ined further by gel filtration chromatography (*18*). We have shown that, when a Triton X-100 extract of rabbit reticulocytes that had been incubated with [^{125}I]-transferrin is fractionated by gel filtration, two peaks having ^{125}I activity are obtained. The first peak, corresponding to a molecular weight near 450,000, is believed to represent a complex of transferrin with its receptor, while the second peak corresponds to free transferrin (*18*). Using the same techniques, we obtained qualitatively similar results with induced and uninduced Friend cells incubated with ^{125}I-labeled mouse transferrin. However, the free transferrin peak of uninduced cells was nearly ten times larger than that of induced cells, while the 450,000-molecular-weight peak of induced cells was about five times greater. These observations suggest that transferrin receptors are present in both uninduced and induced cells, but that the receptor-transferrin complexes of uninduced cells may be more labile than those of induced cells.

On the basis of the foregoing observations, we conclude that the Friend erythroleukemic cells contain specific cell surface receptors for transferrin prior to the acquisition of hemoglobin-synthesizing capacity. We estimate that untreated Friend cells have about 130,000 binding sites per cell, whereas after treatment with dimethyl sulfoxide each cell appears to have about 250,000 sites. By comparison, rabbit reticulocytes have been estimated to contain 200,000 to 560,000 binding sites per cell (*19*) and rat reticulocytes about 190,000 sites (*20*). Lymphoma cells displayed nearly as many transferrin-binding sites as the untreated erythroleukemic cells. Whether this is a general property of lymphoid cells remains to be established; the ability of lymphocytes to bind zinc transferrin suggests that this may be the case (*21*).

The transferrin-binding capacity of erythroleukemic cells increases about threefold on the basis of cell volume, or twofold on a per cell basis, as these cells differentiate, diminish in size, and accumulate hemoglobin in the presence of dimethyl sulfoxide. Whether this increase is a result of de novo synthesis of receptors is not known. Previous studies have indicated that transferrin receptors are metabolically stable in reticulocytes and that reticulocytes may be unable to synthesize transferrin receptors (*22*). The use of the Friend erythroleukemic cells cultured in dimethyl sulfoxide may provide an opportunity to study the metabolism of these surface receptors during erythroid differentiation.

Note added in proof: Three variant erythroleukemic cell lines, unable to produce hemoglobin in response to dimethyl sulfoxide, also failed to increase transferrin-binding capacity in the presence of this agent.

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Cubanite: A New Sulfide Phase in CI Meteorites

Abstract. *Cubanite ($CuFe_2S_3$), previously unobserved in meteorites, has been discovered in two carbonaceous chondrites, Orgueil and Alais. The association of this mineral with low-copper pyrrhotite suggests that it formed in a low-temperature environment on the meteorite parent body.*

Carbonaceous meteorites in class CI (*1*) have a unique mineralogical makeup. Phases which occur in these objects include fine-grained phyllosilicate minerals (which constitute a major portion of the meteorites), carbonates, oxides, anhydrous silicates, and sulfur in three oxidation states: as elemental sulfur, sulfides, and sulfates. This assemblage of minerals, and the approximately solar element abundances reflected in the CI bulk composition, have led to considerable speculation about the environment of their formation. There are basically two schools of thought on the matter. One view (*2*) is that most of the observed minerals were produced by reaction of previously condensed solids with a cooling (below approximately 700°K) gas in the nebula. According to the second view (*3, 4*), alteration of preexisting phases on a parent body, possibly in the presence of liquid water, is responsible for the CI mineral suite. We report here the presence of a hitherto unobserved sulfide, cubanite ($CuFe_2S_3$), in two CI meteorites, Alais and Orgueil. The occurrence of this mineral, and its relationship to other phases present, may add some constraints to the discussion of conditions during the formation of these meteorites.

We first observed cubanite in the sink fraction of a methylene iodide density separate of Orgueil. In both Orgueil and Alais it exhibits a distinctive stubby prismatic habit (Fig. 1) and is easily differentiated visually from the predominant sulfide of these meteorites, pyrrhotite (*5*), which occurs as hexagonal plates. Crystal faces of the separated cubanite grains show little tarnish or corrosion, in contrast to the pyrrhotite which frequently has a frosted appearance under the binocular microscope and often exhibits pitted crystal faces at higher magnifications. Results of electron microprobe analyses of cubanite separated from both Alais and Orgueil are shown in Table 1. The mineral is stoichiometric cubanite within the precision of the analyses, and no zoning was observed. It is anisotropic in polished section.

We have not observed cubanite in situ in thin sections of either Orgueil or Alais, presumably because of its rarity, the extremely heterogeneous distribution of minerals within these meteorites, and the relatively small amount of material sampled in the sections. In spite of the high copper content of this mineral (~ 24 percent), a simple mass balance based on the number of cubanite grains recovered from samples of known weight indicates that only a few percent of the total copper is held in cubanite. Published values for the copper content of Orgueil are 149 and 330 parts per million (ppm) (separate bulk samples), and of Alais, 260 ppm (*6*). On the basis of our separates, we estimate the cubanite grain size as about 1.25×10^{-7} cm^3, corresponding to cubes 50 μm on a side. The copper concentrations cited above, if entirely due to cubanite, would require about 2000 such crystals per gram of meteorite. Even assuming only 10 percent efficiency in our mineral separation procedures, recoveries from both Alais and Orgueil indicate that cubanite crystals in this size range are at least an order of magnitude less abundant.

The observed distribution among different phases in Orgueil of elements that might be expected to behave similarly to copper does not lead to any clear-cut conclusions about the site of the remaining copper. For example, although manganese is distributed about equally between carbonates and phyllosilicates, virtually all of the nickel occurs in the phyllosilicate phases (*7*). However, although cubanite appears to be host for only a portion of the total copper in these meteorites, the fact that it contains a trace element as an essential component at ~ 24 percent (by weight) reflects the great mobility of copper and presumably also other elements.

Laboratory studies of the Cu-Fe-S system (*8*) show that above about 300°C pyrrhotite in equilibrium with cubanite contains significant copper. However, the copper content of CI pyrrhotite is below the detection limit of the microprobe, about 100 ppm. This finding suggests either that the sulfides equilibrated with each other at very low temperatures or were formed independently under similar conditions. The large grain size (up to several hundred micrometers) and euhedral morphology of both cubanite and pyrrhotite seem incompatible with a single precursor phase for both minerals; in such a case pyrrhotite-cubanite intergrowths would be expected.

Table 1. Electron microprobe data for the composition of Alais and Orgueil cubanite (in percentage by weight).

Sample	Cu	Fe	S	Total
		Orgueil		
1	23.1	41.5	36.5	101.1
2	22.8	41.7	36.7	101.2
3	23.0	41.6	35.9	100.5
4	23.6	42.3	36.5	102.4
5	22.5	41.3	35.7	99.5
6	23.1	41.3	35.8	100.2
7	23.9	41.8	36.7	102.4
8	23.0	41.3	36.7	101.0
9	23.4	41.8	36.9	102.1
10	23.9	40.7	35.5	100.1
11	23.5	41.2	36.7	101.4
12	23.3	40.6	36.9	100.8
		Alais		
1	22.9	40.6	36.5	100.0

In terrestrial occurrences cubanite generally is found in deposits considered to be of relatively high-temperature origin (*9*), such as the pyrrhotite-pentlandite deposits at Sudbury, Ontario, or the contact metamorphic deposits at Fierro, New Mexico, where it is associated with chalcopyrite and magnetite. However, in rarer instances, it is observed in lower-temperature vein deposits and cavities, as at Morro Velho, Brazil, where it occurs with dolomite and pyrrhotite. Dolomite and pyrrhotite are also associated with the CI cubanite. Terrestrial cubanite is also frequently found in oriented intergrowths with chalcopyrite. No pyrite or chalcopyrite has been observed in Orgueil or Alais.

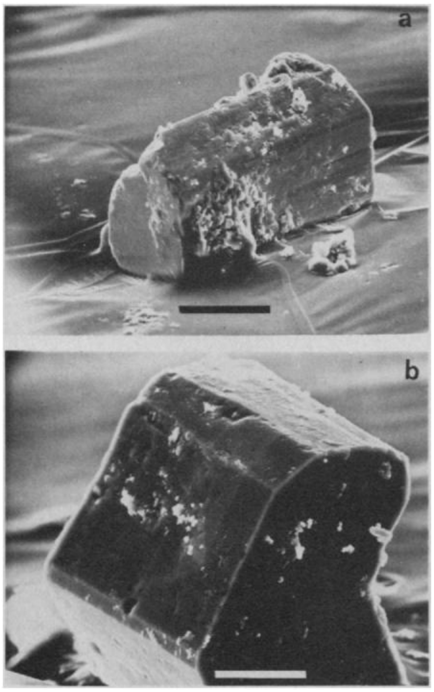

Fig. 1. Cubanite crystals observed with the scanning electron microscope. Note the uncorroded surfaces and the typical prismatic habit. (a) Crystal separated from Alais (scale bar, 45.5 μm). (b) Crystal separated from Orgueil (scale bar, 20.5 μm).

Ramdohr (*10*) has described a mineral of similar composition, "chalcopyrrhotite," from a large number of meteorites. However, it is isotropic with a sphalerite structure, unlike the cubanite we observe. In addition, chalcopyrrhotite contains up to 30 percent or more of several other elements, for example, zinc, tin, nickel, and germanium, not present in the cubanite from Orgueil and Alais (*11*).

The presence of pure cubanite in the CI meteorites, coexisting with carbonates and low-copper pyrrhotite, is suggestive of a low-temperature aqueous environment. Such conditions have been postulated by others (*3, 4*). Since the presumed parent bodies of the CI meteorites must have been relatively small in order that their breakup did not destroy the sensitive mineralogical assemblage, liquid water could not have remained for long close to the surface. Rather, an effectively sealed, closed system (*3*), driven by internal heating, must have been in operation. At some stage, a small amount of true surface-exposed material was mixed into this deeper regime, as evidenced by the presence of solar flare–irradiated olivine in both Alais and Orgueil (*12*).

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References and Notes

1. We follow here the classification scheme of J. T. Wasson [*Meteorites* (Springer-Verlag, Berlin, 1974)] in which carbonaceous meteorite types are designated CI, CM, CO, and CV. These classifications are equivalent to the previously used designations C1, C2, C3(O), and C3(V), respectively. The older scheme implies that carbonaceous meteorites constitute an extension of the petrologic sequence of the ordinary chondrites [W. R. van Schmus and J. A. Wood, *Geochim. Cosmochim. Acta* **31**, 747 (1967)], whereas in reality the intertype differences are primarily chemical in nature.

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