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Carbon-rich chondritic clast PV1 from the Plainview H-chondrite regolith breccia: Formation from H3 chondrite material by possible cometary impact

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Abstract—Chondritic clast PV1 from the Plainview H-chondrite regolith breccia is a subrounded, 5-mm-diameter unequilibrated chondritic fragment that contains 13 wt% C occurring mainly within irregularly shaped 30–400-μm-size opaque patches. The clast formed from H3 chondrite material as indicated by the mean apparent chondrule diameter (310 μm vs. ~300 μm in H3 chondrites), the mean Mg-normalized refractory lithophile abundance ratio (1.00 ± 0.09×H), the previously determined O-isotopic composition ($\Delta^{17}O$ = 0.66‰ vs. 0.68 ± 0.04‰ in H3 chondrites and 0.73 ± 0.09‰ in H4-6 chondrites), the heterogeneous olivine compositions in grain cores (with a minimum range of Fa1-19), and the presence of glass in some chondrules. Although the clast lacks the fine-grained, ferroan silicate matrix material present in type 3 ordinary chondrites, PV1 contains objects that appear to be recrystallized clumps of matrix material. Similarly, the apparent dearth of radial pyroxene and cryptocrystalline chondrules in PV1 is accounted for by the presence of some recrystallized fragments of these chondrule textural types. All of the chondrules in PV1 are interfused indicating that temperatures must have briefly reached ~1100°C (the approximate solidus temperature of H-chondrite silicate). The most likely source of this heating was by an impact. Some metal was lost during impact heating as indicated by the moderately low abundance of metallic Fe-Ni in PV1 (~14 wt%) compared to that in mean H chondrites (~18 wt%). The carbon enrichment of the clast may have resulted from a second impact event, one involving a cometary projectile, possibly a Jupiter-family comet. As the clast cooled, it experienced hydrothermal alteration at low water/rock ratios as evidenced by the thick rims of ferroan olivine around low-FeO olivine cores. The C-rich chondritic clast was later incorporated into the H-chondrite parent-body regolith and extensively fractured and faulted. *Copyright © 2005 Elsevier Ltd*

1. INTRODUCTION

Carbon is a minor component of chondritic meteorites: type 3 ordinary chondrite (OC) falls typically contain 0.3–0.6 wt% C, two CV3 falls (Allende and Bali) also contain 0.3–0.6 wt% C, CM2 falls contain ~1.8 wt% C, and CI Orgueil contains 2.8 wt% C (Jarosewich, 1990). Poorly graphitized carbon occurs within metallic Fe-Ni grains and as relatively abundant sub-millimeter-size carbon-rich aggregates in some type 3 OC (McKinley et al., 1981; Scott et al., 1981a; Brearley, 1990; Mostefaoui et al., 2000). Far more C (6–13 wt%) is present in four enigmatic chondritic clasts described by Scott et al. (1981a,b). The clasts range in diameter from 1 to 11 mm and occur in H-chondrite regolith breccias: PV1 from Plainview (1917) (hereafter Plainview), DT1 and DT2 from Dimmitt, and WN1 from Weston. The clasts have also been reported to lack the fine-grained ferroan-silicate-rich matrix material (Scott et al., 1981a,b, 1988; Brearley, 1990) that occurs ubiquitously in type 3 ordinary (Huss et al., 1981) and carbonaceous (McSween and Richardson, 1977) chondrites.

Previous studies have concluded that the C-rich chondritic clasts formed in the solar nebula and are thus most likely composed of primitive material (Scott et al., 1981b, 1988; Brearley, 1990). In contrast, the present study of the PV1 chondritic clast indicates that most features were produced by asteroidal processes.

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2. ANALYTICAL PROCEDURES

A significant fraction of clast PV1 occurs within University-of-New-Mexico thin section UNM 273 of the Plainview H-chondrite regolith breccia (Fig. 1a). We studied this thin section microscopically in transmitted and reflected light and prepared a mosaic back-scattered electron (BSE) image of the clast. A grid was superimposed on this image; labels of chondrules and other objects in the image reflect their location on this grid. All BSE images were made with the LEO 1430 VP scanning electron microscope (SEM) at UCLA using a 15 keV acceleration voltage and a working distance of ~19 mm. Chondrule and grain sizes were measured on the BSE images. Mineral compositions were determined with the JEOL JXA-8200 electron microprobe at UCLA using natural and synthetic standards, an accelerating voltage of 15 keV, a 15-nA sample current, 20-s counting times, and ZAF corrections.

A 5.46-mg chip of PV1, obtained from the University of New Mexico, was separated for instrumental neutron activation analysis (INAA). The sample was irradiated at the University of California, Irvine (UCI) reactor with a neutron flux of $\sim 1.8 \times 10^{12}$ cm^{-2} s^{-1}. Samples were irradiated for two minutes and then counted immediately to determine elements producing very short-lived radioisotopes (Mg, Al, Ca, V and Mn). Samples were irradiated again for 4 h and counted several times over a period of ~6 weeks to determine elements producing longer-lived species (Na, K, Ca, Sc, Cr, Mn, Fe, Co, Ni, Zn, Ga, As, Se, La, Sm, Eu, Tb, Ho, Yb, Lu, Ir and Au). The INAA procedure is described in Kallemeyn et al. (1989). The estimated relative sample standard deviations are 6%–10% for K, Eu, Yb and Lu, and ≤5% for all other elements.

3. RESULTS

3.1. Petrography and Mineralogy

3.1.1. Plainview whole rock

Plainview is an H-chondrite regolith breccia (fig. 1 of Fodor and Keil, 1976) containing solar-wind-implanted rare gases (Schultz

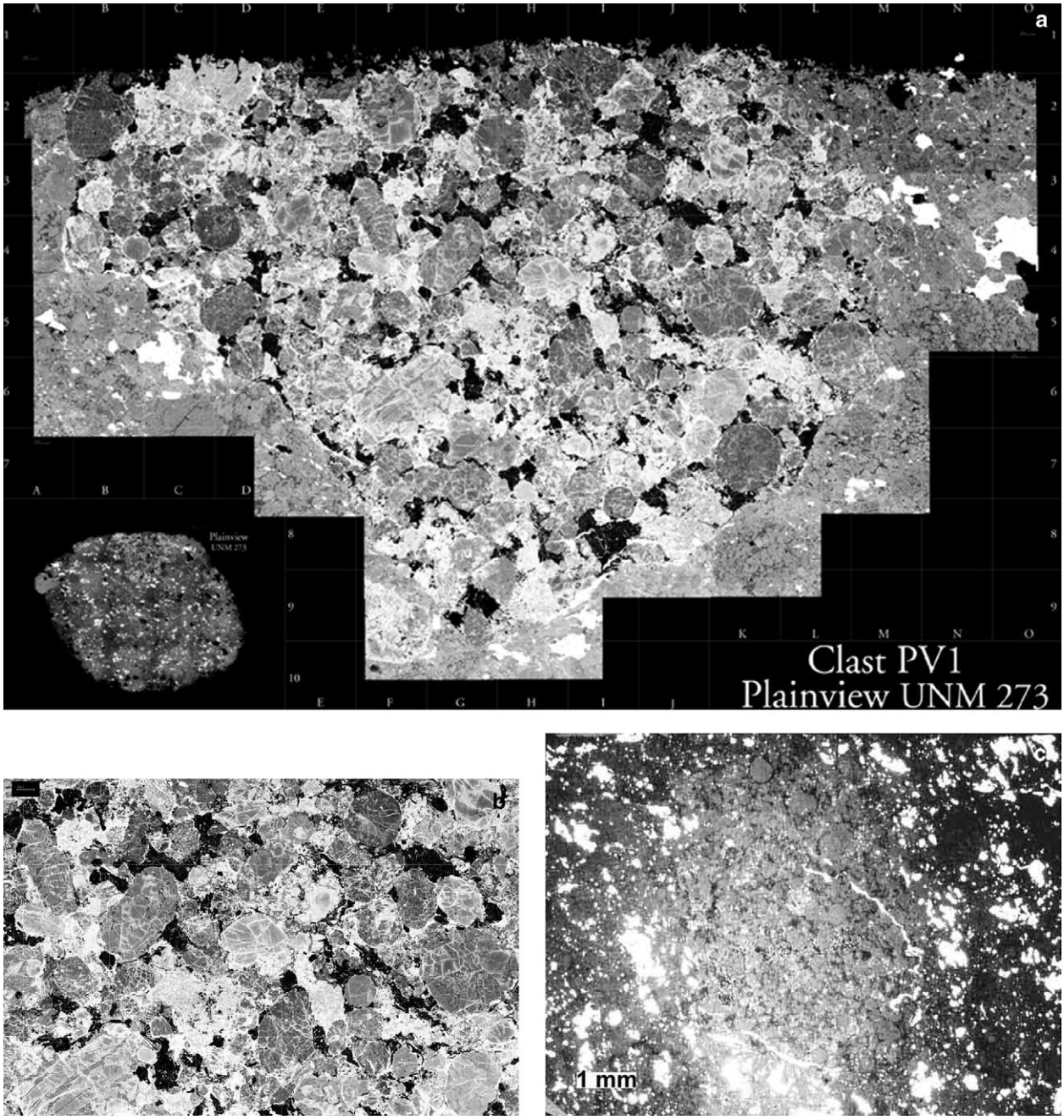

Fig. 1. Clast PV1. (a) Back-scattered electron (BSE) image of the PV1 clast and the surrounding Plainview host. The grid used in locating and identifying components is superposed on the image. The location of the clast relative to the entire thin section is shown at lower left. (b) Portion of a mosaic of the BSE image of PV1 within the Plainview host. The clast contains abundant C-rich aggregates (black) and fused chondrules (shades of gray) of different textural types and compositions. Small scale bar at upper left is 100 μm long. (c) Reflected light image of PV1 showing prominent veins of metallic Fe-Ni (white) penetrating the clast from the Plainview host.

and Kruse, 1989). The meteorite was found in Hale County, Texas; ~700 kg have been recovered (Grady, 2000). Plainview contains ~30 vol% H5 clasts, ~1 vol% light-colored impact-melt-rock clasts, ≤1 vol% exotic clasts (mainly phyllosilicate-bearing CM2 chondrite fragments), and <1 vol% shocked (but unmelted) H-chondrite clasts of different petrologic types (Fodor and Keil, 1976; Rubin, 1982); the remaining ~70 vol% consists of clastic chondritic material surrounding recognizable clasts.

The Plainview whole rock comprises subrounded ~0.02–40-mm-size clasts surrounded by glassy-to-microcrystalline feldspathic material (Bischoff et al., 1983). Plainview was classified as shock-stage S3, indicating that the examined portions of the breccia experienced a peak shock pressure of 5–10 GPa (Stöffler et al., 1991). Plainview contains opaque shock veins, melt pockets and weakly developed melt dikes (Stöffler et al., 1991).