PALEOMAGNETIC EVIDENCE FOR LOCALIZED CHONDRULE FORMATION AND RAPID PARENT BODY ACCRETION IN THE PROTOPLANETARY DISK

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Introduction: Macroscopic chondrules and the microscopic matrix between them are the main components of chondritic meteorites, with bulk chemical compositions of most elements within a factor of two of the canonical solar composition. But various chondrites have different chondrule/matrix ratios, different dominant chondrule types, and different mean chondrule and matrix compositions [1]. Chondrules and matrix are chemically complementary, because when normalized to relative abundance, they sum to chondritic (i.e., solar) regardless of meteorite type.

"Complementarity" [2,3] makes compelling the hypothesis that chondrules formed from the local heating of mineral dust aggregates, and that surrounding dust combined (without mixing with extra-local materials) with those chondrules to form parent bodies of ~solar composition. Thus chondrule formation is variably effective, highly localized, and subsequent accretion is rapid.

Other evidence supports this scenario. Observed differences in the physical, textural and chemical properties of chondrules from different chondrite groups, and different chondrule cooling rates indicate relatively localized formation events [4]. Recent simulations indicate very rapid accretion rates of boulder-sized objects into planetesimals in disks [5]. Recent paleomagnetic data on individual chondrules also supports this scenario.

Results: Chondrules in Bjurböle (L/LL4) [6] and Allende (CV3) [7] have relatively stable natural remanent magnetization directions randomly oriented with respect to one another, therefore were magnetized before accretion. Recent high-precision magnetic studies [8,9] of ~10 chondrules separated from each of the Karoonda (CK4), Bjurböle and Allende meteorites yield paleointensities that bear on the magnitude and spatial-temporal extent of magnetic fields in the early disk, the extent of magneto-rotational instabilities promoting momentum and mass transport [10], and whether current sheets produced by MRI could heat chondrule precursors [11]. Allende and Karoonda give statistically significant paleointensity estimates, suggesting that a different field was experienced, in common, by the chondrules in each meteorite. Bjurbole chondrule paleointensities are also statistically distinct but are probably more a result of the intrinsic magnetic properties of the chondrules than ancient magnetic fields. These data support the hypothesis of localized chondrule formation and rapid accretion, consistent with 'complementarity'[1-3].

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