised by a collection of NE-facing erosional canyons that coalesced laterally into the main SE-trending Chicontepec paleo-canyon; this canyon network was filled in the Early Eocene. Using the 2012 study chronostratigraphic scheme, recent micropaleontological studies were performed on a unique outcrop containing a bitumen bed within one of these paleo-canyons. The results suggest that the basin's water level fell rapidly by at least 200 m, starting after 55.8 Ma and leading to subaerial exposure of the bathyal beds for a maximum of 850,000 years prior to canyon refill. Evidence of rooting (limonite tubes) occurs in the bathyal turbidites below the bitumen bed. At this time, the paleo-canyons in the TMB were eroded by fluvial systems feeding directly into the central Gulf basin, probably a land-locked sea. The interpreted large and rapid fall and rise of water level between 55.8 – 54.95 Ma supports the "Gulf of Mexico drawdown hypothesis", i.e., that the GoM may have been isolated from the world's oceans due to the closure of the Florida Straits as the Cuban arc collided with the Bahamas and northeast Yucatán. The timing of the interpreted drawdown coincides with the Paleocene-Eocene Thermal Maximum (PETM), hinting that the PETM may have been caused or assisted by the release of methane from hydrates in the GoM margins and abyssal plain.

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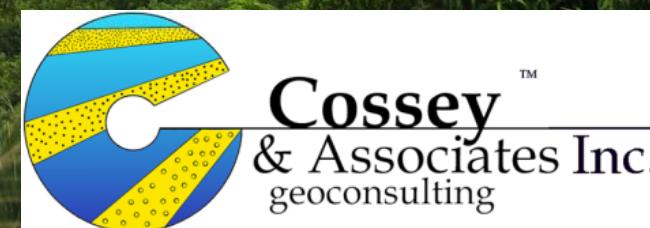
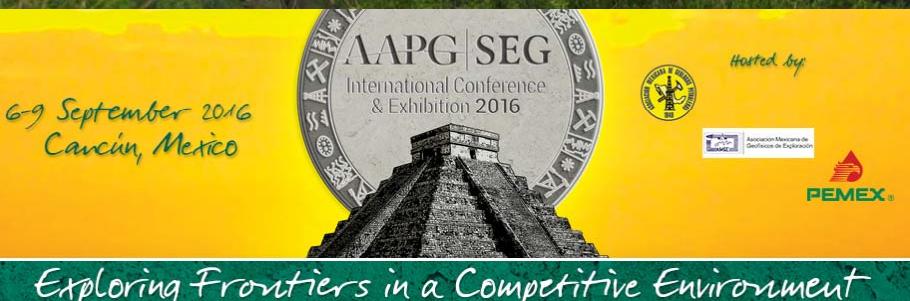
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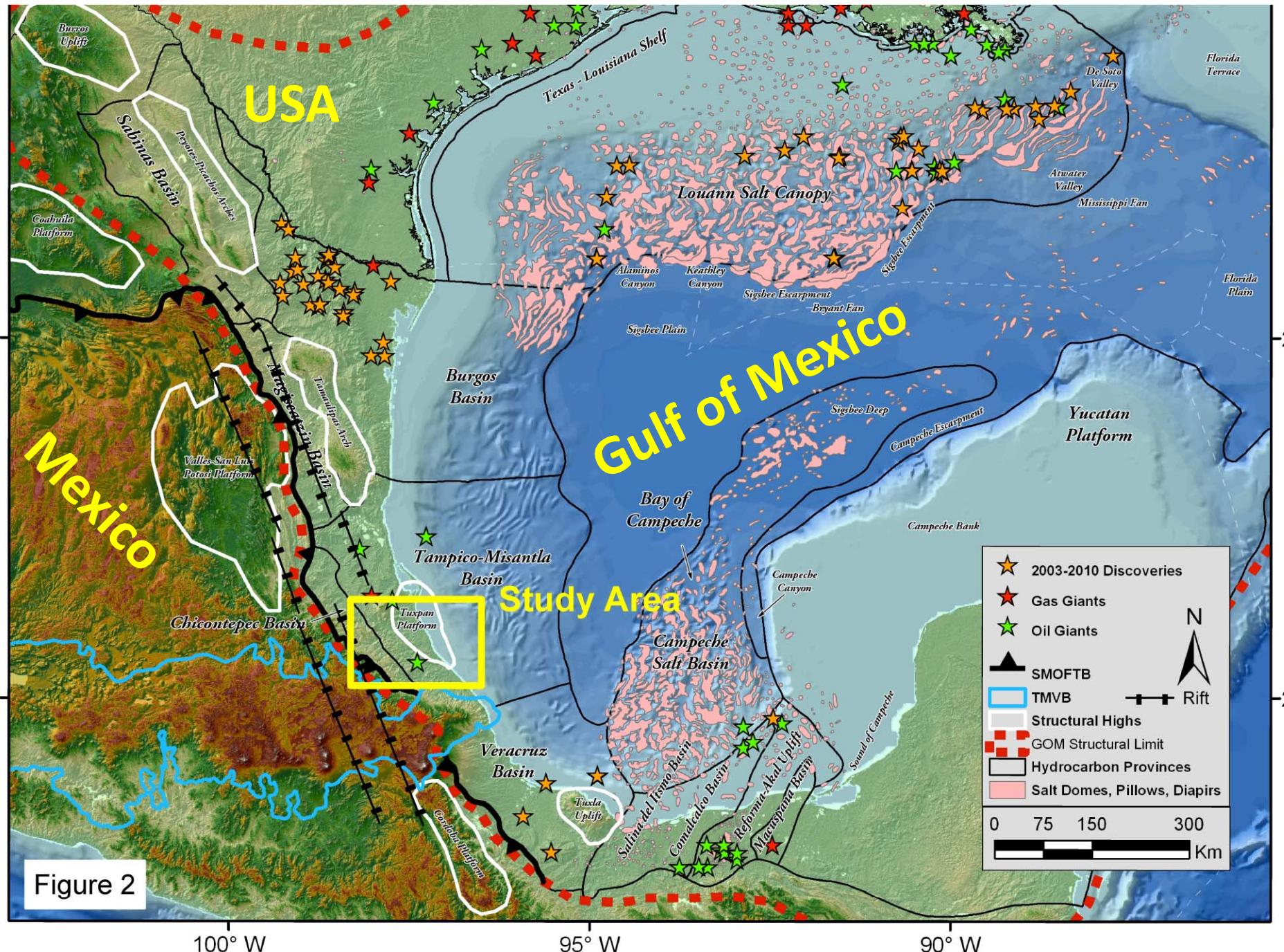
¹ Cossey and Associates Inc., Durango, CO, USA. ² University of Houston, Houston, TX, USA. ³ Digital Prospectors, Dallas, TX, USA., ⁴ Yax Balam Inc., TX, USA. ⁵ Tectonic Analysis, U.K.



Outline

- Location
- GOM Isolation theory
- Paleogeography and Stratigraphy
- Paleocanyons and Acatepec Canyon
- Key Bitumen Bed
- Conclusions



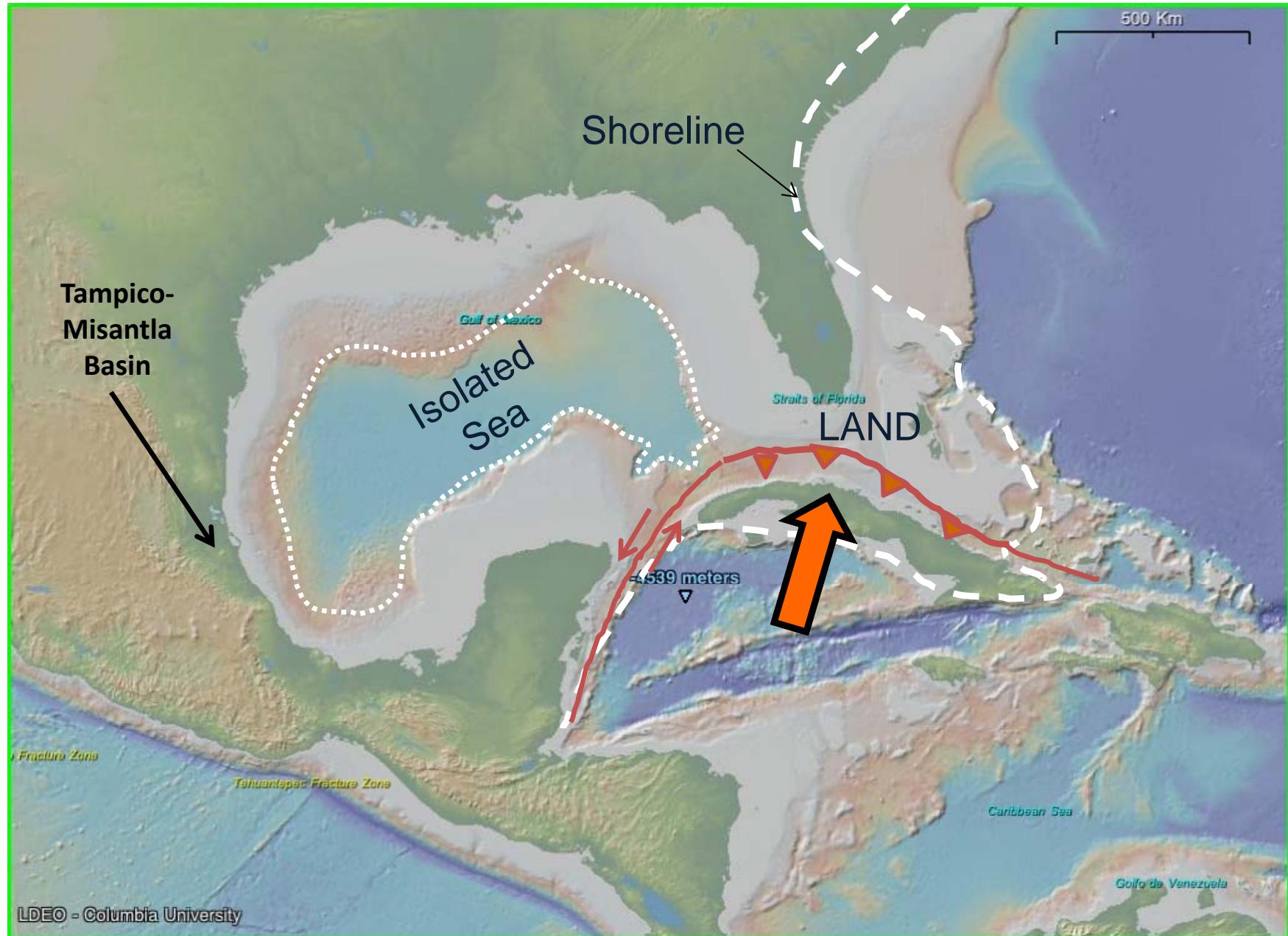


From: Ewing, 1991

Gulf of Mexico Isolation and Drawdown Theory

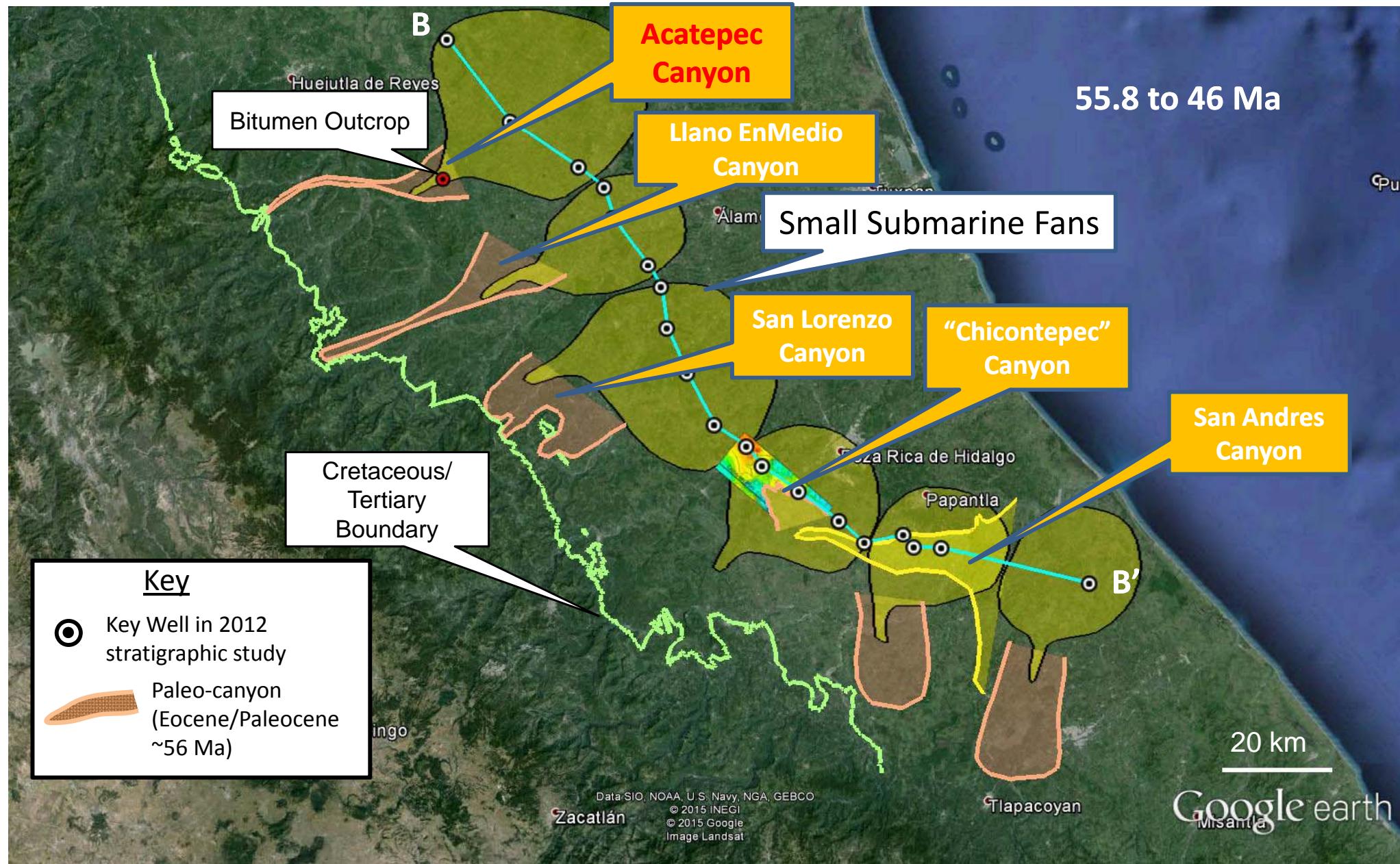
- Initial paper by Rosenfeld and Pindell, 2003
- GoM isolated from world's oceans as Cuban Arc docked against Florida/Bahamas Block.
- Subsequent evaporation caused level of GoM to lower by up to 2,000m at estimated rates of 1m/yr.
- Ended with rapid, catastrophic breakthrough and marine refill (analogue is Mediterranean during Messinian).
- Lot of evidence for this event exists around the GOM and is mounting.
- Requires “Out of the box” Sequence Stratigraphic thinking !!
- We will examine a key bitumen bed outcrop at the Paleocene/Eocene boundary and it's relationship to the drawdown and the PETM.

Early Eocene Paleogeography

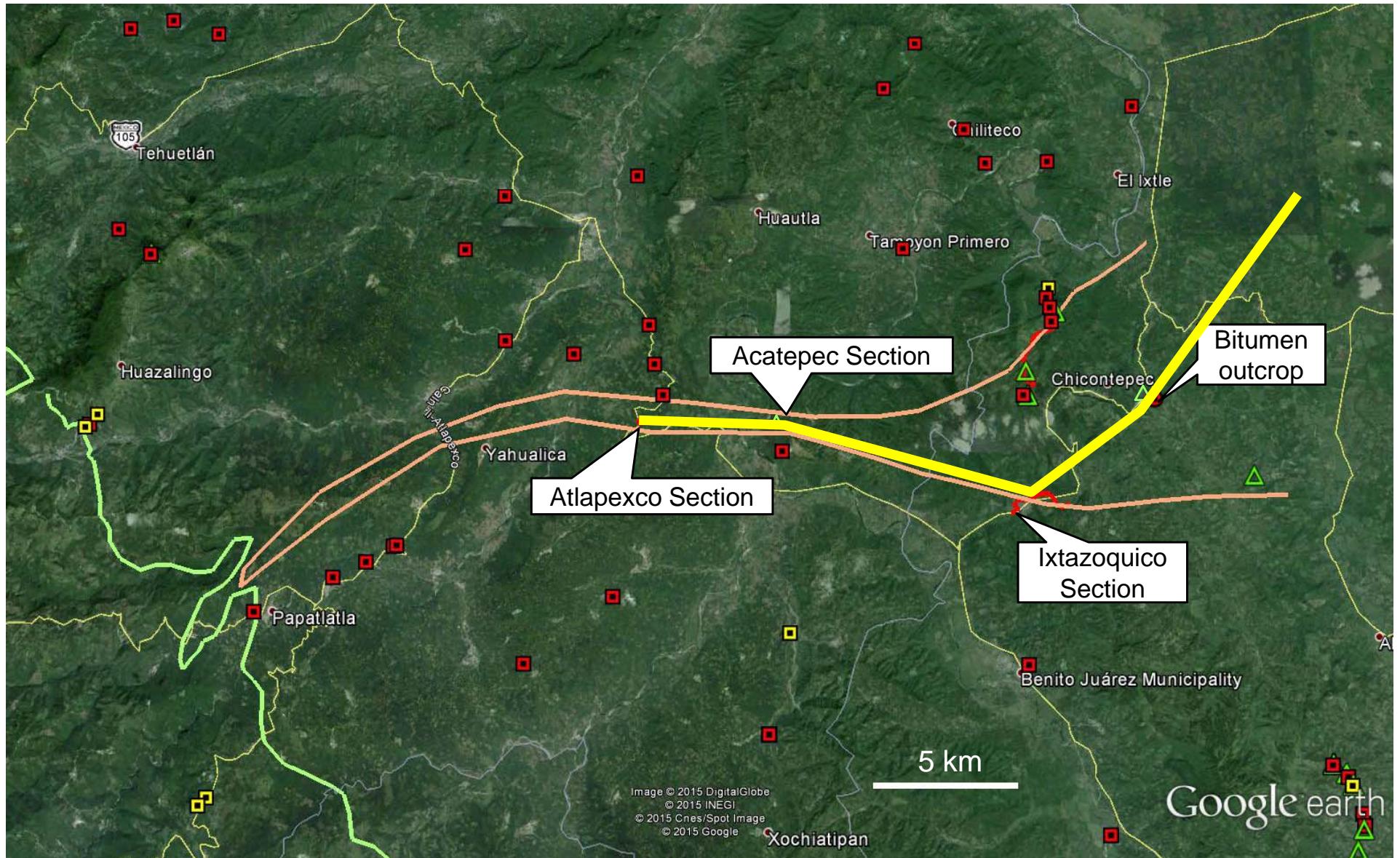


From: Rosenfeld, 2014

Lower Eocene Paleogeography



Acatepec Canyon



- ▲ Eocene sample
 - Upper Paleocene sample
 - Paleocene (undifferentiated)
- Paleocanyon Outline
 - Cretaceous Boundary

Atlapexco Road Cut

Eocene
Canyon-fill Debrite
(Pebbly-Mudstone)

Paleocene
Thin and Medium-Bedded
Turbidites

Canyon Margin (SB)



Canyon Margin Close-Up

Eocene Debris

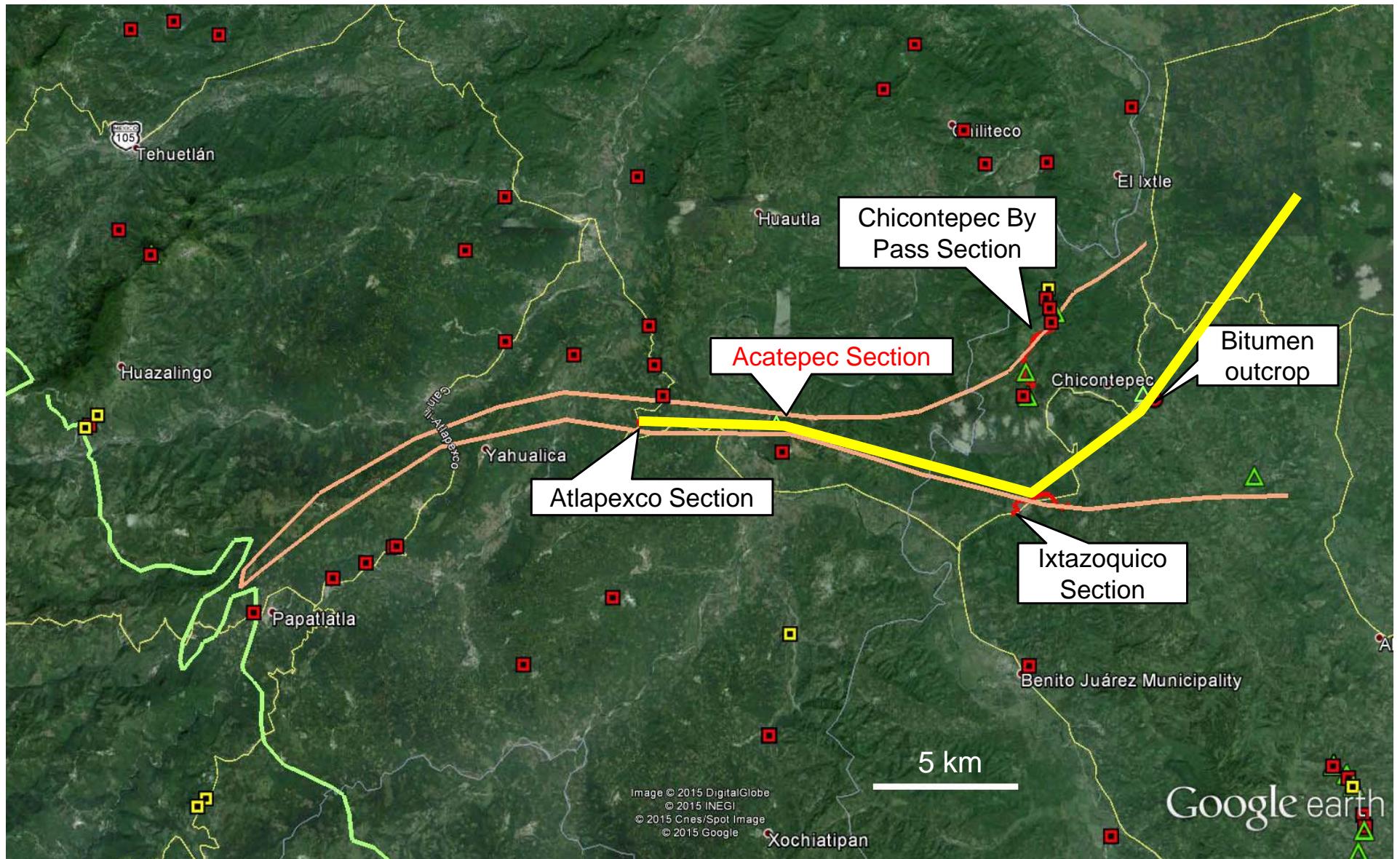
Erosional Base

Paleocene
Thin and Medium-Bedded
Turbidites

Margin Fault

Margin Fault

Acatepec Canyon

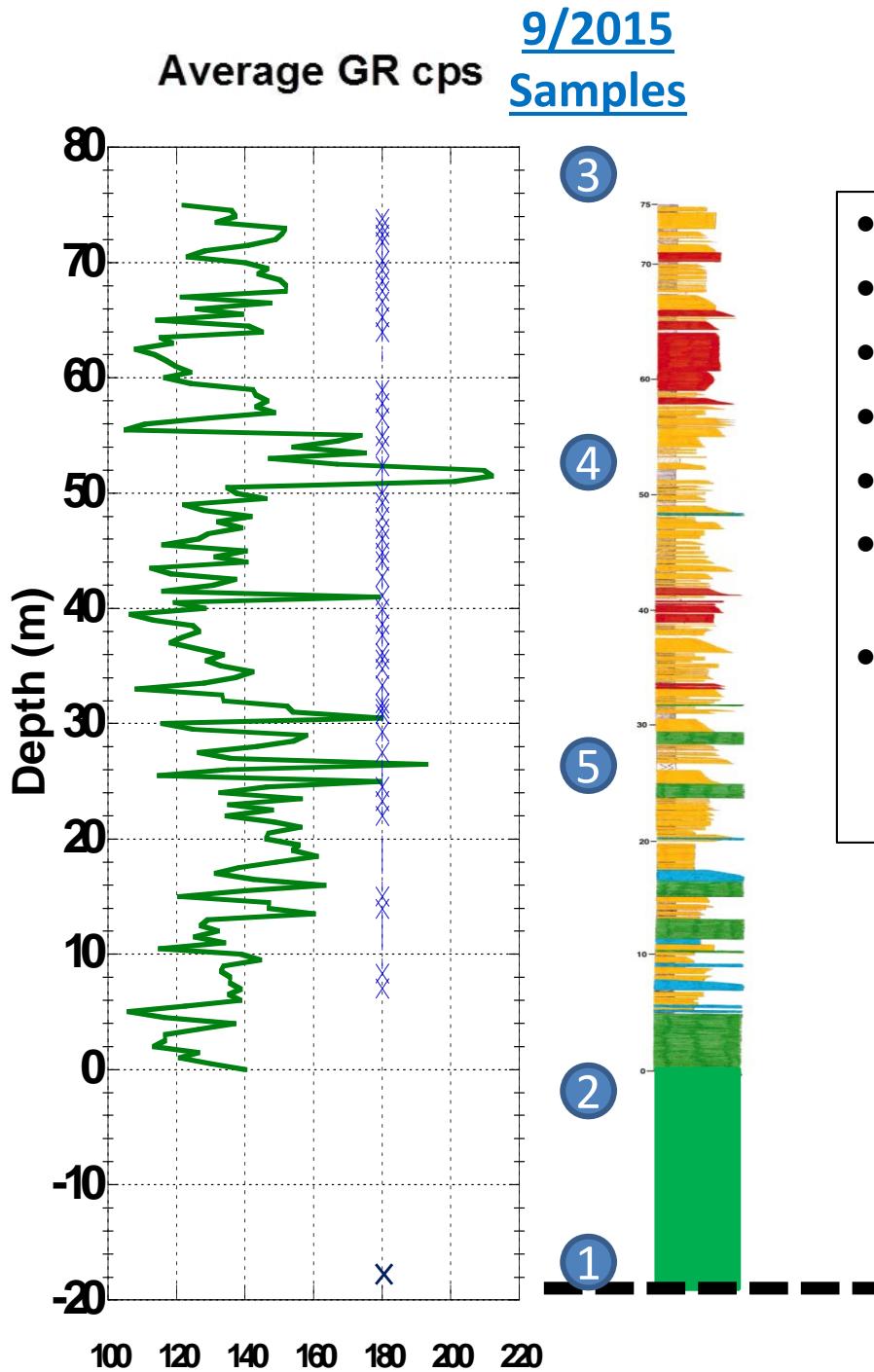


- ▲ Eocene sample
 - Upper Paleocene sample
 - Paleocene (undifferentiated)
- Paleocanyon
- Cretaceous Boundary

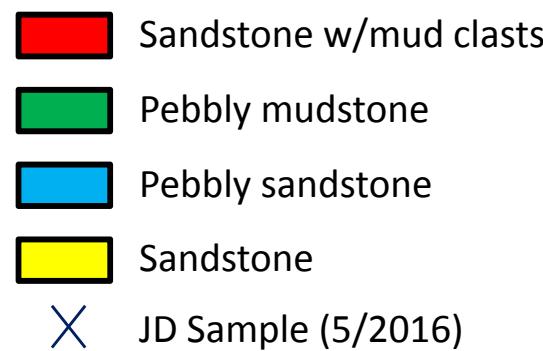


The outcrop is located in a road cut near Acatepec town (Hidalgo State). About 100m of section was measured and described in detail at individual bed-scale (5cm resolution). In addition to this, an outcrop gamma ray (GR) log was acquired with a resolution of 0.5m (sample rate).

Acatepec Outcrop

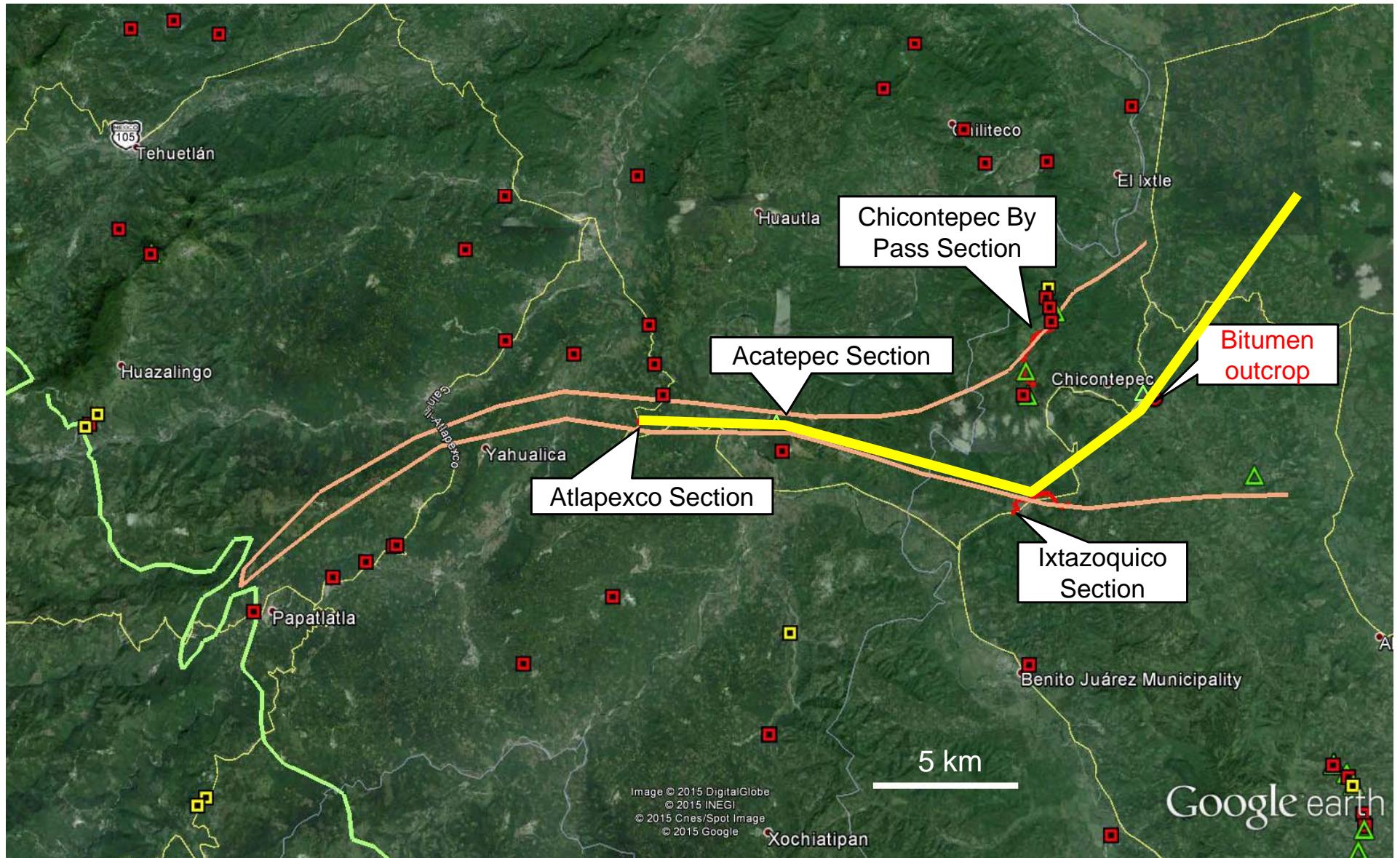


- High Net/Gross (82%) Bathyal Environment
- Paleocurrents to East (50 - 100 degrees)
- Abundant organic material and bioturbation
- Interpreted as a Typical Canyon-fill sequence
- Sample 4 (High GR) - Barren
- Sample 5 contains *Fasciculithus richardii*
 - Last occurrence at the onset of PETM (P/E boundary)
- Samples 1 and 3 – Palynology and nannofossil analysis indicates late Paleocene to early Eocene age.



Canyon erosional base
(~Paleocene/Eocene contact?)

Acatepec Canyon



- ▲ Eocene sample
- Upper Paleocene sample
- Paleocene (undifferentiated)
- Paleocanyon Outline
- Cretaceous Boundary

3D Setting of Outcrop

2015





2015 Field excavations and Drilling

2015 Field excavations



2016 Field excavations

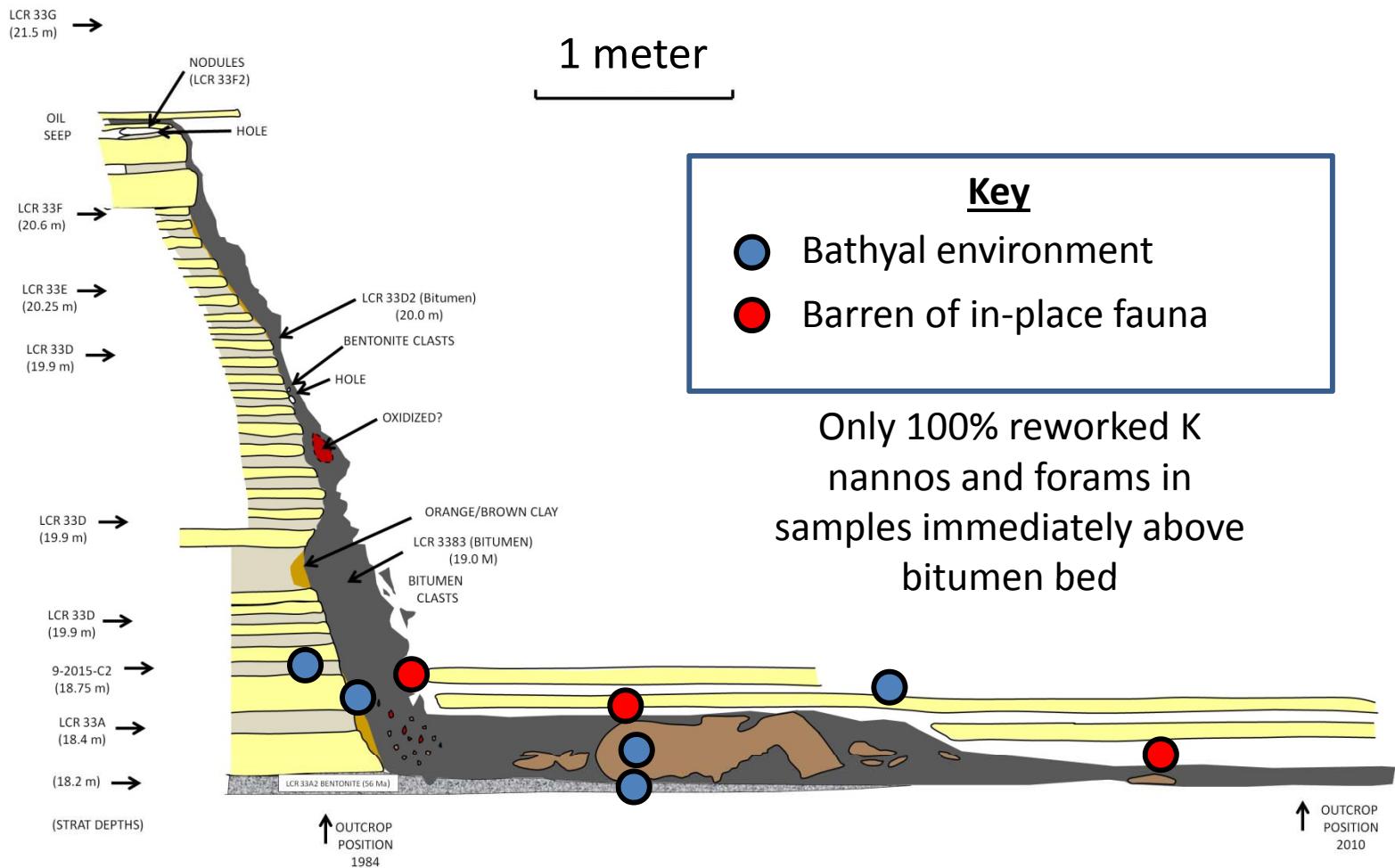


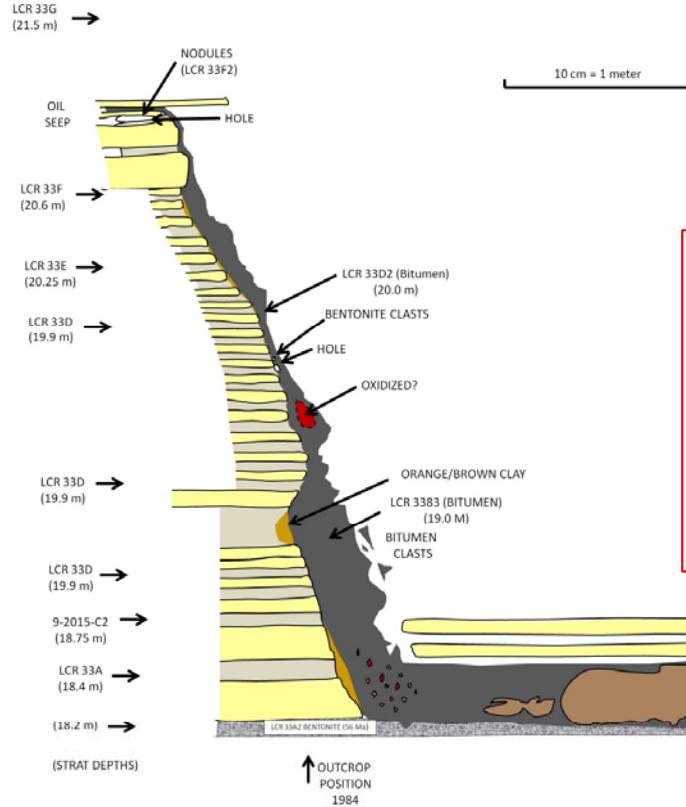
Bitumen Bed General Description

- Bitumen is only lightly biodegraded – could have been pasteurized at depth and then leaked to surface.
- Barren of in-place fauna immediately (2 cm) above, but significant increase in reworked Cretaceous sediments above.
- Contains brown shale clasts.
- Other characteristics:
 - Low Sulfur
 - Conchoidal fracture
 - Fluoresces under UV light
 - No stratification, no macerals, non-continuous fractures (slits) typical of bitumens
 - Oil and gas is released immediately on exposure to UV light
- Conclusion is that the bed is a fossil bitumen bed
- Key evidence of limonite tubes in section 0-1.7 m below bitumen bed.

Stratigraphic Up

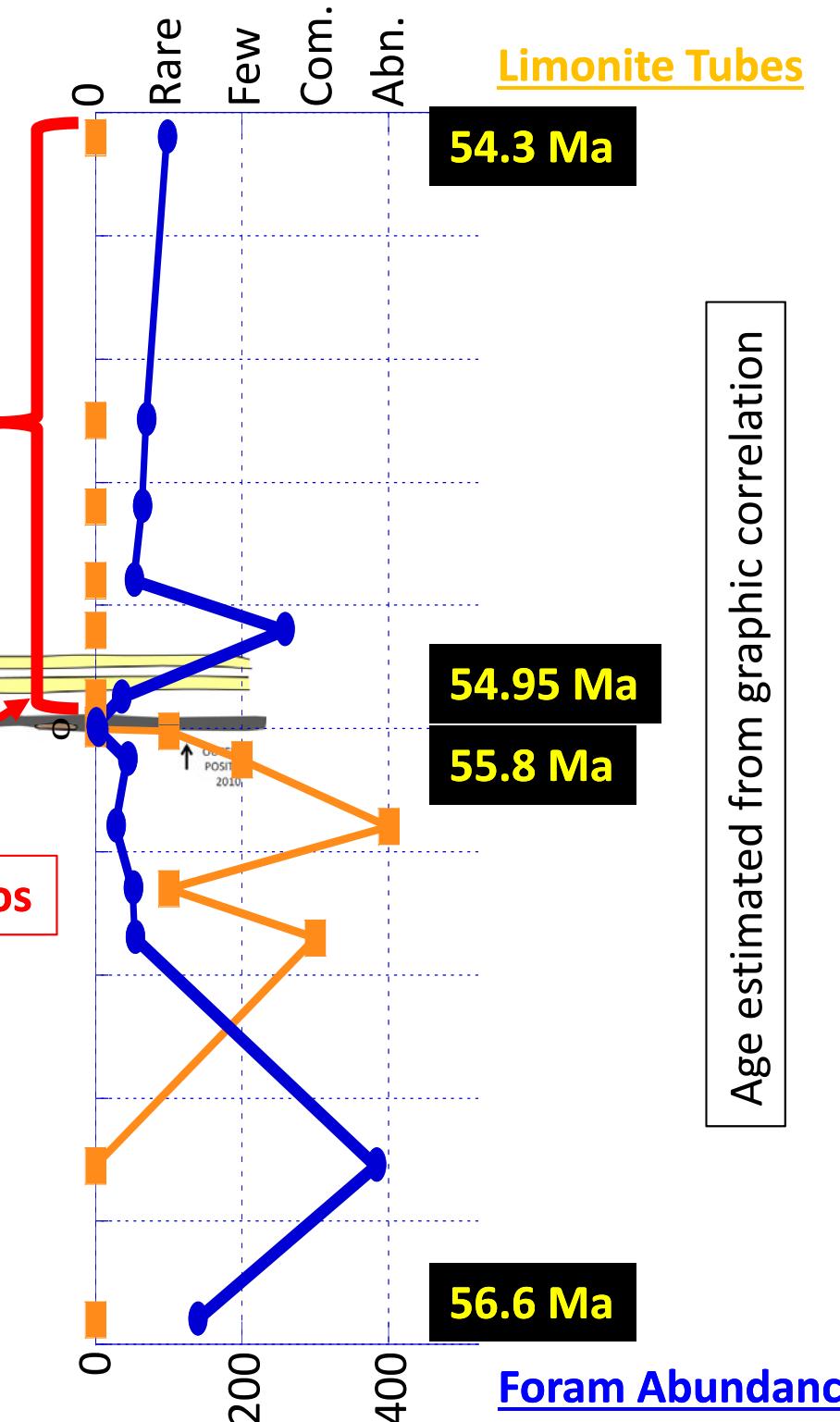
Chicontepec Bitumen Bed Outcrop





**Limonite
Tubes and
Pollen
Absent from
Samples**

100% reworked K nannos



Age estimated from graphic correlation

Biostratigraphic Evidence

Limonite Tubes

54.3 Ma

54.95 Ma

55.8 Ma

56.6 Ma

Foram Abundance

Limonite Tubes 25 cm below bitumen bed

2 mm

DL0
L=2.003 mm

1.0 mm

Modern Analogue – Carpinteria CA



The Clasts

- Many large clasts have delicate edges - not transported far
 - Large clast contains limonite tubes
- Clasts appear to have been entrained within oil seep, did not fall down cliff
 - Large clast was pliable – deformed 90 degrees
- Red clasts appear baked?
 - Not all clasts show red rims
 - Red clasts are derived from late Paleocene (nannos).

Clast within bitumen bed



Large red rimmed sdst clasts in bitumen bed

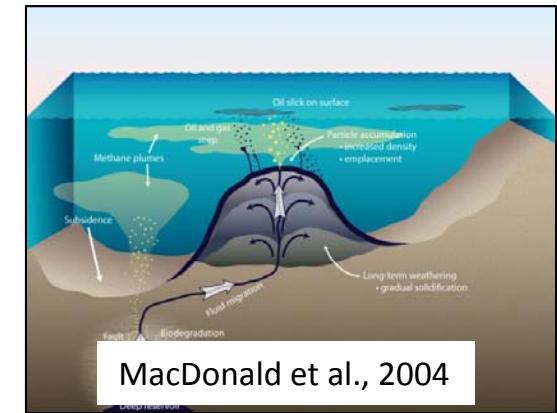
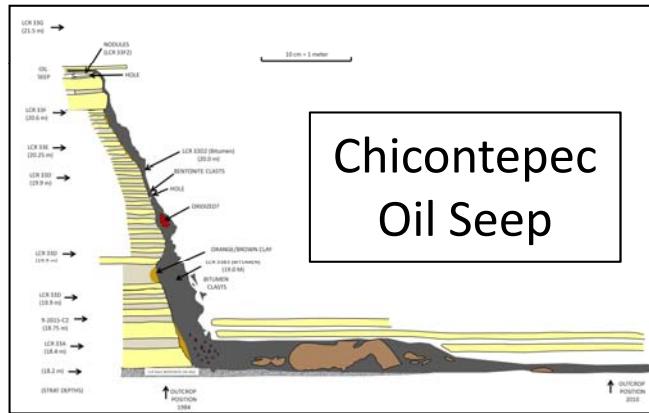


- Bricks are heated to 1000°C in a kiln
- Forest fires can attain temperatures of 800°C

Many small red clasts within bitumen bed



Subaerial vs. Submarine Oil Seep



- Relatively smooth upper surface. → • Very rough upper surface.
- Thinnest at top, thickest at base (flows downhill). → • Thickest at top, thinnest at base (solidifies rapidly).
- Bitumen does not contain any fauna. Underlying sequence contains limonite tubes (rooting). → • Rich in chemosynthetic communities of tubeworms, bacterial mats and bivalves.
- Contains shale clasts with delicate edges which have fallen down the cliff. → • Contain slabs of authigenic carbonate.
- Occurs in a low created by an erosional unconformity and is only lightly biodegraded. → • Occurs on the crest of uplifted areas of the sea floor and is highly biodegraded.
- Analogue is cliffs at Carpinteria, CA. → • Present-day Campeche Knolls, Mexico.

Conclusions

- A subaerial exposure and erosion of bathyal sediments caused by a rapid sea level fall and rise of greater than 200 m occurred at the Paleocene/Eocene boundary in the GoM.
- The underlying rooted bathyal turbidite sediments are preserved by a fossilized subaerial oil seep near the village of Chicontepec, Eastern Mexico
- The authors believe this is a record of the isolation, drawdown and catastrophic refill of the Gulf of Mexico at about 56Ma (Paleocene/Eocene boundary).
- Work is ongoing in this region to test the hypothesis that this event is linked to the onset of the PETM.

GoM Exploration Implications

- Basin burial history needs to be modified
- Exposed carbonates would have had porosity enhanced by fresh-water diagenesis (karsting)
- Canyon-fills may contain preserved fluvial sediments
- Large volumes of Paleocene and older sediments were reworked into deep GOM at 55.8-54.95 Ma
- Trap seals may have been breached, many traps may have leaked and then undergone a second HC filling after the GoM returned to “normal”

Thank You!!

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- Thanks also to Lynne Goodoff for early geophysical support and first alerting me to the presence of unconformities (discordancias) in the basin.
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