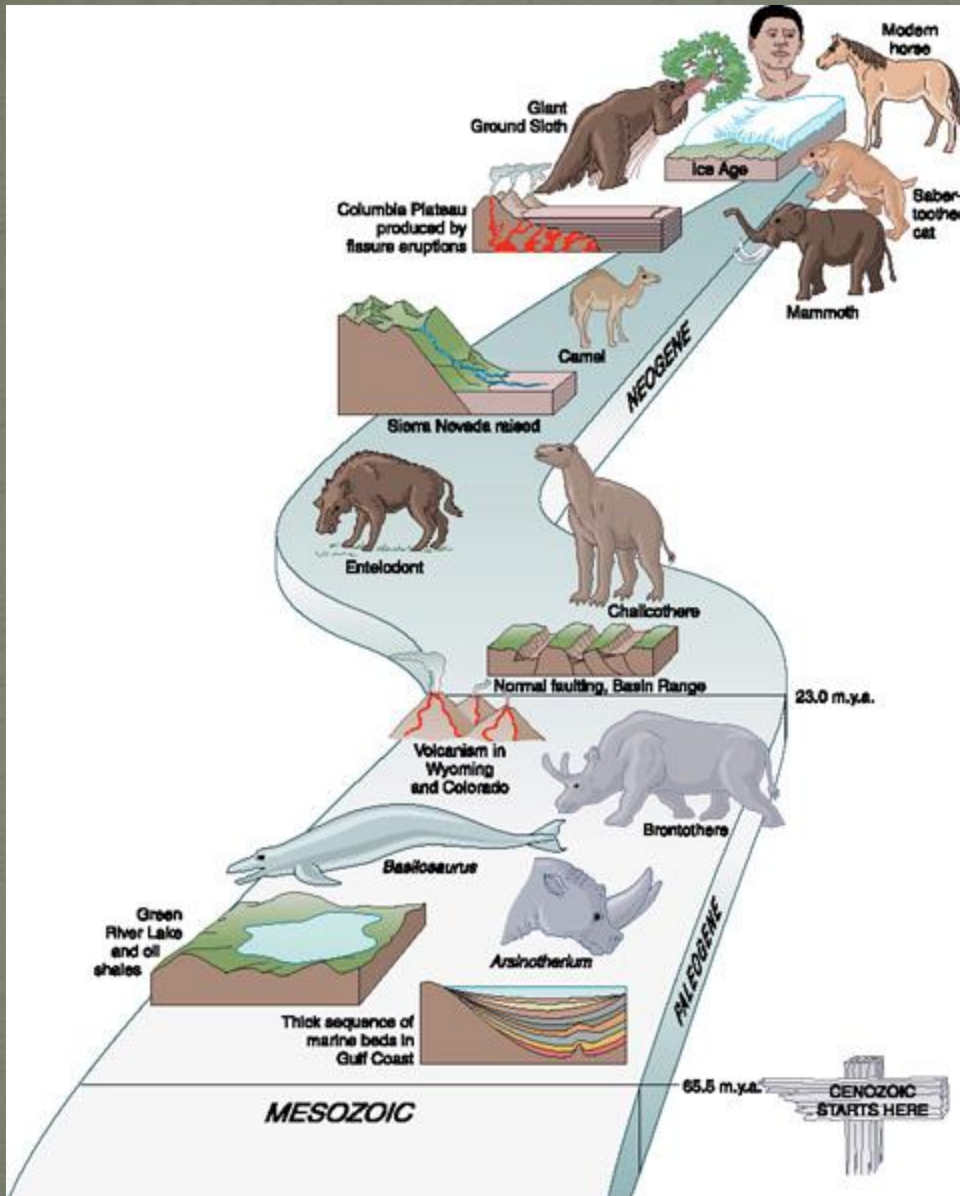
Cenozoic Era



The Cenozoic Era

The Era of Mammals
(or the era of insects)

The Cenozoic Era

- 66 my ago to the present
- Name "Cenozoic" = "new life" or "recent life“
- The Cenozoic Era followed the extinction of the dinosaurs and many other organisms
- Cenozoic rocks contain modern types of plants and animals, more advanced than those in the Paleozoic and Mesozoic.
- The Cenozoic is the time of:
  - Adaptive radiation of the mammals
  - Cooling of the Earth's climate resulting in the Ice Ages
  - Evolution of humans
-

The Cenozoic Era (66-0my)

- The Cenozoic Era consists of three periods:
  - Paleogene (66-23my)
  - Neogene (23-2.56my)
  - Quaternary (2.56-0my)

Paleogene (66-23 my)

- Oligocene (34-23my)
  - Chattian (Up.)
  - Rupellian (L.)
- Eocene (56-34my)
  - Priamponian (Up.
  - Bartonian (Up.)
  - Lutetian (M.)
  - Ypresian (L.)
- Paleocene (66-56my)
  - Thanetian (Up.)
  - Selandian (M.)
  - Danian (L.)

Neogene (23-2.56my) (Marine)

Pliocene (5.3-2.6 my)
- Piacenzian (Up.)
- Zanclean (L.)

Miocene (23-5.3 my)
- Messinian (Up.)
- Tortonian (Up.)
- Serravallian (M.)
- Langhian (M.)
- Burdigalian (L.)
- Aquitanian (L.)

Neogene (23-2.56my) (continental)

Pliocene (5.3-2.6 my)	Rousinian
Miocene (23-5.3 my)	Turolian (Up.) Vallesian (M.) Astaracian (M.) Orleanian (L.) Agenian (L.)

Quaternary (2.56-0my) (Marine)

Holocene (0,0117-0my)

- Meghalayan (Up.)
- Northgrippian (M.)
- Greenlandian (L.)

Pleistocene (2,6-0,011my)

- Tyrrhenian (Up.)
- Milacian (Up.)
- Sicilian (Up.)
- Chibanian (M.)
- Calabrian (L.)
- Gelasian (L.)

Quaternary (2.56-0my) (Terrestrial)

Holocene (0,0117-0my)

Pleistocene (2,6-0,011my)

- Oldenburgian(Up.)
- Biharian (Up.)
- Villafranghian (L.)

Quaternary (2.56-0my) (Lithics)

Neolithic (6.000-3.200)

Mesolithic (10.000-6.000)

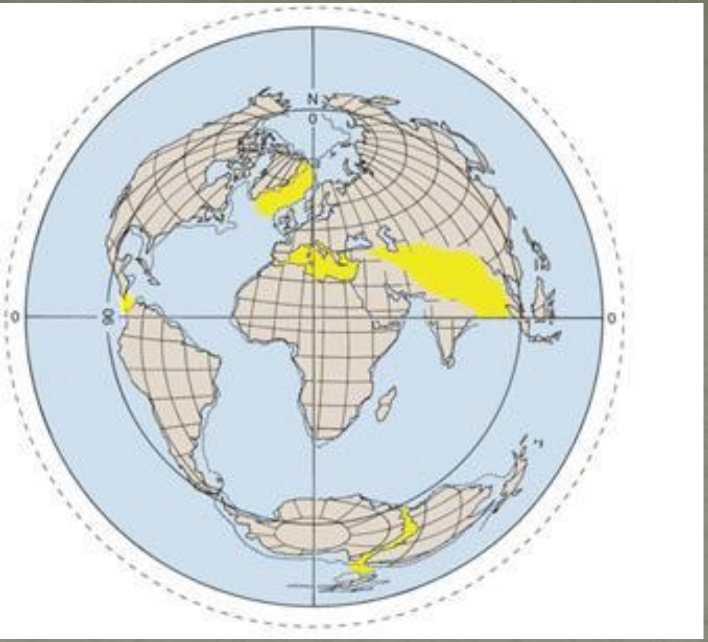
Paleolithic (2.5-0.01 my)

Upper

Middle

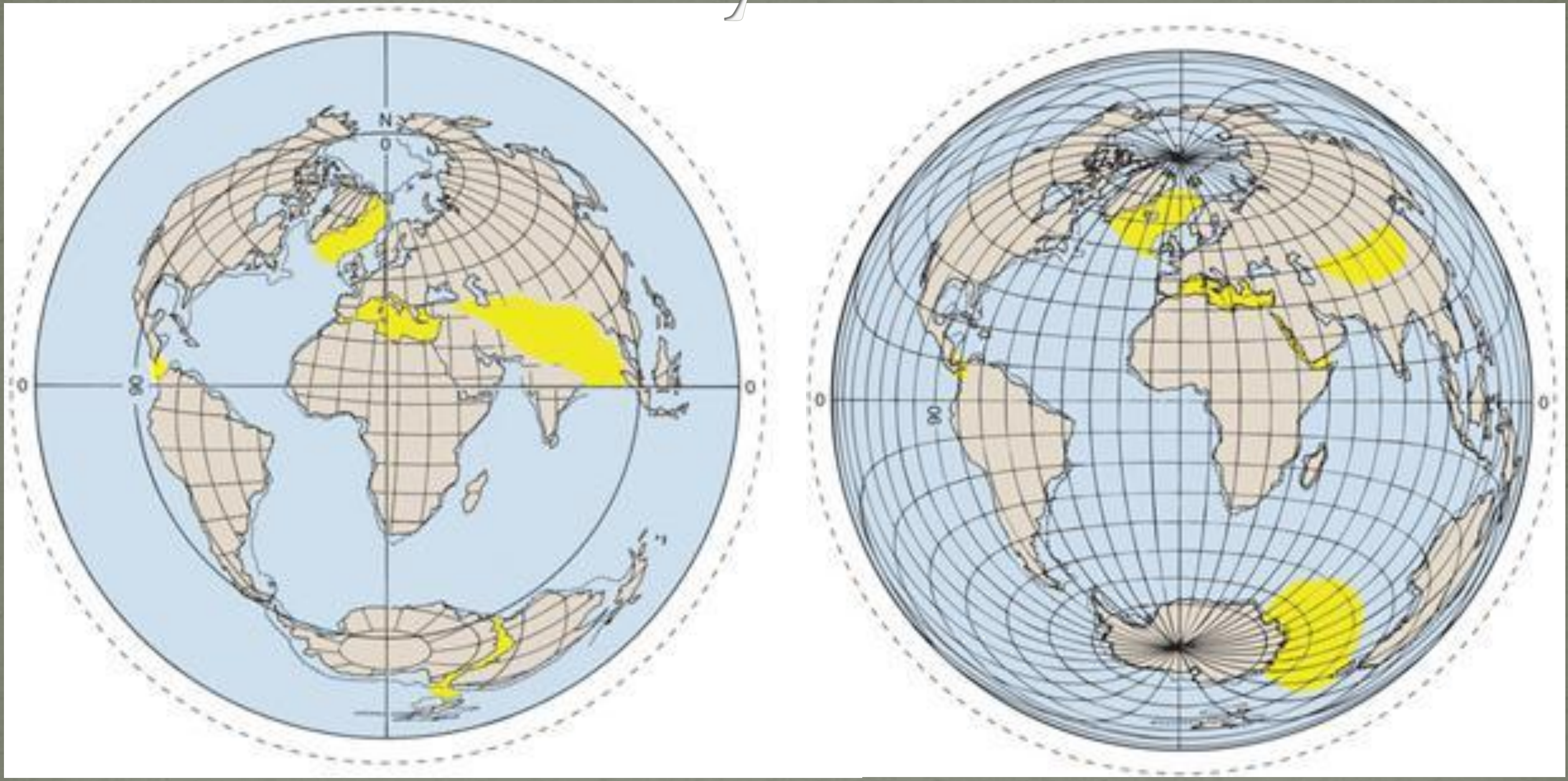
Lower

Epigravettian
Gravettian
Aurignacian
Mousterian
Acheulean
Oldowan



Position of the continents during the Eocene, about 50 m.y. ago.
Antarctica and Australia are still connected.
India has not yet collided with Asia.
North and South America are not yet connected.
South America is connected or nearly connected with Antarctica.

Eocene vs. Today



Closure of the Tethys Sea

- Collision of Africa and India with Eurasia, forming the Alps and Himalayas.
- Tethys Sea deposits were deformed into mountain ranges.
- Detachment of Arabia from Africa, opening of the Red Sea, Collision of Arabia with Eurasia (Caucasus Mountains)
- Collision of North and South America

Important continental breakups:

1. North Atlantic rift separated Greenland from Scandinavia
2. Australia separated from Antarctica (55my).
3. Rifting occurred between Africa and Arabia, forming the Red Sea and the Gulf of Aden.
4. Formation of rift valleys in East Africa, along with associated lakes and volcanoes

Tectonic and Paleographic Changes and Their Effects on Climate

- Orogenic and volcanic activity were intense along the western edge of the North and South American plates.
- This caused the formation of the Isthmus of Panama (3my ago), a land bridge linking North and South America.
- The land bridge provided a path for plant, animal, and human migration between the Americas.

Tectonic and Paleographic Changes and Their Effects on Climate

- The Panama land bridge blocked the westward flow of the North Atlantic Current. The current was deflected to the north (turning to the right, as a result of the Coriolis Effect), and formed the Gulf Stream.
- The Gulf Stream transported warm water northward and resulted in bringing warmer climates to northwestern Europe.
- Gulf Stream also supplied warm, moist air toward the North Pole, which would ultimately result in precipitation which helped build the glacial ice sheets.

Tectonic and Paleographic Changes and Their Effects on Climate

- Glaciation led to regressions.
- Continental interiors were not flooded by epicontinental seas during the Cenozoic.
- Marine transgressions were limited.
- Overall cooling trend during the Cenozoic.
  - Tropical and subtropical plants were replaced by temperate plants, such as grasses.
  - Tropical plants retreated toward the equator.

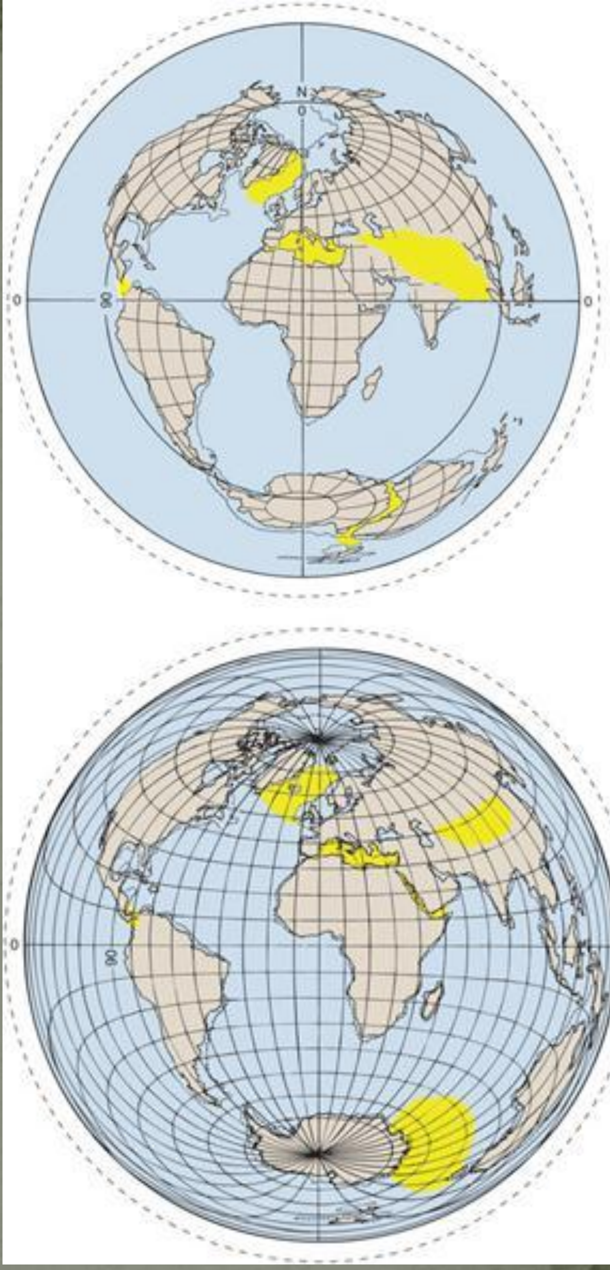
Global Surface Cooling

- There was a 10° C (18° F) temperature drop at end of Cretaceous Period.
- Several warming trends occurred in the late Paleocene and Eocene, as indicated by:
  - Fossils of palm trees and crocodiles in Minnesota, Germany, and near London.
  - Fossils of trees from temperate zones in Alaska, Norway and Greenland.
  - Coral reefs in latitudes 10-20° closer to the poles than at present.

Antarctica in the Paleogene

- The climate was semitropical and mild in Antarctica during the Paleogene, as indicated by fossil spores and pollen, despite the fact that it sat on the South Pole.
- Before Antarctica separated from Australia, it was warmed by currents moving southward from more equatorial latitudes.

- Australia began to separate from Antarctica in the early Eocene, about 55 m.y. ago.
- After separation, circumpolar currents developed around Antarctica, cutting it off from equatorial currents.
- This resulted in temperature decrease and glacial conditions over Antarctica.



Global Surface Cooling

- Temperatures dropped by about 8-13° C (roughly 22° F) near the Eocene-Oligocene boundary, as indicated by isotope data from brachiopods from New Zealand.
- Antarctic sea ice began to form by 38 m.y. ago.
- **Greenhouse conditions were replaced by icehouse conditions.**

Worldwide cooling resulted in:

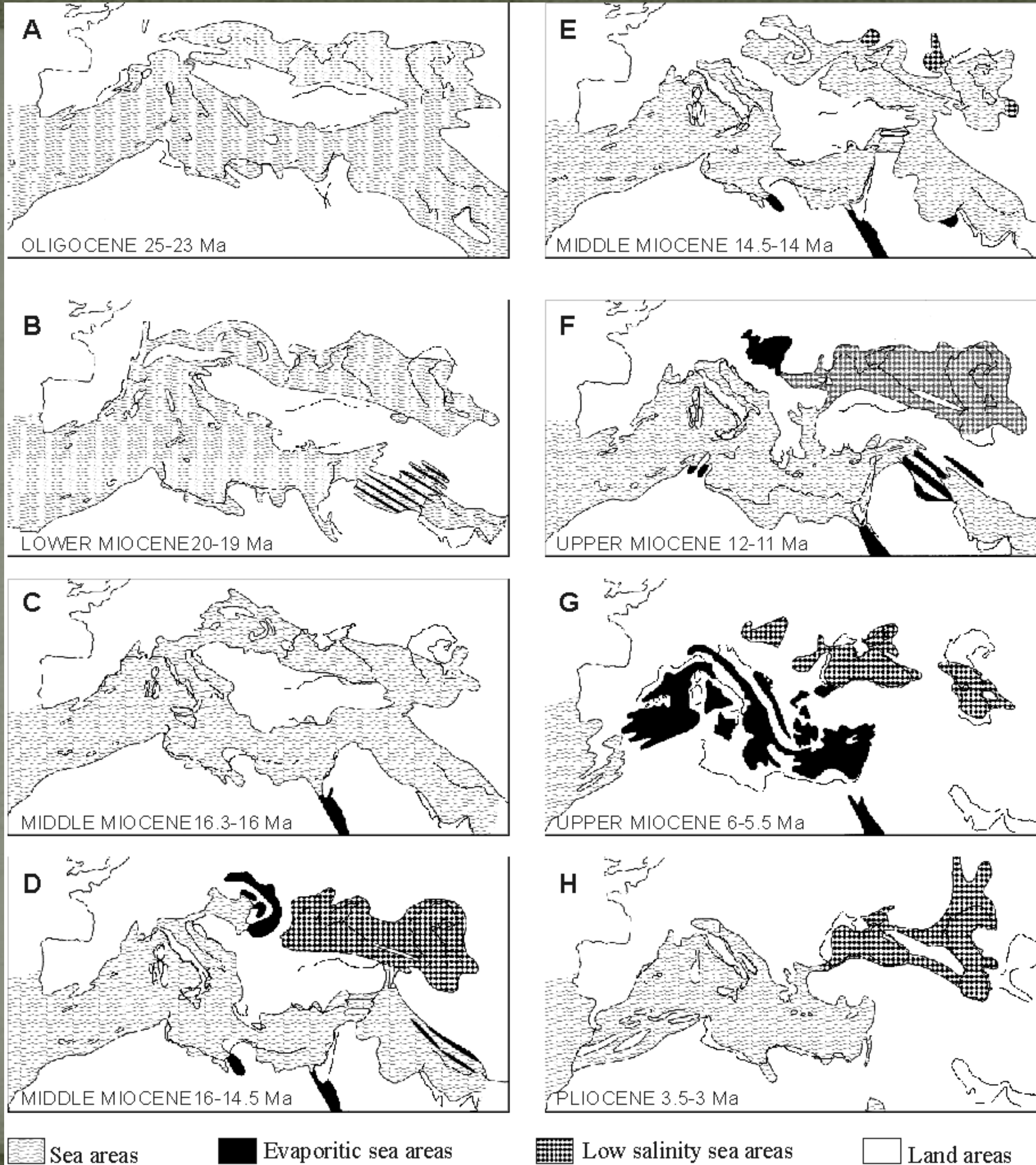
1. First Cenozoic widespread growth of glaciers in Antarctica about 38-22 m.y. ago.
2. Global sea level dropped by about 50 m in the Early Oligocene, as glaciers formed.
3. Cold, dense polar water flowed northward across ocean bottom.
4. Upwelling of cold bottom waters affected world climate.
5. Grand Coupure extinction event

6. Decrease in diversity and extinctions of many:
    - marine molluscs
    - planktonic and benthonic foraminifera
    - ostracodes
7. Extinctions were earlier and more severe at higher latitudes.
8. Reefs shifted toward the equator.
9. Calcarous biogenic deep sea sediments (foraminiferal ooze) shifted toward the equator and were replaced by siliceous biogenic sediments (diatom and/or radiolarian ooze) at higher latitudes.

10. Changes in pollen indicate long term cooling and drying.
    - Temperate and tropical forests shifted toward the equator.
    - Grasslands expanded.
    - Rainforests became confined to tropical, equatorial areas.
11. Glaciation occurred in other areas in Pliocene (and younger) deposits - Sierra Nevada, Iceland, South America, and Russia.

Messinian salinity crisis

- Sea level drop, associated with glaciation in the Miocene plus tectonic activity, resulted in the isolation of the Mediterranean basin (5,96-5,33 my).
- Deep canyons were cut by rivers feeding the Mediterranean.
- The Mediterranean Sea dried up producing thick (1000-2000 m) evaporite deposits (gypsum, halite).
- During the 630,000 years of the crisis, the Mediterranean was filled and dried at least 8 times, as an evaporation is not enough to justify the thickness of the evaporites


A
OLIGOCENE 25-23 Ma
E
MIDDLE MIOCENE 14.5-14 Ma
B
LOWER MIOCENE20-19 Ma
F
UPPER MIOCENE 12-11 Ma
C
MIDDLE MIOCENE16.3-16 Ma
G
UPPER MIOCENE 6-5.5 Ma
D
MIDDLE MIOCENE16-14.5 Ma
H
PLIOCENE 3.5-3 Ma
Sea areas
Evaporitic sea areas
Low salinity sea areas
Land areas

Antarctic Ice

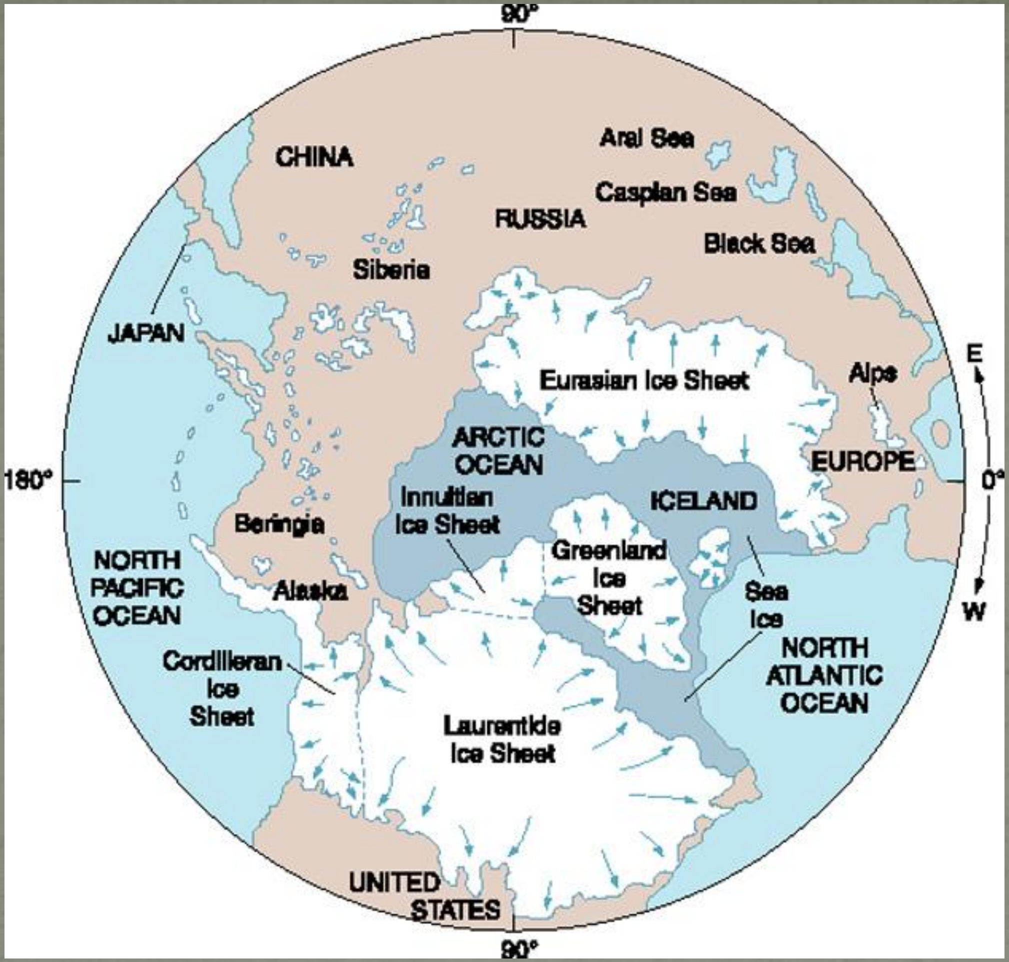
- Antarctica has been covered by glaciers for at least the past 15 m.y.
- The Antarctic ice sheet began to form in the Eocene.
- Glacial conditions established by the Miocene
- East Antarctic ice cap present since middle Miocene.
- In the latest Miocene (about 5 m.y. ago), ice volume in Antarctica was greater than today.

Antarctic Bottom Waters

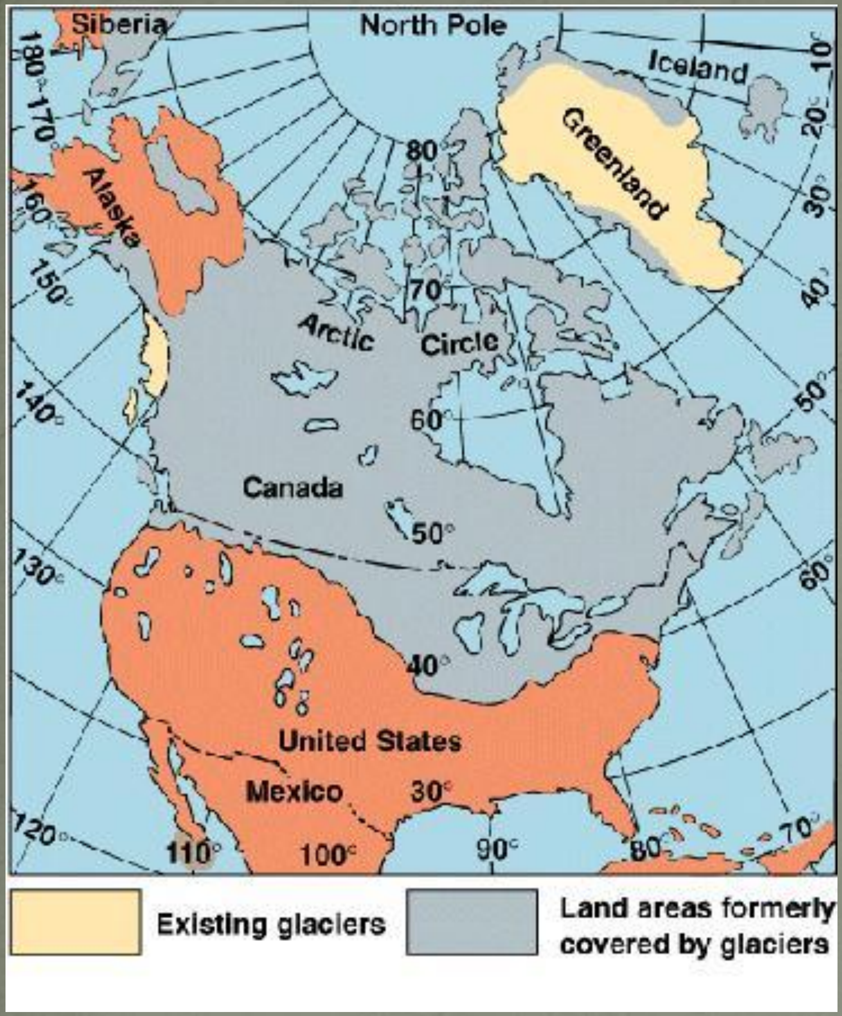
- The cold waters around Antarctica were dense, and sank to the ocean floor around Antarctica. (Cold water is denser than warmer water.)
- Cold, dense ocean-floor waters moved downward and outward, away from Antarctica.
- The northward movement of cold dense waters contributed to cool conditions during the late Eocene and early Oligocene, and ultimately led to the Pleistocene Ice Age.

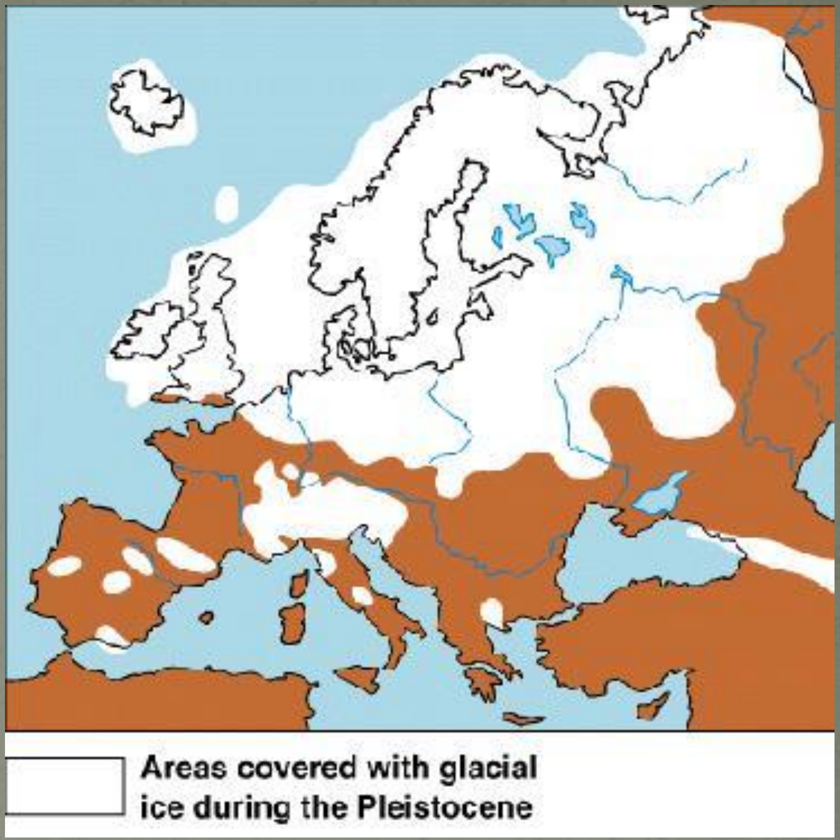
The Pleistocene

- The most extensive glaciations began about 1 m.y. ago.
- The end of the Pleistocene is when the ice sheets melted to approximately their current extent atn the end of the last glacial period.
- Sea Level Rise (Flood Mythology)
- More than 40 million km^3 of snow and ice covered about 1/3 of Earth's land area.
- Continental glaciers covered much of North America and Europe.
- Alpine glaciers covered parts of the Cordilleran Mountain range in western North America, the Alps, and other mountain ranges of Europe.



Pleistocene glaciers, North hemisphere


Siberia
North Pole
Iceland
Greenland
Alaska
Arctic Circle
Canada
United States
Mexico
180°
170°
160°
150°
140°
130°
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
Existing glaciers
Land areas formerly covered by glaciers

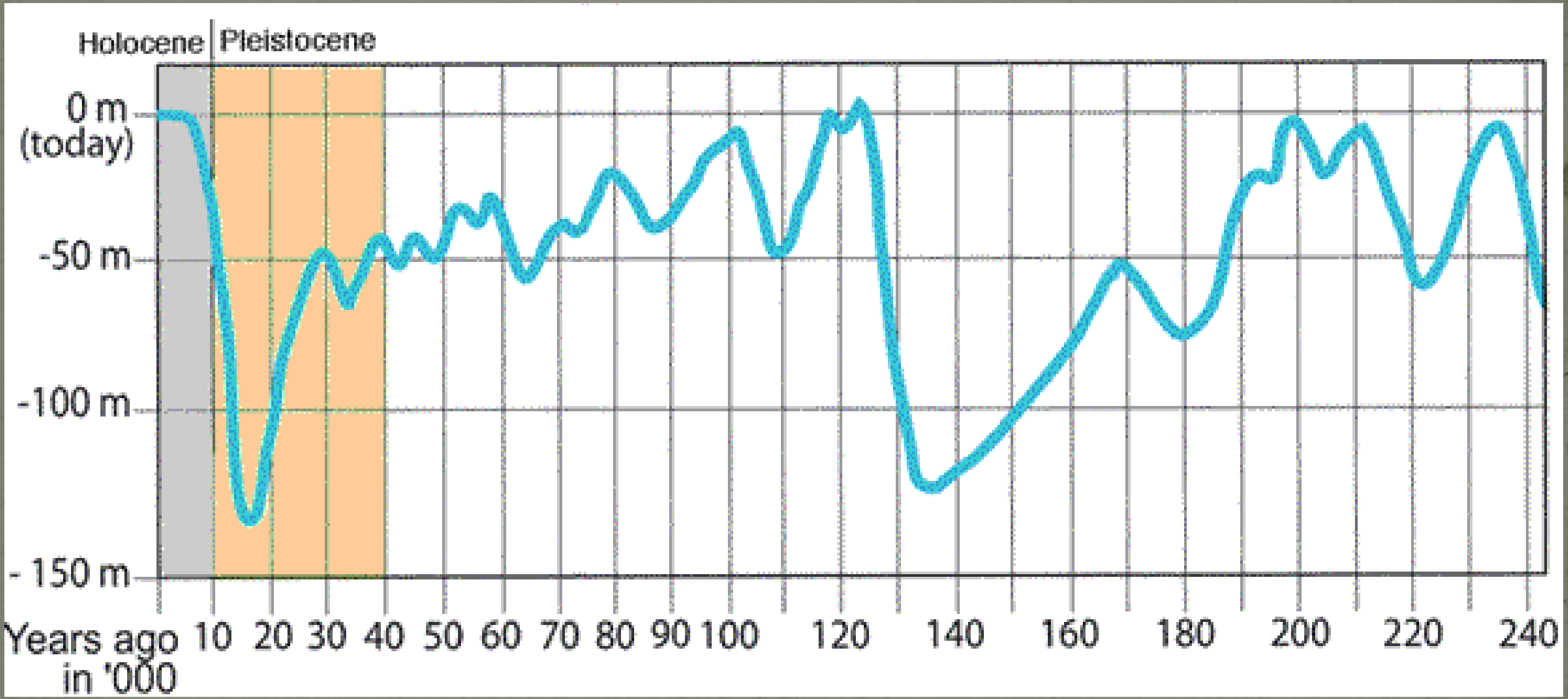

Areas covered with glacial ice during the Pleistocene

The Little Ice Age

- Cold spells recurred periodically into the Holocene.
- The "Little Ice Age" lasted from 1540 – 1890. Temperatures were several degrees cooler than today.
- Loss of harvests, famine, food riots, and warfare in Europe.
- Cold conditions correlate with periods of low sunspot activity.
- A time of extremely low sunspot activity from 1645 -1715 is known as the Maunder Minimum.

As a result of the Ice Age:

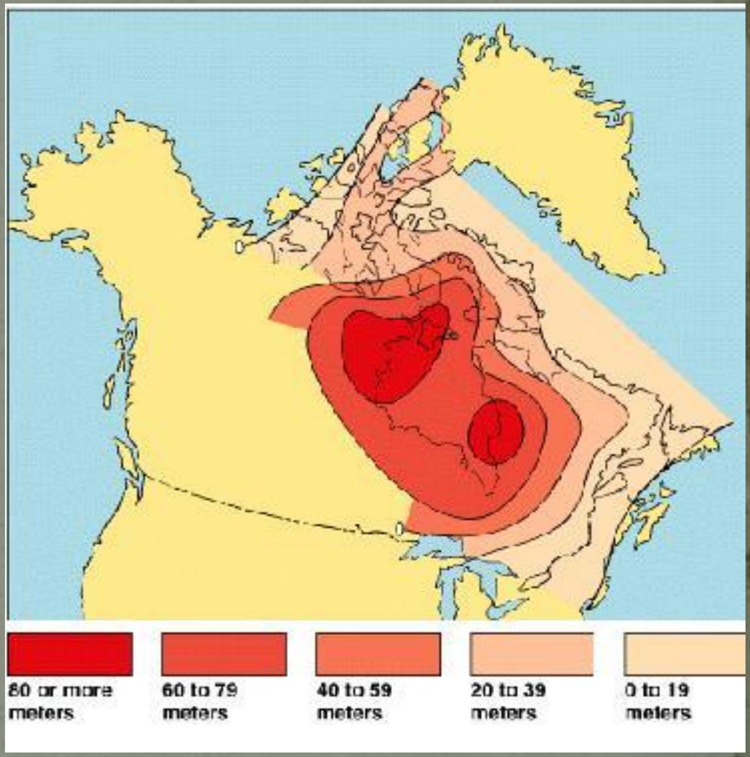
1. Climatic zones in the Northern Hemisphere were shifted southward.
2. Arctic conditions prevailed across Europe
3. Sea level dropped as much as 130 m and the shoreline shifted seaward, exposing the continental shelves as dry land.
4. Streams cut deep canyons into the continental shelves and on land.
5. The land was sculpted by glaciers
6. U-shaped valleys formed in mountainous areas


Holocene
Pleistocene
0 m
(today)
-50 m
-100 m
- 150 m
Years ago
in '000
10 20 30 40 50 60 70 80 90 100 120 140 160 180 200 220 240

7. Land bridges existed and led to migrations of mammals, including humans
    - Across the Bering Sea between Siberia and Alaska
    - Between Australia and Indonesia
    - British Isles were attached to Europe
8. Rainfall increased at lower latitudes.
9. Large lakes **were** formed
10. Winds coming off glaciers blew sediment southward forming löess deposits (Missouri River area, central Europe, northern China)
11. Parts of northern and eastern Africa that are currently arid had abundant water and were fertile and populated by nomadic tribes.

10. Winds coming off glaciers blew sediment southward forming löess deposits (Missouri River area, central Europe, northern China)
11. Parts of northern and eastern Africa that are currently arid had abundant water and were fertile and populated by nomadic tribes.

12. Weight of the ice depressed the continental crust to as much as 200-300 m downward.
13. Uplift (isostatic rebound) after ice melted. Coastal features are now elevated high above sea level.



Map illustrating post-glacial uplift in North America.

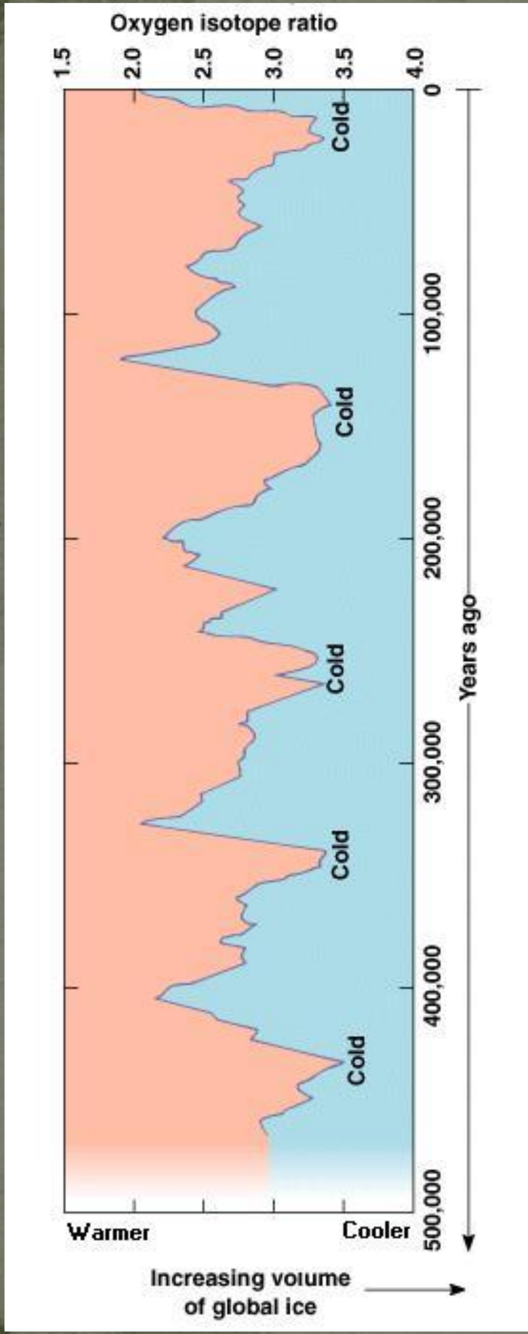
Advance of the Ice Sheets

- The Late Pliocene and Pleistocene had strong, rapid, climatic fluctuations.
- Ice ages are characterized by glacial expansions separated by warmer interglacial intervals.
- Before the mid-1970's, the Pleistocene was divided into four glacial stages with intervening warmer interglacial stages.
- More recent investigations have shown that there may have been as many as 30 glacial advances over the past 3 million years (roughly **every 100,000 years**.) Coincides with the closure of S. and N. America. Stopping equatorial circulation, creating deserts

Stratigraphy of Pleistocene Deposits

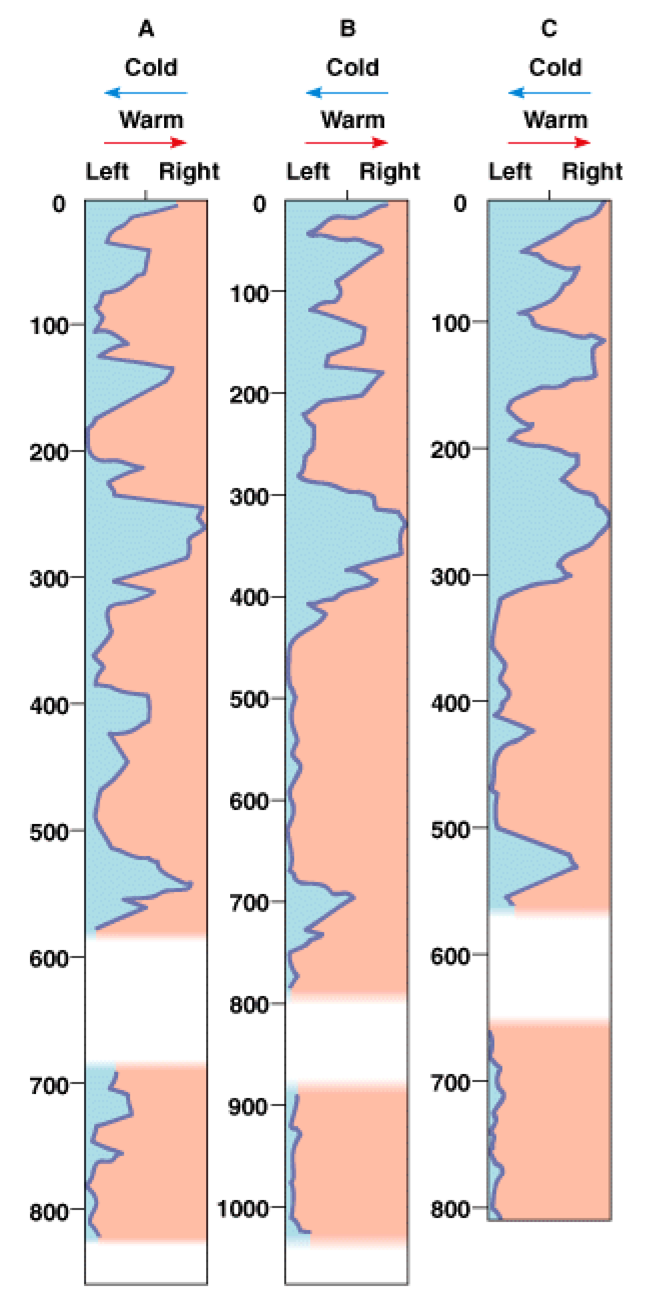
Pleistocene deposits are difficult to date and correlate.

Pleistocene sedimentary deposits, however, may show evidence of fluctuating climatic conditions, which can be used to mark times of glacial advance and retreat.



Graph representing variations in the oxygen isotope ratios in foram shells (and in the global volume of ice) over the past 500,000 years.

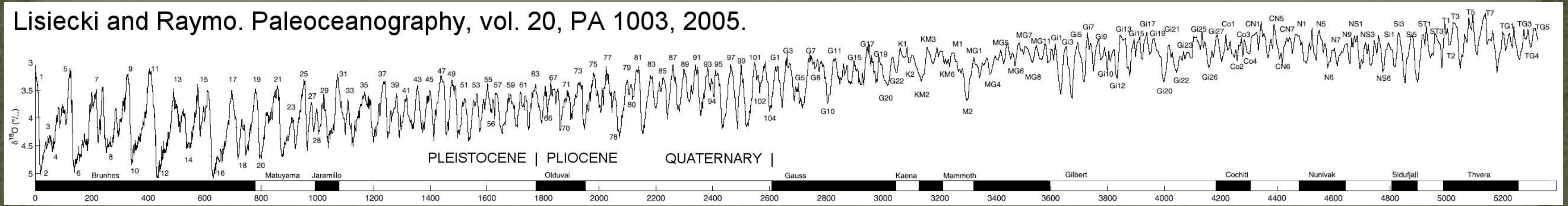
also angiosperm leaf margins with continuous rims indicate warm, while toothed cold environments.



*Graphs illustrating the percentages of right-coiling and left-coiling foraminifera, **Globorotalia truncatulinoides**.*

The vertical scale is depth in deep sea sediment cores, in centimeters.

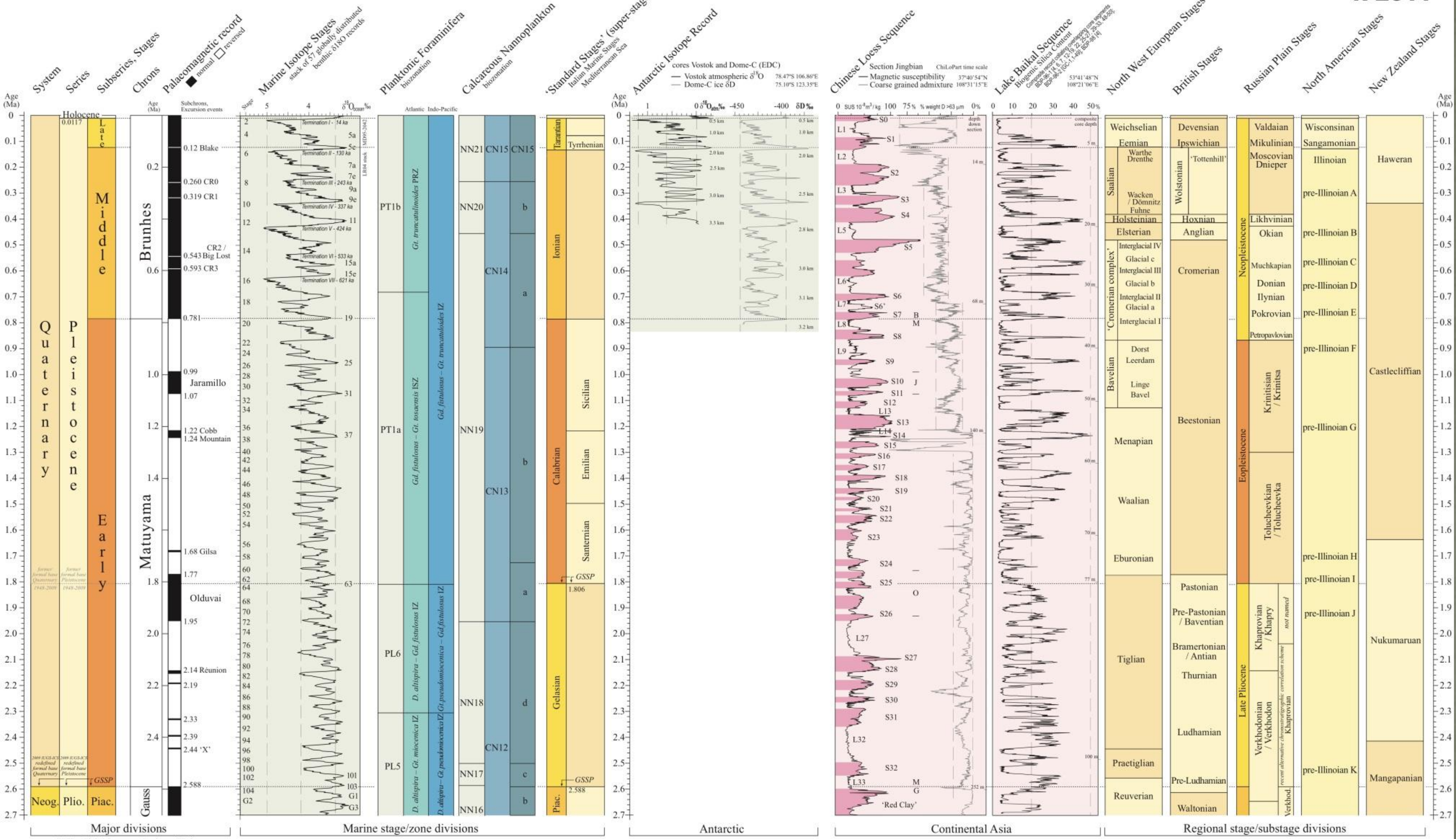
Marine Isotope Stages



- Marine isotopic stages (MIS), or OIS stages, represent alternations of warm and cold periods in Earth's paleoclimate,
- They result from oxygen isotope elements reflecting changes in temperature from deep core marine samples.
- The numbering is done upside down starting today (MIS 1 on the scale)
- The scales with even numbers have high levels of O^{18} and represent the cold glacial periods
- Single-number stages have low C^{18} values representing warm interglacial intervals
- Data derived from pollen and plankton from marine sedimentary cores, sapropels etc.
- They were developed by Cesare Emiliani in the 1950s, and today are widely used to express Palaeoclimatologically and Chronologically the Quaternary

Global chronostratigraphical correlation table for the last 2.7 million years

v. 2011



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http://www-qpg.geog.cam.ac.uk/

Universiteit Utrecht
http://www.geo.uu.nl/

INQUA 1928
International Union for Quaternary Research (INQUA), Stratigraphy and Chronology Commission (SACCOM).
http://www.inqua.tcd.ie/

International Union of Geological Sciences (IUGS), International Commission on Stratigraphy (ICS), Subcommission on Quaternary Stratigraphy (SQS).
http://www.stratigraphy.org/

IUGS

Why Did Earth's Surface Cool?

There was both a long-term decline in temperatures, as well as an oscillation of glacial and interglacial stages.

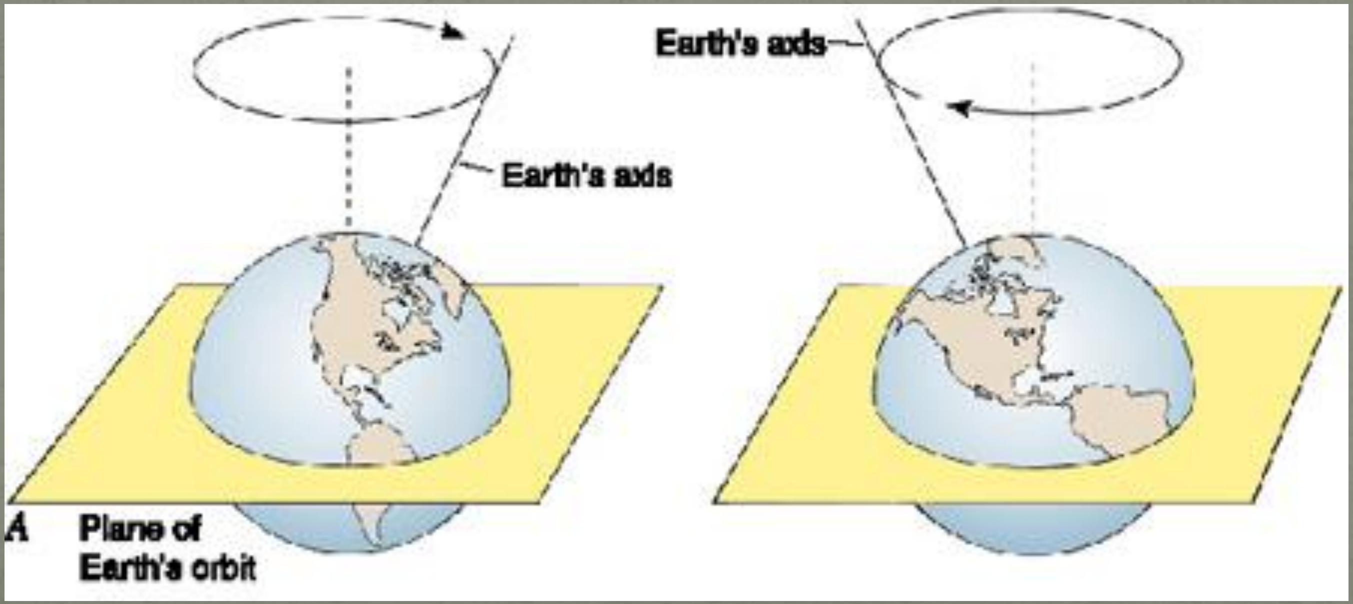
Any hypothesis for the cooling must consider both of these factors.

Milankovitch Cycles

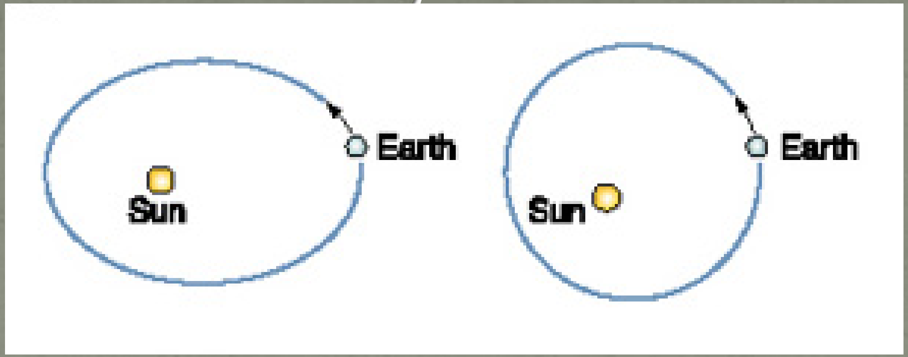
- A widely accepted hypothesis for the temperature fluctuations is related to Earth's orbital oscillations.
- This hypothesis was developed by Yugoslavian mathemetician Milutin Milankovitch, and it is referred to as the Milankovitch cycles.
- The cyclic climatic changes result from changes in the distance and angular relationships between the Earth and Sun due to periodic fluctuations in Earth's orbit

Milankovitch Cycles

1. Precession - Earth's axis wobbles or moves in a circle like a spinning top over 26,000 years, affecting the amount of solar radiation received at the poles.



Milankovitch Cycles

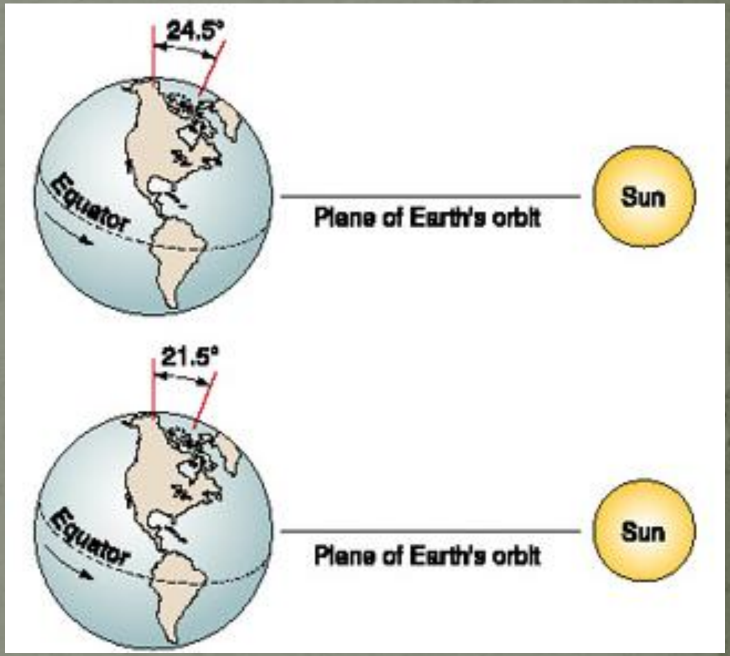


2. Eccentricity - Earth's orbit around the Sun changes from more circular to more elliptical by about 2% over about 100,000 years, moving the Earth closer to or farther from the Sun, and varying the amount of solar radiation received by the Earth.

Milankovitch Cycles

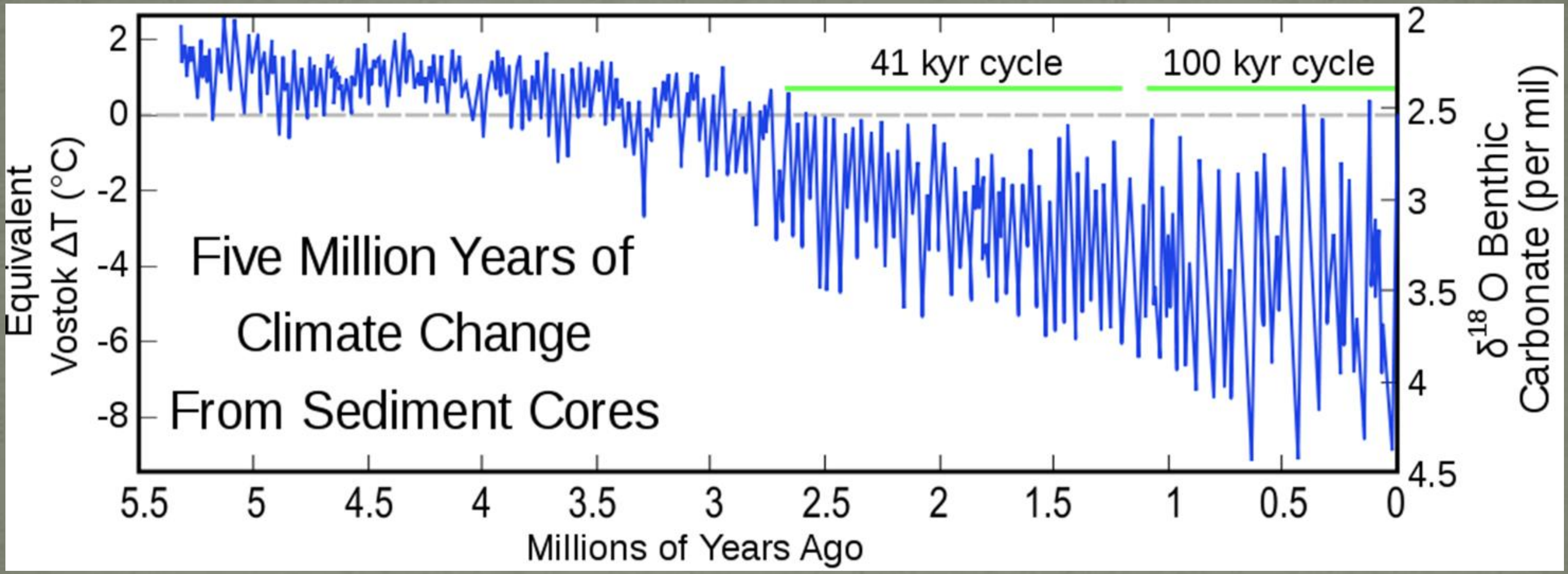
3. Obliquity, Angle of tilt of Earth's axis - currently about 23.5º, this tilt angle causes the seasons.

   Tilt angle varies from about 21.5º - 24.5º over about 41,000 years, changing length of days and amount of solar radiation received at the poles.



Milankovitch Cycles

- The combination of these variables periodically results in a change in the amount of solar radiation received by the Earth, which causes cycles of cooling and periodic glaciations.
- Milankovitch cycles correspond well to glaciation episodes, which have occurred every 100,000 years over the past 600,000 years, as indicated by oxygen isotope data.



Five Million Years of
Climate Change
From Sediment Cores
41 kyr cycle
100 kyr cycle
Equivalent
Vostok ΔT (°C)
δ18O Benthic
Carbonate (per mil)
Millions of Years Ago
2
0
-2
-4
-6
-8
2.5
3
3.5
4
4.5
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

But why don't we have a record of recurring glaciations throughout geologic time?

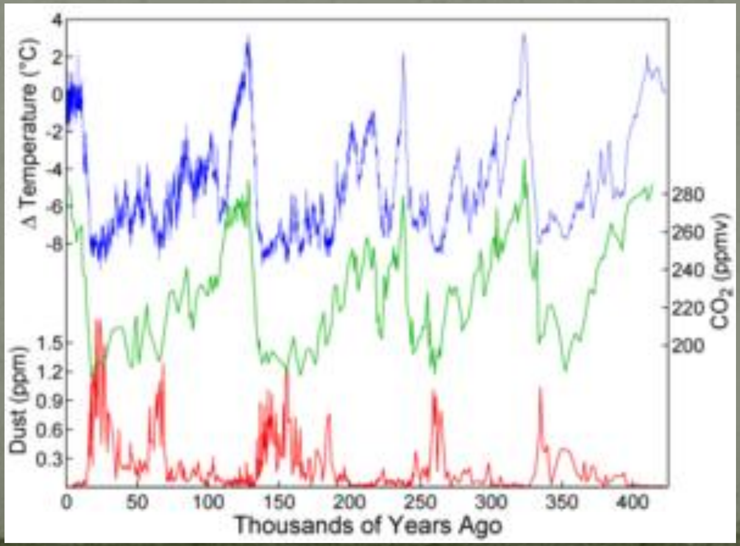
Other factors are involved.

1. Albedo or reflectivity of the Earth

If Earth's albedo increased, due to snow cover, cloud cover, or dust in the atmosphere, the atmospheric temperatures would decrease due to reflection of solar radiation into space.

As snow cover increased, albedo would increase, producing a positive feedback relationship, accelerating the rate of glacial growth.
A 1% loss of incoming solar energy would result in a temperature drop of about 8° C, which might be sufficient to trigger glacial buildup.

2. A decrease in atmospheric CO_2 would cause a decrease in the greenhouse effect, and lead to cooling.
3. Conversely, an increase in atmospheric CO_2 would cause warming, which would result in more rapid evaporation, more cloud cover, and an increase in albedo, which could trigger glaciation.



4. Plate tectonics is important in that a continent must lie on or near a pole for snow to build up to form a glacier.
5. Plate tectonics is further involved because the formation of the Isthmus of Panama diverted the Gulf Stream northward about 3.5 million years ago. The warm, moist air associated with this ocean current led to an increase in snowfall in northern areas and the development of continental glaciers.

If climatic cyclicity is related to Earth's orbit, it is possible to speculate on future climatic trends.

Calculations for the next 20,000 years suggest a trend toward extensive glaciation in the Northern Hemisphere.

But what is the impact of human activities, such as increased burning of fossil fuels and the associated buildup of greenhouse gases???

The Age of Mammals

- The Cenozoic Era is sometimes called the Age of Mammals.
- During the Cenozoic, mammals came to dominate the Earth, much as reptiles had done during the Mesozoic.
- A spectacular adaptive radiation of mammals near the beginning of the Cenozoic resulted in the appearance of mammals as diverse as bats and whales, descending from shrew-like mammalian ancestors in as little as 12 m.y.

Appearance of *Homo sapiens*

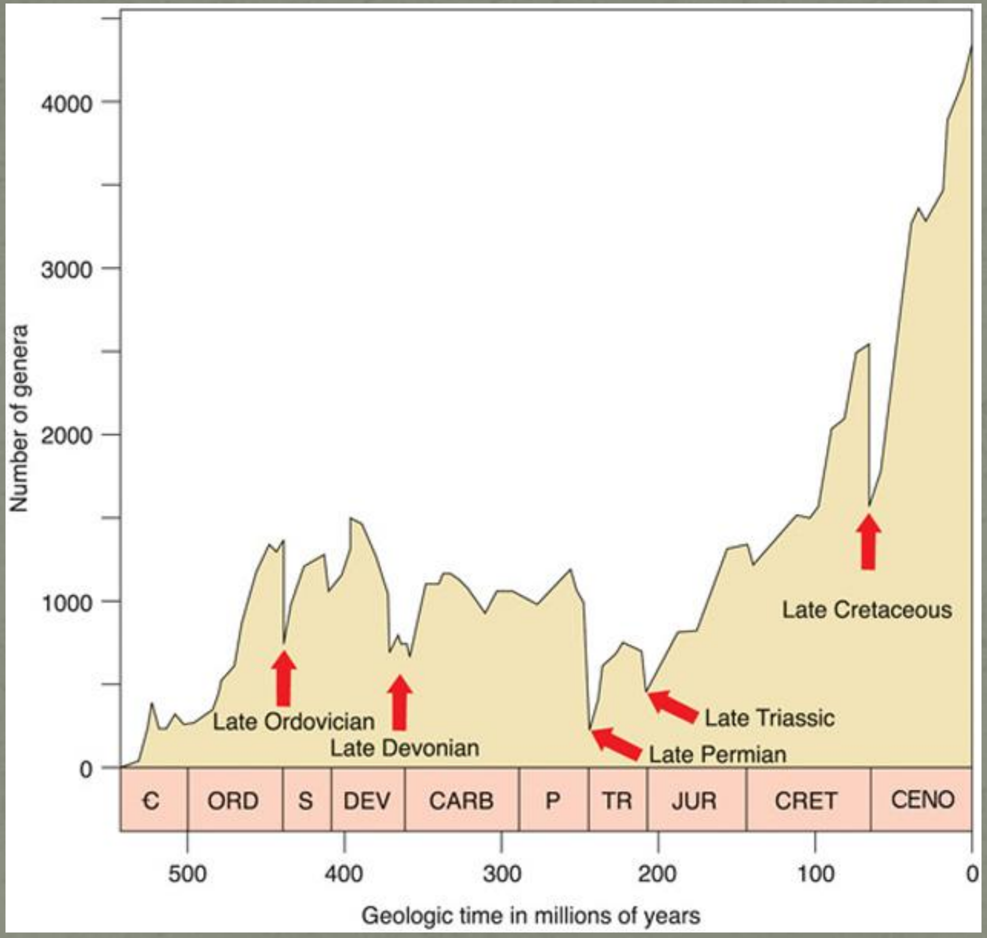
- The appearance and evolution of primates led to the ancestors of humans by the Neogene.
- *Homo sapiens* appeared in the Pleistocene Epoch.

- We know more about the life of the Cenozoic Era than we know about life of any other time.
- This is because the fossils are better preserved and have had less time to be destroyed, they are stratigraphically uppermost, and more accessible for study.
- In addition, Cenozoic fossils more closely resemble life today.

Causes of Biologic Changes

- Biologic changes in the Cenozoic can be tied to changes in the environment and geographic change.
- Changes in climate to cooler and dried conditions, led to the expansion of the grasslands, which influenced the evolution of herbivorous mammals.
- Continental breakup as a result of plate tectonics, stimulated biological diversity. This resulted in distinct faunal radiations on separate landmasses, and in isolated marine basins.

Diversity of Life in the Cenozoic



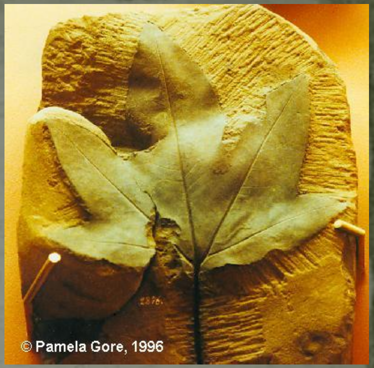
Recovery from the Extinctions

- At the beginning of the Cenozoic Era, diversity was much lower than it had been in the Cretaceous, as a result of the extinctions.
- Recovery from the extinctions was rapid (explosive), and diversity quickly climbed to a level much higher than had ever existed previously.
- Following the Cretaceous extinction, diversity of marine and terrestrial organisms increased sharply, and rose to present levels.

Eocene-Oligocene boundary

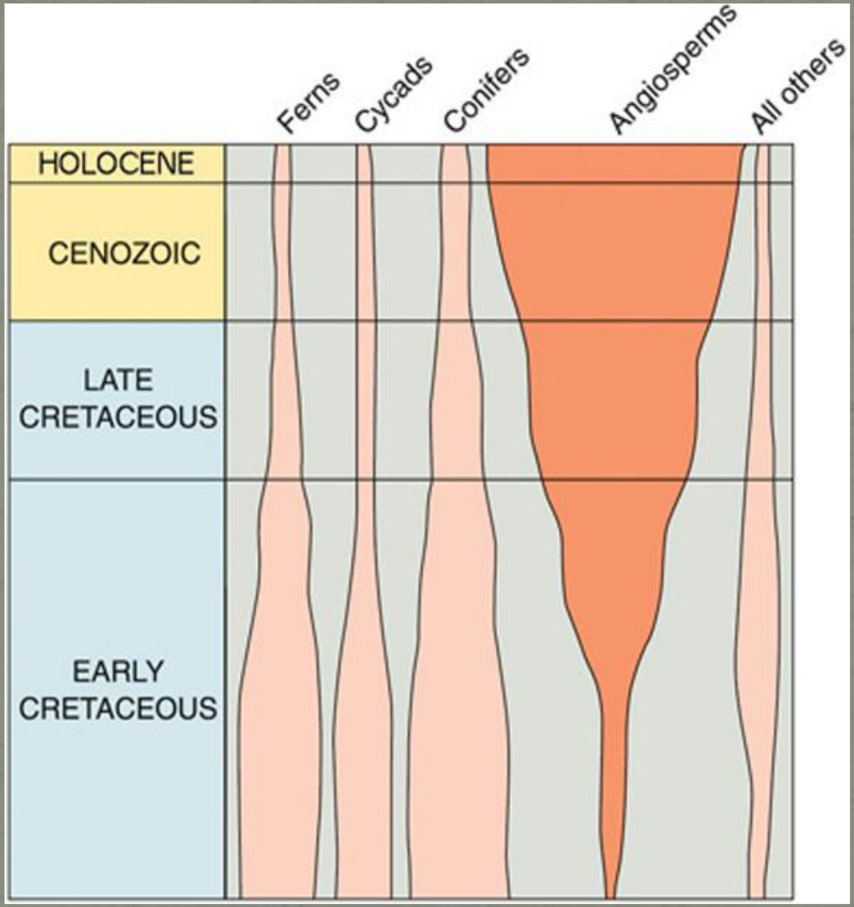
- A slight drop in diversity in the Paleogene marks an extinction event at the Eocene-Oligocene boundary (Grande Coupure), which was associated with dramatic worldwide cooling.
- Many species of marine molluscs, foraminifera, and ostracodes were affected.
- Marine organisms were affected more severely by the extinction than were terrestrial organisms.

Cenozoic Plant Life



- The flowering plants or angiosperms appeared in the Cretaceous, and diversified throughout the Cenozoic to become the dominant vascular land plant on Earth.
- Ferns, cycads, conifers, and other plants declined relative to the angiosperms, from the Cretaceous through the Cenozoic.

Cenozoic Plant Life



Grasslands Expand and Mammals Respond

- Grasses, a flowering plant commonly eaten by grazing mammals, became widespread during the Miocene.
- The expansion of the grasslands across the plains of North America and other continents was related to cooling and drying of the global climate.
- Mammals evolved in conjunction with the spread of the grasslands.

Teeth Adapt to Grasses

- Many grasses contain siliceous secretions, and because they grow close to the ground, grasses are often coated with fine particles of soil. As a result, grasses are abrasive to the teeth of grazing mammals.
- To compensate for the tooth abrasion resulting from chewing grasses, the major groups of herbivorous mammals evolved high-crowned cheek teeth that continue to grow at the roots during part of the animals' lives.

Teeth Adapt to Grasses

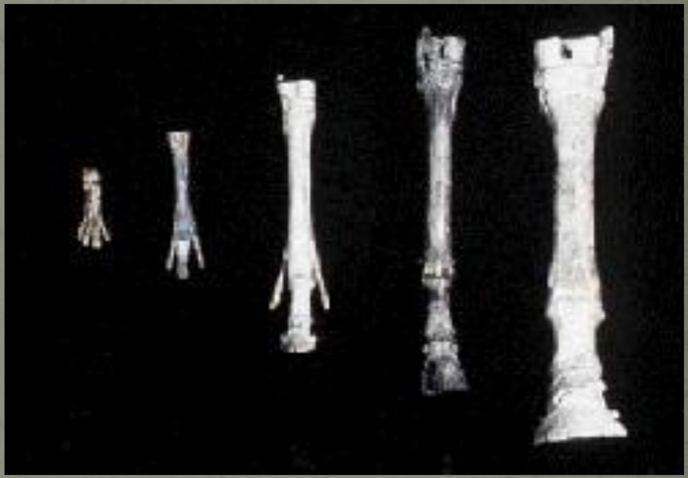
- The resistant enamel of the teeth became infolded.
- As the teeth wore down, a complex pattern of enamel ridges became apparent on the grinding surface of the teeth.
- The incisors (front teeth) gradually aligned into a curved arc, which served for biting the grasses.
- The length of the face in front of the eyes increased in the grazing mammals to provide space for these teeth (for example, in the horses).

Limbs Adapt to Grasslands

- The limbs of grazing mammals changed to become better adapted to life on the grasslands.
- Grasslands provide few places to hide from predators, so grazing herbivores developed modifications to run more quickly.
- The bones of the limbs and feet were lengthened, strengthened, and modified by natural selection to permit rapid fore-and-aft motion, and to prevent rotation.
- The ankle was elevated, and the grazing mammals ran on their toes like sprinters.

Limbs Adapt to Grasslands

- Many grazing mammals gradually developed **hoofs** as an adaptation to protect the bones of the toes as they ran across the hard prairie sod.
- Mammals with hoofs are called **ungulates**.
- These grazing mammals also lost some of their side toes.



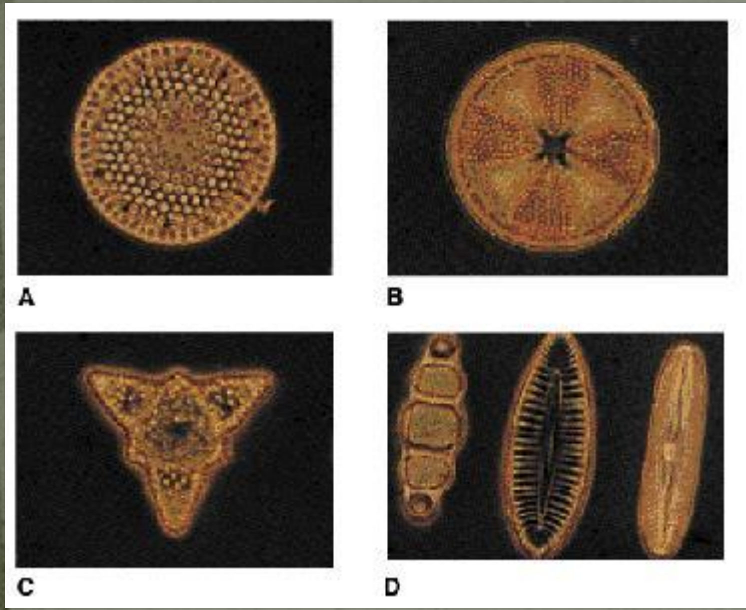
Evolution of the lower foreleg in horses

Cenozoic Life in the Seas

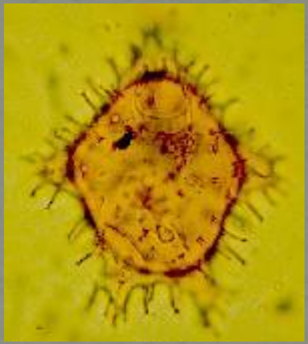
Marine Phytoplankton

- Entire families of phytoplankton became extinct at the end of the Mesozoic. Only a few species in each major group survived into the Cenozoic.
- Surviving species of phytoplankton diversified rapidly in the Paleogene due to decreased competition.
- Cenozoic phytoplankton include:
  - Diatoms
  - Dinoflagellates
  - Coccolithophorids

Marine Phytoplankton



Diatoms



Dinoflagellates.

Coccolithophorids

Marine Zooplankton

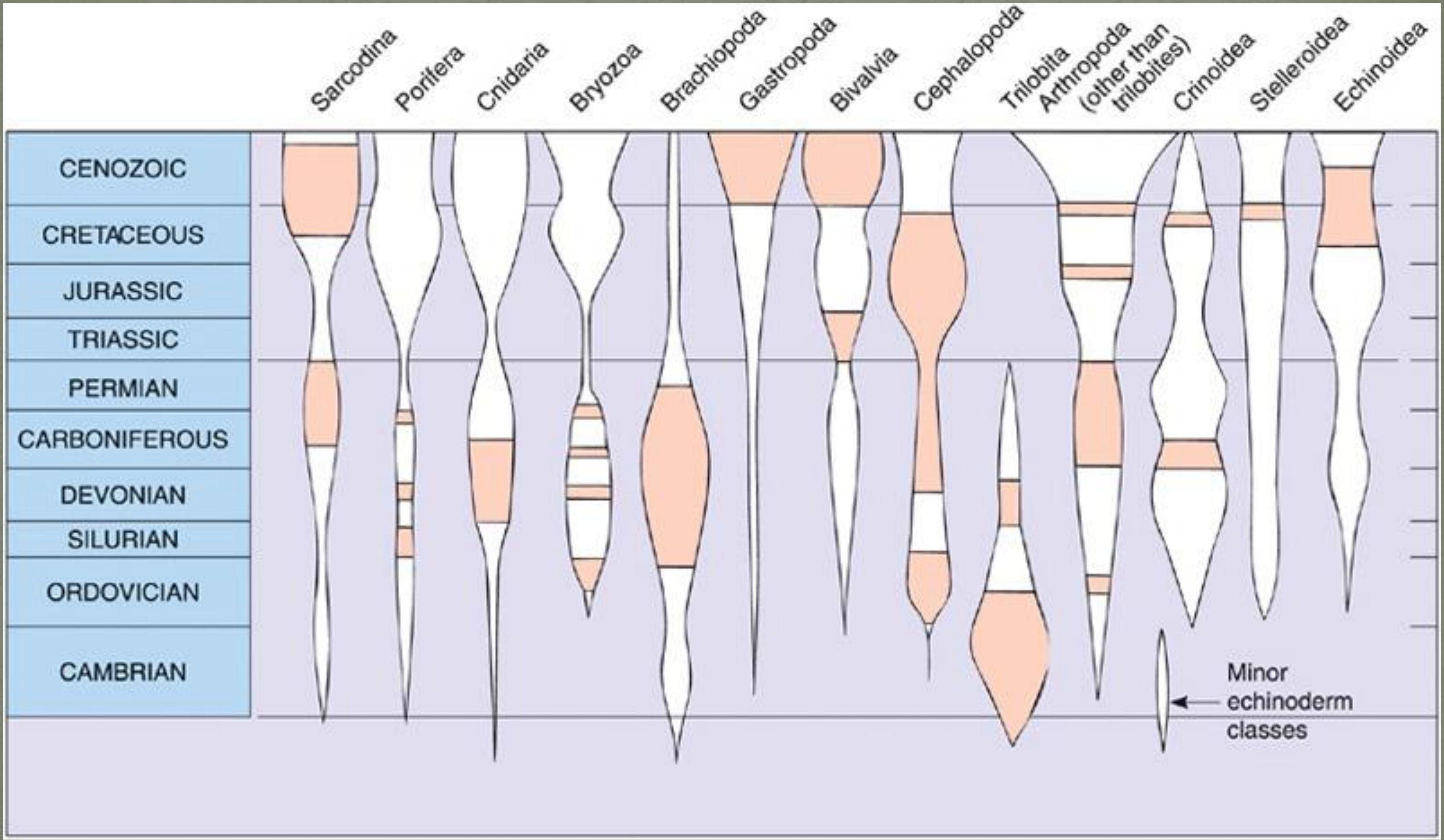
- Zooplankton diversified in the Cenozoic, and became abundant in the seas. Cenozoic zooplankton include:
  - Benthonic foraminifera
  - Planktonic foraminifera
  - Radiolarians

Planktonic foraminifera

Significance of Foraminifera

- Large benthic foraminifera resembling coins in size and shape, called nummulitic foraminifera, lived in the Tethys seaway and other areas. Their remains accumulated to form thick beds of nummulitic limestone, which were used to build the Great Pyramids and Sphinx in Egypt.
- Forams are useful in correlating rocks of Cenozoic age, particularly in oil fields around the world.
- Benthonic forams can be used as water depth indicators.

Invertebrates



Dominant Cenozoic Invertebrates

- Sponges
- Scleractinian corals
- Bryozoans
- Brachiopods
- Molluscs
  - Bivalves
  - Gastropods
  - Cephalopods
- Arthropods
  - Crustaceans
  - Insects (on land)
- Echinoderms
  - Starfish
  - Echinoids

Molluscs

- Cephalopods are also present, but not as widespread and abundant as previously.
- Cenozoic cephalopods include *Nautilus*, and other forms shell (or with a redu
  - Squid
  - Octopus
  - Cuttlefish

derms

Echinoderms are also present in the Cenozoic, particularly free-moving types (as opposed to the attached crinoids of the Paleozoic). Echinoderms include the echinoids (sea urchins, sand dollars, sea biscuits), and the starfish.

Arthropods - Crustaceans

- Modern crustaceans (such as crabs, shrimp, lobsters, barnacles) became well established in the seas during the Cenozoic.

Arthropods - Insects

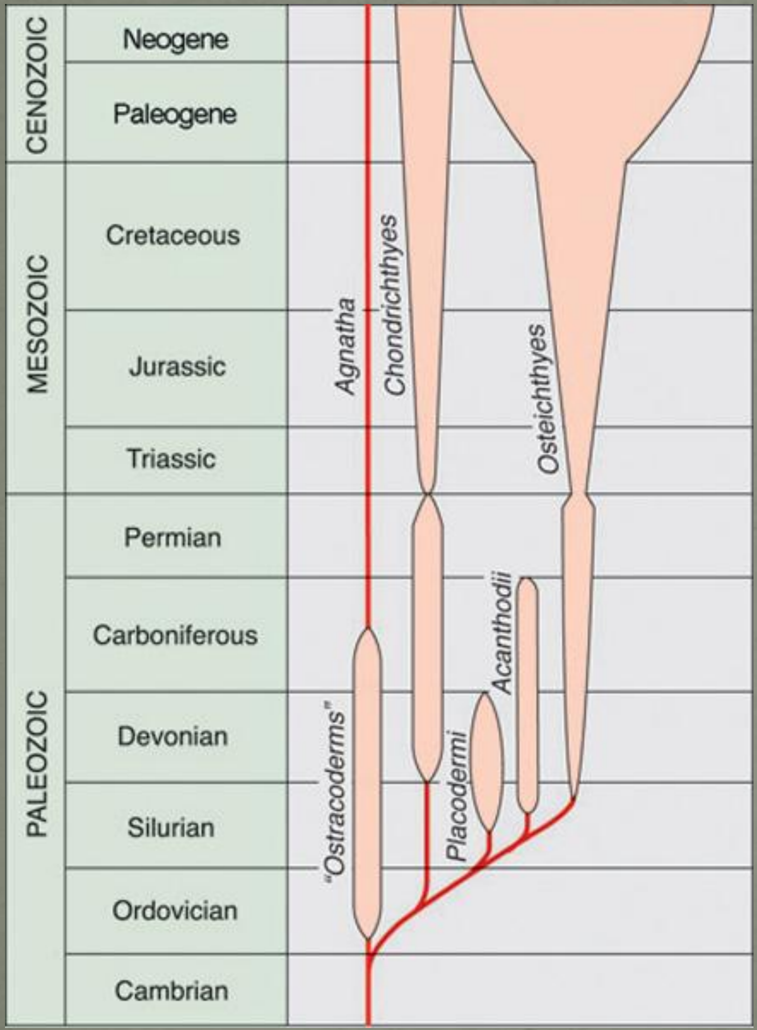
- One of the world's best locations for insects is the Oligocene Florissant Formation, Florissant Fossil Beds National Monument, Colorado.
- Insect fossils are preserved in fine volcanic ash which has been compressed to form shale.
- The ash settled into an ancient lake, burying insects and plants.

Cenozoic Vertebrates

Cenozoic vertebrates include:

- Fishes
- Amphibians
- Reptiles
- Birds
- Mammals

Fishes



The bony fishes or teleost fishes thrived during the Cenozoic in marine and freshwater environments.

Ψάρια

Καρχαρίες

***Procarcharodon megalodon*, Ρέθυμνο, Μέσο Μειόκαινο**

Snakes

- Snakes began to diversify during the Miocene.
- Poisonous snakes evolved with specialized teeth for injecting venom into their prey.
- The diversification of snakes may be linked to the diversification of mammals, which serve as their prey.
- Fossil snakes are found in rocks as old as Early Cretaceous.

Birds

- Bird fossils are rarely preserved, so the Cenozoic fossil record of birds is poor.
- Birds have undergone extraordinary adaptive radiation to produce:
  - Songbirds
  - Forest birds (owls)
  - Seagoing birds
  - Wading birds
  - Flightless aquatic birds (penguins)
  - Flightless land birds (ostrich, emu)

Cenozoic Migrations

- The southern continents (South America, Australia, and Antarctica) were separated from North America and Eurasia during most of the Cenozoic.
- As a result, distinctive assemblages of mammals developed on the southern continents, showing convergent evolution with northern hemisphere species.

Africa _ Eurasia

- Several times in contact and several migrations and exchanges took place
  Eocene
  In Lower Miocene, “the proboscidean datum”
  In Upper Miocene, “the Hipparion datum”
  From upper Miocene and then united continuously

Bering Strait

- Bridge between North America and Eurasia three times during the lower Upper Miocene camp, one in the Pliocene and during Pleistocene.
  A. Hipparions, mastodons,
  B. camels, horses, canines, proboscideans
  C. Camels, horses, mammoths, bears, felines, man.

The development of the **Panamanian land bridge** about 3 m.y. ago (during the Late Pliocene) led to the migration of mammals between North and South America.

Panamanian Land Bridge

- Marsupials went northward
- Placentals went southward
- Eventually, the marsupials began to decline.
- All of the hoofed marsupials became extinct.
- Ground sloths and glyptodonts also became extinct.
- The land bridge caused many species of South American marsupial mammals to go extinct, because of migrants from the north.

Bering Land Bridge

- The Bering land bridge existed between North America and Eurasia during the Pleistocene (now occupied by the Bering Sea).
- Camels, horses, mammoths, and a wide variety of other land mammals migrated across the Bering land bridge during the Pleistocene.
- The land bridge was also used by early humans to enter North America at least 14,000 years ago.

Extinction of the Large Pleistocene Mammals

At the end of Pleistocene many large mammals and birds lived in different parts of the world. Odd toed and even toed ungulates, proboscideans (mammoth) giant sloths, giant kangaroos, Epiornis, dinornis, etc Odd-toed

Entering the Holocene they become extinct and extinctions coincide with the appearance of man in these regions.

*Extinct Irish elk, **Megaloceros***

Extinction of the Large Pleistocene Mammals

- Most of these large land vertebrates began to become extinct around 8000 years ago.
- Why? There are two hypotheses:
  - Human hunting and predation
  - Climate change associated with global warming at the end of the last Ice Age.

- Towards the end of the Late Quaternary, at about 50,000 years ago, Eurasia and North America lost about 36% and 72% of genera of large mammals respectively
- The climate and humans have shaped the demographic history of wooly rhinoceros, wooly mammoth, wild horse, reindeer, Bison.
- Although climate change alone may explain the disappearance of certain species, such as the Eurasian muskox and the rhinoceros, a combination of climatic and anthropogenic effects seems to be responsible for the extinction of others, including the Eurasian bison of the steppe and the wild horse. The causes for the extinction of the wooly mammoth still remain unclear
- In general, the percentage of species that became extinct was higher in continents experiencing the most dramatic climate change, which entails the important role of climate in the loss of species. However, the continental pattern of megafaunal extinctions in North America and Australia coincided with the first occurrence of man, suggesting a possible anthropogenic contribution to the extinction of the species

Table 1 Megafaunal extinctions (genera) during the last 100 kyr (after Wroe *et al.*, 2004)

Continent	*Extinct*	*Living*	*Total*	*Extinct (%)*	*Landmass (km^2)*
Africa	7	42	49	14.3	30.2×10^6
Europe	15	9	24	60.0	10.4×10^6
North America	33	12	45	73.3	23.7×10^6
South America	46	12	58	79.6	17.8×10^6
Australia	19	3	22	86.4	7.7×10^6

Table 6 Timing of extinction of the Eurasian Pleistocene megafauna

Taxon	*Common name*	*Last 100 ka*	*100–50 ka*	*50–16 ka*	*16–11.5 ka*	*11.5–0 ka*	*Reference*
Mammalia							
Carnivora							
Hyaenidae							
Crocuta	Hyena				X		Stuart, 1991
Proboscidea							
Mammuthus	Mammoth				X		Stuart, 1991
Palaeoloxodon	Straight-tusked elephant		X				Stuart, 1991
Perissodactyla							
Rhinocerotidae							
Stephanorhinus	Rhinoceros			X			Stuart, 1991
Coelodonta	Woolly rhinoceros				X		Stuart, 1991
Artiodactyla							
Hippopotamidae							
Hippopotamus	Hippopotamus		X				Stuart, 1991
Camelidae							
Camelus	Camel				?		Stuart, 1991
Cervidae							
Megaloceros	Giant deer					X	Stuart, 1991
Bovidae							
Spirocerus	Antelope			X			Stuart, 1991
Ovibos	Musk ox					X	Stuart, 1991

After Barnowsky AD, Koch PL, Feranec RS, Wing SL, and Shabel AB (2004) Assessing the causes of Late Pleistocene extinctions on the continents. *Science* 306: 70–75.

The 6th Mass Extinction Event

- Our species is responsible for most or almost all recorded extinctions.
- The first human arrivals in islands have caused extinctions in the fauna (New Zealand, Madagascar, giant lemurs and epiornis, large mammals of Cyprus, Crete)
- Looking at the situation today and considering the mechanisms of humanly induced extinctions (overgrazing, imported species, habitat destruction, environmental destruction), we see that the rate of extinctions is increasing.
- The main reasons for this are: overpopulation, the current technology that may become potentially disastrous, and the encroachment and destruction of the richest habitats, rain forests and coral reefs.
- New data show that the rate of extinction is greater than that at the end of the Cretaceous.

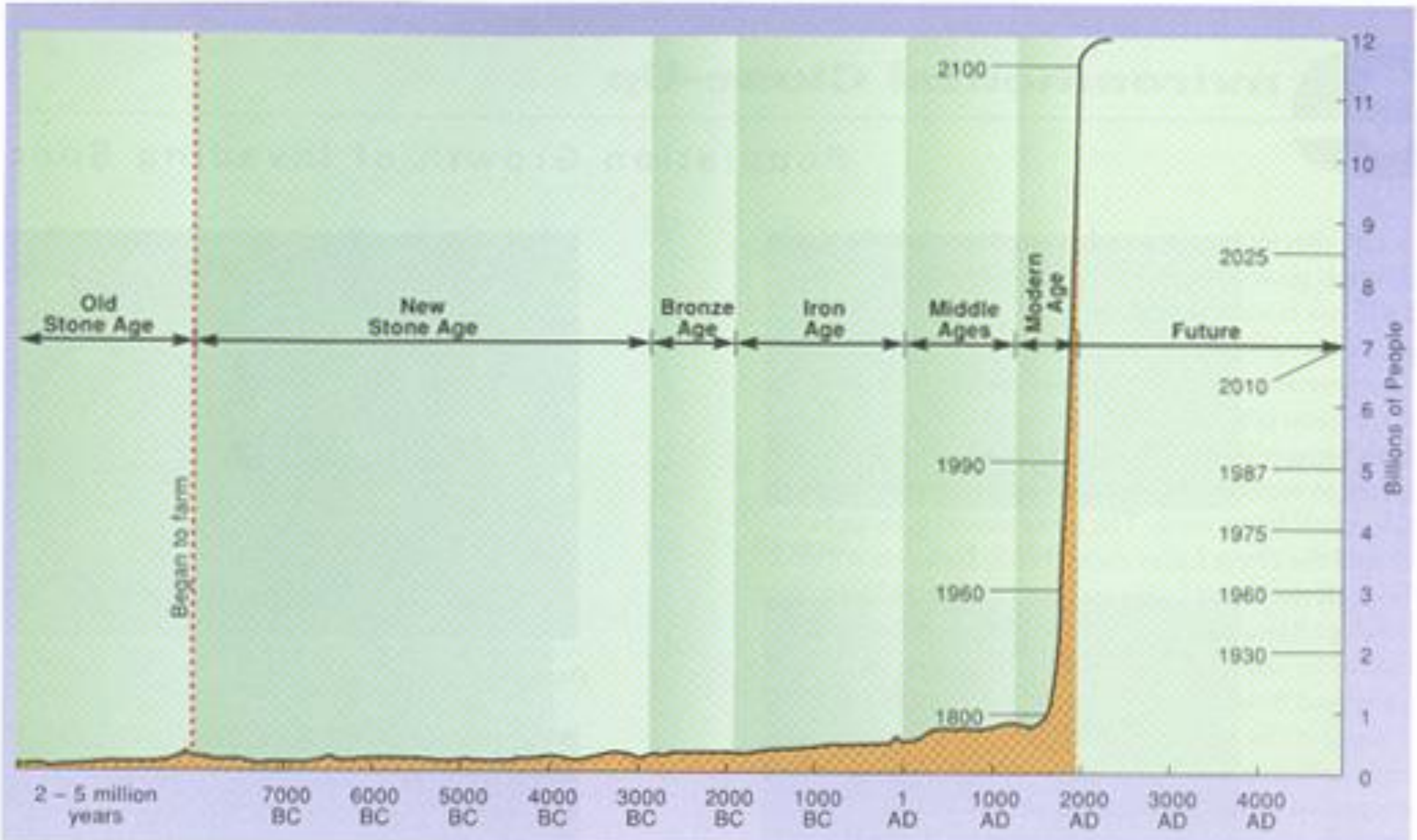


Figure 6.9

Human Population Growth From A.D. 1800 to A.D. 1930, the number of humans doubled (from one billion to two billion) and then double again by 1975 (four billion) and could double again (eight billion) by the year 2025. How long can this pattern continue before the earth's ulti carrying capacity is reached?

Source: Data from Jean Van Der Tak, et al., "Our Population Predicament: A New Look" in Population Bulletin, Vol. 34, No. 5, December 1979, Population Reference Bureau, Washington, DC.

Table 1. World population milestones. Source: United Nations Secretariat, Department of Economic and Social Affairs, The World At Six Billion (1999), p. 8.

World population reached:	Year	Time to add 1 billion
1 billion	1804	
2 billion	1927	123 years
3 billion	1960	33 years
4 billion	1974	14 years
5 billion	1987	13 years
6 billion	1999	12 years
7 billion	2010	11 years
8 billion	**2022**	**12 years**

Today 8.2 billion

Within 220 years 7.2 billion people have been added……………

The 6th Mass Extinction Event

(Pimm et al., 2014, Science 30/5/2014)

«Today most species have small territories, while the numbers of small territories grow rapidly even in known species. They are geographically concentrated and disproportionately likely to be threatened or already being disappeared. The new extinction rates were estimated at about 1000 times the probable typical rate of extinctions. Future rates depend on many factors and tend to grow …… »

The 6th Mass Extinction Event

- We are in the midst of a new mass extinction event, and for the time being, we are unable to control it in the near future.
- Extinctions affect all habitats on land and sea.
- When extinctions touch the primary producers then we will face the risk of ecosystem collapse and thus this will lead to the peak of a massive extinction event……………

What will follow….

Pangaea Ultima