Evidence of the Earth's Evolutionary History

Lecture 4

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Preamble

– Although we believe that the terrestrial planets all have essentially the same chemical constituents, the atmospheres ,where they exist, are very different.

- This diversity means that atmospheric composition is a sensitive indicator of the evolutionary history of the planets.

Argon and Helium Out gassing and the Earth's potassium Content

– The isotope ^{40}Ar , which is produced in the Earth by decay of ^{40}k ,has leaked to the atmosphere by volcanism and by weathering of crustal rocks. The argon is retained in the atmosphere and approximately 1% of the atmosphere.

- ^{4}He , produced by uranium and thorium decays , also leaks to the atmosphere.

Argon and Helium Out gassing (continued)

– Although ^{4}He is produced in the Earth in greater abundance than ^{40}Ar it is only a very minor constituent of the atmosphere.

- The ratio of ^{40}Ar to ^{4}He leaking to the atmosphere indicates the K / (U + Th) ratio of the Earth.

- It also allows the rate of tectonic cycling of mantle material through a volcanic stage to be estimated.

Evolution of the Crust

– Oceanic crust is produced at mid – ocean ridges at a rate estimated to about 3.4km^2/ year .

- The total volume generated in the life of the Earth exceeds the present volume of the crust by a factor of order of 20 , so no more than a tiny fraction could be converted to continental crust.

Evolution of the Crust (continued)

- As the oceanic crust drifts towards the subduction zones, the oceanic crust accumulates sediment washed off the continents and some of this sediment is recycled into continental material.

- The processes of sedimentary recycling are central to history of crustal development.

Evolution of the Crust (continued)

-The genesis and evolution of continental crust is one of the fundamental questions that remains unresolved in the geosciences. Models that have been proposed for crustal growth include:

1. early extraction of all the crust from the mantle.
2. long-term growth or
3. episodic periods of crustal growth.

- In addition many models have been proposed that estimate the average composition of continental crust through time.

Evolution of the Crust (continued)

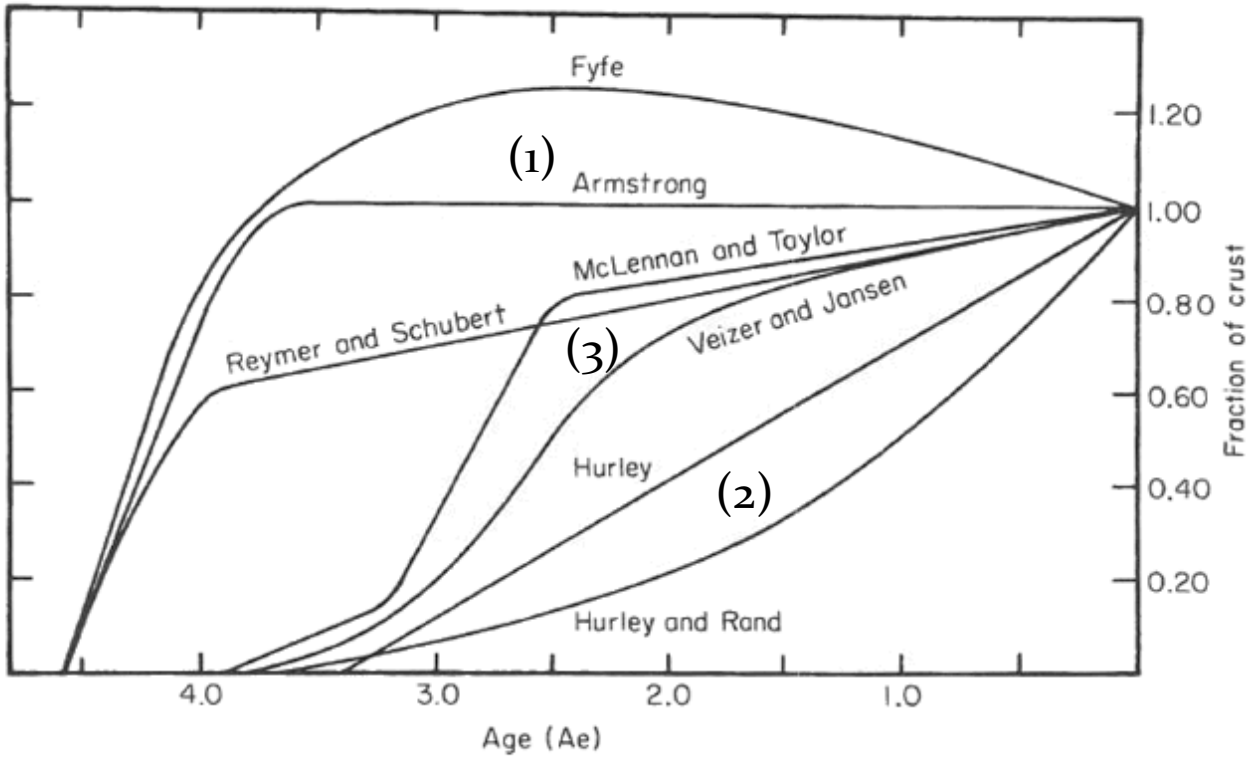

Fig. 10.1. A selection of crustal growth models. Models shown include those of Reymer & Schubert [2], Armstrong [5], Fyfe [15], Hurley [17], Hurley & Rand [18], Veizer & Jansen [20, 23] and McLennan & Taylor [24].

Evolution of the Crust (continued)

-The figure above presents a summary of the crustal growth models which includes the following authors' work:

(1) Early differentiation of virtually all of the continental crust at 3.9 Ga ago and subsequent steady state recycling of this crust.

(2) Uniform growth rate or accelerated growth rate.

(3) Episodic growth of continental crust .

The fossil record : crises and extensions

- Evolution and the proliferation of species are environmentally controlled.
- The fossil record is a record of the environment.
- The earliest forms of life on the Earth extend back at least 3.5 billion years.
- The appearance of fossilizable animals really began only 600 million years ago and then expanded very rapidly.

The fossil record : crises and extensions (continued)

- The paleontological periods is punctuated by environmental crises.
- The ultimate causes of the crises have been the subject of debate for as long as the sharp boundaries have been recognized.
- There is an evidence of a major cometary impact coinciding with the boundary between the cretaceous and tertiary periods , 65 million years ago, when two – third of all species ,including dinosaurs , disappeared.

The fossil record : crises and extensions (continued)

– The feature of the C-T boundary that originally attracted attention was the presence an apparently global thin sedimentary record, rich in Iridium (Ir). This is a siderophile (iron – loving) element , and association with other siderophile elements in meteoritic proportions of an extraterrestrial source.

The fossil record : crises and extensions (continued)

- Another coincidence with the C-T boundary was the emergence of voluminous flood basalts in what is now the Deccan area of India.
- Single flows of order 10000 km^3 in the volume evidently appeared rapidly and the out gassing of such large volumes could have affected the atmosphere , and hence the climate , for several years at a time , depending on whether the sulphurous gases reached the stratosphere.

The fossil record : crises and extensions (continued)

- The extinctions caused by volcanism could be almost as sudden as those from asteriodal impact.
- A feature of the C-T boundary sediments that requires a special explanation is the abundance of soot.
- The total quantity , about 10^{15} kg , can be explained only by enormous fires.

The fossil record : crises and extensions (continued)

– Ignition of fires that consumed more than 50% of the world's vegetation , would itself , constitute an environmental catastrophe, but it is difficult to see either an impact or volcanism as the cause .

- The soot does not appear to be typical of burning vegetation.

- It is more plausible to suppose that a vast oil or coal deposit was exposed and burned. This could have resulted from volcanism more easily than from an impact.

The fossil record : crises and extensions (continued)

- The most nearly complete extinction event occurred 250 million years ago, at the boundary between the Permian and Triassic periods , when 95% of all species disappeared.
- This coincided with a massive , rapid outpouring of flood basalt in what it is now Siberia.
- Volcanism as a cause of mass extinctions is very strong , to some observers unassailable , although doubters remain.

References

-Stacey F. and Davis P., Physics of the Earth, Cambridge University Press, 2008.

- Lowrie, W., Fundamentals of Geophysics, Cambridge University Press, 2007.