MINERALOGIC AND PETROLOGIC STUDY OF THE LOW-TEMPERATURE MINERALS IN CARBONACEOUS CHRONDRITES

GRANT NSG 7132

Final Report

Principal Investigator

Dr. John A. Wood

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Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

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and the Harvard College Observatory
are members of the
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"Mineralogic and petrologic study of the low-temperature minerals in carbonaceous chondrites"

With the support of grant NSG 7132, "Mineralogic and petrologic study of the low-temperature minerals in carbonaceous chondrites," McSween, Richardson, and Wood have investigated a number of chemical and mineralogical problems in the carbonaceous chondrites. We have attempted to place all of our studies, from those of low-temperature phases in matrix and in fracture-fillings to those of high-temperature chondrules and inclusions, into a framework which allows us to model chemical processes in the early solar nebula.

The type I carbonaceous chondrites are characterized by a network of narrow mineralized fractures, which have long been known to contain hydrated magnesium sulfate. One phase of the work supported by this grant involved a study of the individual mineral species in these veins, in an attempt to understand the mineral deposition sequence and the effect on the late-stage chemical environment on the meteorite parent body. Samples and petrographic thin sections of the Orgueil, Ivuna, and Alais chondrites were examined by optical, x-ray, and SEM techniques. Mineral species identified as primary vein constituents were epsomite ($MgSO_4.7H_2O$), gypsum ($CaSO_4.2H_2O$), and a calcium-magnesium carbonate. Relative abundances and textural relationships have suggested that fracture mineralization was a multi-stage process, with individual mineralizations closely associated with impact brecciation events. Mass balance considerations raised by observations in this study and in our subsequent investigation of carbonaceous chondrite matrix (see below) support the prevailing view that the source of the fracture-filling minerals was local. By inference they also suggest that the phyllosilicate matrix has been chemically altered and that there are probably very few "primitive" mineral phases in the "primitive" Cl chondrites. This work is currently being prepared for publication (Richardson, 1977). Some preliminary observations and modeling were reported at the 1976 Spring meeting of A.G.U. (Richardson, 1976).

During the tenure of this grant, we also undertook a broad study of the major element chemistry of carbonaceous chondrite matrices. We borrowed petrographic thin sections of 32 carbonaceous chondrites, representing all petrographic types, and performed broad beam analyses of selected areas of matrix in each by electron microprobe. Statistical interpretations of the analytical data indicate that carbonaceous chondrite matrices can be separated into chemical subgroups which correspond closely to petrographic-chemical subgroups for the bulk meteorites [i.e., Cl, C2, C3(V), C3(O)]. We also infer the presence of a dispersed Ni-S-bearing phase in C2 matrix material, and have been able to draw comparisons between our inferred phase and observed but uncharacterized phases reported in other studies. The chemical effects of metamorphism on C3(O) and C3(V) matrices were also studied in conjunction with a broader set of investigations of metamorphism in C3 meteorites (see below). Metamorphosed matrices were all shown to be depleted in magnesium relative to unmetamorphosed matrices. Consideration of our analytical data in the light of currently known isotopic, chemical, and mineralogical constraints on early solar system processes have led us to conclude that matrix is chiefly a solar system condensation product which contains a small amount of admixed interstellar dust. The results of this work were summarized at the 1976 annual meeting of the Meteoritical Society (Richardson and McSween, 1976), and have recently been accepted for publication in extended manuscript form (McSween and Richardson, 1977).

A systematic survey of the type III carbonaceous chondrites was also undertaken. The two subclasses of C3 chondrites (the Ornans and Vigarano subtypes) were surveyed and reasons for the petrographic and chemical variations observed were explored. Meteorites of the Ornans subtype constitute a metamorphic sequence (McSween, 1976, 1977a). Variations among chondrites of the Vigarano subtype are more complex; although some meteorites are slightly metamorphosed, there appear to be several previously unrecognized subgroups within this classification (McSween, 1977b).

After establishing which C3 chondrites have been altered by metamorphism, the various components which comprise the unaltered meteorites were isolated and studied individually. Matrix compositions were reported by McSween and Richardson (1977), as discussed previously. The petrographic and chemical properties of isolated olivine grains in C3 chondrites were studied by McSween (1977c), who concluded that these grains were derived from broken chondrules, and thus represented crystallization from a melt rather than condensation from a vapor. Similarities between olivine grains in C3 chondrites and those of C1 and C2 chondrites suggest a common origin.

The constraints imposed by petrographic and chemical features on the origin of chondrules and inclusions were investigated by McSween (1977d, 1977e). The bulk compositions of inclusions follow the trajectory of equilibrium condensation, and chondrule compositions in the same meteorites apparently define an extension of this trend. Chondrule compositions cannot be easily rationalized in terms of dust fusion or impact sampling models. A condensation model in which the compositional trajectory dips into the liquid stability field at a certain point is advocated. Chondrule liquids can be stabilized by altering the composition of the gas with which chondrules are in equilibrium through dust fractionation (Wood and McSween, 1976). These studies thus lead to the philosophically satisfying conclusion that all the components of C3 carbonaceous chondrites are related by a common process.

In the closing months of the grant a new project was begun, which will continue under the new meteoritic grant. The most widely used system for classifying chondritic meteorites was developed about 10 years ago by Van Schmus and Wood (1967). This system puts chondrites into a matrix determined by the composition (primarily iron content) and the metamorphic history of the meteorite. Approximately 80% of the known meteorites are chondrites, and only about half of these have been classified by the Van Schmus and Wood system. We have searched the meteorite literature, and have catalogued the known chondrites (by name; place and date of fall or find; classification and any controversy concerning the same; and possible sources of sample material for our study). In the near future this catalogue will be circulated to the international meteoritic community in an attempt to solicit additional classifications and/or material for study in this laboratory. There are many anomalous meteorites among the chondrites, and we hope that an examination of the unclassified or controversially classified chondrites will lead to additional knowledge about their formation and possible evolution.

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