Asteroidal differentiation — the record in meteorites

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Early in solar system history, an intense energy source modified the small rocky bodies that had accreted from nebular condensates. The consensus view is that this energy source was the decay of short-lived ^{26}Al, perhaps with a contribution from short-lived ^{60}Fe. Differentiated meteorites and primitive achondrites preserve records of the states of asteroids as differentiation was ending. Reading these records provides clues to the nature of the energy source and the mechanisms of differentiation. I will examine the records from the acapulcoite-lordanite clan, ureilites, main-group pallasites, magmatic iron meteorite groups, brachinites and howardite-eucrite-diogenite (HED) clan meteorites.

The acapulcoite-lodranite clan and the ureilites contain evidence that their parent asteroids reached temperatures where basaltic melts were produced. The mineralogies of lodranites and ureilites are dominantly olivine and low-Ca pyroxene, and these meteorites are highly depleted in incompatible lithophile elements. The acapulcoite-lodranite and ureilite parent bodies were heated to the point where on the order of 20-30% melting had taken place, but there is no evidence for more extensive melting. Assuming a ^{26}Al energy source, the implication is that transport of the Al-rich basalt out of the mantle outpaced radiogenic heating, and thus shut down furhter differentiation.

Main-group pallasites, magmatic iron meteorites and HED clan meteorites, on the other hand, provide evidence for total or near total melting of asteroids. The silicate phase of pallasites is magnesian olivine; their minor and trace element contents suggest that they are refractory melting residues. The degree of melting was high, perhaps on the order of 80%. The compositions of the most Ir-rich magmatic irons suggest near total melting of the metallic phase, and thus high degrees of melting on their parent asteroids. The compositions of basaltic eucrites are most consistent with them being residues from the crystallization of a largely molten asteroid. For these meteorite groups, the rate of heating outpaced the rate at which the melt could be extracted from the interiors, again, assuming ^{26}Al was the energy source.

The nature of the heat engine and asteroidal differentiation processes will be discussed as they can be inferred from the petrology and composition of achondrites, irons and stony irons.

Higashi-akaishi peridotite body from a hanging wall of an oceanic subduction zone at the east Eurasian margin – An introduction

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Tectonic and fluid processes in depths of subduction zones are controlled by complicated factors, such as shapes and ages of subducting plates, petrological structures and flow patterns in mantle wedges and thermal states, all of which are generally variable with time and local settings. In constructing the image of a subduction zone, the records in naturally occurring samples are valuable if they are interpreted in terms of the thermal and tectonic histories.

The Higashi-akaishi garnet-bearing peridotite body has a km-scale exposure in the Sanbagawa belt, SW Japan, that represents high-pressure type metamorphic units of oceanic metasediments and metavolcanics. The body occupies the highest structrural level of the metamorphic belt together with eclogite-bearing mafic bodies, indicating it provides results of crust-mantle interactions at a subduction boundary.

The tectonic framework of the peridotite is defined by changes of deformational fabrics and associated petrological information on pressure-temperature conditions; the main fabric at the subduction to the UHP is an olivine-dominant microstructure with a B-type lattice preferred orientation and, subsequently, that at the exhumation to crustal levels is an antigorite-dominant foliated structure. The tectonic and structural evolutions record a cooling of a subduction zone and continuous affects of H_2O-rich fluids.

A recent progress has been made on the initial state for the subduction zone processes. Geochemical and petrological studies on the layered components of dunite, wehrlite, clinopyroxenite and garnet-bearing pyroxenite show that the peridotites and pyroxenites are related to products of an extremely high degree of partial melting: residual mantle and cumulates from intrusions of the differentiated magmas, suggesting extensive hydrous melting triggered by an subduction initiation.

These lines of observations indicate that the Higashi-akaishi peridotite body is a valuable piece of mantle recording various stages of a cycle in a hot subduction zone. It is one of the best place to look at physical and chemical processes in depth of young subduction zone as those ongoing beneath SW Japan.