EARTH'S GEOCHEMISTRY

(Summary of lecture by Stein Jacobsen on 15 Feb 2005 - Group 3)

From planetary formation models we know that the solar system formed as the solar nebula collapsed to form a disk around the protosun. As the temperature of the gas and dust in the nebula cooled, different chemical elements condensed progressively. The elements that condense at a higher temperature are called refractory and condense first as the solar nebula collapses and cools. The elements that condense last (lower temperatures) are called volatile elements. A large collection of meteorites have been available for scientists to study. There are two main groups: primitive and differentiated. Primitive meteorites are called chondrites. Differentiated meteorites include achondrites, irons and stony irons. Solar atmosphere abundances are practically the same as for CI meteorites (a type of chondrite), except for a few elements such as N, C, O (volatiles lost by meteorites), Li and B (lost to nuclear reactions in the sun). CAIs (calcium aluminum rich inclusions) occur in some meteorites. Since CAIs have the highest condensation temperature of minerals, they are the earliest minerals formed.

OXYGEN IN THE SOLAR SYSTEM

Oxygen has various isotopes like O17 and O18. There are two trends in the graph showing the isotopic composition in the solar system: the terrestrial fractionation line that has a slope of 0.5 where the Earth and the Moon lie; and a second line where the carbonecous chondrites lie. The fact that the Earth and moon have the same Oxygen isotope ratios may have an interesting implication. If the moon is composed of the debris of the impactor in the Moon-forming event (as dynamical models have suggested), this impactor must have formed relatively close to the Earth (within the orbit of Mars).

ACCRETION

There are two types of theories for planet accretion: a homogenous accretion, where the material accreted and then differentiated; and a heterogeneous accretion where the planet accreted from heterogeneous material and differentiated simultaneously as it accreted. Data favors the heterogeneous accretion theory suggesting that the Earth went through three main stages. This is shown in the figure that shows the depletion relative to CI and refractory elements as a function of increasing siderophile (iron-loving) behaviour. It has been suggested that (80-90% of) the Earth formed from very reducing material (Fe and other siderophile elements went into the core). The next 10-20% were more oxidixing and all but the most siderophile elements went into the mantle (with siderophile elements going into the core). The last stage (0.4%) is the ***late veneer*** where all the siderophile elements remained in the mantle due to the very oxidizing conditions. In the graph, the most siderophile elements are all very similarly depleted (they lie on a horizontal line) which suggests this late addition of these elements.

K AND U IN THE SOLAR NEBULA

The composition of the bulk Earth is calculated from solar nebula condensations for refractory elements. The estimate of the bulk Earth and measurements of the surface of the Earth both indicate that the K/U is about 10^4 to 2x10^4 making it a robust result. The Uranium concentration is less well constrained but a good estimate is about 20 ppb +- 5ppb. K/U ~10^4 Th/U ~ 4 (in MORB Th/U ~ 2.6 -> not chondritic, it has fractionated)

OTHER ISOTOPIC SYSTEMS

Three isotopic systems were reviewed: Sm-Nd, Rb-Sr and 4He-3He. The Sm-Nd system condensates at a very high temperature, therefore it is believed that there is a homogeneous distribution among all objects in the solar system. All three isotopic systems show that the crust of the Earth is enriched in incompatible elements and that there must be a reservoir in the planet that is depleted. It is important to notice that the location of this reservoir is not constrained by geochemistry.