

**Knowledge Base and Textbook Readings for Geology 2C, Historical Geology
Spring 2006**

Exam 2

7. Radiometric Dating

Wicander (Ch.4: 63-69)

Lord Kelvin's estimate of the age of the Earth based on cooling rate.

Radioactivity – what is it and how can it be used to date rocks? Isotopes, radioisotopes, mass spectrometer, half life, parent isotope, daughter isotope, uranium-lead decay series, potassium-argon dating. Concordant ages.

C14 dating – how it works and how it is different from other types of radiometric dating.

Henri Bequerel, Marie and Pierre Curie, Ernst Rutherford, Bertram Boltwood

8. The Hadean Eon

Wicander (Ch.8: 136-139)

Formation of the Earth to age of oldest remaining rock (Acasta Gneiss, app. 3.9 GA)

Origin of the solar system from the solar nebula: evidence for events in the early history of the solar system – meteorites, surface of Moon and Mercury, Orion nebula – stars with accreting solar disks.

Chondritic meteorites – remnants of planet formation

Formation of planets by accretion in solar nebula – Sun forms, collapses, begins to fuse, Jupiter forms, remaining planets condense.

Formation of the Moon by collision between Earth and Mars-sized planet.

Differentiation of the Earth into core, mantle, and crust

Early interval of heavy meteoritic bombardment – remelting of crust

Formation of the atmosphere and oceans from volcanic outgassing

Early atmosphere richer in CO₂ – compensated for weaker early sun (greenhouse effect)

Acasta Gneiss – oldest surviving bedrock – continental crust, implies existence of oceans, atmosphere, and plate tectonics.

Zircon grains – imply formation of continental crust earlier in the Hadean

Lab 4 Igneous and Metamorphic Rocks, and Plate Tectonics

Lab 4, Historical Geology Laboratory Manual

Wicander (Ch.3: 39-45)

3 sources of magma related to plate tectonic boundaries – melting of dry mantle, wet mantle, continental rock

Igneous rocks associated with divergent plate boundaries – gabbro, basalt

Sedimentary rocks associated with divergent plate boundaries – red beds (arkose, mudstone), fluvial (river) and lacustrine (lake) deposits.

Igneous rocks associated with converging plates – andesite, granite

Metamorphic rocks associated with plate collision and mountain building – slate, phyllite, schist, gneiss, marble.

Sedimentary rocks associated with converging plates – thick sequences of gravel, sand, and mud deposited in foreland basins (bowling ball on a mattress analogy).

Progressive metamorphism, low grade to high grade reflecting increasing temperature, pressure, and depth of burial.

9. The Archean Eon

Wicander (Ch.8: 140-152)

Archean rocks – greenstone (metamorphic volcanic sediments, banded iron formations (BIF), granite and gneiss (pods of continental crust forming over subduction zones).
Isua rocks from Greenland – evidence for small protocontinents and volcanic island arcs (pillow basalts, greywacke, BIFs, chert) but no large continents.

Significance of BIFs – production of oxygen, presumably by photosynthesizing bacteria, uptake of oxygen by iron in oceans, leaving no oxygen to diffuse into atmosphere.

Archean plate tectonics – many small plates, rapid recycling of crust, small protocontinents – collision of protocontinents to produce regions of gneiss surrounded by greenstone

Evidence for bacterial life: microfossils in chert, stromatolites (sedimentary structures – mud mounds produced by bacterial mats), carbon isotope ratios

Apex chert – oldest preserved microfossils of bacteria? Or just inorganic carbon smudges?

Carbon dioxide levels reduced from the Hadean due to the weathering of rock on the continents (uses up carbon dioxide) and the formation of limestone in the oceans (carbon dioxide from the atmosphere becomes trapped in the crust as carbonate rock).

So why didn't the Earth freeze in the Archean under a weak sun?

Methane hypothesis – methanogenic bacteria thrived in the Archean under anaerobic (oxygen poor) conditions. Production of methane caused greenhouse effect in atmosphere, warming the Earth. Earth didn't get too hot because reaction of methane produced smog at high concentration (>1000 times modern level) blocking out sunlight.

Pongola Group and Witwatersrand Supergroup – rock formations that show existence of larger continents with continental shelves and terrestrial river systems.

Evidence for low oxygen in the Archean atmosphere: absence of terrestrial red beds, presence of uraninite and pyrite in subaerial sediments.

10. The Proterozoic Eon

Wicander (Ch.9: 153-170)

Cratonization – assembly of large continents

First extensive red beds – evidence for rise in atmospheric oxygen levels

Oxygenation of the atmosphere removed methane – reduced greenhouse warming.

Diversification of stromatolites – formation of extensive carbonate (limestone) in the ocean leading to removal of CO₂ from the atmosphere

Gowgonda Formation - first evidence for glaciation and ice age – caused by drawdown of CO₂ by carbonate formation and by loss of methane.

Late Proterozoic - Snowball Earth theory – period of wild oscillations in global climate from extremely cold to extremely warm. Evidence for snowball Earth – glacial sediments (till) interlayered with thick limestones (cap carbonates). Carbon isotope evidence for high productivity in oceans prior to glaciation, followed by a drop in ocean productivity following glaciation.

Carbon dioxide cycle – Hothouse climate and equatorial continents promote limestone formation which removes CO₂ from the atmosphere. Drawdown of CO₂ causes cooling, which slows and then stops limestone production as Earth freezes. During Icehouse conditions, volcanoes add CO₂ back to the atmosphere. By the time marine ecosystems and limestone production recovers, CO₂ levels are very high, leading to Hothouse climate. Cycle repeats until plate tectonics move continents away from the equator.

Evolution of eukaryotic cells by symbiosis of prokaryotes (bacteria)

Radiation of eukaryotic cells, decline in stromatolites (bacteria being grazed by protists), evolution of sex

11. The Dawn of Animal Life

Wicander (Ch.9: 164-169)

Increasing evidence for complex eukaryotic organisms in the Late Proterozoic.

Acritarchs – fossil cysts of marine algae (dinoflagellates)

1.0 Ga to 600 Ma – increasing evidence for evolution of multicellular organisms: multicellular algae, carbonaceous impressions, trace fossils (simple burrows) made by metazoans (animals)

Ediacaran fossils – appear following the Varanger Glaciations (Snowball Earth), may be a unique radiation of animal life or may be early, non-skeletonized members of modern marine animal groups (jellyfish, soft corals, mollusks, etc.). Preserved as impressions in sandstones, possibly after being covered by bacterial mats.

Latest Proterozoic “shells” – calcium carbonate produced by animals? *Cloudina* and enigmatic things from Namibian limestones.

Fossil embryos preserved by phosphatization – jellyfish and possible worm embryos.

Possible mass extinction of Ediacaran organisms – did they die off or just stop getting preserved?

Phanerozoic Eon begins at 544 Ma (beginning of the Cambrian Period) – marked by appearance of large animal trace fossil. Next come small shelly fossils – tiny plates and shells of animals. These are followed in the fossil record by trilobites, echinoderms, brachiopods, etc – large, recognizable animals.

Cambrian Explosion – rapid appearance of most major groups of metazoans in the fossil record. Why did it happen? Atmospheric oxygen levels, evolutionary arms race, evolutionary novelty triggering an adaptive radiation?

Fossil lagerstätte (extremely unusual deposits that preserve soft-bodied organisms) from the Cambrian – Burgess Shale, Chengjiang Formation – show that almost all major groups (phyla) of animal life evolved by the end of the Early Cambrian, including vertebrates.

Lab 7 Interpreting Geologic History from Cross Section

Lab 7, Historical Geology Laboratory Manual

Geological Formation – formally named rock unit

Steno’s principles: Law of Original Horizontality, Law of Superposition, Cross-cutting Relationships

Geological Events: deposition, transgression, regression, erosion, unconformity, igneous intrusion, uplift, folding, faulting, metamorphism

14. Geologic History of NY – The Grenville Orogeny

Wicander (Ch.9: 157)

Grenville Orogeny – Late Middle Proterozoic collision between eastern North America and Amazonia (part of South America) during assembly of Rodinia supercontinent.

Metamorphic and meta-igneous rock underlying much of eastern North America Exposed where uplifted in New York – Adirondacks, Hudson Highlands, Manhattan Prong

Grenville Mountain range eroded during Late Proterozoic – 500 my nonconformity formed in NY.

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