The role of water in early solar system evolution: Insights from primitive chondritic meteorites

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Evidence from primitive chondritic meteorites shows that water was widely available in the inner solar system during the earliest stages of solar system formation. Over the last 15 years, it has become widely recognized that meteorites from essentially all the chondrite groups retain a record of interaction with liquid water early in solar system history. For many chondrites, this process occurred at low temperatures (<50C) and resulted in replacement of primary high temperature phases by an assemblage of phyllosilicates, carbonates, sulfides, sulfates and oxides. However, recent evidence of a more cryptic nature also indicates some chondrites such as the CV, CO and ordinary chondrites experienced fluid-assisted metamorphism at temperatures in excess of 200ºC.

A major topic of discussion concerns the environment under which interaction of nebular solids occurred. Many workers have proposed that the bulk of alteration occurred after accretion of asteroidal parent bodies. In this model, nebular dust accreted into asteroids along with significant quantities of water ice. Subsequent asteroidal heating resulting from the decay of short-lived radionuclides such as ^{26}Al initiated melting of the ice and the formation of liquid water. However, an alternative scenario is that at least some alteration could have occurred in the solar nebular or in ephemeral protoplanetary bodies prior to final parent body assembly. This evidence to support this so-called preaccretionary alteration is largely textural in character and is, in many cases ambiguous. These two models have interesting implications for the reservoirs of water that may have been present in the raw building blocks of the terrestrial planets. For the asteroidal alteration model, hydrous phases would have required a finite time to develop on asteroidal parent bodies. Mn – Cr dating of carbonates indicates that alteration started within ~4 Ma of CAI formaton. On the other hand, for the preaccretionary model, hydrous materials (probably phyllosilicates) would have been present within the first 1-2 Ma of solar system history. In either case, it seems likely that a significant amount of water would have become sequestered in phyllosilicate phases within 10 Ma of molecular cloud collapse and been available in a relatively stable form for accretion into the terrestrial planets.

The history of water on Venus

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Remote sensing and in-situ measurements give an atmospheric water abundance of 30 PPM on Venus. The D/H ratio (150 times terrestrial) indicates a history of water loss (Donahue et al. 1997). Venus is commonly thought to have experienced an early transition from a wet, more Earth-like past to its current highly desiccated state (Kasting, 1988). The randomly distributed and relatively pristine crater population reveals a later transition, with a rapid decrease in resurfacing rate between 300 and 1000 Myr ago (Schaber et al, 1992; McKinnon et al, 1997). The accompanying decline in outgassing rate would have caused large climate changes (Bullock and Grinspoon, 2001) and globally synchronous plains deformation (Solomon et al, 1999). We are exploring the possibility that these two apparent transitions may be part of a single, continuous planetary transformation. The loss of water through evaporation, photodissociation and H escape would have led to a change from plate tectonics to single plate behavior, as the shut-off of subducting hydrated sediments led to the desiccation of the mantle and loss of an asthenosphere. Current estimates of the timescale for water loss are highly uncertain. We are modeling clouds in wet, hot atmospheres in an effort to better constrain the albedo, energy balance and timescale for water loss. If clouds stabilized the moist greenhouse and Venus' oceans persisted for several billion years, rather than the canonical (but unconstrained) hundreds of millions, then the loss of water could have initiated changes in global convective style which led directly to the observed surface features. This might mean that Venus was a (conventionally defined) habitable planet for most of its history.

References

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