ABSTRACT

ELEMENTAL AND ISOTOPIC STUDY OF DIFFERENTIATED METEORITES AND IMPLICATIONS FOR THE ORIGIN AND EVOLUTION OF THEIR PARENT BODIES

Iron meteorites are differentiated meteorites composed largely of Fe–Ni alloys. The metallic phase of many iron meteorites shows a texture called the Widmanstätten pattern, which develops as a two-phase intergrowth of kamacite (α-bcc, ferrite) and taenite (γ-fcc, austenite), and forms by nucleation and growth of kamacite from taenite during slow cooling of the parent body.

Selected iron meteorites – octahedrites of different structural and chemical groups (Canyon Diablo, Toluca, Bohumilitz, Horh Uul, Alt Biela, Nelson County, Gibeon and Joe Wright Mountain) were studied with intention to evaluate the scale and extent of Fe isotopic heterogeneities in iron meteorites and to find the possible link between the isotopic variations and thermal histories of the respective meteorite parent bodies. The Fe isotopic compositions of kamacite and taenite in the studied meteorites, obtained by three independent analytical techniques with different spatial resolution capabilities (laser ablation and solution MC ICP-MS and SIMS) show significant variations of up to ~4.5‰ in δ^{56}Fe. The taenite is isotopically heavier compared to kamacite in all studied meteorites. There is no correlation between the Fe isotope composition of the taenite-kamacite pairs and the bulk Ni content of the studied meteorites (thus no obvious relation to the width of taenite lamellae). The results indicate that there is no relationship between samples of the same chemical group IA (Bohumilitz, Canyon Diablo, and Toluca) and iron isotopic composition of their Fe-Ni phases. There is also no similarity in Fe isotopic composition amongst magmatic or non-magmatic members.

The SIMS data indicate that the taenite lamellae are not homogeneous in their isotopic composition. This suggests that spatial resolution has a significant effect of the measured Fe isotopic composition and that the bulk Fe isotope analysis of taenite by solution MC ICP-MS may not record the maximum isotopic variability for the kamacite-taenite pairs. The previously recorded differences in the bulk iron isotope composition are real and can in part be due to the variable amount of taenite analyzed during bulk sampling of the meteorites. The small scale isotopic heterogeneities within the meteorite samples can explain the apparent differences in Fe isotopic composition previously reported for meteoritic irons in the literature.

The new laser ablation MC ICP-MS data from the studied iron meteorite samples revealed a systematic correlation between the kamacite–taenite Fe isotopic offset $\Delta^{56}Fe_{taen\text{-}kam}$ and the meteorite cooling rates (5–500 °C/My) determined using metallographic methods based on Ni diffusion in taenite. This correlation is interpreted as resulting from Fe isotopic fractionation driven by diffusion between kamacite and taenite lamellae and variable cooling rates of the studied meteorites. Data presented in this study suggest that the differences in Fe isotopic composition between different iron meteorite groups reflect variations in their respective cooling histories and provide us with new insights into the evolution of iron meteorite parent bodies during the early phases of Solar system evolution.

Two articles on elemental and isotope geochemistry, and magnetic properties of meteorites are also part of this thesis. These articles comprise the results which were obtained and published during my PhD study and are enclosed as supplementary material in the appendix.