MINERALOGY OF CHONDRITIC INTERPLANETARY DUST PARTICLE IMPACT RESIDUES FROM LDEF

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SUMMARY: A detailed structural and compositional analysis of several impactor residues was performed utilizing transmission electron microscopy, energy dispersive spectroscopy, and electron diffraction. Residues from the interior of several craters in gold surfaces were removed with a tungsten needle, mounted in EMBED-812 epoxy, and ultramicrotomed. The presence in these residues of equilibrated ferromagnesian minerals, recrystallization textures, glass, and melted metal and sulfide bodies decorating grain boundaries is indicative of varying degrees of shock metamorphism in all impact residues we have characterized.

INTRODUCTION: Impactor residues in materials exposed on the Long Duration Exposure Facility (LDEF) satellite are being characterized to establish the nature and abundance of meteoritic and orbital debris materials in the low-Earth orbit (LEO) environment [1], and also the effect hypervelocity impacts will have on spacecraft. In this study, simple techniques were developed for the study of selected chondritic (containing Si, Mg, Fe, +/- Al, Ca, S, Mn, and Ni in appropriate amounts) impactor residues in shallow craters in gold plates, from the LDEF experiment of Fred Horz [2-4]. A detailed structural and compositional analysis of several of these impactor residues was performed utilizing transmission electron microscopy, energy dispersive spectroscopy, and electron diffraction. The immediate goal of this continuing work has been to determine the effects of the impact process on impactor mineralogy and mineral composition of chondritic interplanetary dust particles (IDPs), and to compare these impactor residues to chondritic IDPs collected from the stratosphere.

SAMPLE PREPARATION AND ANALYTICAL PROCEDURES: Residues from the interior of several craters in gold [2] were removed with a tungsten needle, mounted in EMBED-812 epoxy, and ultramicrotomed into 90nm-thick sections. Observation of the sections on carbon-coated copper grids was done by transmission electron microscopic techniques using JEOL 100CX and 2000FX analytical electron microscopes. Chemical analyses of crystalline areas were performed with a PGT System 4 and energy dispersive X-ray spectrometer and reduced with the PGT dedicated software. The structural state of all analyzed materials were assessed by electron diffraction, which proved to be a critical step, considering the non-crystalline nature of many materials observed.

RESULTS: We examined the mineralogy of residues from three impact features: nos.102, 121, and 295. Impact residue 102 has very finely-divided crystalline pyroxene and olivine, showing abundant evidence of intense shock, these being planar deformation features, mosaicism, and, in some instances, evidence of recrystallization (120° grain intersections). Compositional analyses of these ferromagnesian phases are now being performed. The matrix consists of frothy ferromagnesian glass. Spherical bodies of Fe-Ni metal and pyrrhotite abound locally, particularly at grain boundaries. (See Figure 1.) Impact residue 121 contains fragmental grains of olivine (Fo_{57-67}), orthopyroxene (En_{63-64}), Fe-Ni metal, and abundant glass. The olivine and pyroxene grains show abundant evidence of shock (see above for criteria). Impact residue 295 contains shocked, fragmental olivine (Fo_{56-71}) and orthopyroxene (En_{71}), pyrrhotite, and glass.

The compositions of olivines and orthopyroxenes in all residues characterized in this study are equilibrated compared to anhydrous chondritic IDPs, and also Fe-rich compared to hydrous chondritic IDPs. They are also Fe-rich as compared to ferromagnesian from partially melted chondritic IDPs [5], which are typically on the order of Fo_{90} and En_{90}. The presence of equilibrated and shocked ferromagnesian minerals, recrystallization textures, glass, and melted metal and sulfide bodies decorating grain boundaries, is indicative of varying degrees of shock metamorphism in all impact residues we have characterized. Our failure to locate any magnesian olivines or pyroxenes is illustrative of the pervasive shock metamorphism of these particular residues. Nevertheless, we are continuing to search for more pristine IDP impactor residues.

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REFERENCES: [1] See et al. (1990) Planetary Science Branch Special Pub. 84, JSC 24608, 586 p.; [2] Horz and Bernhard (1992) NASA Tech. Memorandum 104750, 210 p.; [3] Bernhard and Horz (1992) LPSC XXIII, p. 93-94.; [4] Bernhard et al. (1993) Proceedings of the Second LDEF Post-Retrieval Symposium (in press); [5] Zolensky and Barrett (1993) Microanalytical J. (in press).

Figure 1 Impact shock effects in chondritic IDP residue 102: (a) frothy ferromagnesian glass, (b) 180° olivine grain intersections, and (c) metal and sulfide blebs decorating olivine grain boundaries.