ANNEALING AND CHONDRULE FLATTENING BY FRICTIONAL SHEAR HEATING IN OBLIQUE IMPACTS

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LAP 04581 is a 16-g shock-stage-S2 LL5 chondrite that offers an opportunity to examine connections between impacts and thermal metamorphism. The rock has a recrystallized matrix, homogeneous olivine and orthopyroxene, a ≥1-cm-long troilite vein, and flattened POP and BO chondrules (with aspect ratios ranging from 2.2 to 3.0). The long axes of the chondrules are subparallel to the troilite vein. It is unlikely that the flattened chondrules are simply elongated chondrule fragments because ≤3% of LL3 chondrule fragments have aspect ratios ≥2.2 [1]. The prominent chondrules in LAP 04581 were thus probably derived from normal spheroidal chondrules by a flattening process. Chondrule flattening is associated with chondrule preferred orientation [2], most likely caused by collisions [3]. Most meteorites with flattened chondrules and a petrofabric are matrix-rich carbonaceous chondrites, e.g., CV3 Leoville [2], Bali [4], Efremovka [5], Grosnaja [5] and ALH 85006 [5], and CR2 Renazzo [6].

Shock-recovery experiments on CV3 Allende [7] and CM2 Murchison [8] created foliations and produced flattened chondrules, facilitated by the collapse of matrix pores under shock pressure [5,7]. The flattened chondrules in LAP 04581 most likely formed in an analogous manner, i.e., via impact-induced collapse of matrix pores and the squeezing of chondrules into pore spaces. Because type-5 chondrites do not contain fine-grained porous matrix material, the chondrules in LAP 04581 were probably flattened prior to metamorphism, i.e., when the rock was an LL3 chondrite. Matrix material is moderately abundant in LL3 chondrites (e.g., ~15 vol.% in Semarkona [9]).

The centimeter-size troilite vein in LAP 04581 appears to have formed by shear. Oblique impacts can produce substantial frictional shear heating and cause elongation of melted materials along the trajectory of the projectile [10,11]. Because shock pressures and temperatures decrease with decreasing impact angle [12], oblique impacts may involve relatively little shock and little melting of target materials. Oblique impacts are uncommon; e.g., only ~3% have impact angles ≤10º [12]. Thus, few OC have experienced high amounts of shear due to oblique impacts and few OC have significantly elongated chondrules. Although silicate melting in many oblique impacts is minor to negligible [12], these impacts can generate significant amounts of frictional heating by shearing [11]. It seems likely that annealing of LAP 04581 to petrologic type 5 was caused by such frictional shear heating during an oblique impact. LAP 04581 represents a case in which metamorphism was caused by collisional heating (cf. [13,14]), not by the decay of short-lived radionuclides.

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