Chronostratigraphy vs. biostratigraphy – the value of absolute ages in Gulf of Mexico regional geologic studies

Robert B. Witrock

(*Minerals Management Service,*

US Interior Department, New Orleans)

PPDM … the business driven standard

Teaching resources on geologic time and stratigraphy

- online resources from the www.chronos.org web site

- Education and Outreach
  - **Educational Resources**
    - Existing Educationa...
    - Stratigraphy Exerci...
    - Understanding Geolo...
- Education and Outreach Working Group

Educational Resources

Existing Educational Resources for Geosciences and Geological Time

History of the Earth Poster

International Stratigraphic Commission-CHRONOS poster with 2004 Geologic Time Scale and Tower of Time graphics [download 1.9 Mb]

Digital Library for Earth System Education

DLESE

eGuide to Paleoclimates

eGuide to Paleoclimates

Stratigraphy Exercises

Sequence Stratigraphy (Grades 13 and up) University of South Carolina Department of Geology

Chronostratigraphy (Grades 13 and up) University of South Carolina Department of Geology

Correlation and Strata: Findasaurus Museum of Paleontology, University of California, Berkeley (Grades K-8)

What stories do rocks tell?" TERC (Grades 6-14)

How did the layers of the Grand Canyon form? TERC (Grades 6-14)

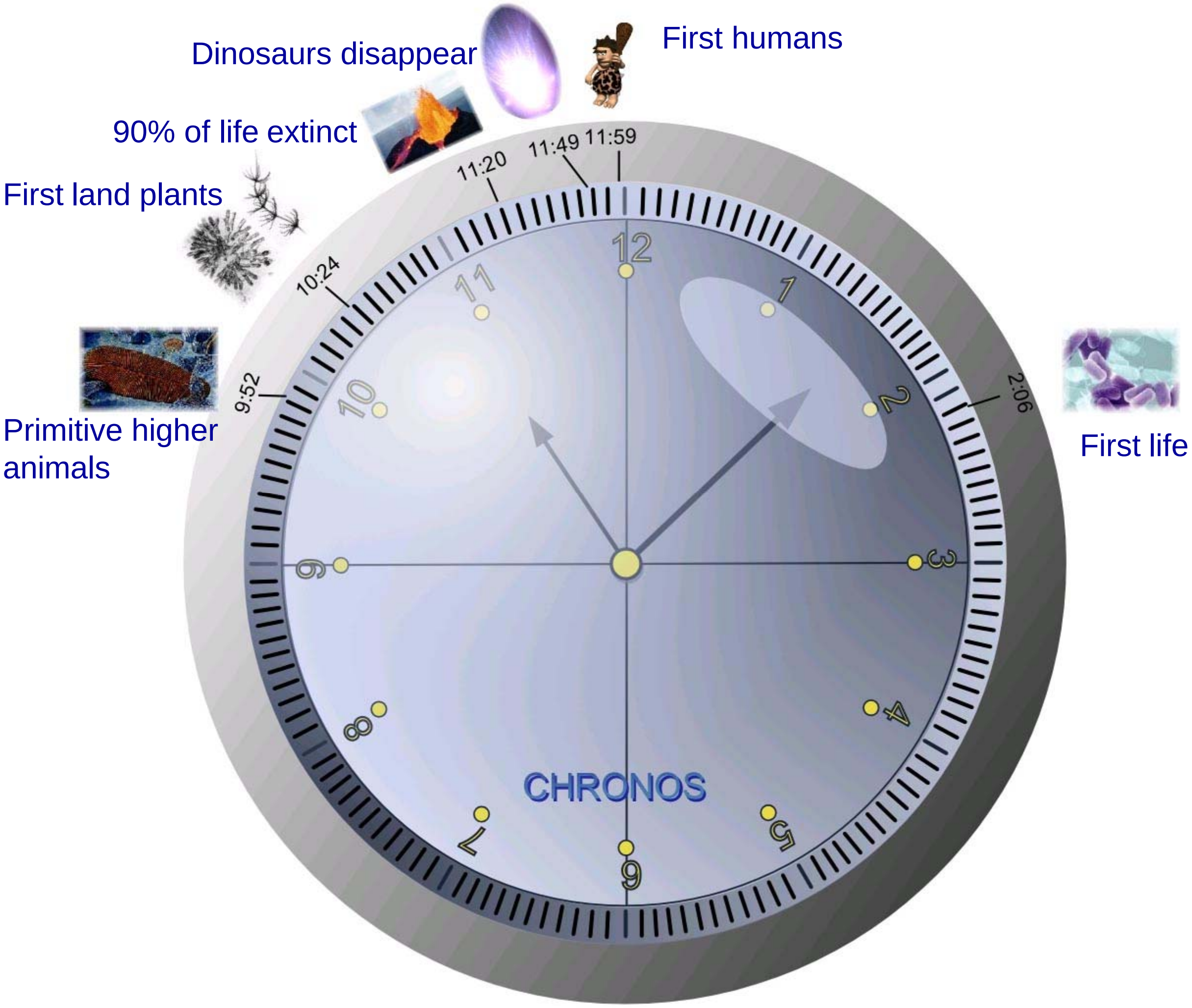
Determining Age of Rocks and Fossils Museum of Paleontology, University of California, Berkeley (Grades 9-12)

Understanding Geologic Time

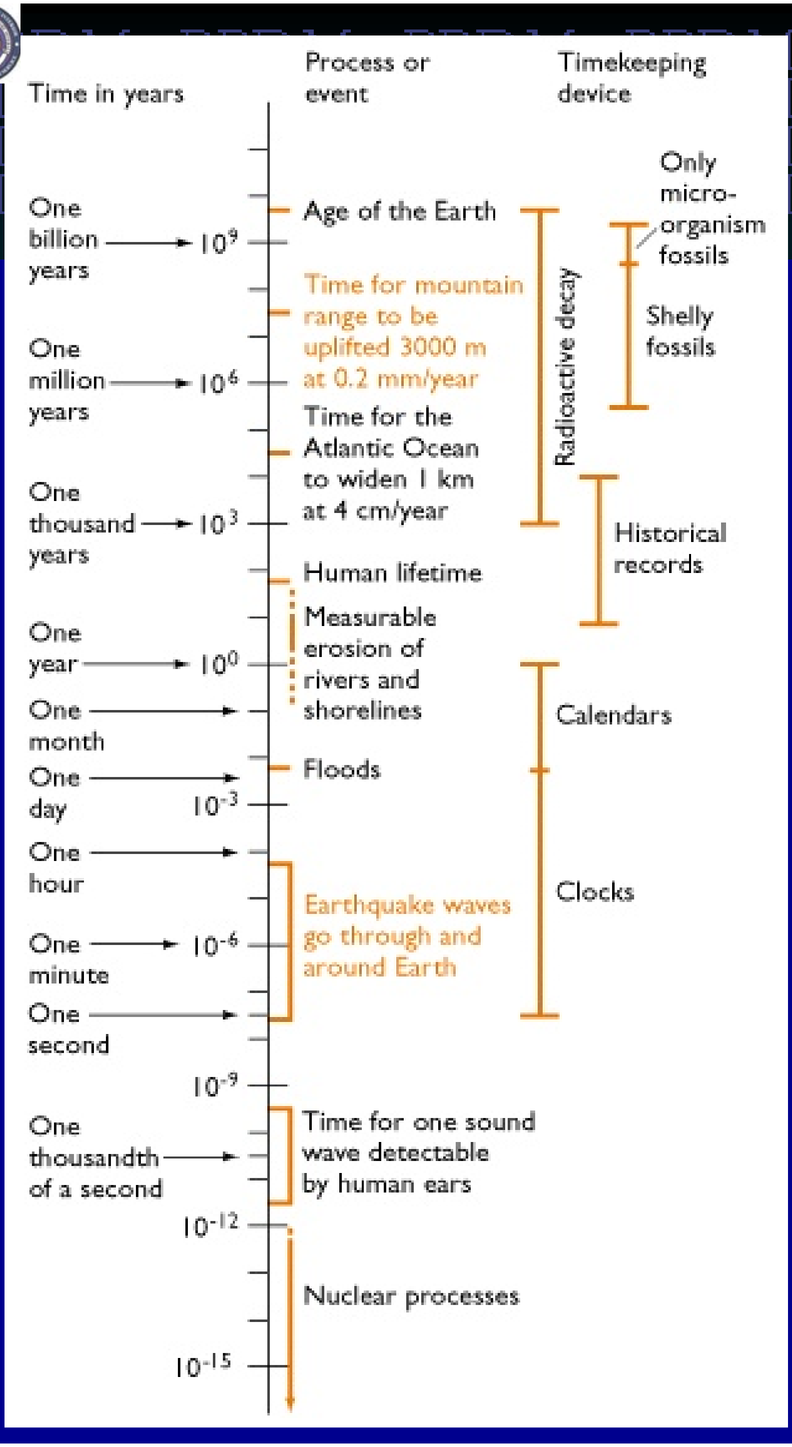
The Geologic Clock

CHRONOS

- a series of fortunate (or unfortunate) events in the history of life

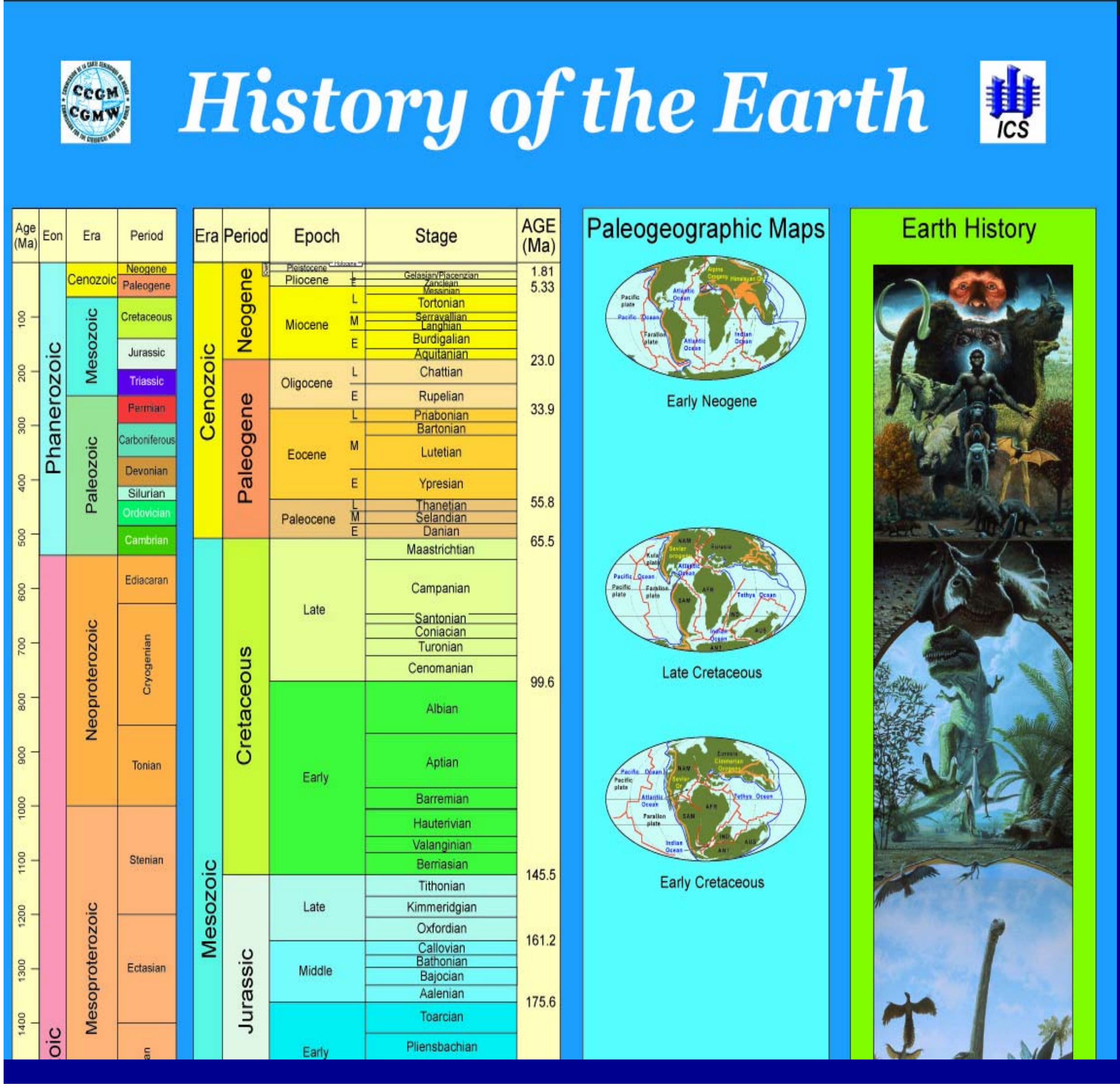


Geology deals with a wide range of times and rates



- much of science deals only with the *possible* and the *present*, asking only what **can** happen.
- geology is a *historical* science…it asks what **did** happen and **when**.

Geology deals with a wide range of times and rates



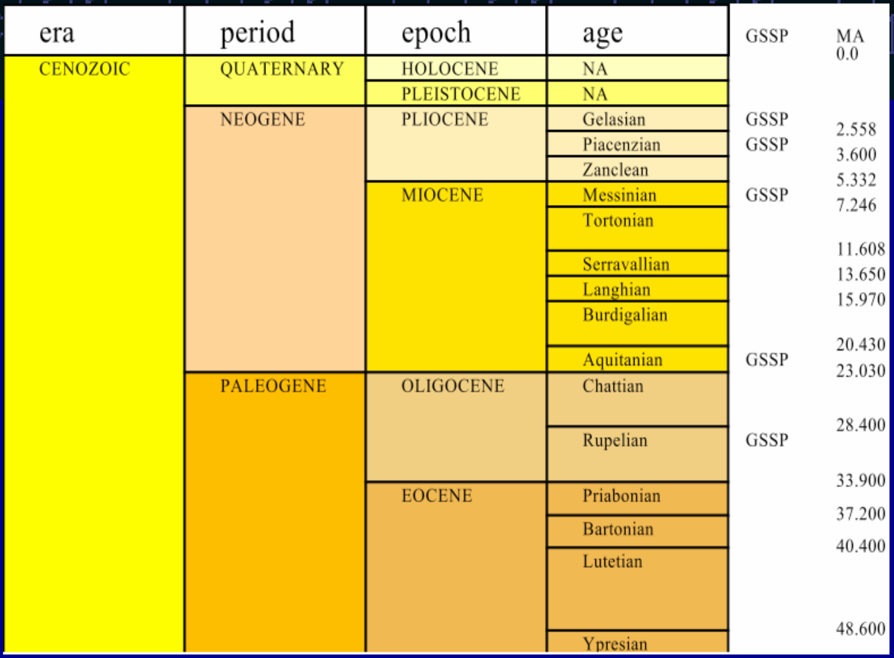
History of the Earth

Age (Ma)	Eon	Era	Period
	Phanerozoic	Cenozoic	Neogene
			Paleogene
100		Mesozoic	Cretaceous
			Jurassic
200			Triassic
		Paleozoic	Permian
300			Carboniferous
			Devonian
400			Silurian
			Ordovician
500			Cambrian
600	oic	Neoproterozoic	Ediacaran
700			Cryogenian
800			
900			Tonian
1000		Mesoproterozoic	
1100			Stenian
1200			
1300			Ectasian
1400			an

Era	Period	Epoch		Stage	AGE (Ma)
Cenozoic	Neogene	Pleistocene		Holocene	
		Pliocene	L E	Gelasian/Piacenzian Zanclean	1.81
		Miocene	L	Messinian	5.33
			L	Tortonian	
			M	Serravallian	
			M	Langhian	
			E	Burdigalian	
			E	Aquitanian	
	Paleogene	Oligocene	L	Chattian	23.0
			E	Rupelian	
		Eocene	L	Priabonian	33.9
			L	Bartonian	
			M	Lutetian	
			E	Ypresian	
		Paleocene	L	Thanetian	55.8
			M	Selandian	
			E	Danian	
Mesozoic	Cretaceous	Late		Maastrichtian	65.5
				Campanian	
				Santonian	
				Coniacian	
				Turonian	
				Cenomanian	
		Early		Albian	99.6
				Aptian	
				Barremian	
				Hauterivian	
				Valanginian	
				Berriasian	
	Jurassic	Late		Tithonian	145.5
				Kimmeridgian	
				Oxfordian	
		Middle		Callovian	161.2
				Bathonian	
				Bajocian	
				Aalenian	
		Early		Toarcian	175.6
				Pliensbachian	

- when considering events in the unobservable past, two basic needs are:
- to establish the *relative order* of events and
- to fix the *absolute age* of events.

Geologic Time Scale



era	period	epoch	age	GSSP	MA 0.0
CENOZOIC	QUATERNARY	HOLOCENE	NA		
		PLEISTOCENE	NA		
	NEOGENE	PLIOCENE	Gelasian	GSSP	2.558
			Piacenzian	GSSP	3.600
			Zanclean		5.332
		MIOCENE	Messinian	GSSP	7.246
			Tortonian		11.608
			Serravallian		13.650
			Langhian		15.970
			Burdigalian		20.430
			Aquitanian	GSSP	23.030
	PALEOGENE	OLIGOCENE	Chattian		28.400
			Rupelian	GSSP	33.900
		EOCENE	Priabonian		37.200
			Bartonian		40.400
			Lutetian		48.600
			Ypresian		

2004 Global Time Scale published by the International Commission on Stratigraphy,

available digitally at www.chronos.org and www.stratigraphy.org

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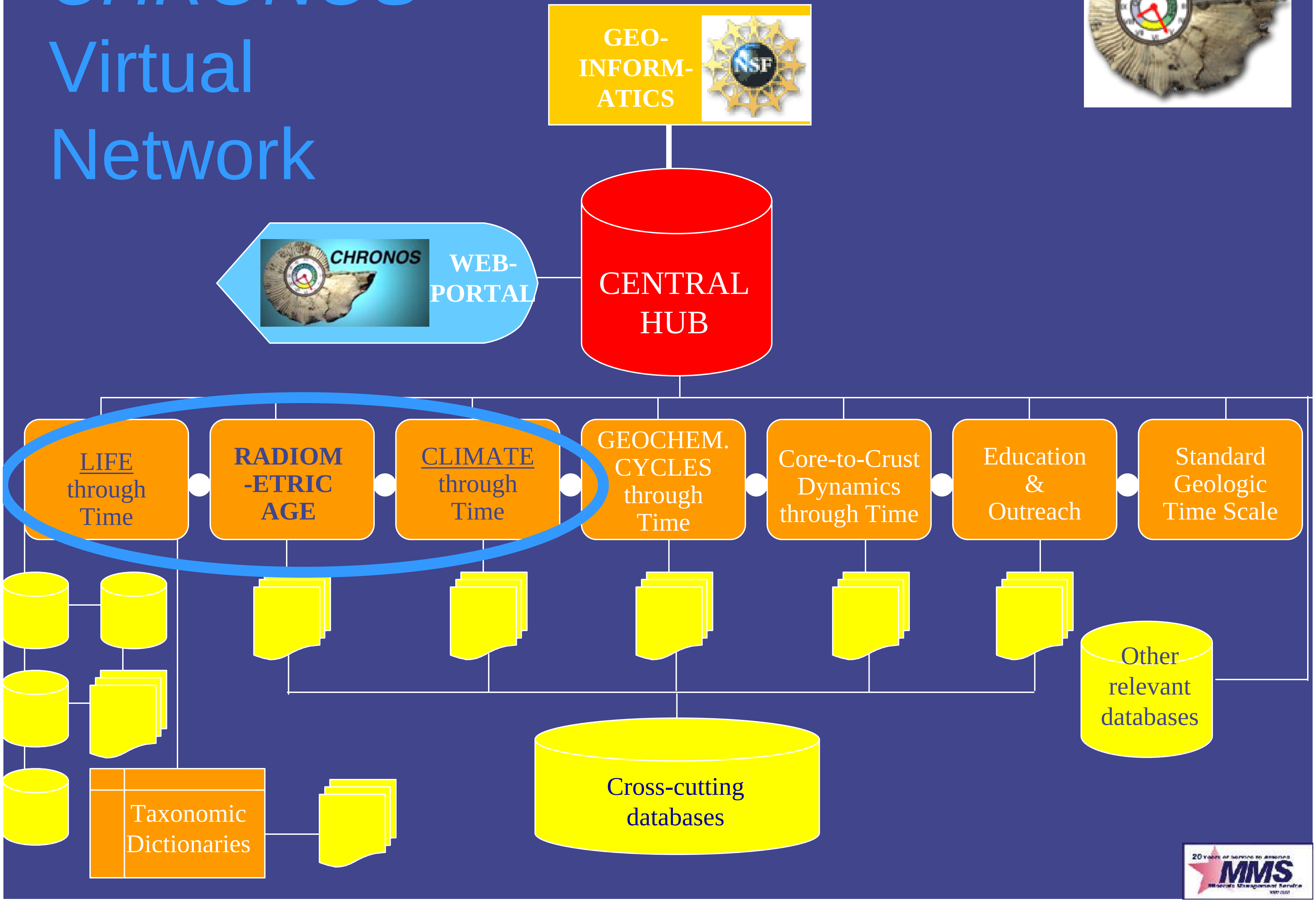
CHRONOS Virtual Network



GEO-INFORM-ATICS

CENTRAL HUB

WEB-PORTAL

LIFE through Time

RADIOM-ETRIC AGE

CLIMATE through Time

GEOCHEM. CYCLES through Time

Core-to-Crust Dynamics through Time

Education & Outreach

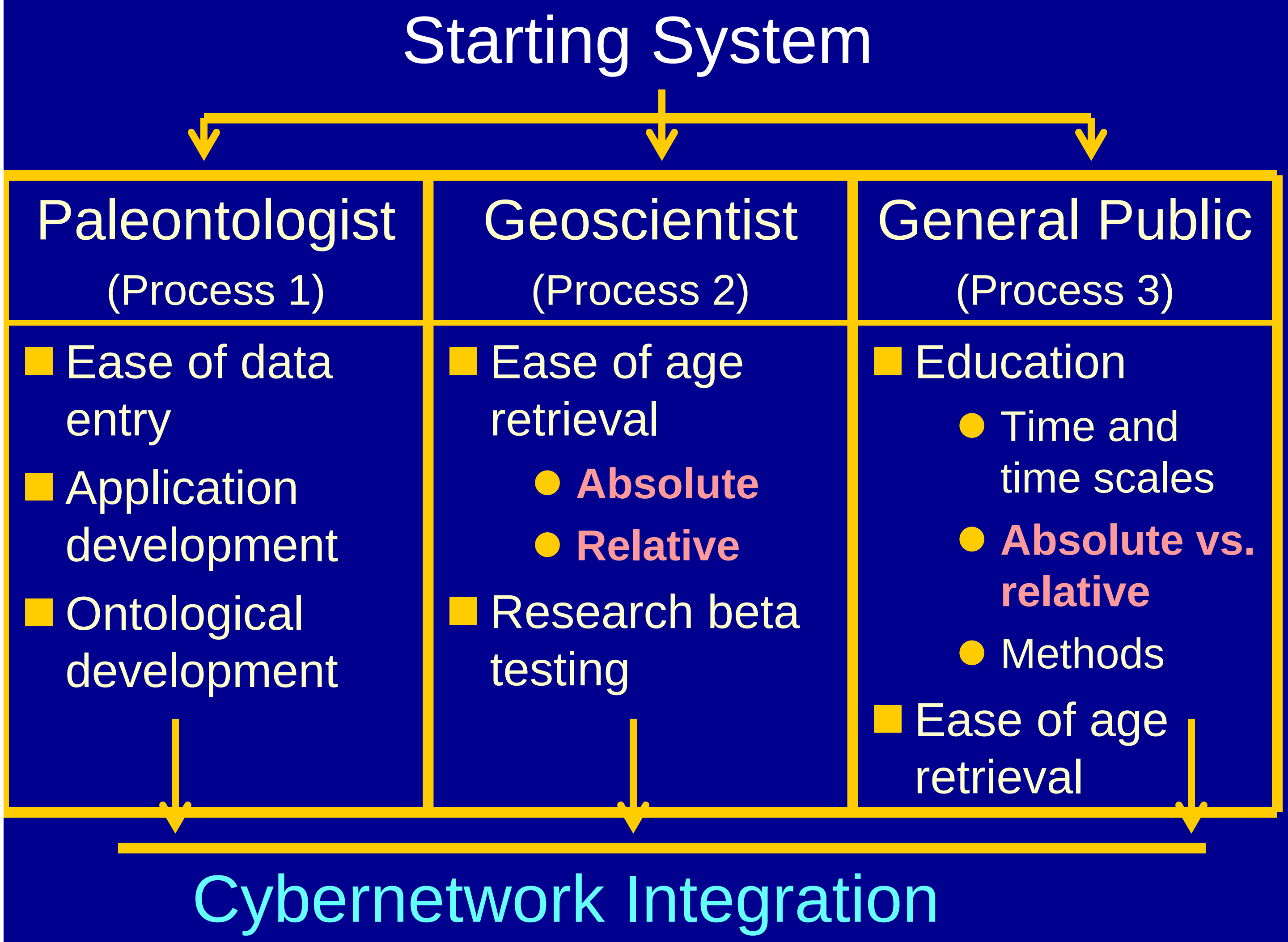
Standard Geologic Time Scale

Taxonomic Dictionaries

Cross-cutting databases

Other relevant databases

Template for Database Conversion



Starting System

Paleontologist
(Process 1)

- Ease of data entry
- Application development
- Ontological development

Geoscientist
(Process 2)

- Ease of age retrieval
  - **Absolute**
  - **Relative**
- Research beta testing

General Public
(Process 3)

- Education
  - Time and time scales
  - **Absolute vs. relative**
  - Methods
- Ease of age retrieval

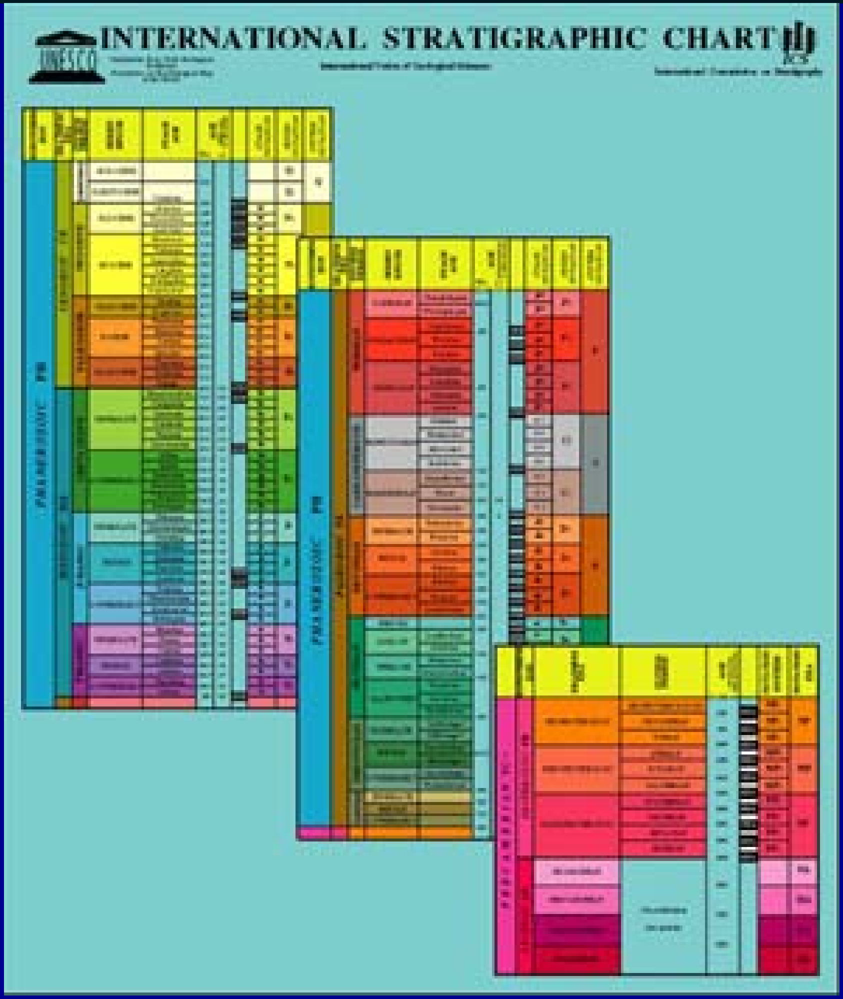
Cybernetwork Integration

Chronostratigraphy as integrated into GEON model for graphic correlation

from http://www.geongrid.org/sitevisit/platon.ppt#308,3,Template for Database Conversion

Geologic Time Scale

- coordinated with the International Stratigraphic Commission
- XML interface to the database to store the 2004 GTS (stage descriptions, GSSPs) with standard USGS and international color scheme

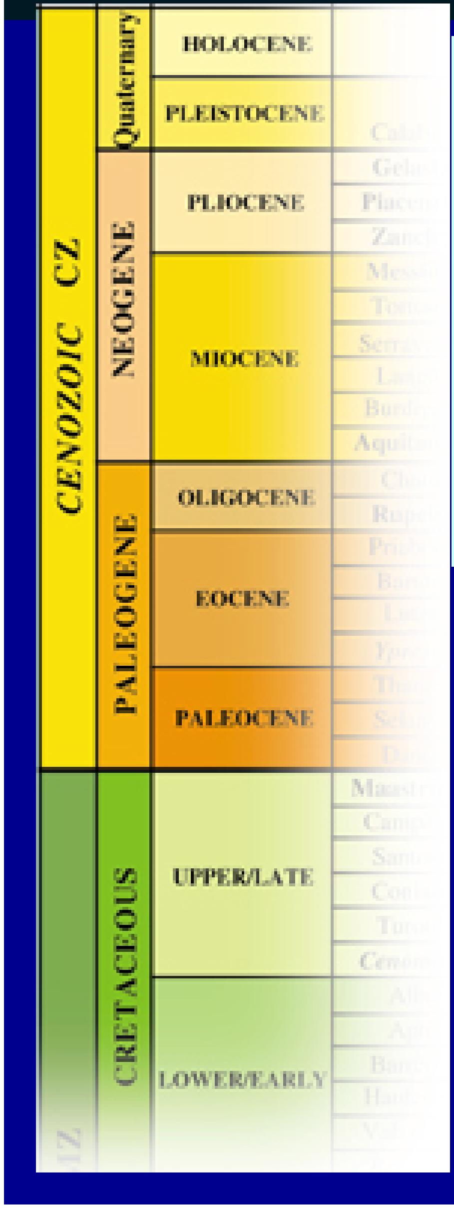


INTERNATIONAL STRATIGRAPHIC CHART

Stratigraphy

- lithostratigraphy (rock types)
- biostratigraphy (fossils)
- magnetostratigraphy (magnetic reversal time scale)
- chemostratigraphy (chemical or isotopic methods for correlating; e.g., oxygen isotopes)
- chronostratigraphy

Stratigraphic and time units



Geologic time units	Chronostratigraphic units	Biostratigraphic units	Rock-stratigraphic units
Era Period Epoch Age -------------------	-------------------- System Series Stage chronozone	biozone	(Group Formation Member Bed)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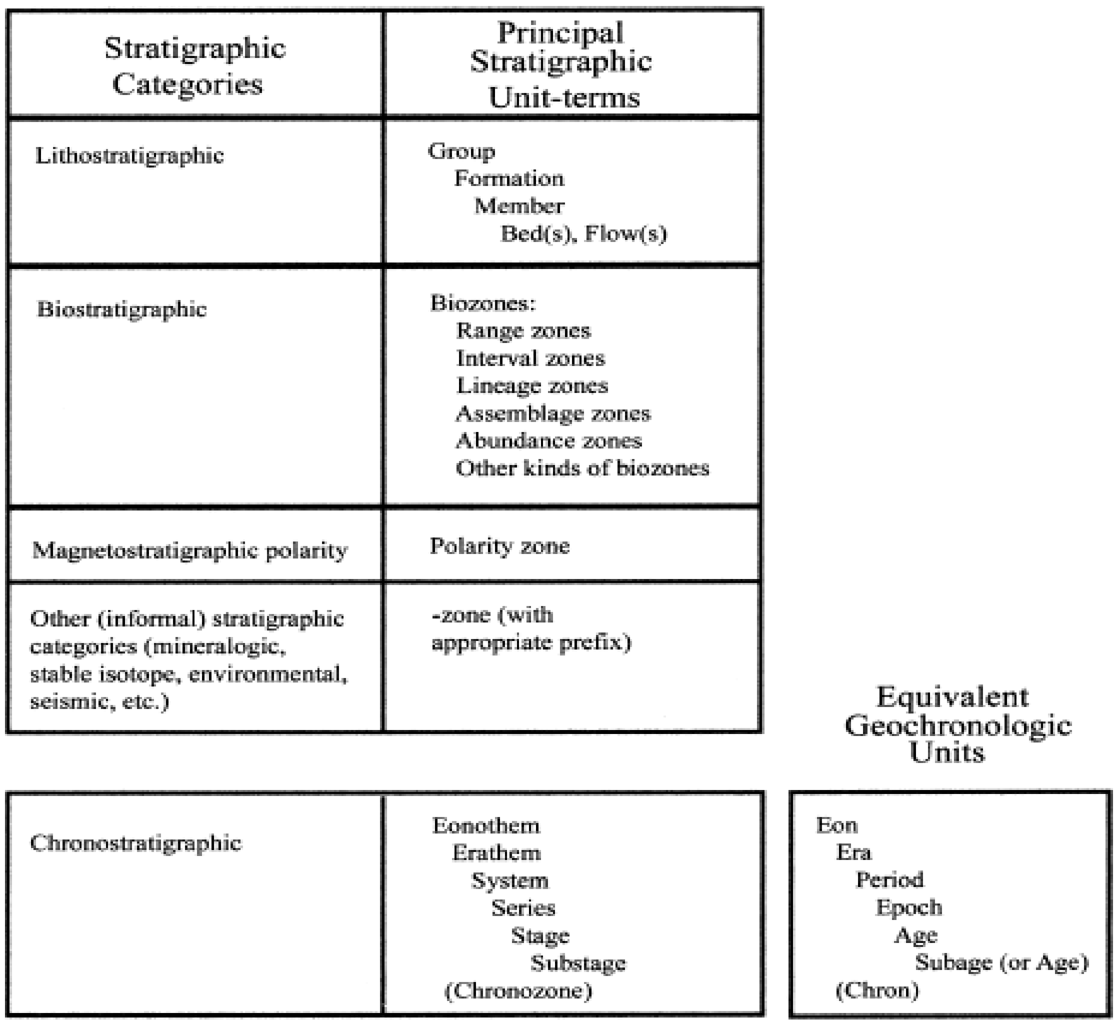
A Cretaceous Band on the Run


© 2001 Brooks/Cole Publishing/ITP

A Cretaceous Coelocanth

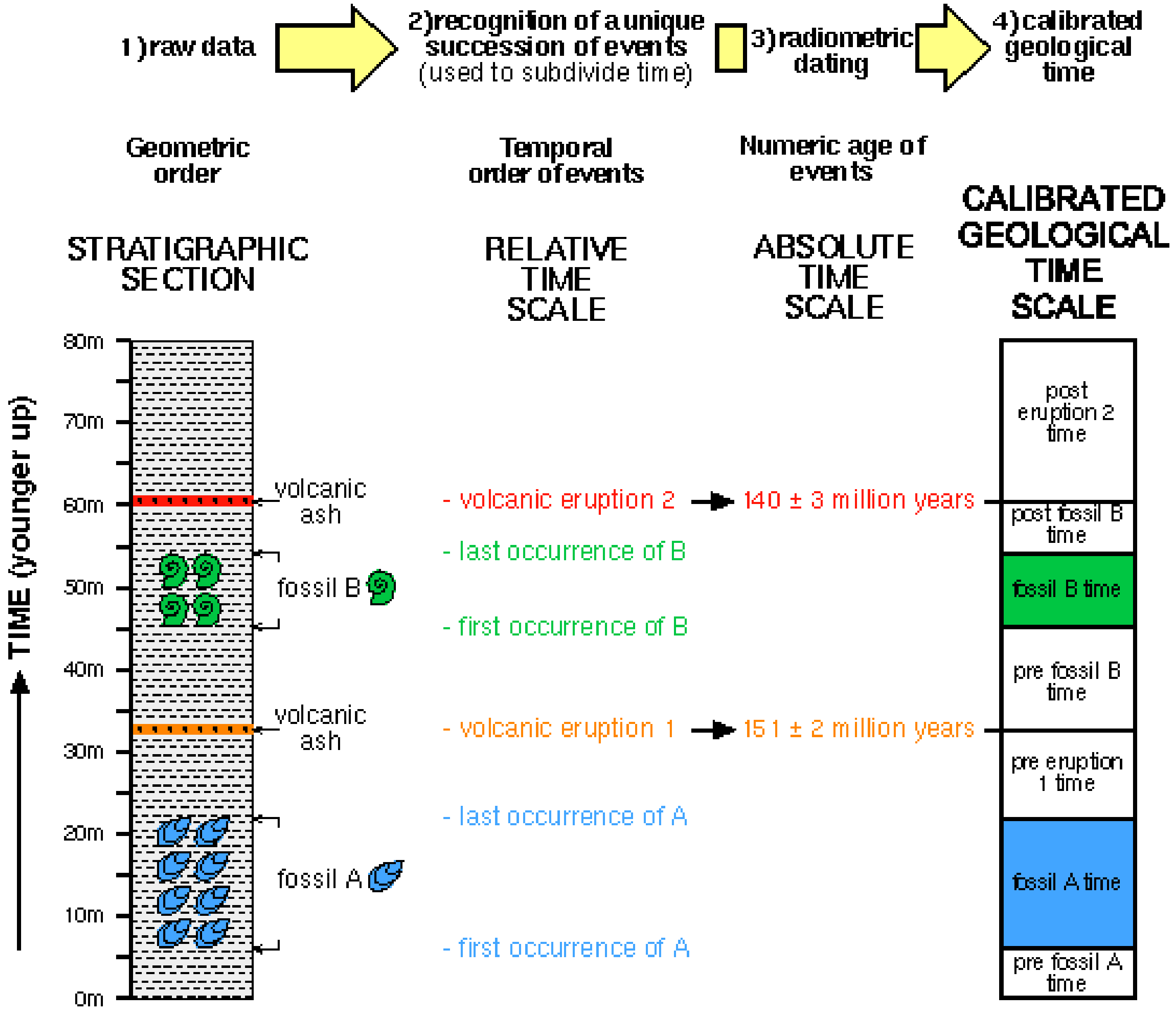
Stratigraphic and time units



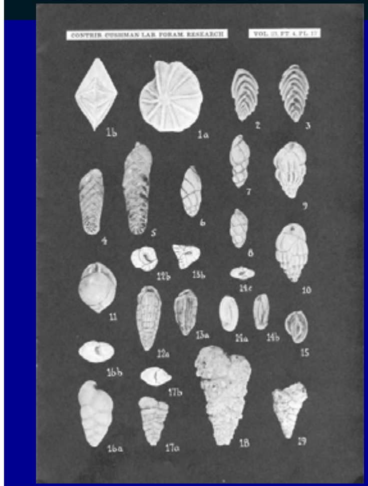
Stratigraphic Categories	Principal Stratigraphic Unit-terms	Equivalent Geochronologic Units
Lithostratigraphic	Group Formation Member Bed(s), Flow(s)	
Biostratigraphic	Biozones: Range zones Interval zones Lineage zones Assemblage zones Abundance zones Other kinds of biozones	
Magnetostratigraphic polarity	Polarity zone	
Other (informal) stratigraphic categories (mineralogic, stable isotope, environmental, seismic, etc.)	-zone (with appropriate prefix)	
Chronostratigraphic	Eonothem Erathem System Series Stage Substage (Chronozone)	Eon Era Period Epoch Age Subage (or Age) (Chron)

Fig. 10.2. Summary of categories and unit-terms in stratigraphic classification (modified from Salvador, 1994).

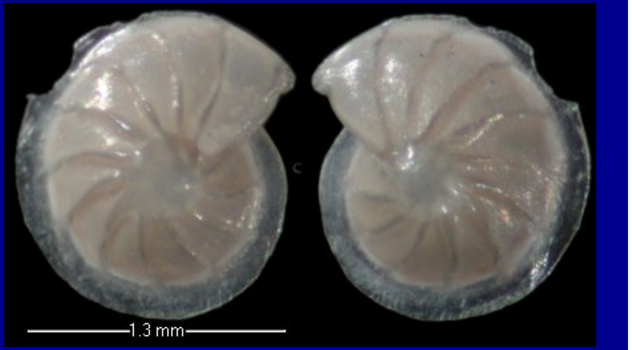
Combination of relative and absolute dating methods



Biostratigraphy: Biography of *Robulus*



- can we determine the age of a fossil?
- “birth, lifecycle events, and death” of a species known as *Robulus* E:



Last Appearance Datum (LAD) (= extinction point)

acme (peak in abundance of the species)

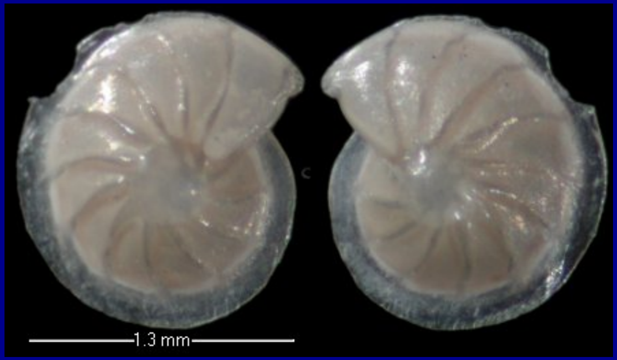
increase in abundance

decrease in abundance

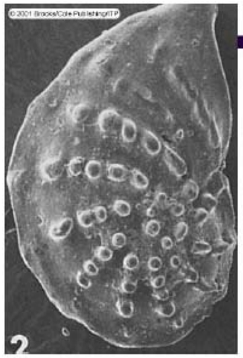
increase in abundance

First Appearance Datum (FAD) (= origination point)

Chronostratigraphy: Chronicles of Robulus



<u>chronologic</u> events
during the species range
of *Robulus* E:



- *Lenticulina mexicana*
- Eocene, Louisiana

6.15 mya = Last Appearance Datum (LAD) (= extinction point)

6.35 mya = acme (peak in abundance of the species)

6.40 mya = increase in abundance

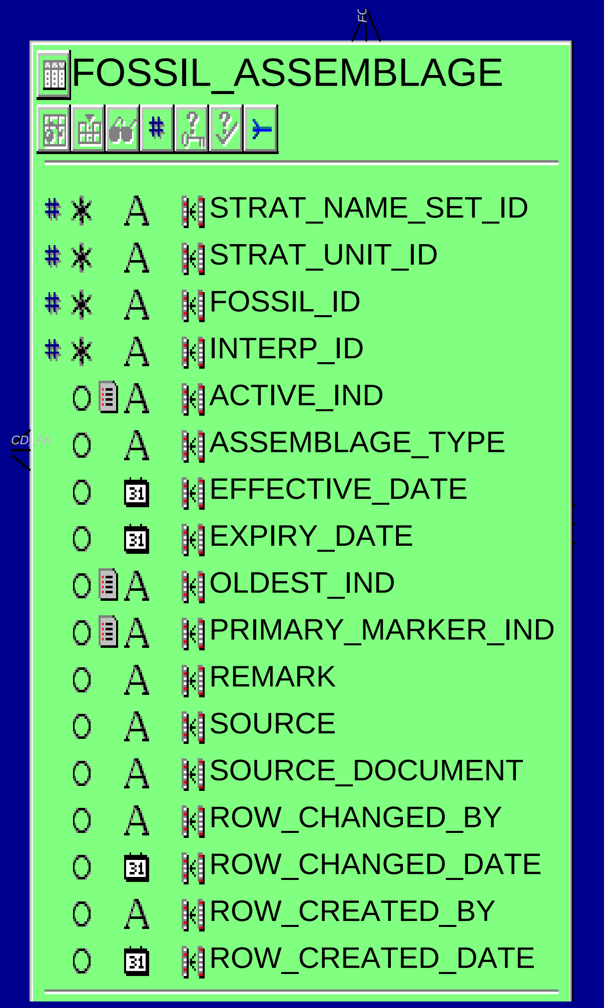
6.80 mya = decrease in abundance

7.25 mya = increase in abundance

8.00 mya = First Appearance Datum (FAD) (= origination point)

Biostratigraphy: relative age reconstruction

- PPDM and MMS incorporate biostratigraphic markers (extinction events, microfossil increases, acmes)
- biostratigraphic markers indicate a **relative age** for a given strata
- for example, Upper Miocene paleo marker X is younger than Middle Miocene marker Y, therefore the occurrence of marker X indicates a younger relative age of the strata in which it occurs than the strata where marker Y is found
- Within the PPDM biostratigraphic model, the **absolute age** of the paleo marker can be stored



FOSSIL_ASSEMBLAGE

* A STRAT_NAME_SET_ID
* A STRAT_UNIT_ID
* A FOSSIL_ID
* A INTERP_ID
O A ACTIVE_IND
O A ASSEMBLAGE_TYPE
O 31 EFFECTIVE_DATE
O 31 EXPIRY_DATE
O A OLDEST_IND
O A PRIMARY_MARKER_IND
O A REMARK
O A SOURCE
O A SOURCE_DOCUMENT
O A ROW_CHANGED_BY
O 31 ROW_CHANGED_DATE
O A ROW_CREATED_BY
O 31 ROW_CREATED_DATE

Chronostratigraphy

- the analysis of geologic strata using any time-significant event

- types of time-significant events
    - paleobiologic
    - isotopic (iridium spike at end of Cretaceous)
    - isotopic ratio $^{13}C/^{12}C$, $^{18}O/^{16}O$ (PETM)
    - paleomagnetic (periodic magnetic pole reversals)

Chronostratigraphy and Time

- Chronostratigraphy:

1. the study of the rocks (sediments) deposited within a certain time interval
2. is measured in space and time (how much sediment was deposited within that time interval)

- Geochronology:

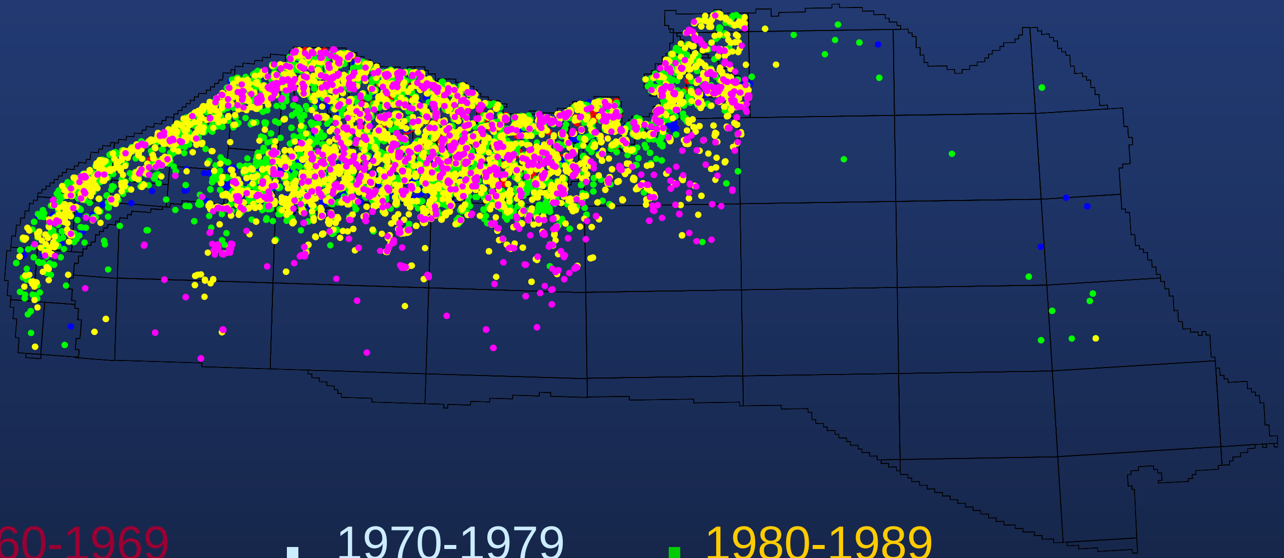
1. the study of the time interval
2. is measured in time units [millions of years (Mya)]

20 Years of Service to America
MMS
Minerals Management Service

Chronostratigraphy and Time

- Hedberg (International Stratigraphic Guide, 1976)
- related Chronostratigraphy and Geochronology to the sand flowing through an hourglass
- the sand flow in a given time interval =
  chronostratigraphy
- the time interval = geochronology

Number of Gulf of Mexico offshore wells containing paleontological data and information, 1960-2002*



🟥 1960-1969 🟦 1970-1979 🟩 1980-1989

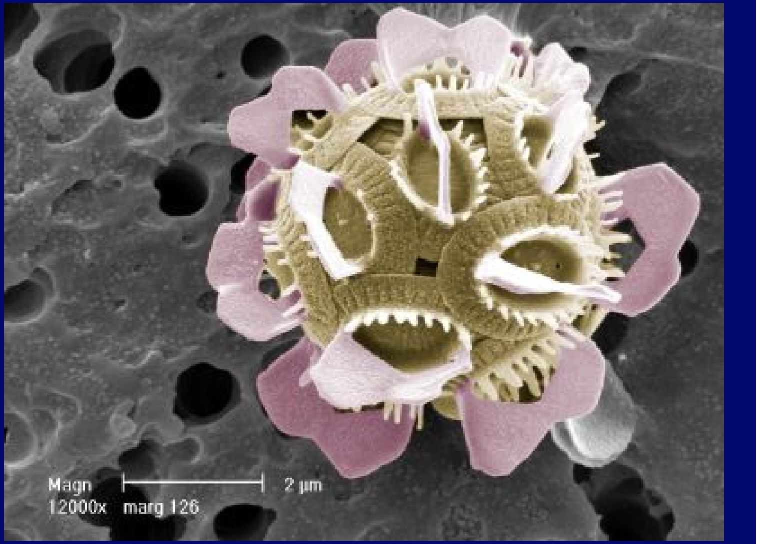
⬜ 1990-1999 **🟪 2000-2002**

**Source: MMS Gulf of Mexico Region Technical Information Management System paleontological database, March 2002.*

MMS Gulf of Mexico offshore paleontologic reports

- MMS has 10,000 paleo reports from ~6,000 wells drilled since 1947 in the Gulf of Mexico

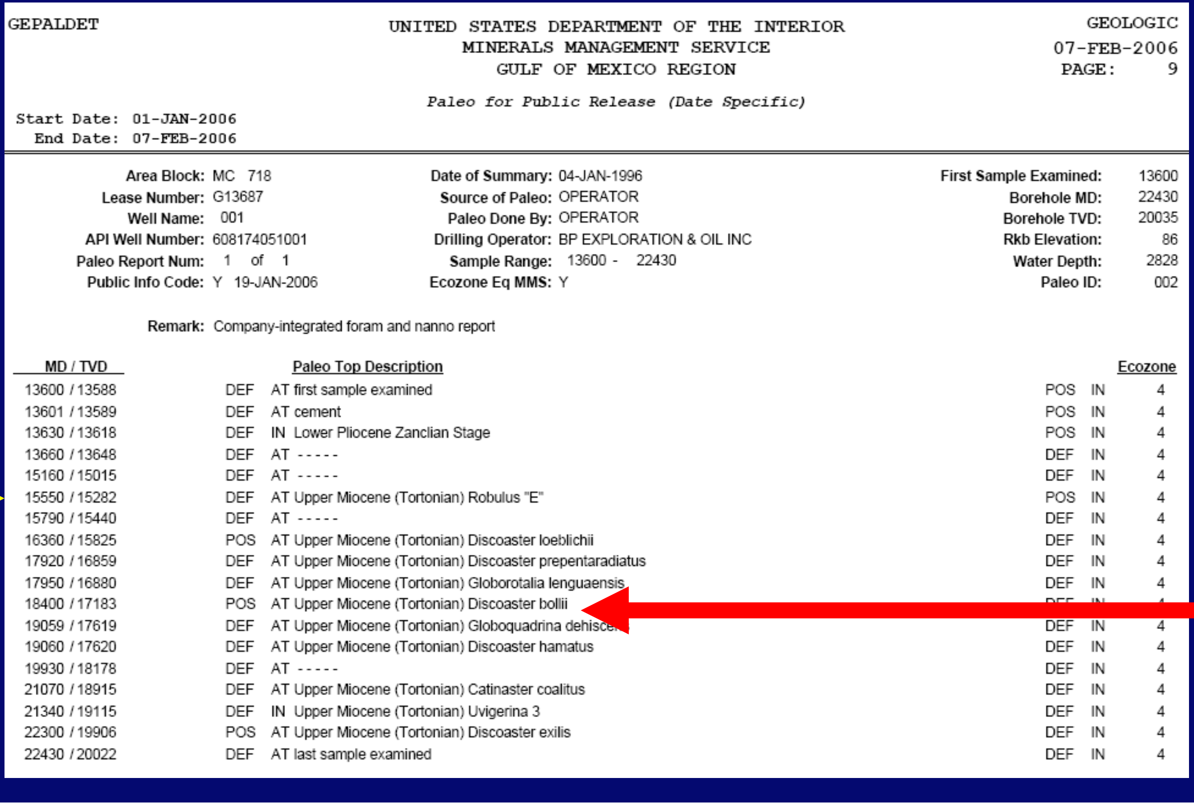
- These reports contain 90,000 biostratigraphic markers (forams and calcareous nannofossils)



MMS GOM offshore paleontologic reports

- Of the 90,000 biostratigraphic markers, 75,000 are excellent (definite) calls (high confidence of pick)
- The remaining 15,000 biostratigraphic markers are possible determinations (rare occurrence, reworking, etc)

definite
Robulus E



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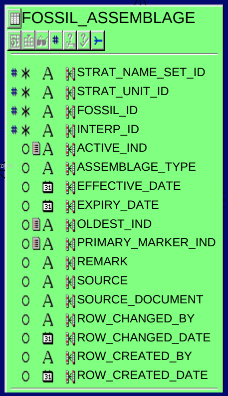
GEPALDET              UNITED STATES DEPARTMENT OF THE INTERIOR              GEOLOGIC
                           MINERALS MANAGEMENT SERVICE                    07-FEB-2006
                              GULF OF MEXICO REGION                       PAGE:     9

                     Paleo for Public Release (Date Specific)
 Start Date:  01-JAN-2006
   End Date:  07-FEB-2006

        Area Block: MC   718          Date of Summary: 04-JAN-1996   First Sample Examined:  13600
      Lease Number: G13687            Source of Paleo: OPERATOR             Borehole MD:     22430
         Well Name:  001              Paleo Done By: OPERATOR               Borehole TVD:    20035
   API Well Number: 608174051001      Drilling Operator: BP EXPLORATION & OIL INC   Rkb Elevation:  86
  Paleo Report Num:  1   of   1       Sample Range:  13600 -   22430        Water Depth:      2828
  Public Info Code: Y  19-JAN-2006    Ecozone Eq MMS: Y                     Paleo ID:          002

            Remark: Company-integrated foram and nanno report

   MD / TVD               Paleo Top Description                                        Ecozone
 13600 / 13588      DEF   AT first sample examined                               POS   IN    4
 13601 / 13589      DEF   AT cement                                              POS   IN    4
 13630 / 13618      DEF   IN  Lower Pliocene Zanclian Stage                      POS   IN    4
 13660 / 13648      DEF   AT -----                                               DEF   IN    4
 15160 / 15015      DEF   AT -----                                               DEF   IN    4
 15550 / 15282      DEF   AT Upper Miocene (Tortonian) Robulus "E"               POS   IN    4
 15790 / 15440      DEF   AT -----                                               DEF   IN    4
 16360 / 15825      POS   AT Upper Miocene (Tortonian) Discoaster loeblichii     DEF   IN    4
 17920 / 16859      DEF   AT Upper Miocene (Tortonian) Discoaster prepentaradiatus DEF IN    4
 17950 / 16880      DEF   AT Upper Miocene (Tortonian) Globorotalia lenguaensis  DEF   IN    4
 18400 / 17183      POS   AT Upper Miocene (Tortonian) Discoaster bollii         DEF   IN    4
 19059 / 17619      DEF   AT Upper Miocene (Tortonian) Globoquadrina dehisce     DEF   IN    4
 19060 / 17620      DEF   AT Upper Miocene (Tortonian) Discoaster hamatus        DEF   IN    4
 19930 / 18178      DEF   AT -----                                               DEF   IN    4
 21070 / 18915      DEF   AT Upper Miocene (Tortonian) Catinaster coalitus       DEF   IN    4
 21340 / 19115      DEF   IN  Upper Miocene (Tortonian) Uvigerina 3              DEF   IN    4
 22300 / 19906      POS   AT Upper Miocene (Tortonian) Discoaster exilis         DEF   IN    4
 22430 / 20022      DEF   AT last sample examined                                DEF   IN    4
```

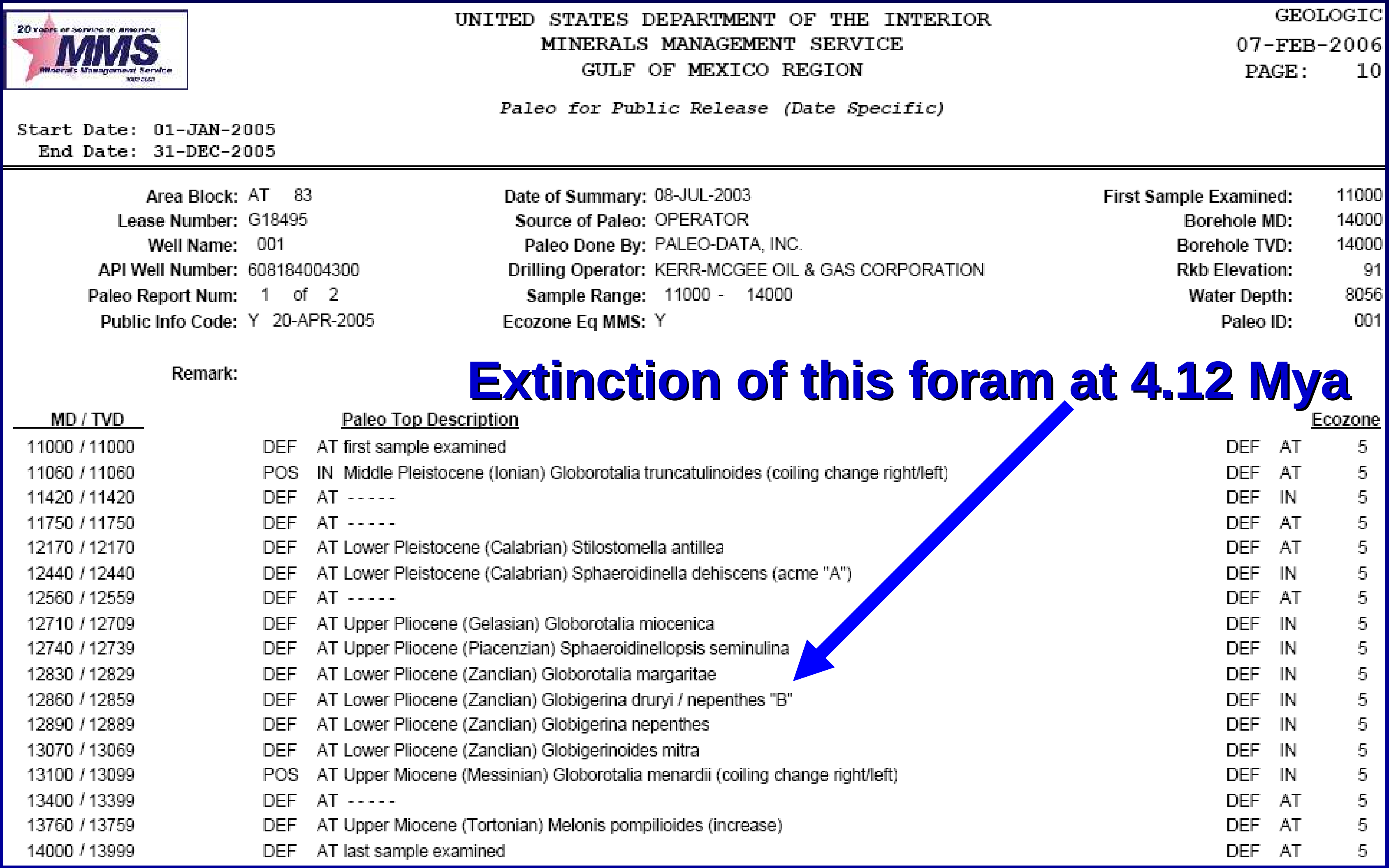


FOSSIL_ASSEMBLAGE

```
# * A STRAT_NAME_SET_ID
# * A STRAT_UNIT_ID
# * A FOSSIL_ID
# * A INTERP_ID
o   A ACTIVE_IND
o   A ASSEMBLAGE_TYPE
o     EFFECTIVE_DATE
o     EXPIRY_DATE
o   A OLDEST_IND
o   A PRIMARY_MARKER_IND
o   A REMARK
o   A SOURCE
o   A SOURCE_DOCUMENT
o   A ROW_CHANGED_BY
o     ROW_CHANGED_DATE
o   A ROW_CREATED_BY
o     ROW_CREATED_DATE
```

possible
Discorbis bollii

Can we incorporate absolute age?



UNITED STATES DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE
GULF OF MEXICO REGION

GEOLOGIC
07-FEB-2006
PAGE: 10

Paleo for Public Release (Date Specific)

Start Date: 01-JAN-2005
End Date: 31-DEC-2005

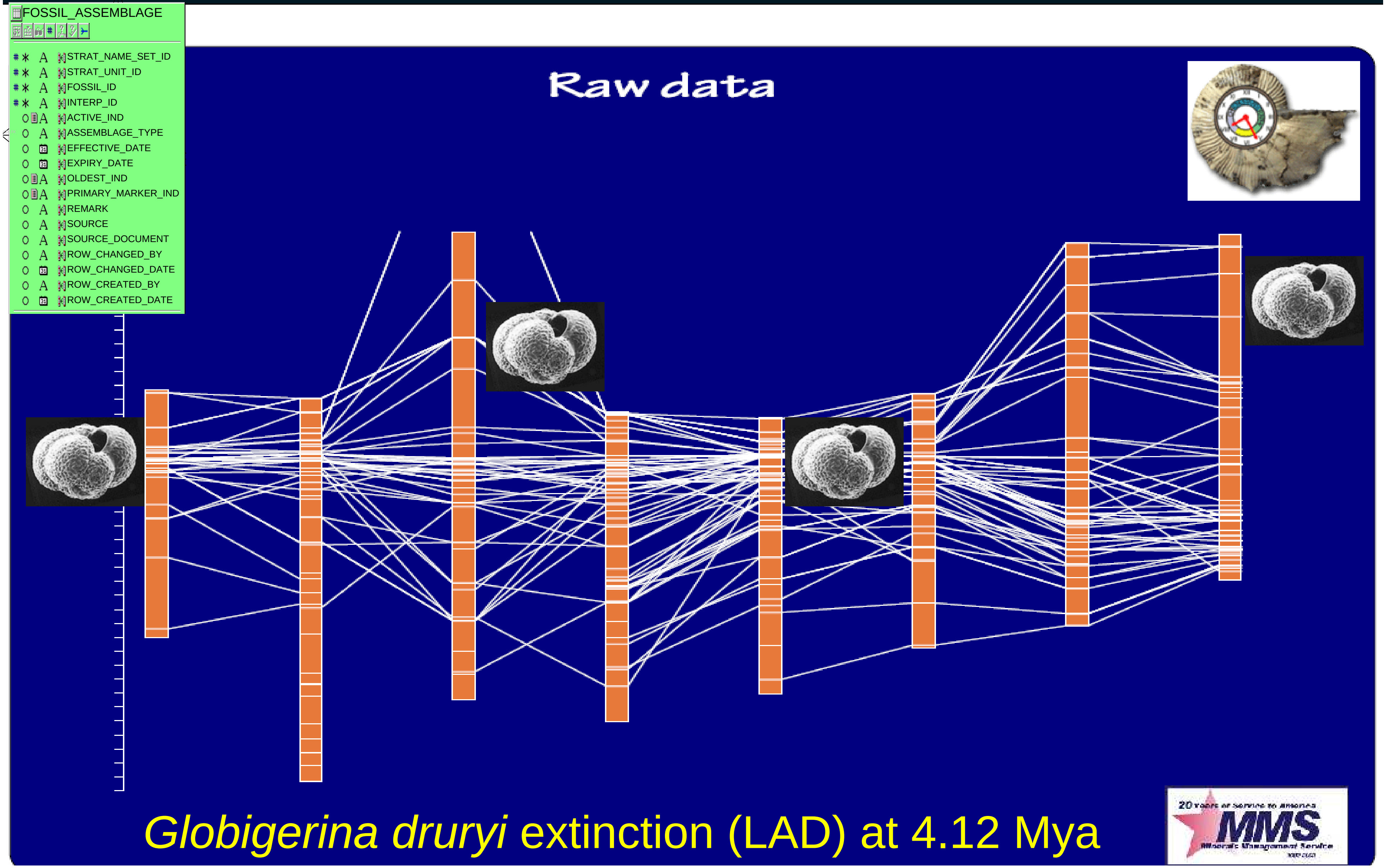
Area Block:	AT 83	**Date of Summary:**	08-JUL-2003	**First Sample Examined:**	11000
Lease Number:	G18495	**Source of Paleo:**	OPERATOR	**Borehole MD:**	14000
Well Name:	001	**Paleo Done By:**	PALEO-DATA, INC.	**Borehole TVD:**	14000
API Well Number:	608184004300	**Drilling Operator:**	KERR-MCGEE OIL & GAS CORPORATION	**Rkb Elevation:**	91
Paleo Report Num:	1 of 2	**Sample Range:**	11000 - 14000	**Water Depth:**	8056
Public Info Code:	Y 20-APR-2005	**Ecozone Eq MMS:**	Y	**Paleo ID:**	001

Remark:

Extinction of this foram at 4.12 Mya

MD / TVD		Paleo Top Description			Ecozone
11000 / 11000	DEF	AT first sample examined	DEF	AT	5
11060 / 11060	POS	IN Middle Pleistocene (Ionian) Globorotalia truncatulinoides (coiling change right/left)	DEF	AT	5
11420 / 11420	DEF	AT - - - - -	DEF	IN	5
11750 / 11750	DEF	AT - - - - -	DEF	AT	5
12170 / 12170	DEF	AT Lower Pleistocene (Calabrian) Stilostomella antillea	DEF	AT	5
12440 / 12440	DEF	AT Lower Pleistocene (Calabrian) Sphaeroidinella dehiscens (acme "A")	DEF	IN	5
12560 / 12559	DEF	AT - - - - -	DEF	AT	5
12710 / 12709	DEF	AT Upper Pliocene (Gelasian) Globorotalia miocenica	DEF	IN	5
12740 / 12739	DEF	AT Upper Pliocene (Piacenzian) Sphaeroidinellopsis seminulina	DEF	IN	5
12830 / 12829	DEF	AT Lower Pliocene (Zanclian) Globorotalia margaritae	DEF	IN	5
12860 / 12859	DEF	AT Lower Pliocene (Zanclian) Globigerina druryi / nepenthes "B"	DEF	IN	5
12890 / 12889	DEF	AT Lower Pliocene (Zanclian) Globigerina nepenthes	DEF	IN	5
13070 / 13069	DEF	AT Lower Pliocene (Zanclian) Globigerinoides mitra	DEF	IN	5
13100 / 13099	POS	AT Upper Miocene (Messinian) Globorotalia menardii (coiling change right/left)	DEF	IN	5
13400 / 13399	DEF	AT - - - - -	DEF	AT	5
13760 / 13759	DEF	AT Upper Miocene (Tortonian) Melonis pompilioides (increase)	DEF	AT	5
14000 / 13999	DEF	AT last sample examined	DEF	AT	5

Can we incorporate absolute age?

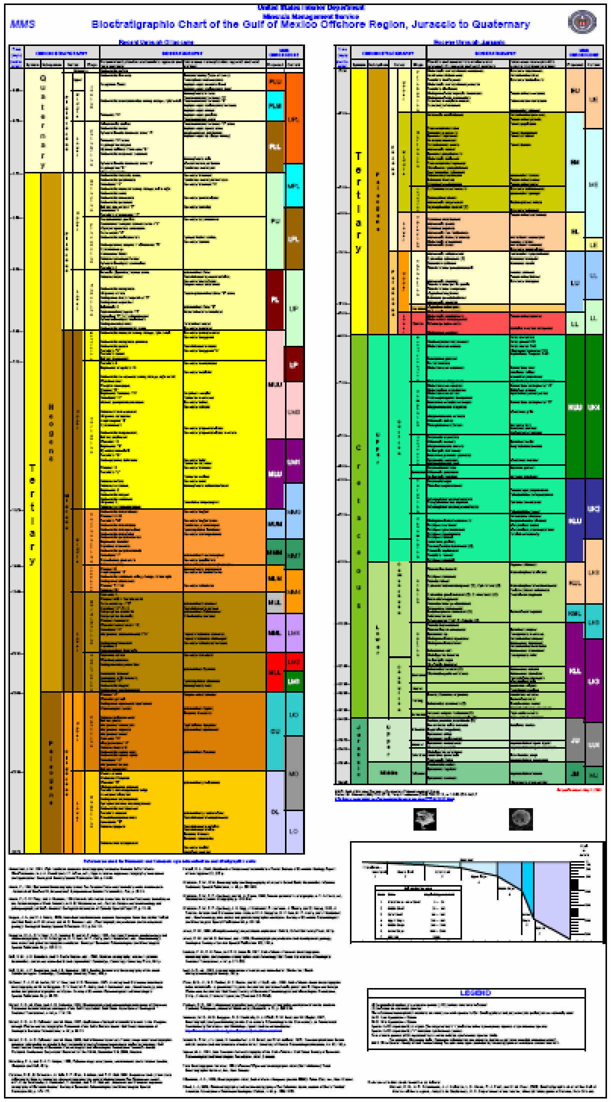


FOSSIL_ASSEMBLAGE

STRAT_NAME_SET_ID
STRAT_UNIT_ID
FOSSIL_ID
INTERP_ID
ACTIVE_IND
ASSEMBLAGE_TYPE
EFFECTIVE_DATE
EXPIRY_DATE
OLDEST_IND
PRIMARY_MARKER_IND
REMARK
SOURCE
SOURCE_DOCUMENT
ROW_CHANGED_BY
ROW_CHANGED_DATE
ROW_CREATED_BY
ROW_CREATED_DATE

Globigerina druryi extinction (LAD) at 4.12 Mya

MMS Biostratigraphic Chart of the Gulf of Mexico Offshore Region



United States Interior Department
Minerals Management Service

MMS Biostratigraphic Chart of the Gulf of Mexico Offshore Region, Jurassic to Quaternary

- Contains 500 biostratigraphic markers (forams, coccoliths, ostracods) in relative age position
- Absolute age (Mya) given for all Jurassic to Neogene stage boundaries
- Scale of time on the chart is nonlinear

Biostratigraphy of the Pleistocene-Pliocene boundary for the Gulf of Mexico offshore region

	Mya	**Foram marker (paleoevent)**	**Nannofossil marker (paleoevent)**
PLEIST			Helicosphaera sellii
		Sphaeroidinella dehiscens acme "B“	Lithostromation perdurum
		Angulogerina "B“	Calcidiscus macintyrei
		Uvigerina hispida	
PLIOCENE	1.77-	Globorotalia crassula acme,	Discoaster brouweri,
		Globorotalia praehirsuta	Calcidiscus macintyrei increase
		Cristellaria "S“	Discoaster brouweri "A“
		Globorotalia menardii coiling change, L-to-R	
		Globorotalia exilis	
		Globorotalia miocenica	Discoaster pentaradiatus
		Globorotalia pertenuis	
		Bolivina imporcata / "P“	Discoaster surculus
		Lenticulina 1	
	2.60 -	Textularia crassisepta / "P“	

Adding absolute age to the nonlinear biostratigraphy at the Plio-Pleistocene boundary of the GOM offshore

	Mya	**Foram marker (paleoevent)**	Mya	**Nannofossil marker (paleoevent)**	Mya
PLEIST				Helicosphaera sellii	1.35
		Sphaeroidinella dehiscens acme "B“	1.59	Lithostromation perdurum	1.50
		Angulogerina "B“	1.10 to 2.30	Calcidiscus macintyrei	1.59
		Uvigerina hispida	1.70		
PLIOCENE	1.77-	Globorotalia crassula acme,	1.77	Discoaster brouweri,	1.95
		Globorotalia praehirsuta	1.83	Calcidiscus macintyrei increase	1.85
		Cristellaria "S“	2.02	Discoaster brouweri "A“	2.10
		Globorotalia menardii coil L-to-R	2.20		
		Globorotalia exilis	2.25		
		Globorotalia miocenica	2.30	Discoaster pentaradiatus	2.30
		Globorotalia pertenuis	2.40		
		Bolivina imporcata / "P“	2.50	Discoaster surculus	2.55
		Lenticulina 1	2.25 to 2.52		
	2.60 -	Textularia crassisepta / "P“	2.54		

Chronostratigraphic chart of Pleistocene-Pliocene boundary of the Gulf of Mexico offshore region

Age	(Mya)	Foram marker (paleoevent)	Nannofossil marker (paleoevent)
Pleistocene	1.30		
	1.35		Helico. sellii
	1.40		
	1.45		
	1.50		Lithostr. perdurum
	1.55		
	1.60	Sphaeroidinella dehiscens acme A	Calc. macintyrei
	1.65		
	1.70	Uvigerina hispida	
	1.75		
Pliocene	1.80	Globorot. crassula acme, Globorot. praehirsuta	
	1.85		Calc. macintyrei increase
	1.90		
	1.95		Discoaster brouweri
	2.00	Cristellaria S	
	2.05		
	2.10		Discoaster brouweri A
	2.15		
	2.20	Globorot. menardii coil L-to-R	
	2.25	Globorot. exilis	
	2.30	Globorot. miocenica	Discoaster pentaradiatus
	2.35		
	2.40	Globorot. pertenuis	
	2.45		
	2.50	Bolivina P	
	2.55	Textularia P	Discoaster surculus
	2.60		

Here, paleomarkers are arranged along a linear timescale (in Mya)

Chronostratigraphic chart for the Plio-Pleistocene boundary of the Gulf of Mexico

	Helicosphaera sellii
Sphaeroidinella dehiscens acme "B“	Lithostromation perdurum
Angulogerina "B“	Calcidiscus macintyrei
Uvigerina hispida	
Globorotalia crassula acme,	Discoaster brouweri,
Globorotalia praehirsuta	Calcidiscus macintyrei increase
Cristellaria "S“	Discoaster brouweri "A“
Globorotalia menardii coiling change, L-to-R	
Globorotalia exilis	
Globorotalia miocenica	Discoaster pentaradiatus
Globorotalia pertenuis	
Bolivina imporcata / "P“	Discoaster surculus
Lenticulina 1	
Textularia crassisepta / "P“	

Age	(Mya)	Foram marker (paleoevent)	Nannofossil marker (paleoevent)
Pleistocene	1.30		
	1.35		Helico. sellii
	1.40		
	1.45		
	1.50		Lithostr. perdurum
	1.55		
	1.60	Sphaeroidinella dehiscens acme B	Calc. macintyrei
	1.65		
	1.70	Uvigerina hispida	
	1.75		
Pliocene	1.80	Globorot. crassula acme, Globorot. praehirsuta	
	1.85		Calc. macintyrei increase
	1.90		
	1.95		Discoaster brouweri
	2.00	Cristellaria S	
	2.05		
	2.10		Discoaster brouweri A
	2.15		
	2.20	Globorot. menardii coil L-to-R	
	2.25	Globorot. exilis	
	2.30	Globorot. miocenica	Discoaster pentaradiatus
	2.35		
	2.40	Globorot. pertenuis	
	2.45		
	2.50	Bolivina P	
	2.55	Textularia P	Discoaster surculus
	2.60		

Note: The benthic forams Angulogerina B and Lenticulina 1 are omitted from the chronostratigraphic chart since they have variable extinction dates dependent on dip position.

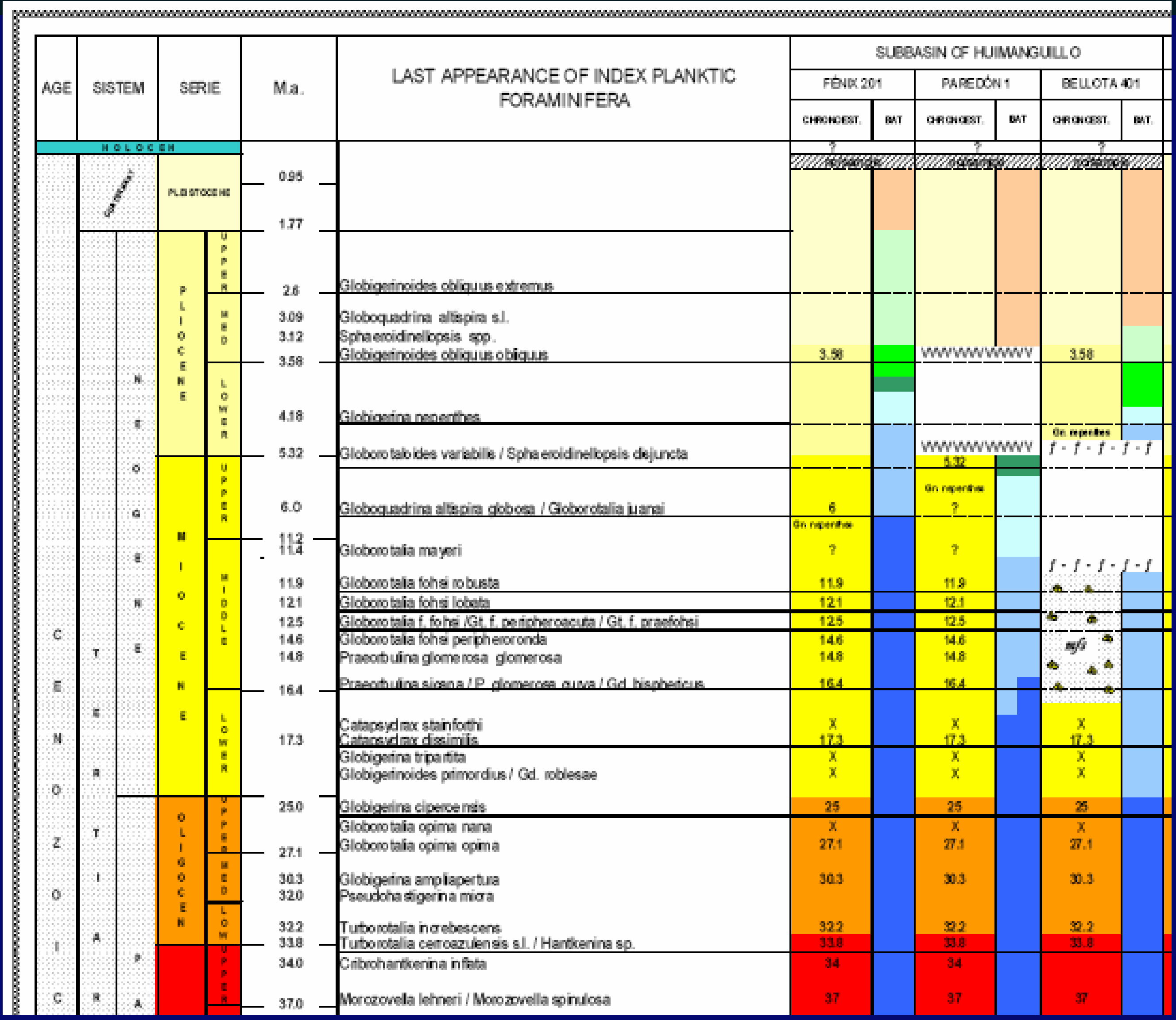
Chronostratigraphic chart for the Plio-Pleistocene boundary of the Gulf of Mexico

Sphaeroidinella dehiscens acme "B"	Helicosphaera sellii
Angulogerina "B"	Lithostromation perdurum
Uvigerina hispida	Calcidiscus macintyrei
Globorotalia crassula acme,	Discoaster brouweri,
Globorotalia praehirsuta	Calcidiscus macintyrei increase
Cristellaria "S"	Discoaster brouweri "A"
Globorotalia menardii coiling change, L-to-R	
Globorotalia exilis	
Globorotalia miocenica	Discoaster pentaradiatus
Globorotalia pertenuis	
Bolivina imporcata / "P"	Discoaster surculus
Lenticulina 1	
Textularia crassisepta / "P"	

Age	(Mya)	Foram marker (paleoevent)	Nannofossil marker (paleoevent)
	1.30		
	1.35		Helico. sellii
	1.40		
	1.45		
Pleistocene	1.50		Lithostr. perdurum
	1.55		
	1.60	Sphaeroidinella dehiscens acme B	Calc. macintyrei
	1.65		
	1.70	Uvigerina hispida	
	1.75		
	1.80	Globorot. crassula acme, Globorot. praehirsuta	
	1.85		Calc. macintyrei increase
	1.90		
	1.95		Discoaster brouweri
	2.00	Cristellaria S	
	2.05		
	2.10		Discoaster brouweri A
	2.15		
Pliocene	2.20	Globorot. menardii coil L-to-R	
	2.25	Globorot. exilis	
	2.30	Globorot. miocenica	Discoaster pentaradiatus
	2.35		
	2.40	Globorot. pertenuis	
	2.45		
	2.50	Bolivina P	
	2.55	Textularia P	Discoaster surculus
	2.60		

Note: The benthic forams Angulogerina B and Lenticulina 1 are omitted from the chronostratigraphic chart since they have variable extinction dates dependent on dip position.

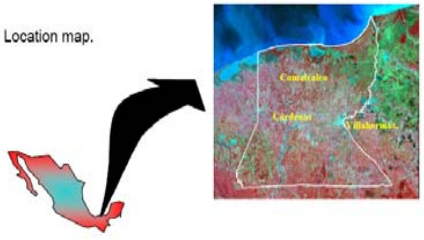
Chronostratigraphic analysis



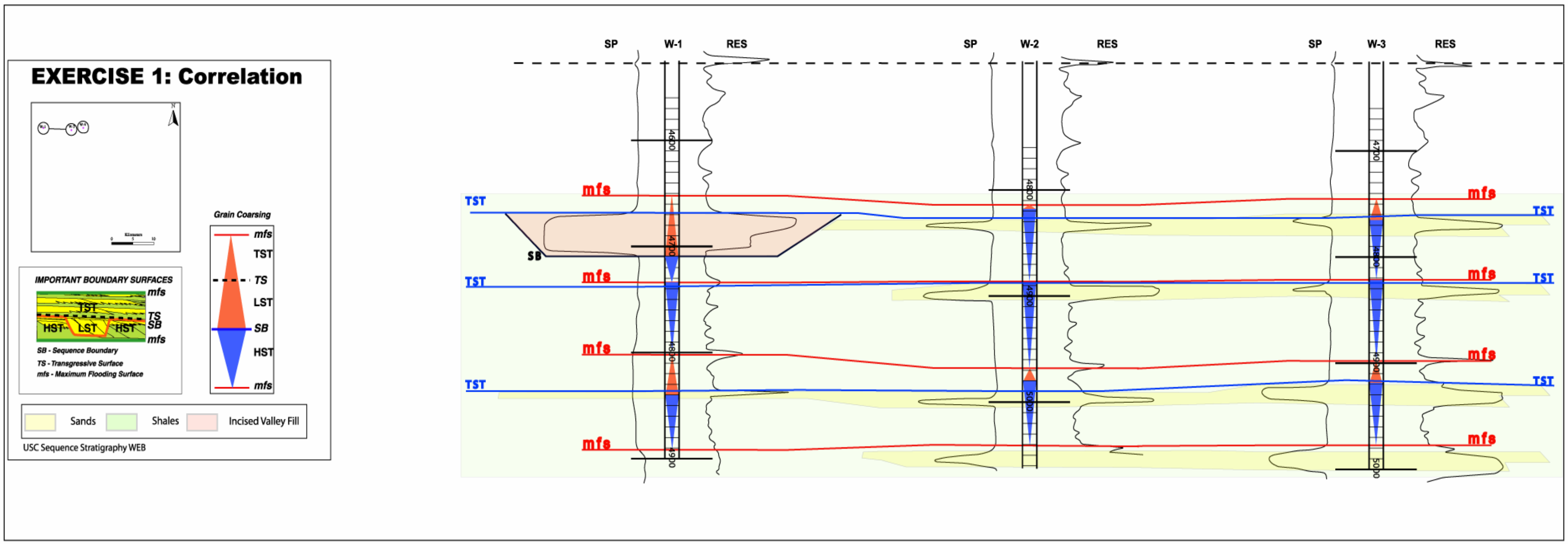
M.a.	LAST APPEARANCE OF INDEX PLANKTIC FORAMINIFERA	FÉNIX 201 CHRONOEST.	PAREDÓN 1 CHRONOEST.	BELLOTA 401 CHRONOEST.
0.95				
1.77				
2.6	Globigerinoides obliquus extremus			
3.09	Globoquadrina altispira s.l.			
3.12	Sphaeroidinellopsis spp.			
3.58	Globigerinoides obliquus obliquus	3.58	WWWWWWWWWWV	3.58
4.18	Globigerina nepenthes			Gn. nepenthes
5.32	Globorotaloides variabilis / Sphaeroidinellopsis dejuncta		WWWWWWWWWWV 5.32	f - f - f - f - f
6.0	Globoquadrina altispira globosa / Globorotalia juanai	6	Gn. nepenthes ?	
11.2 11.4	Globorotalia mayeri	Gn. nepenthes ?	?	f - f - f - f - f
11.9	Globorotalia fohsi robusta	11.9	11.9	
12.1	Globorotalia fohsi lobata	12.1	12.1	
12.5	Globorotalia f. fohsi /Gt. f. peripheroacuta / Gt. f. praefohsi	12.5	12.5	
14.6	Globorotalia fohsi peripheroronda	14.6	14.6	
14.8	Praeorbulina glomerosa glomerosa	14.8	14.8	
16.4	Praeorbulina sicana / P. glomerosa curva / Gd. bisphericus	16.4	16.4	
	Catapsydrax stainforthi	X	X	X
17.3	Catapsydrax dissimilis	17.3	17.3	17.3
	Globigerina tripartita	X	X	X
	Globigerinoides primordius / Gd. roblesae	X	X	X
25.0	Globigerina ciperoensis	25	25	25
	Globorotalia opima nana	X	X	X
27.1	Globorotalia opima opima	27.1	27.1	27.1
30.3	Globigerina ampliapertura	30.3	30.3	30.3
32.0	Pseudohastigerina micra			
32.2	Turborotalia increbescens	32.2	32.2	32.2
33.8	Turborotalia cerroazulensis s.l. / Hantkenina sp.	33.8	33.8	33.8
34.0	Cribrohantkenina inflata	34	34	34
37.0	Morozovella lehneri / Morozovella spinulosa	37	37	37

Biostratigraphic distribution within Tertiary sub-basins of SE Basin of Mexico (Cardenas, C. and Marin, C., Biostratigraphy (PEMEX), 2004, Biostratigraphy as a fundamental tool in the analysis of the SE Basin of Mexico, AAPG International Confererence, Cancun.

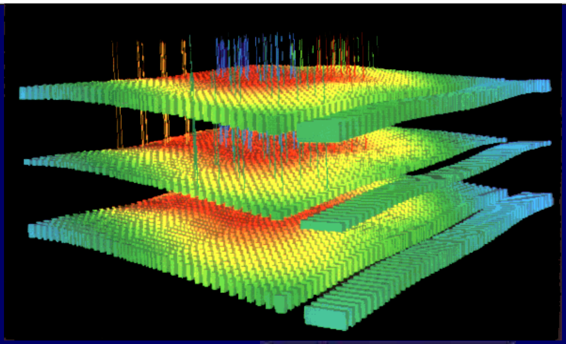
Fig. 1. Location map.



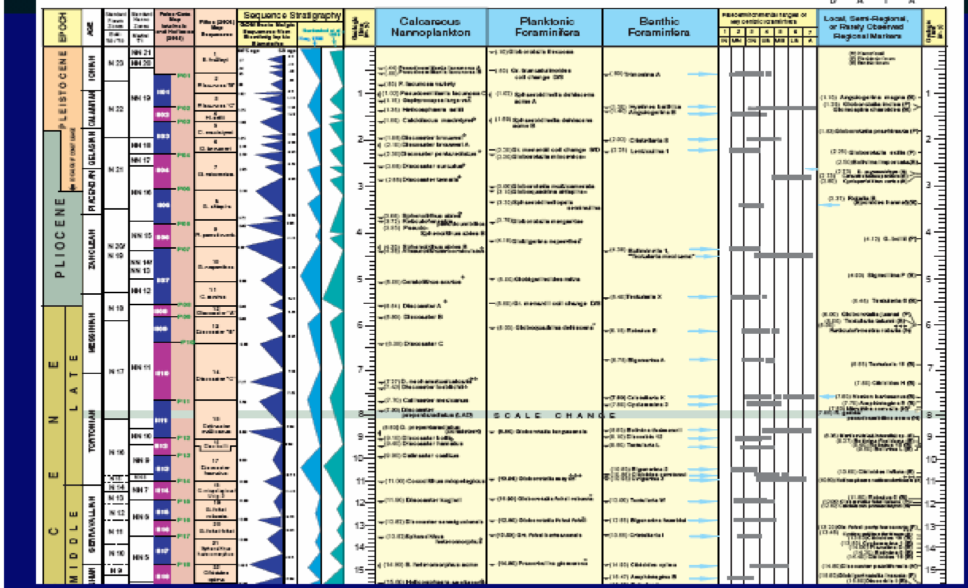
Correlations of maximum flooding surfaces



The timing of maximum flooding surfaces (mfs) is determined by chronostratigraphy.

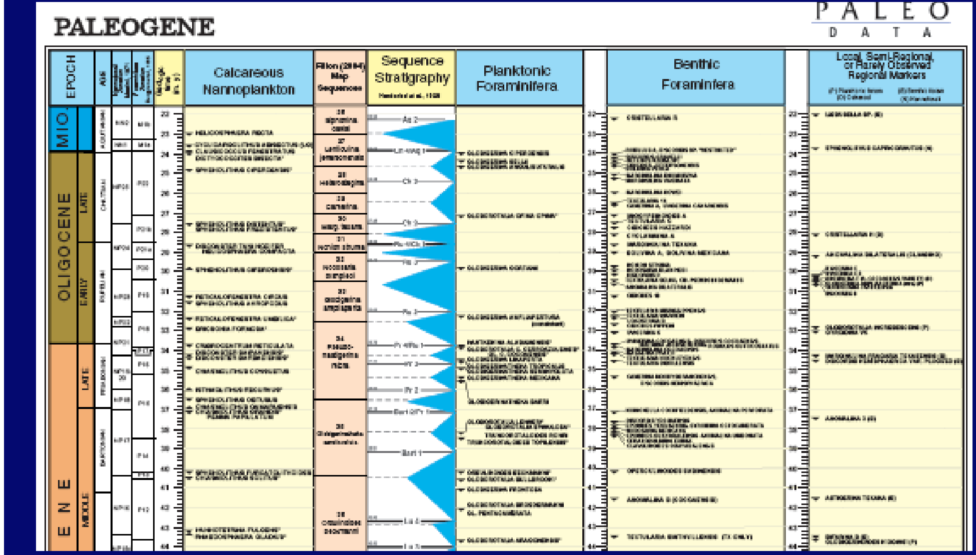


Condensed sections and Chronostratigraphy


EPOCH | AGE | Calcareous Nannoplankton | Planktonic Foraminifera | Benthic Foraminifera | Local, Semi-Regional, or Rarely Observed Regional Markers

PLEISTOCENE | PLIOCENE | MIDDLE MIOCENE

SCALE CHANGE

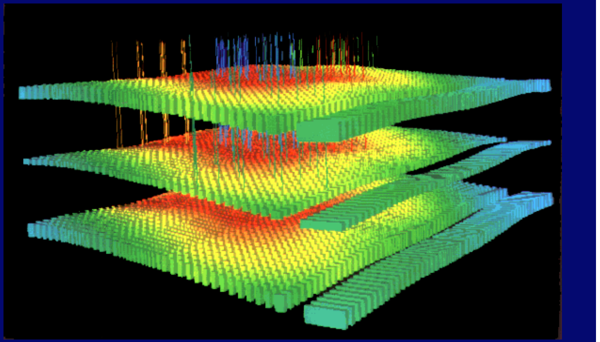

PALEOGENE

PALEO DATA

EPOCH | Calcareous Nannoplankton | Sequence Stratigraphy | Planktonic Foraminifera | Benthic Foraminifera | Local, Semi-Regional, or Rarely Observed Regional Markers

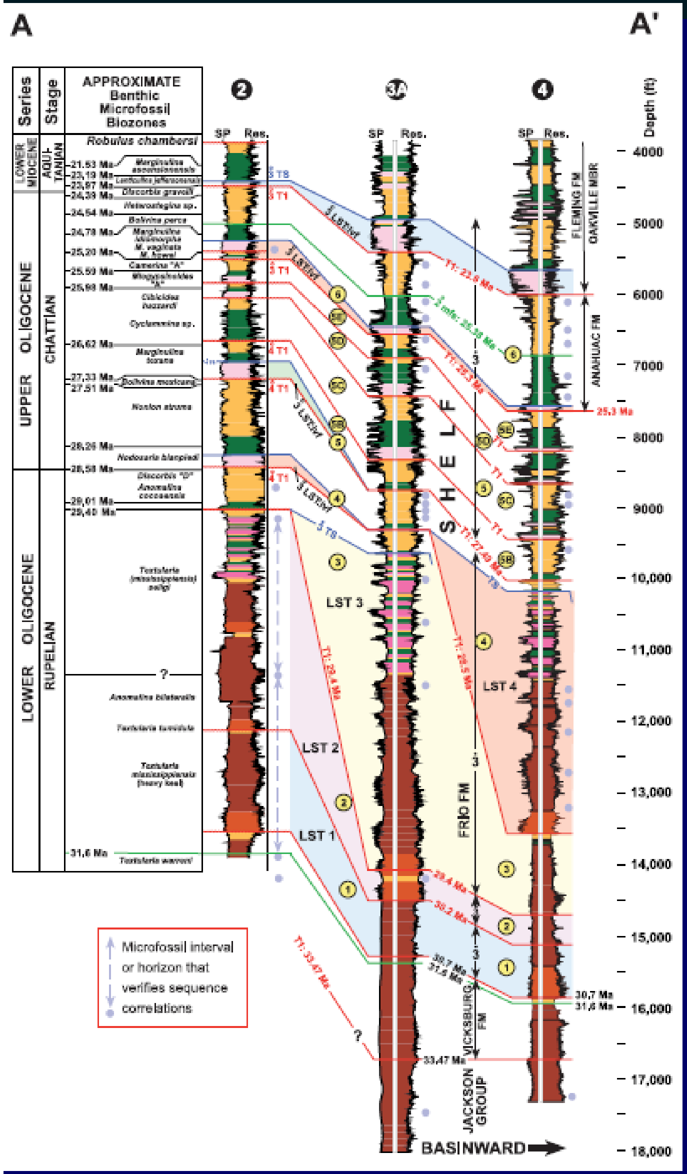
MIO | OLIGOCENE | EOCENE

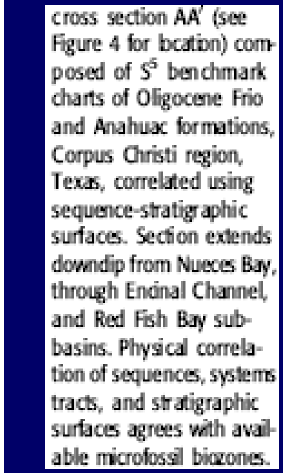
Chronostratigraphic signatures can be used with condensed sections and maximum flooding surfaces (mfs) to reconstruct the sequence stratigraphy of a geologic basin, such as the Gulf of Mexico



Source: PaleoData, Inc., Neogene and Paleogene Biostratigraphic Charts, Gulf of Mexico, 2004

Chronostratigraphic analysis



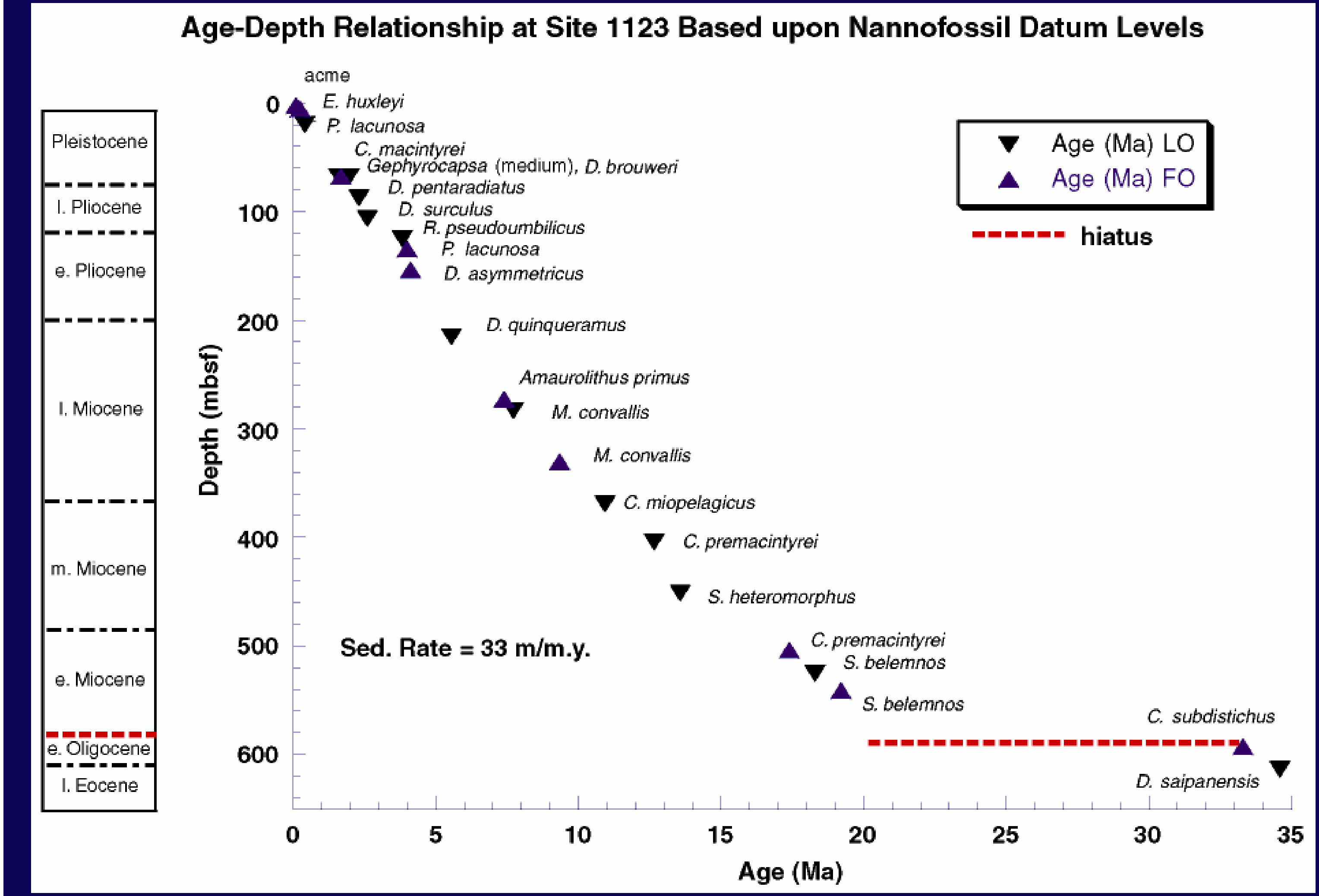


cross section AA' (see Figure 4 for location) composed of S^5 benchmark charts of Oligocene Frio and Anahuac formations, Corpus Christi region, Texas, correlated using sequence-stratigraphic surfaces. Section extends downdip from Nueces Bay, through Encinal Channel, and Red Fish Bay subbasins. Physical correlation of sequences, systems tracts, and stratigraphic surfaces agrees with available microfossil biozones.

- Chronostratigraphic determinations can aid in calibrating key depositional surfaces such as sequence boundaries and maximum flooding surfaces

Brown, Loucks and Trevino, 2005, Site-specific sequence-stratigraphic section benchmark charts are key to regional chronostratigraphic systems tract analysis in growth-faulted basins. AAPG Bulletin v. 89, no. 6, pp. 715-724.

Graphic correlation: detecting an unconformity using chronostratigraphy



LO = last occurrence, or last appearance datum (LAD)

FO = first occurrence, or first appearance datum (FAD)

Reality check

- challenges in using ages (confidence level in the age date of fossil event)
- various sources of biostratigraphic interpretation (different consultants or companies may identify a particular marker differently!) may give different fossil picks resulting in differences of opinion in age for a given well or basin area
- Sampling issues:
  1. related to drilling
  2. dependent on the method of collecting samples
  3. the Signor-Lipps effect (sudden paleobiologic events may appear gradual)
  4. the Elvis effect (the reappearance of a fossil after its extinction – usually due to reworking)

Bioturbation

- is one major cause of reworking
- the main pulse is altered
- the signal input is spread out
- it is shifted down (earlier) in the sediment record)
- Often the signal becomes skewed
- becomes important when you sample only a portion of the elements or individuals in a sample

Bioturbation: sedimentation rate

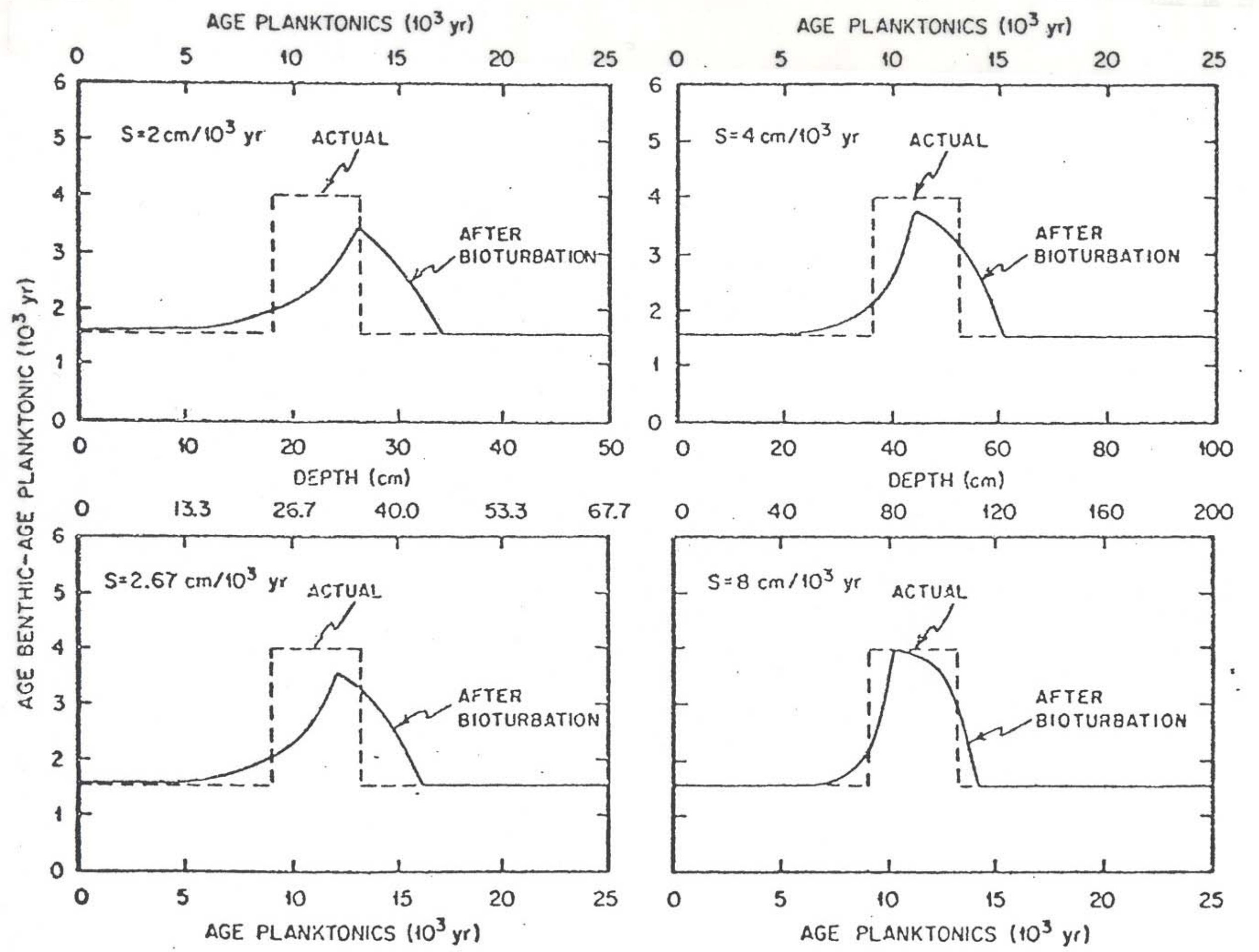


Fig. 5. Impact of bioturbation on a hypothetical age pattern (no abundance changes or dissolution effects). The dashed lines are the hypothetical age differences if there were no bioturbation. The solid lines are the age differences after bioturbation. The separate panels give results for specific sedimentation rate.

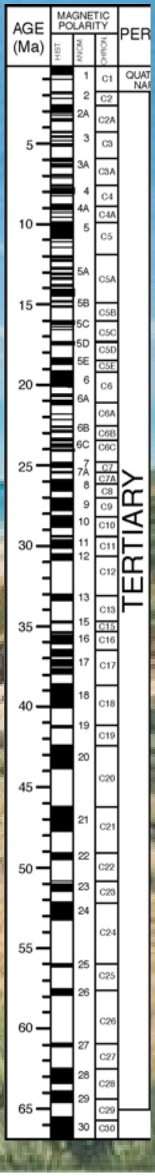
Slower sedimentation rate results in a more altered and shifted signal

Sedimentary record cyclicity and chronostratigraphy

- Seasonal, annual to centennial cycles
  - Lake varves, tree rings, corals, cave deposits
- Millennial and higher cycles
  - Lake and ocean sediments, loess
- Orbital ‘tuning’ applied sequence of cyclical sediments => cyclostratigraphy
- Cyclostratigraphy requires validation with radioisotope geochronology
- Chronostratigraphy can be integrated into the cyclostratigraphic model

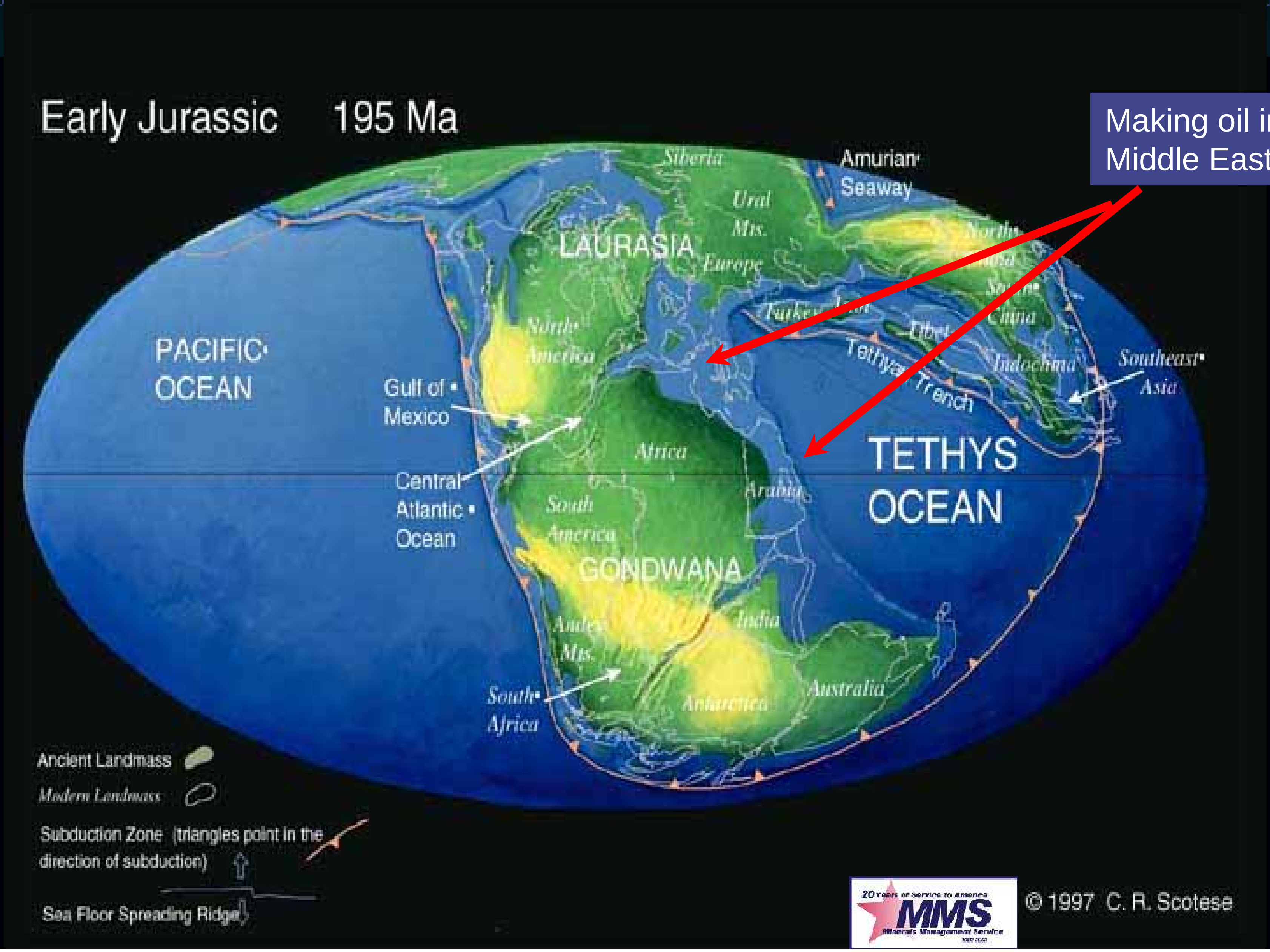
Magnetostratigraphy and paleomarkers

- We can relate magnetostratigraphy to fossil events



Reconstructing the Early Jurassic

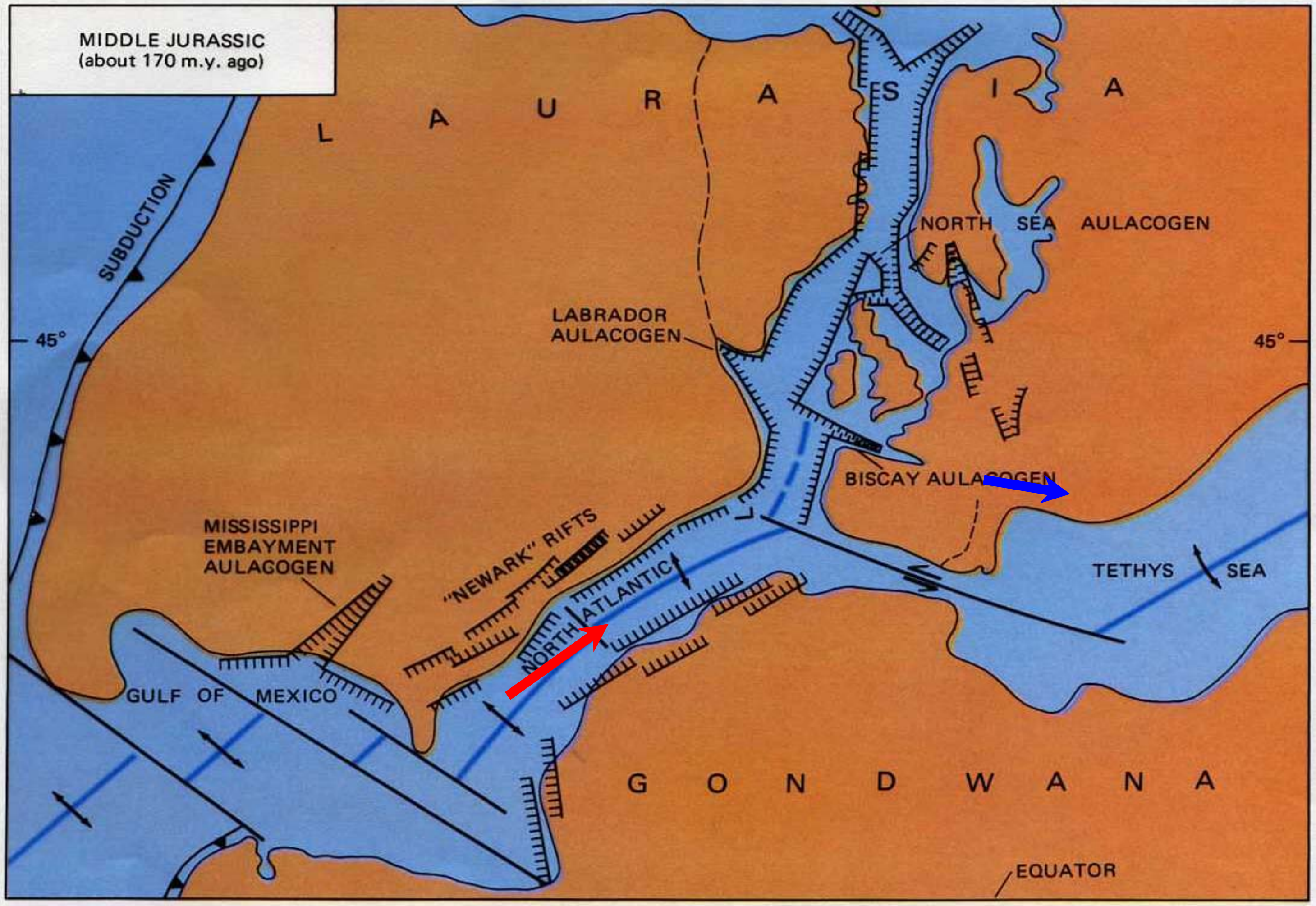
Making oil in the Middle East!



© 1997 C. R. Scotese

Middle Jurassic Gulf of Mexico: break up along old sutures- almost

Tethys Sea went through to the Gulf of Mexico and North Atlantic, all connected

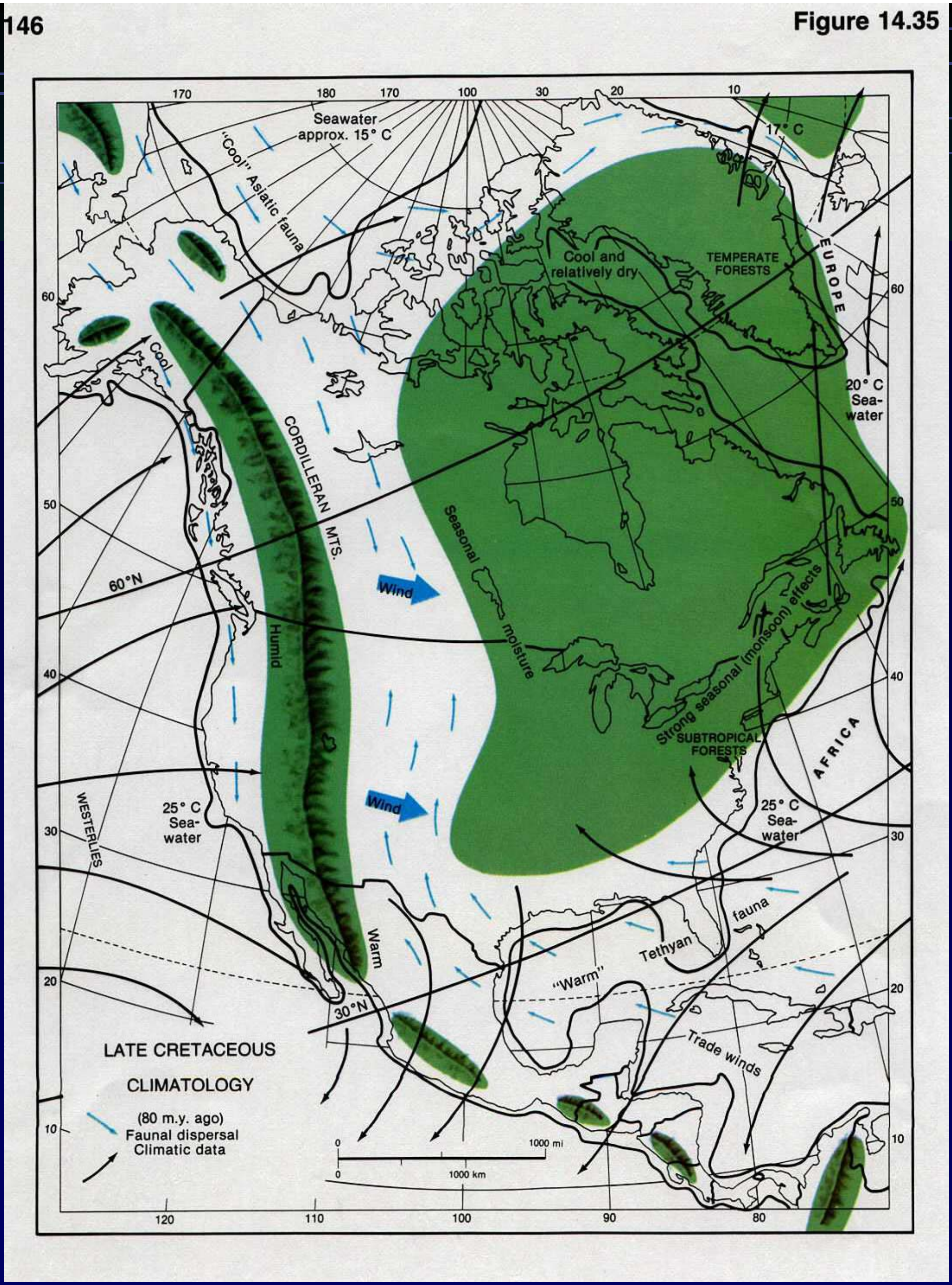


Late Cretaceous paleoclimatology

Greenhouse: six times present CO_2 levels!

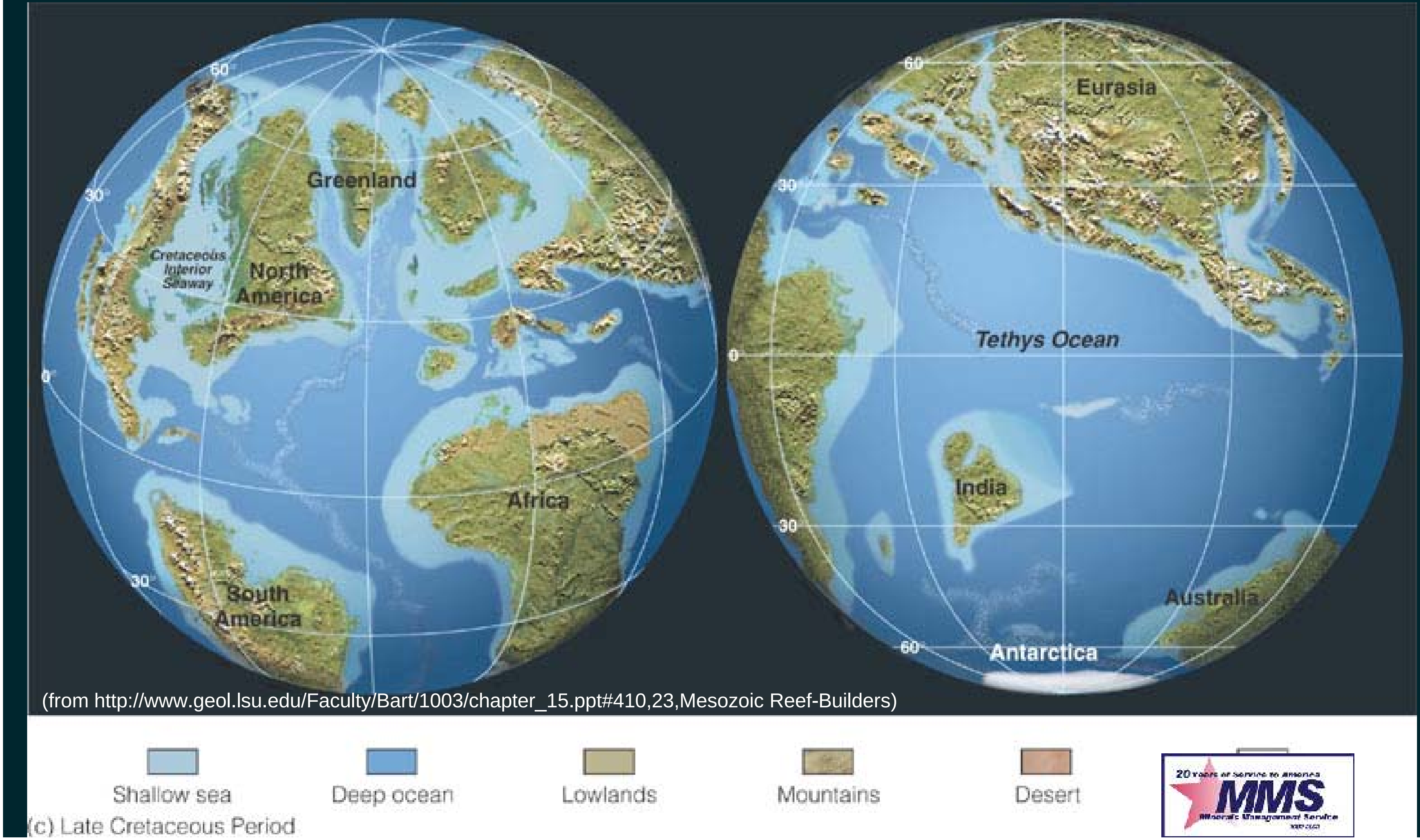
Warm temperatures all the way to the poles

Lots of volcanic activity



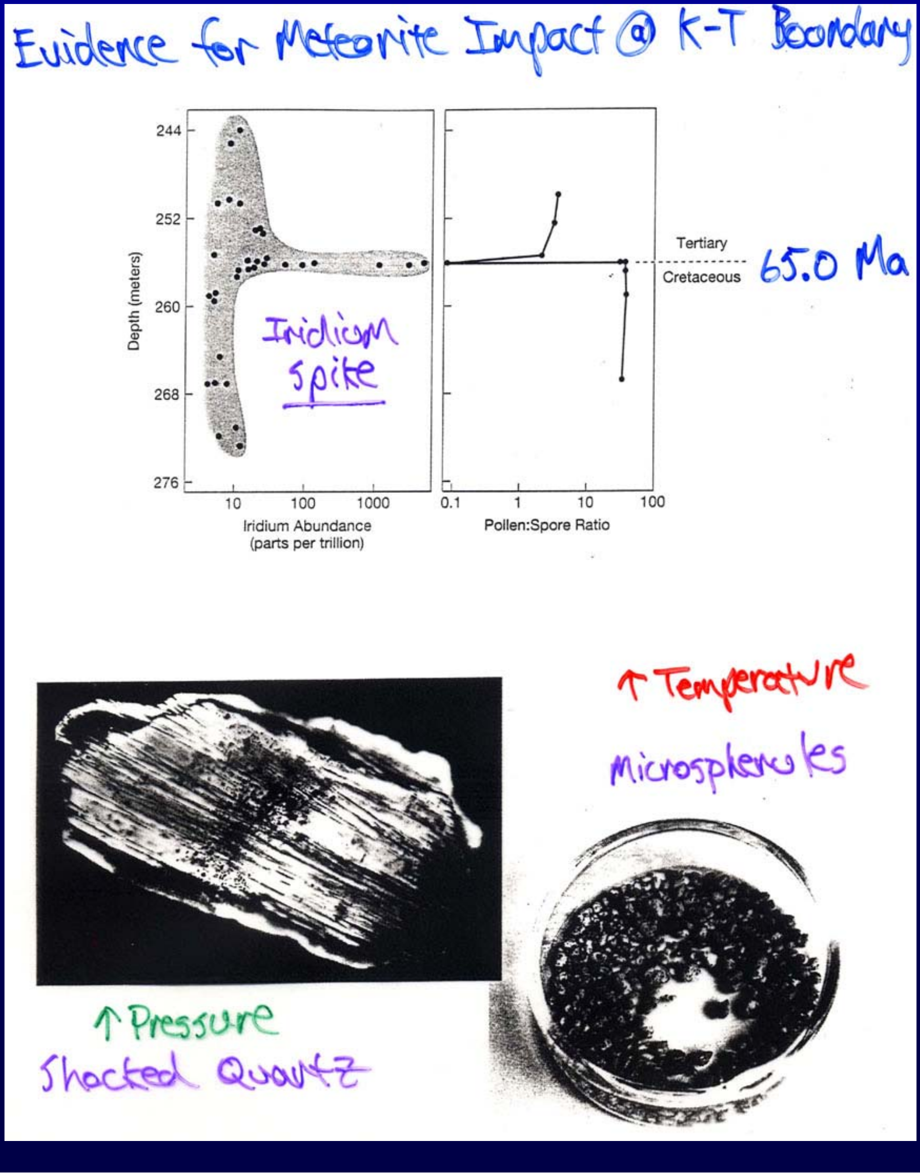
Paleogeography of the World

During the Late Cretaceous Period



(from http://www.geol.lsu.edu/Faculty/Bart/1003/chapter_15.ppt#410,23,Mesozoic Reef-Builders)

Isotope spikes and Chronostratigraphy

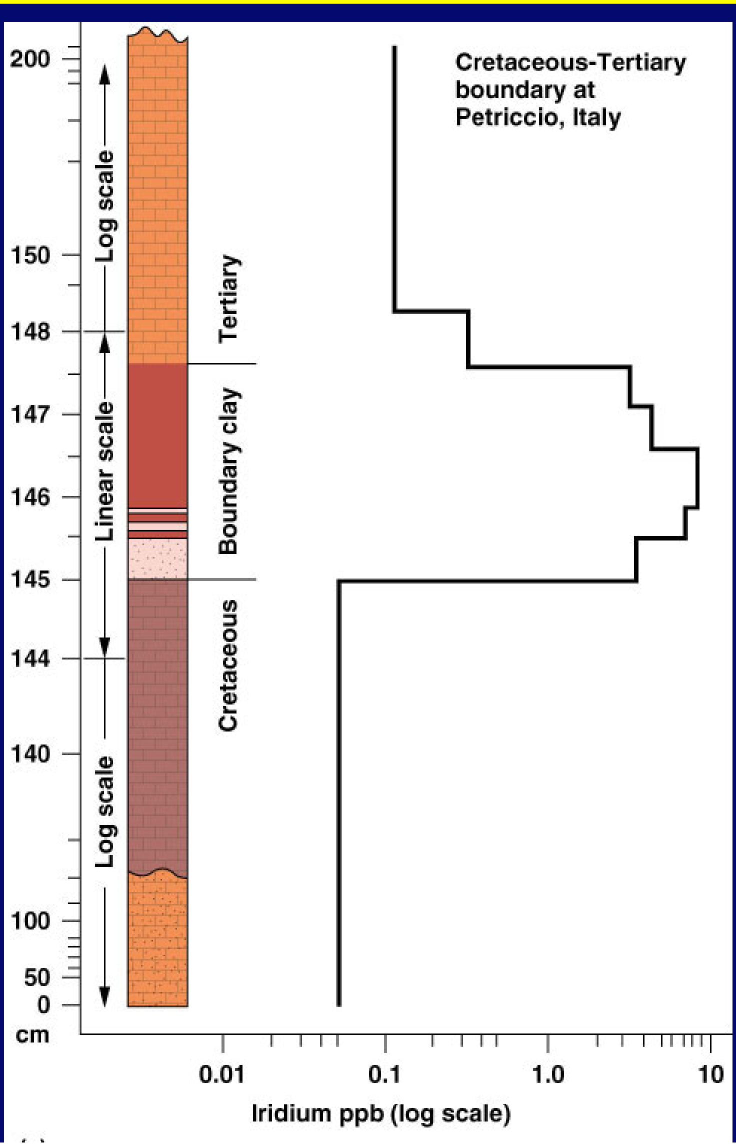


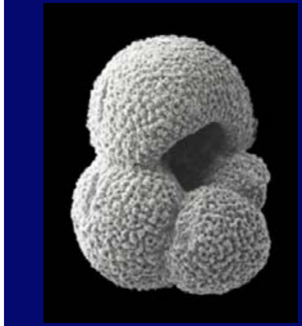
Correlations can be made relating chronostratigraphic data to isotope spikes such as the Iridium spike at the Cretaceous-Paleocene (K-T) boundary

http://stuff.mit.edu/afs/athena/course/12/12.842/www/paleolecture5b.ppt

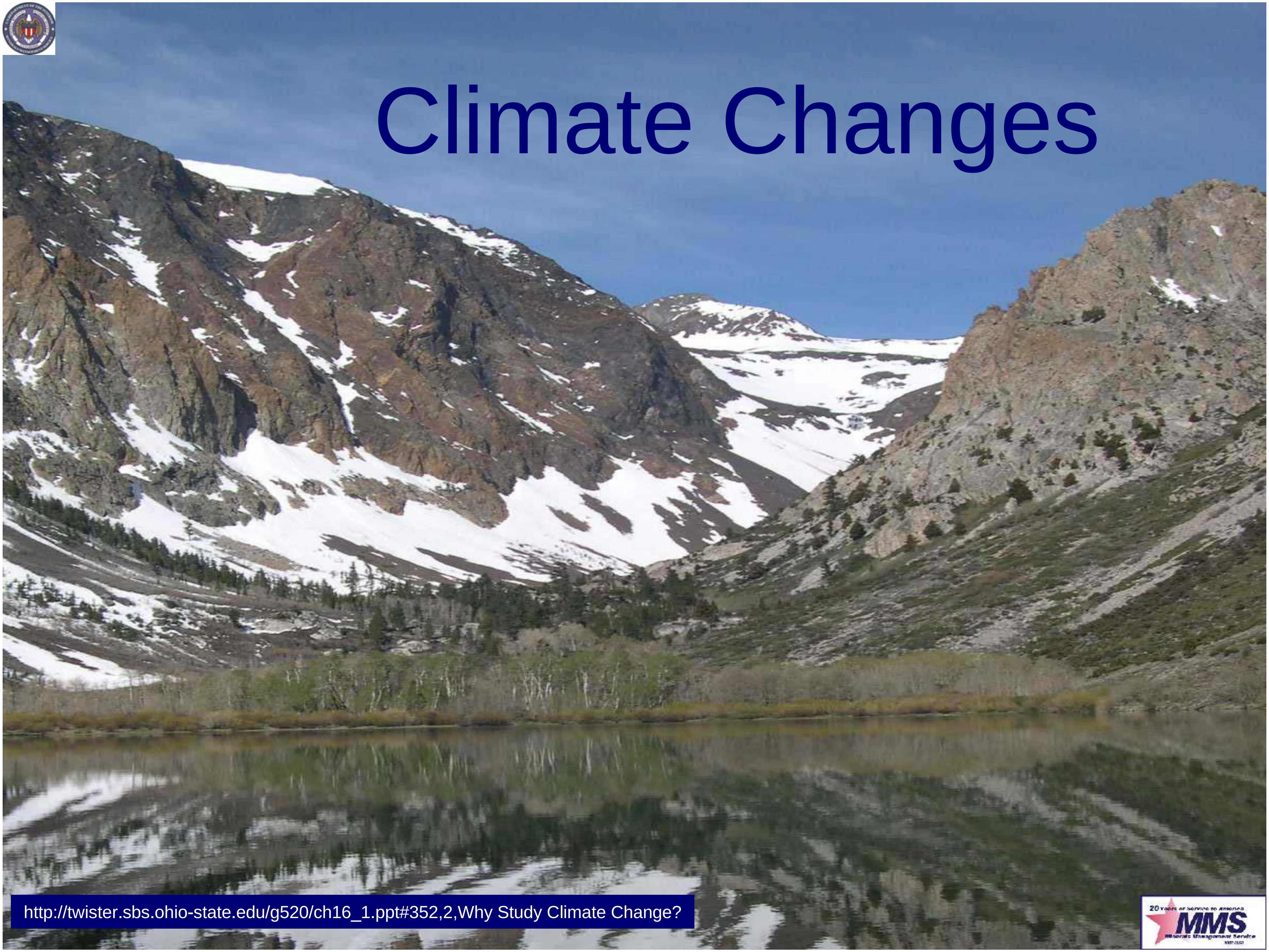
Cretaceous-Tertiary Boundary

At this Cretaceous-Tertiary boundary site in Italy, a 2.5-cm-thick clay layer shows a concentration much higher than expected of the platinum-group element iridium



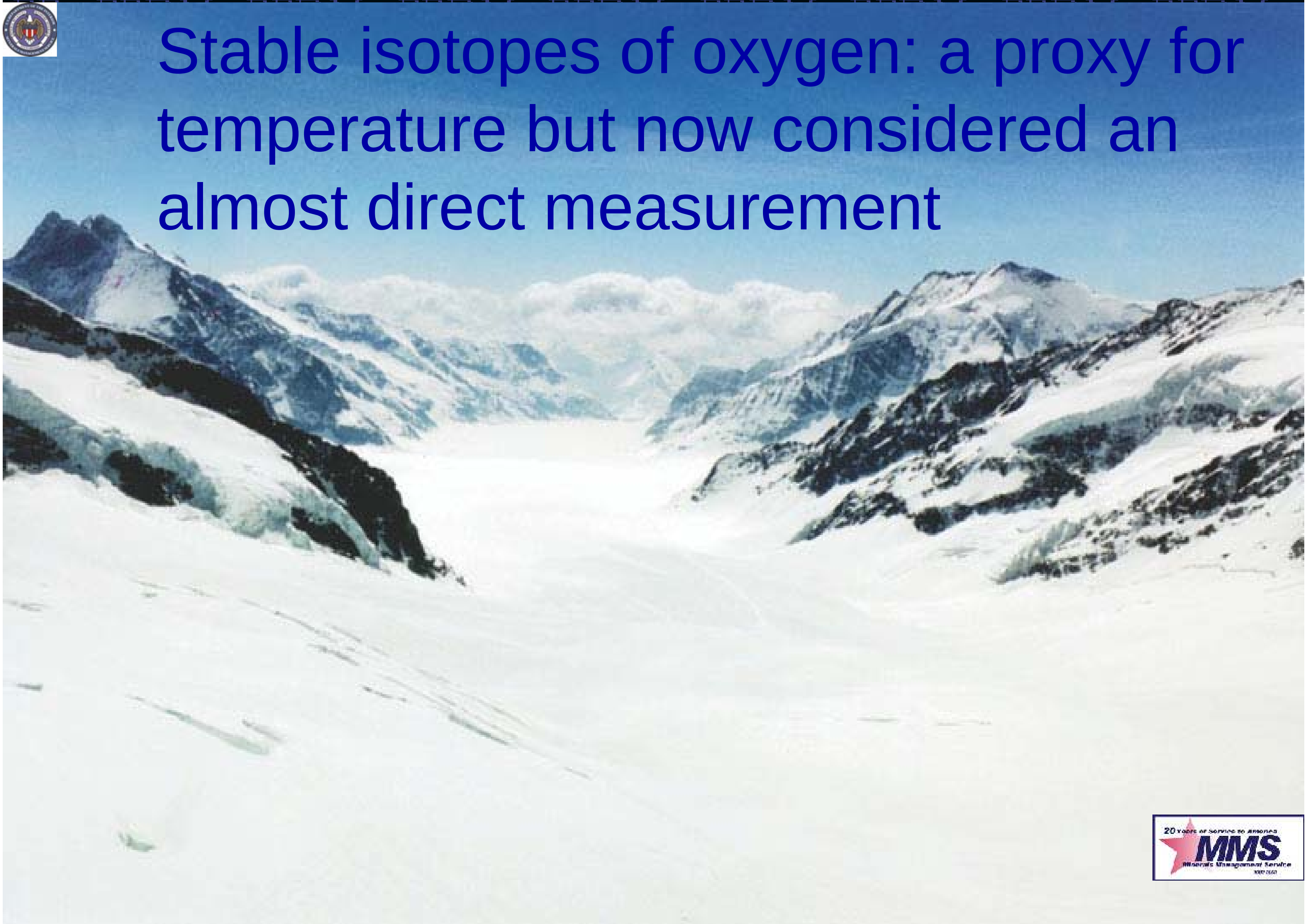


Climate Changes



http://twister.sbs.ohio-state.edu/g520/ch16_1.ppt#352,2,Why Study Climate Change?

Stable isotopes of oxygen: a proxy for temperature but now considered an almost direct measurement



Stable isotopes of oxygen: a proxy for temperature but now considered an almost direct measurement

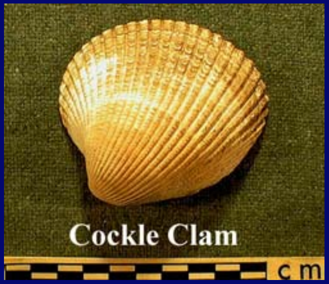
- Stable isotopes: do not decay over time - O_{16} and O_{18}.
- O_{18} is produced from O_{16} through the bombardment of O_{16} by ultraviolet radiation in the uppermost atmosphere.
- Anything that incorporates oxygen into its chemical structure will do so with some ratio of O_{18}/O_{16}. We can measure the ratios of these isotopes in the lab.

http://www.uvm.edu/~cmehrten/courses/earthhist/paleoclimind.ppt#285,10

Paleothermometry

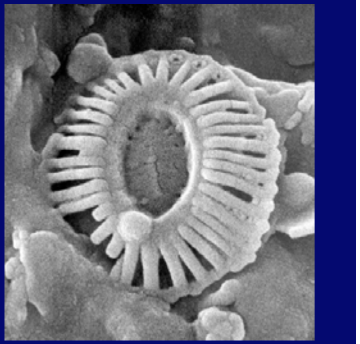
- Past ocean temperature may be determined by several ways:
  - Oxygen isotopes ratios in carbonate shells of foraminifera or in glacial ice
  - Relative abundance of different species of foraminifera
  - Mg/Ca ratios in foram shells
  - Alkenones found in marine organic material

Paleothermometry



If we collect a shell made out of $CaCO_3$, we can analyze the O_{18}:O_{16} ratio by the following formula:

$$\delta O_{18} = \text{delta } O_{18} = [(O_{18}/O_{16} \text{ sample}/O_{18}/O_{16} \text{ standard}) - 1\ ] \times 1000$$



•the standard that your sample is compared to is either one prepared from ocean water or from a fossil standard.

•positive delta O_{18} values mean that your sample is enriched in the heavy O isotope

•negative delta O_{18} values mean it’s depleted in the heavy O_{18}.

http://www.uvm.edu/~cmehrten/courses/earthhist/paleoclimind.ppt#288,13,Slide 13

Oxygen Isotopes and Ice Volume

<u>Oxygen on Earth</u>:

^{16}O (99.8%)

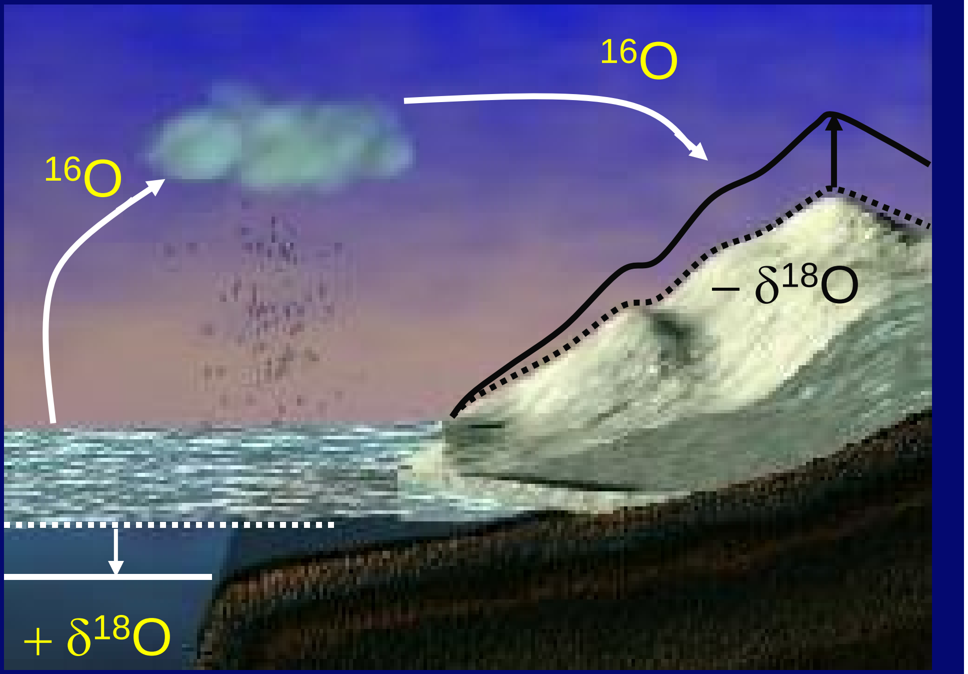
^{18}O (0.2%)

"Delta ^{18}O"

$\delta^{18}O$ (‰) = $^{18}O/^{16}O$ ratio

^{16}O is lighter than ^{18}O, so it is more easily evaporated from the ocean.

So, if ice sheets <u>grow</u> then ocean $\delta^{18}O$ <u>increases</u>.



http://eesc.columbia.edu/courses/v1012/historicalgeo/columbia_human_ev.ppt#272,25,Slide 25

Oxygen and carbon isotope measurement

- It is difficult to measure absolute ratios because of variable fractionation within the instrument, so instead we measure <u>isotope ratio differences</u> between standards and samples. O and C isotope ratios are expressed as difference from the std (‰):

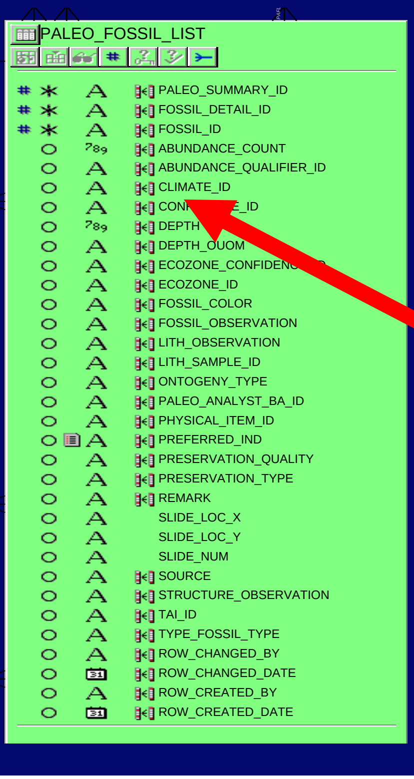
$$\delta^{18}O = \left[\frac{\left(\frac{^{18}O}{^{16}O} \right)_{sample}}{\left(\frac{^{18}O}{^{16}O} \right)_{s\tan dard}} - 1 \right] x1000$$

$$\delta^{13}C = \left[\frac{\left(\frac{^{13}C}{^{12}C} \right)_{sample}}{\left(\frac{^{13}C}{^{12}C} \right)_{s\tan dard}} - 1 \right] x1000$$

http://www.uvm.edu/~cmehrten/courses/earthhist/paleoclimind.ppt#288,13,Slide 13

Methods of Determining Past Climates

- Ocean sediment
- Ice cores
- Coral reefs
- Lake sediment
- Tree rings
- Cave deposits



PALEO_FOSSIL_LIST

PALEO_SUMMARY_ID
FOSSIL_DETAIL_ID
FOSSIL_ID
ABUNDANCE_COUNT
ABUNDANCE_QUALIFIER_ID
CLIMATE_ID
CON E_ID
DEPTH
DEPTH_OUOM
ECOZONE_CONFIDENC D
ECOZONE_ID
FOSSIL_COLOR
FOSSIL_OBSERVATION
LITH_OBSERVATION
LITH_SAMPLE_ID
ONTOGENY_TYPE
PALEO_ANALYST_BA_ID
PHYSICAL_ITEM_ID
PREFERRED_IND
PRESERVATION_QUALITY
PRESERVATION_TYPE
REMARK
SLIDE_LOC_X
SLIDE_LOC_Y
SLIDE_NUM
SOURCE
STRUCTURE_OBSERVATION
TAI_ID
TYPE_FOSSIL_TYPE
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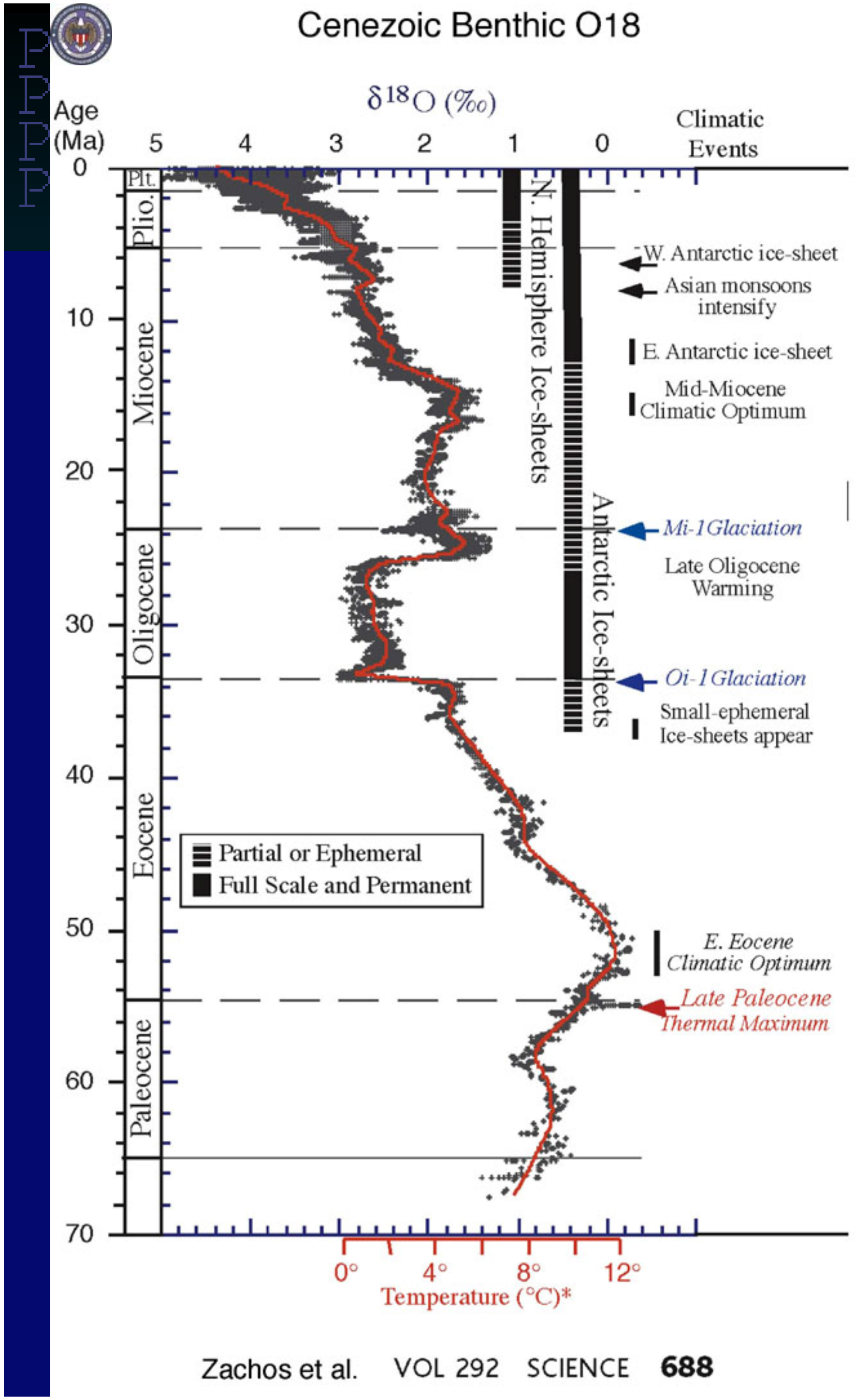
Climate data

http://twister.sbs.ohio-state.edu/g520/ch16_1.ppt#352,2,Why Study Climate Change?

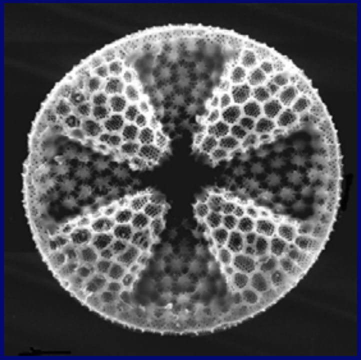


Cenezoic Benthic O18

Zachos et al. VOL 292 SCIENCE **688**

Stable isotopes of oxygen: a proxy for temperature

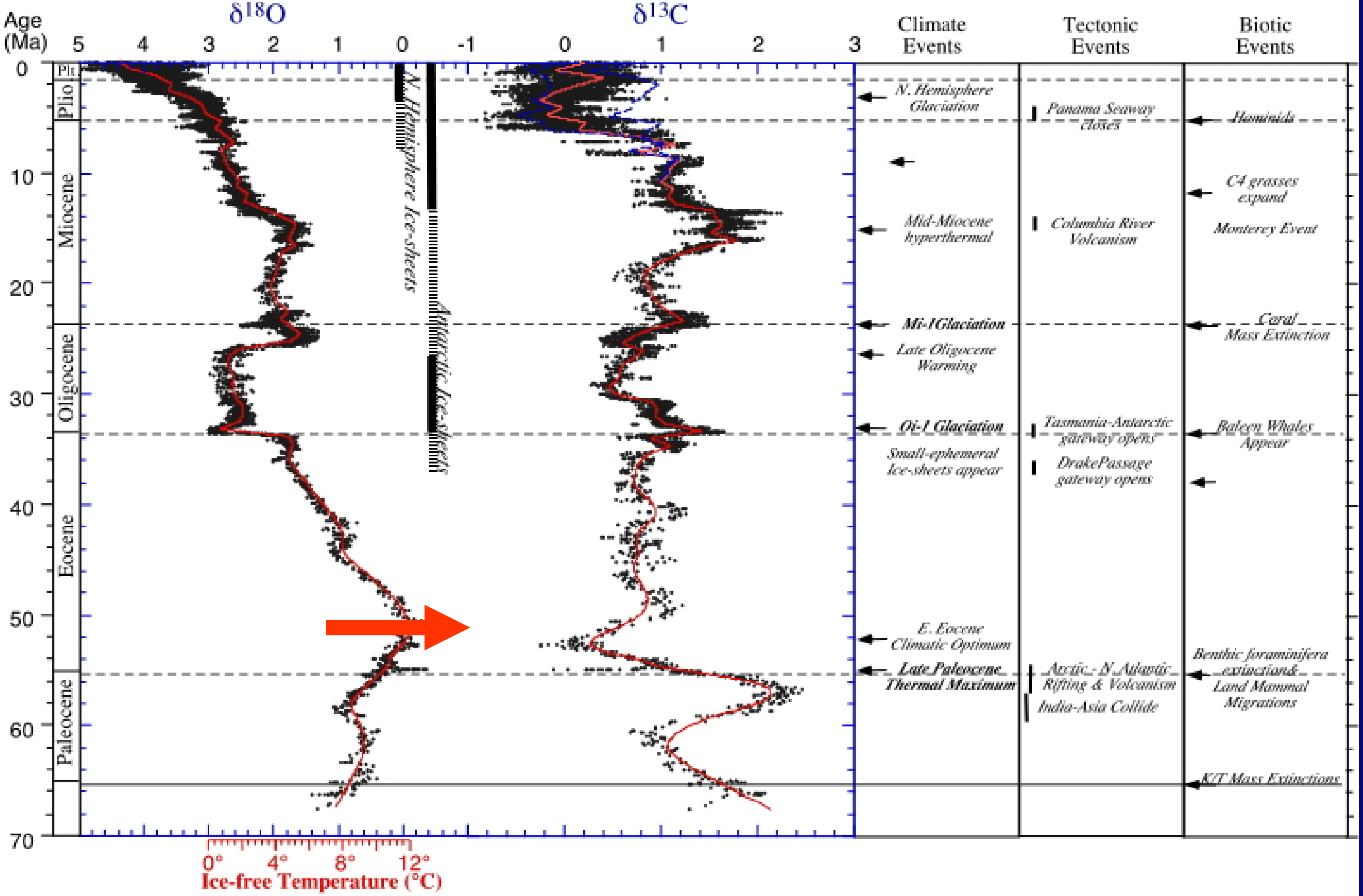
Cenozoic Cooling from 80 Mya to present



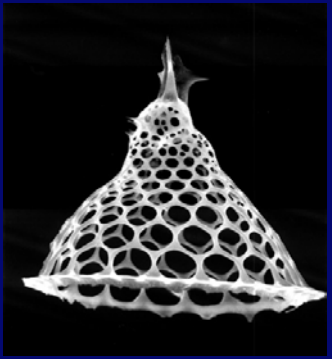
Why?

http://stuff.mit.edu/afs/athena/course/12/12.842/www/paleolecture5b.ppt

Oxygen and carbon isotopes, chronostratigraphy and paleoclimatology



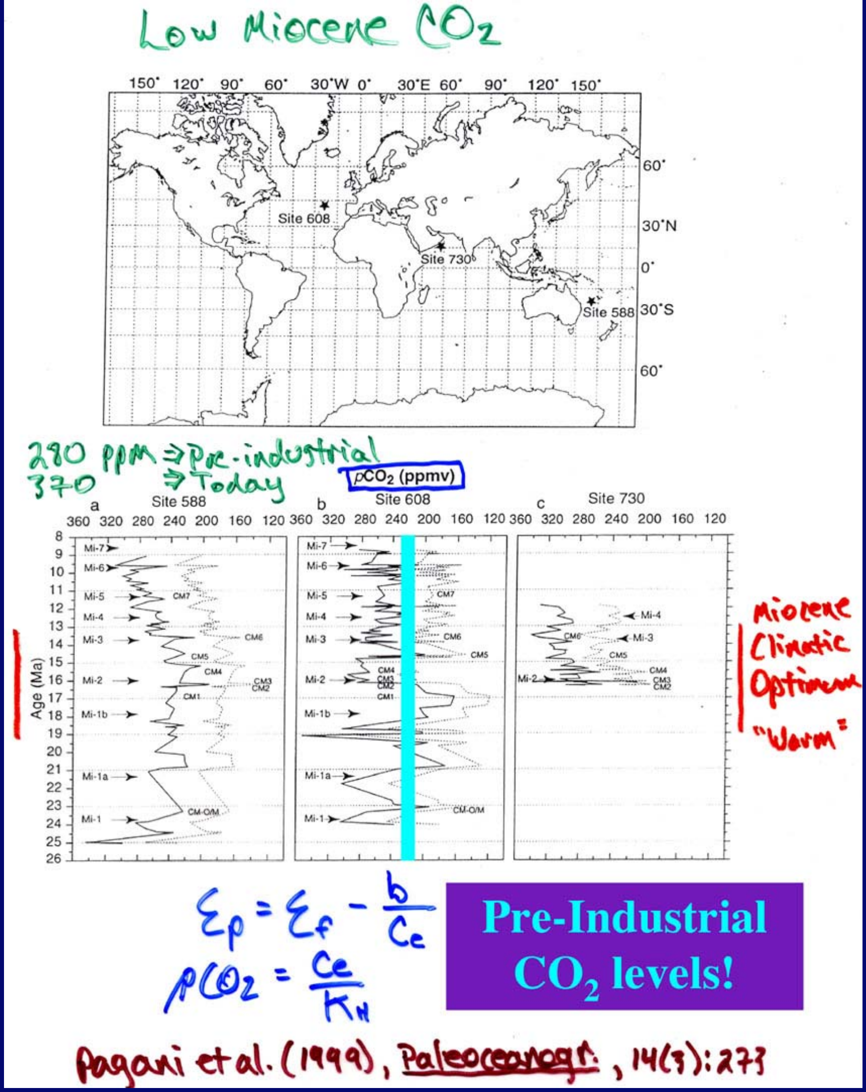
Oxygen isotope values (left column) and carbon isotopic values of the deep sea for the Cenozoic, after Zachos et al., 2001



- Note that more negative δ18O values mean that water temperature was higher, or the polar ice sheets were smaller, or both.

http://www.awi-bremerhaven.de/Modelling/Paleo/lessons/VL_WS0506/14)soil.ppt#779,25,Slide 25

Oxygen and carbon isotopes, chronostratigraphy and paleoclimatology



Low Miocene CO_2

280 ppm ⇒ Pre-industrial
370 ⇒ Today

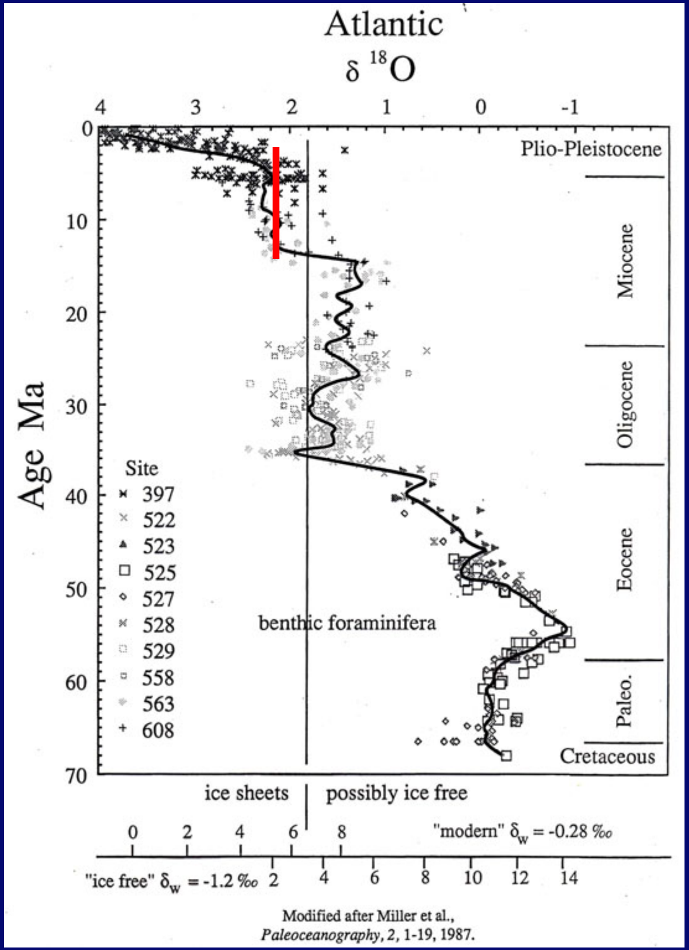
$$\varepsilon_p = \varepsilon_f - \frac{b}{C_e}$$

$$pCO_2 = \frac{C_e}{K_H}$$

Pre-Industrial CO_2 levels!

Pagani et al. (1999), Paleoceanogr., 14(3):273

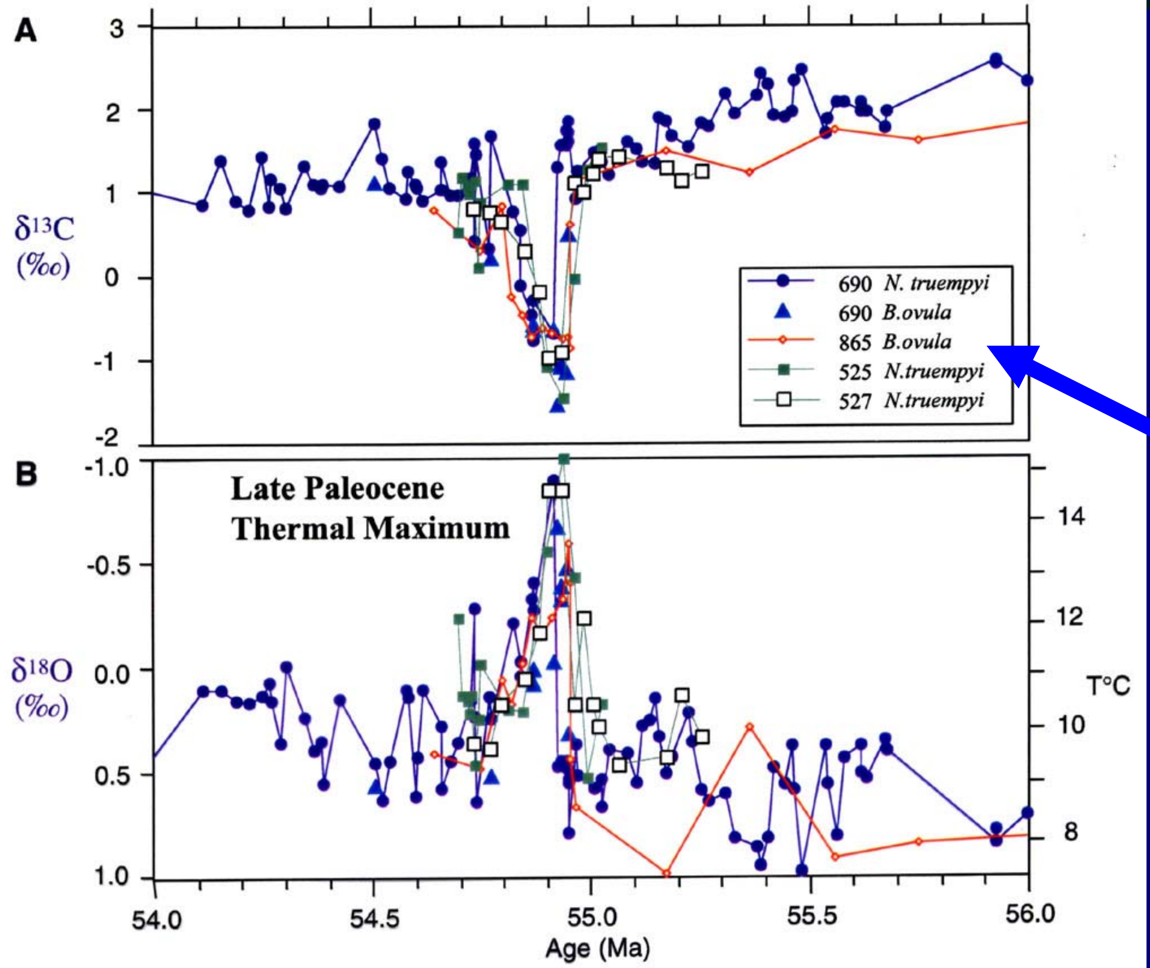
Evidence for <u>low CO_2</u> during a Miocene warm period



Modified after Miller et al., *Paleoceanography*, 2, 1-19, 1987.

http://stuff.mit.edu/afs/athena/course/12/12.842/www/paleolecture5b.ppt

Gas Hydrates, absolute age and the Late Paleocene Thermal Maximum (PETM)



Did a Gas Hydrate Release of Methane (2600 Gt) caused Late Paleocene Thermal Maximum?

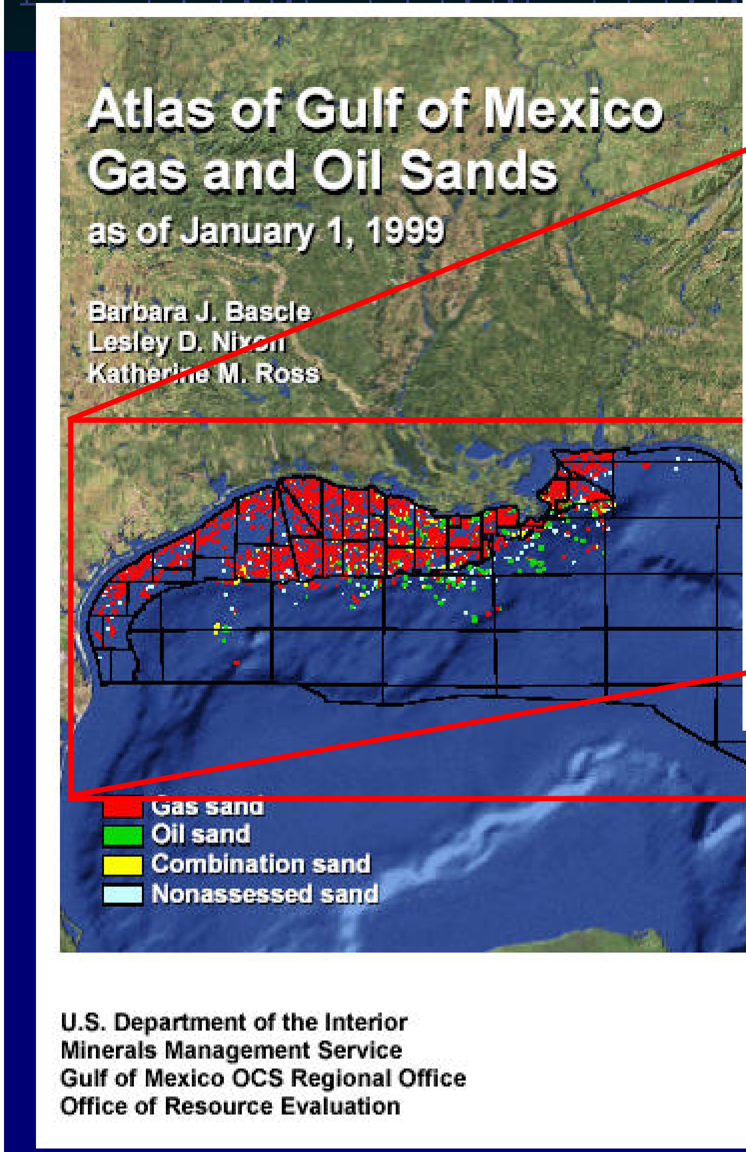
benthic foraminifera from the Atlantic & Pacific

from Zaclos et al, 2001

CO_2 not the only greenhouse gas we need to consider when evaluating warm episodes.

http://stuff.mit.edu/afs/athena/course/12/12.842/www/paleolecture5b.ppt

Chronostratigraphy and geologic plays



Atlas of Gulf of Mexico Gas and Oil Sands

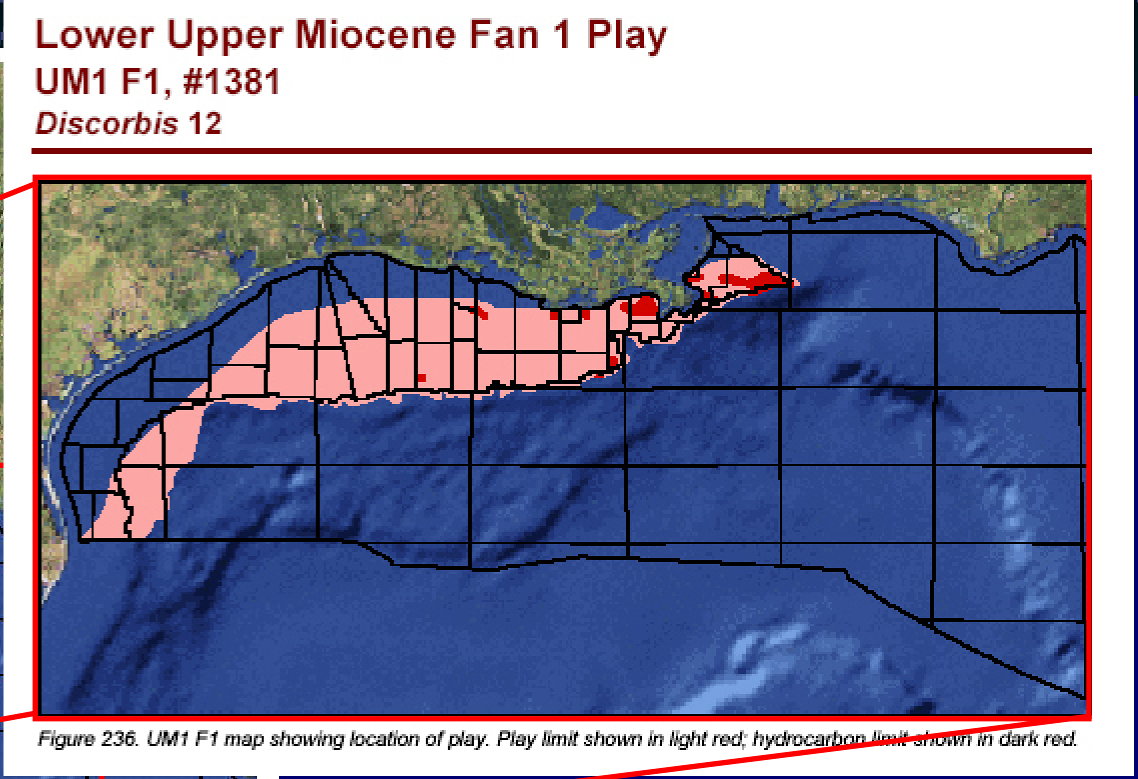
as of January 1, 1999

Barbara J. Bascle
Lesley D. Nixon
Katherine M. Ross

🟥 Gas sand
🟩 Oil sand
🟨 Combination sand
⬜ Nonassessed sand

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Regional Office
Office of Resource Evaluation

New Orleans
September 2001



Lower Upper Miocene Fan 1 Play

UM1 F1, #1381

***Discorbis* 12**

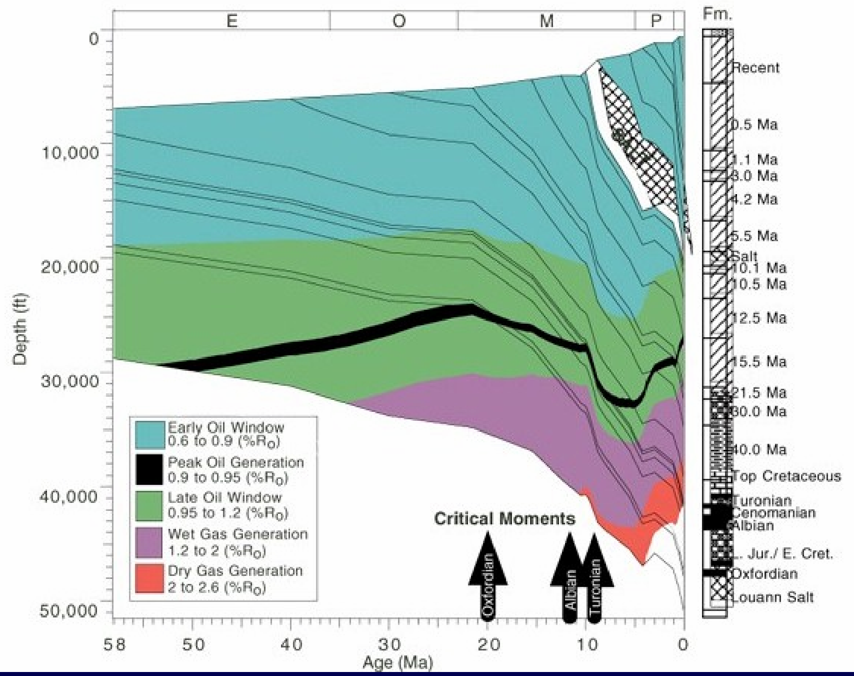
Figure 236. UM1 F1 map showing location of play. Play limit shown in light red; hydrocarbon limit shown in dark red.

- Applying chronostratigraphy to GOM geologic successions, we can more accurately determine the active geologic processes involved in the deposition of GOM sediments. Can we better delineate the play boundaries?

Chronostratigraphy and basin modeling

Absolute ages derived from chronostratigraphic analysis can be used in reconstructing the burial history of a geologic basin and in hydrocarbon systems modeling [e.g., can be applied in BasinMod, or in the RASC (Ranking and Scaling) method i.e., that used by Agterberg and Gradstein 1999*]

Figure 12—Geohistory plot (from BasinMod) of Ewing Bank 950 pseudo-well with thermal maturation overlay. Potential Mesozoic and early Cenozoic standard type II kerogen source rocks pass through the peak oil generation window (~0.90–0.95 %Ro) from 25 to 5 Ma. Location shown in Figure 14.



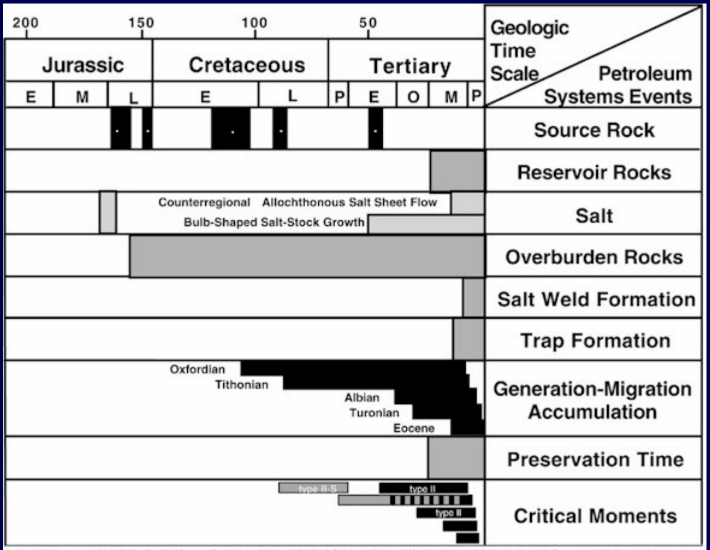


Figure 8—Events chart for the petroleum systems within the northern Green Canyon/Ewing Bank study area showing the temporal relationships of the essential elements and processes. Preservation time represents time since initial critical moment of peak generation. Critical moments represent the time each source rock experienced peak oil generation (0.90–0.95 %Ro) as shown in Figure 12, Figure 13, and Figure 16.

McBride, B. C., Weimer, P. and M. G. Rowan, 1999, The effect of allochthonous salt on the petroleum systems of northern Green Canyon and Ewing Bank (offshore Louisiana), northern Gulf of Mexico, Search and Discovery article #10003, adaptation for online presentation of article, of same title and by same authors, published in AAPG Bulletin, v. 82/5B, p. 1083-1112.

*Agterberg, F.P. and F. M. Gradstein, 1999, The RASC method for ranking and scaling of biostratigraphic events, Earth Science Reviews, v. 46, p. 1-25 .

Chronostratigraphy's role

Can it optimize the predictive power of geologic tools and data at our disposal?

Time for Questions

Thanks for your attention!