

History of the Earth - GLY 302 - Spring 2009

Final Exam Review and Brief Notes

Precambrian Life

oldest signs of life

- 3.8 b.y. chemical fossils ??? (probably not)
- 3.5 b.y. oldest probable fossils of a prokaryote cells
- 3.5 b.y. oldest stromatolites
- 3.2 b.y. stromatolites become abundant (photosynthetic cyanobacteria)

lab experiments producing organic matter from primordial atmosphere

extraterrestrial evidence for organic matter

the kingdoms of life

prokaryotes (bacteria) vs. eukaryotes (all others)

oldest eukaryote fossils: acritarchs (~2 - 1.7 b.y.)

the sexual revolution: diversification of acritarchs ~ 1.1 b.y. = onset of sexual reproduction!?

oldest multicellular animals (metazoans): ~600 m.y., Ediacaran fauna

soft body impressions in sediment of segmented worms, jellyfish, sea pens...

latest Proterozoic phosphatic skeletal parts (e.g. *Cloudina*)

Cambrian Revolution: evolution of hard parts

Early Cambrian "small shellies"

Middle Cambrian very rapid development of most animal phyla including some bizarre

best example: Burgess Shale

periodic flooding of the continents

major, unconformity-bound sedimentary sequences on continents including much marine strata

result of large scale, long period (slow) transgression-regression cycles

apparently caused by changing rates of seafloor spreading

Appalachian Mountain Building - From One Supercontinent to Another

In the aftermath of the breakup of Rodinia 4 major continental masses existed

Laurentia (ancestral North America)

Gondwana (contained cores of Africa, South America, India, Australia, and Antarctica)

Baltica (ancestral northwestern Europe)

Siberia (northern Asia)

Taconic Orogeny (Late Ord)

metamorphic belt (e.g., Manhattan Schist) + clastic wedge

caused by collision with volcanic island arc

evidence: basaltic volcanic rx found with deformed sedimentary rocks

(e.g., the amphibolite [metamorphosed basalt] in Central Park)

Acadian Orogeny (Dev)

metamorphic belt

extensive granite from melting in deepest hottest parts of the orogen

(e.g., granites of "The Granite State" and Maine)

clastic wedge (Catskill redbeds)

same as Caledonide Orogeny in NW Europe

The Old Red Sandstone of Britain equivalent to the Catskill redbeds

Acadian/Caledonian Orogeny the result of collision of Laurentia w/ Baltica (NW Eur)

New continent formed: "Laurussia"

Appalachian Orogeny (Penn-Perm)

produced the folds of the Appalachian Valley & Ridge province

blocks of deep basement rock uplifted - Grenvillian gneisses of the metamorphic highlands

high mountains, metamorphism beneath, clastic wedge forms on flank

Ouachita Orogeny in south-central North America

Mauritanide Orogeny in NW Africa

Hercynian Orogeny in southern Europe

Uralian Orogeny in Urals Mountains separating Europe & Asia

All of these orogenies (Appalachian - Uralian) occurred at the end of the Paleozoic as a result of continental collisions that produced the supercontinent Pangea

Evolution of Vertebrates - Part I, The Fishes

vertebrates are phylum chordata, subphylum vertebrata

oldest chordates were pikaia of the middle Cambrian

oldest vertebrate fossils (scales of jawless fish) are from the upper Cambrian

vertebrates have backbone and braincase

jawless fish (agnathans) had cartilage skeletons, some had bony plates on the head

lampreys and hagfish are about the only remaining jawless fish

Placoderms probably evolved in the Silurian (common in Devonian)

had jaws but no teeth - jaws modified into tooth-like shapes

cartilage skeletons and bony plates armoring their head

some very large predators

now extinct

Acanthodians probably evolved by the Silurian

cartilage skeletons

more streamlined form than placoderms

probably ancestors of the bony, ray-finned fish

now extinct

Sharks, rays & skates probably evolved by the Silurian, common in Devonian

cartilage skeletons

produce thousands of enamel covered teeth in their lifetime

sharks, rays, and skates still survive very successfully

Bony Fish - Ray-fins evolved in the Devonian (from acanthodian!?)

bony skeleton

fine bones support fins

ray-fins are the most diverse of all fish

Bony Fish - Lobe fins evolved in the Devonian

bony skeleton

muscular fleshy lobes support finer bones of the fins

the modern coelacanth and a few others still survive

Invasion of the Land

problems in adapting to life on the land

first land plants (ferns) and land animals (amphibians) need water for reproduction

age of fossil evidence for first land plants

and first land animals ("bugs")

first tetrapods (Late Dev)

Carboniferous: Age of "Amphibians"

first amniotes: Carboniferous

difference between amphibian and amniote eggs

sauropsid and synapsid amniotes

Permian drying (Pangea vast interior dry regions & rain shadows)

led to the dominance of seed ferns (the first gymnosperms) and synapsids

gymnosperms ("naked seeds"), such as modern conifers, use airborne fertilization

Permian: Age of the "Reptiles"

Permo-Triassic mass extinction - the biggest known

apparently related to massive flood basalts in Siberia and China

Mesozoic Life - Age of the Dinosaurs

early Triassic low fossil diversity then re-diversification (adaptive radiation)

sauropsid amniotes become dominant

Mesozoic sauropsids included: turtles, crocodiles, lizards, snakes

marine reptiles (ichthyosaurs, plesiosaurs)

flying reptiles (pterosaurs)

dinosaurs (evolved Late Triassic)

dinosaurs (hole in the hip-socket) evolved late Triassic

(saurischians="lizard hipped" & ornithischians "bird-hipped")

birds evolved in the Jurassic from some small, saurischian (lizard-hipped), raptor

Archaeopteryx: the oldest bird fossils

synapsids dwindled: last remaining branch evolved into the mammals (evolved Late Triassic)

remained small throughout the Mesozoic

Dinosaurs became extinct at end of Cretaceous (Cretaceous-Tertiary mass extinction)

all except the birds, which had evolved in mid Jurassic from a group of dinosaurs

Cretaceous-Tertiary (K/T) mass extinction

killed dinosaurs, ammonites and many others

iridium anomaly, glass spherules, shocked quartz

Chicxhulub crater off Yucatan

tsunami deposits in Caribbean and Gulf Coast

charcoal in western US

- all above point to meteor impact (not extraordinary volcanism) as cause of extinction

"nuclear winter" scenario (smoke & ash obscures sun, it gets cold, plants die, herbivores die...)

Pangea Breakup

Triassic-Jurassic rift basins (e.g., Newark Basin)

half-grabens filled with sedimentary strata (redbeds) and basaltic lava flows

oldest ocean crust in central Atlantic between Africa and North America: ~ 170-165 m.y.

passive margin sequence developed on the margins of the now separate continents

central Atlantic was restricted seaway during Jurassic, climate was arid

extensive salt deposits in subsurface of present day Atlantic and Gulf coast continental shelf

salt diapirs rising through overlying strata have formed petroleum traps

Gondwana began to break up soon after separating from Laurasia (N. Amer + Eurasia)

S. Amer + Africa, then India, then Australia, then New Zealand unzipped from Antarctica

between 155 and 85 m.y. ago (Jur & Cret)

Alpine-Himalayan Mountain Belt

As Gondwana broke up Africa/Arabia and India drifted northward toward Eurasia

India has been colliding with southern Asia and building the Himalayas since 60 m.y. ago

southeast Asia has been squeezed out of the way

Africa/Arabia has been colliding with southern Eurasia since ~ 35 m.y. ago

building the Alps Mountains

Asia Minor (Turkey) seems to be getting squeezed out of Arabia's way

The Mediterranean is the last vestige of the Tethys Sea

The Mediterranean basin dried up ~ 5 m.y. ago but then re-flooded

Western Cordillera

western margin of N. Amer had been passive margin since Rodinia breakup

Devonian Antler Orogeny indicates a change to active margin, convergence, subduction

Jurassic and Cretaceous saw a great increase in rate of subduction-related igneous activity

Late Cretaceous Sevier Orogeny indicates increasing friction/compression

Latest Cretaceous - Eocene Laramide Orogeny:

massive compression, folding, thrust & reverse faults all the way across western 1/3 of

North America, all the way to the Front Range of the Rocky Mountains

Hypothesis:

Jur-Cret: N. Amer. starts moving west away from new Mid-Atlantic ridge

rate of subduction increase, rate of igneous activity increases

Late Cret. N. Amer. getting closer to midocean ridge (East Pacific Rise)

young ocean crust harder to subduct

shallower subduction angle, more friction & compression

Latest Cret-Paleogene midocean ridge just off shore

N. Amer grinds over ocean crust that is too young, hot, and buoyant to sink

into the mantle

extreme friction and compression

North America runs over midocean ridge and subduction stops

San Andreas Fault (system) connects the remaining segments of the still subducting

midocean ridge

Basin & Range extension (normal faults) occurring since subduction of the ridge

Columbia River Flood Basalt, Snake River basalts - Yellowstone: hotspot

Climate: From the Cretaceous Greenhouse to the Cenozoic Icehouse

Cretaceous climate was very warm, no icecaps, reptiles & tropical plants at high latitude
rapid seafloor spreading (high sea level) - rapid outgassing of CO₂ - warm climate
hi sea level, flood basalt eruptions, hi seafloor spread rate
no magnetic reversals (118 - 84 m.y.)
model: superplume rises from CMB cools CMB, vigorous outer core convection, stable magnetic field - no reversals

Cenozoic climate gradually descended to the ice ages

decreasing rate of seafloor spreading - decreasing CO₂ outgassing
major mountain building: Rockies, Alpine-Himalayan mountain belt
increased weathering - removal of CO₂ from atmosphere
opening of Drake Passage and onset of glaciers in Antarctica (~35 m.y.)
glacial dropstones in deep ocean off Antarctica beginning at this time
closure of Isthmus of Panama (~ 3 m.y.) & intensification of the Gulf Stream
increased warmth & moisture caused onset of northern hemisphere glaciation???
increased salinity caused N.Atl downwelling, decreased warmth to Arctic Ocean???

Pleistocene Ice Ages wax and wane with variations in Earth's orbital cycles and resulting small changes in solar insolation striking northern hemisphere during the summer

The "Ice Ages"

northern hemisphere ice began to buildup by 3.5 - 3 m.y., fully glaciated by 2.5 m.y.
many advances and retreats of ice sheets since then modulated by variations of Earth's orbit
cooling also led to drying (e.g., expansion of Sahara)

Milankovitch Cycles

precession cycle (like spinning of top): ~23,000 yrs
tilt cycle (less tilt to more tilt & back): ~41,000 yrs
eccentricity (from more round to more elliptical): ~100,000 yrs

glaciers

snow - firn - ice

glaciers flow outward from zone of maximum accumulation

movement by internal ductile flow and sliding on bottom (where wet-based)

moraines: ridges of poorly sorted glacial till dumped at end of glacier

some North American glacial features

terminal moraines in the midwest

terminal moraines cross New Jersey, Staten Island, Long Island, to Massachusetts

Finger Lakes of New York state were carved by glaciers flowing in former stream valleys

the Hudson fjord was also carved out by glaciers

the Holocene epoch - the present and future climate

climate optimum was about 6,000 yrs ago

several warmer and cooler periods (e.g., Medieval Warm Period and Little Ice Age)

rapid warming since mid 19th century - the industrial revolution

average temperature of past decade or so is warmer than anytime in past 1000 yrs

temperature did rise by statistically distinguishable amount during 20th century

rising CO₂ from burning fossil fuels is responsible for at least part of the warming

sea level rose about 1 foot during 20th century at a rate of ~1-2 mm/yr

expected to be more and faster in 21st century
thermal expansion of the oceans
increasing rate of melting of Greenland ice cap & mountain glaciers
computer climate models far from perfect but..
best constrained models predict several degrees global average temperature rise in 21st century
greatest temperature rise expected in polar regions
Arctic surface temperatures rose ~0.5 degrees C per decade, 1981-2003
more summertime melting around margins of Greenland ice cap past two decades
northern snow cover retreated about 2% per decade, past two decades
Arctic summer minimum sea ice coverage declining 2% - 3% per decade, 1978-2003
sea ice in Arctic Ocean has thinned since the 1950's
Beware the Positive Feedbacks
less snow & ice, less reflection, more absorption of sunlight, increased warming

Paleocene-Eocene evolutionary radiation of mammals

over 20 orders of mammals rapidly evolved after dinosaurs (except birds) became extinct
mammals became dominant land animals of the Cenozoic following extinction of most dinosaurs
mammals learned to fly (bats)
mammals went back to the sea (whales & dolphins)
birds remained successful (and they are living dinosaurs!)

hominid evolution

primates evolve by Paleocene
hominoids - true apes - Oligocene
hominids - by Pliocene
genus *Australopithecus* ("southern man") by ~4 m.y. ago
A. afarensis (Lucy's species)
A. africanus
Paranthropus robustus (robust Australopithecine lineage)
genus *Homo* arose by ~2.4 m.y. ago
Homo habilis ("handy man") fashioned crude stone tools
Homo erectus spread throughout old world
Homo Neanderthalensis in Europe by 100,000 yrs ago
Homo Sapiens in subsaharan Africa by 125,000 yrs ago
north Africa & middle east by 100,000 - 90,000 yrs ago
Europe by ~35,000 years ago
coexisted with Neanderthals for several thousand years
colonized North & South America around 13,000 yrs ago when glaciers broke up
North American large mammal extinctions (mammoths, mastodons, etc.)
cause: overhunting? warming climate? both?
new hypothesis: impact
Clovis hunting culture also appears to have died out then as well