
Of the four major groups of carbonaceous chondrites, CV3 chondrites exhibit the greatest petrologic variation: the mean apparent diameter of chondrules varies by a factor of 1.8 and the modal abundances of olivine aggregates and refractory inclusions vary by factors of 7 and 3, respectively [1,2]. Coarse-grained rims surround 59% of the chondrules in Allende but scarcely 1% of those in Leoville [3]. However, CV-chondrite falls show negligible variations in bulk composition. One chip of Grosnaja has refractory lithophile elements at only ~0.75x CV except for very high (~3x CV) Ca [4]. Additional CV3 chondrites need to be studied to determine the extent of petrologic and compositional variation.

Ningqiang fell on June 25, 1983 in Ningqiang County, Shaanxi Province, China. Four stones with a total mass of 4.6 kg were recovered. Mineralogic and petrographic features of Ningqiang indicate that it is related to CV chondrites; it is the first CV chondrite to fall since 1969.

Ningqiang contains well-defined chondrules and aggregates embedded in a dark, fine-grained matrix. Its high magnetite/metallic Fe-Ni ratio (6.6) and the occurrence of awaruite as the principal metal phase imply that Ningqiang belongs to the oxidized CV3 subgroup.

Ningqiang differs from normal CV3 chondrites, Ningqiang has a very low abundance of refractory inclusions (2±1 vol.%) and high abundances of olivine aggregates (8.2 vol.%) and aggregational chondrules (13.7 vol.%). Relative to oxidized CV3 chondrites, Ningqiang has high metallic Fe-Ni (0.5 vol.%) and more magnetite (3.3 vol.%).

To date, we have INAA data on only one sample. Normalized to Mg, refractory lithophiles are surprisingly low (~1.2x CI or ~0.8x CV). Siderophile abundances are all within 7% of those in mean CV chondrites, whereas that of Se is slightly high. Ningqiang differs from normal CV chondrites in its abundance of refractory lithophiles, but we require a replicate analysis to determine if Ningqiang is truly anomalous.

Aggregational chondrules, similar to those in Mokoia [5], are the most abundant chondrule type in Ningqiang. They range from 350-2100 μm in apparent diameter and have amorphous, irregular morphologies. They contain heterogeneous olivine (Fol-35) and low-Ca clinopyroxene (Fs1-7,Wol-3) as well as abundant metal, sulfide and magnetite. Although these chondrules resemble coarse-grained chondrule rims, they have more magnesian and more heterogeneous olivines and lack discontinuous sulfide rings. It is unlikely for two reasons that aggregation of materials residing in the Ningqiang regolith could have formed these chondrules: (1) magnetite is more abundant in the aggregational chondrules, than in the matrix, and (2) abrasion in
a regolith would not tend to give the chondrules amorphous shapes. Because many igneous chondrules contain magnetite-metal-sulfide assemblages identical to those in the aggregational chondrules, it seems likely that both types of chondrule formed in the same environment.

Aggregational chondrules may have formed in the solar nebula by the incipient melting of fine-grained aggregates. If the chondrule-generating heat-source was weak at the time and place Ningqiang formed, this could also account for the scarcity of coarse-grained chondrule rims (which surround only ~5% of the chondrules in Ningqiang). Although material may have accreted around chondrules, incomplete sintering would have enabled the material to more easily flake off during agglomeration.

Ningqiang also contains 0.2 vol.% of some curious objects that we designate granoblastic chondrules. These rare objects contain 100-200-μm-diameter subhedral olivine grains (some with curved outlines) that form ~120° triple junctures. No mesostasis is present. Chondrule outlines are rounded but not smooth (i.e., they appear to be abraded fragments rather than droplets). Olivine compositions in individual chondrules are moderately homogeneous, e.g., Fa2.2±1.2 in one chondrule. The high abundance and high calcium content (0.35 wt.% CaO) of olivine in these chondrules are consistent with their derivation from common PO or POP chondrules. We have observed PO chondrules in Ornans (C03) with mesostasis-poor regions containing olivines with 120° triple junctures. It seems likely that abraded fragments of such chondrules may be the source of at least some granoblastic chondrules.