
12 glassy silicate spherules separated from deep-sea sediments obtained by GH79-1 cruise by Geol. Survey of Japan at North Pacific Ocean (10-13°N, 167-176°W) and 3 microtektite samples from DSDP core 16, site 216 at Gulf of Mexico (1) were analyzed by instrumental neutron activation analysis (INAA) for rare-earth elements (REE), Sc, Co, Fe, Cr, Mn, Hf, Na, K, Ni, Ir and Au.

7 of glassy spherules analyzed, mostly colorless and transparent, showed uniform enrichment of REE and Sc to about 2-7 times compared with chondritic average values, except Ce (Fig. 1; A). More volatile elements, K, Na, Mn, Co, Fe and Cr, and siderophile elements, Ir, Au and Ni are depleted mostly by an order of magnitude or more compared with the chondritic values. The uniform enrichment of the refractory elements and depletion of Ce and the volatile elements indicate that the spherules were originally chondritic in composition and that the depleted elements were lost by evaporation by heating under relatively high O fugacity, possibly by frictional heating at the time of entering the earth's atmosphere (2,3,4).

3 darker colored spherules showed higher siderophile element concentrations. These spherules showed more fractionated REE abundances relative to the chondritic values (Fig. 1; B). Samples #8 and #15 showed very large depletion of Ce, yet show volatile element concentrations (Mn, Fe and Cr) which are much higher than those in the 7 "chondritic" spherules. Thus the Ce depletion in #8 and #15 cannot be attributed to the process that produced Ce depletion in the "chondritic" spherules, namely the evaporation at the time of entry to the earth's atmosphere.

A pale-green transparent spherule #10 and DSDP microtektites show much higher and more fractionated REE abundance patterns (Fig. 1; C). The REE patterns are essentially similar to those of average crustal rocks, thus indicating terrestrial origin of these spherules.

A colorless, translucent spherule #5 shows very high Na2O (6.03 %) and K2O (8.98 %) concentrations, and very low REE (most are below detection limits), Sc (0.075 ppm), FeO (0.083 %), Cr (8.2 ppm), Co (0.268 ppm), Mn (not detected), Hf (0.277 ppm), and Th (not detected) concentrations. The trace element compositions appear to indicate that the spherule was produced under a marine environment.

Although DSDP microtektites have fairly long burial time interval (35 m.y.) (1) in the ocean bottom, they do not show neither enrichment nor depletion of Ce relative to other REE. Likewise #10 which have REE abundances similar to terrestrial rocks shows no Ce anomaly. It appears that Ce concentrations (relative to other REE) in the glass spherule samples did not
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Figure 1. REE and Sc abundance patterns of spherules and microtektites. (A) "Chondritic" spherules, #6, #9, #12, #13, #14 and #16. #11 is not shown. (B) Spherules with high siderophile element concentrations. #7: FeO(%), 7.3; Ni(ppm), 70; Ir (ppm), 0.01. #8: FeO, 15.6; Ni, 1100; Ir, 0.15; Au, 0.02. #15: eO, 20.2; Ni, 1500. (C) #10 and microtektites, M1, M2, M3.
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change significantly by the interaction with sea water during burial time of tens of millions years. Thus the large depletion of Ce observed in #8 and #15 suggest that the spherules have extraterrestrial origin and that the Ce anomalies have possibly been produced before these samples entered the earth's atmosphere.

In conclusion, REE and other trace element concentrations observed for the spherule and microtektite samples indicate that the tiny spherical glassy grains obtained from deep-sea sediments have wide varieties of both terrestrial and extraterrestrial origins.