crease with decreasing \(^{24} \text{Mn}/^{25} \text{Mn}\) as \(^{26} \text{Mn}\) decays in the bulk of the reservoir to produce the increase in \(^{24} \text{Cr}/^{26} \text{Cr}\). The bulk reservoir would have a close to solar Mn/Cr ratio.

Orquell would form about 3.9 Ma (± 2 Ma) after Allende inclusions. The Mn-Cr system would close 6.7 Ma after inclusion formation in the parent body(s) of Murchison and Murray. In the parent body of Ka- roonda meteorite, this event would have lasted until 14 to 23 Ma after Allende inclusion formation.

With regard to the carbonate (+ sulphate?) phase in C2 and C3, it appears that the aqueous alteration occurred long after (>20 Ma) the parent body metamorphism affecting the other phases of the meteorites. The latter conclusion is in agreement with strontium isotopic data in the meteorite Orquell (3).

In conclusion, despite the uncertainties due to the experimental procedure, a coherent figure is obtained for the \(^{26} \text{Mn} - ^{26} \text{Cr}\) evolution of the carbonaceous chondrites: the data are in agreement with earlier Cr isotopic systematics derived from inclusions (2). References: (1) Rotaru M., Birck J. L. and Allegre C. J. (1990) LPSC 21, 1037. (2) Birck J. L. and Allegre C. J. (1988) Nature 331, 579. (3) MacDougall J. D. and Lugmair G. W. (1990) Meteoritics 24, 297.

Shock metamorphism and formation of accretionary dust mantles as fundamental nebula processes. A. Bischoff and K. Metzler. Institut für Planetologie, Wilhelm-Klemm-Str. 10, 4400 Münster, Germany.

Chondrites are the most important source of information about processes in the early solar system. Many carbonaceous chondrites are, however, not regarded as pristine rocks unaffected by secondary alteration processes. Concerning the history of the CM-chondrites the consensus of most petrographic studies is that the formation of phyllosilicates, for example, is basically the result of aqueous processes within meteorite parent bodies (i.e., after accretion). Virtually all chondrites are shocked to some degree. Many of their components are definitely shocked already prior to the accretion of the parent bodies. Here, we are presenting distinct features in chondrites that clearly were caused by processes prior to the parent body accretion. These indicators include the dust mantles around coarse-grained objects in CM-chondrites, textures observed in dark inclusions from Allende and impact-induced effects in various constituents of carbonaceous and ordinary chondrites.

Most CM-chondrites are fragmental or regolith breccias (1). They consist of mm-sized lithic fragments that clearly represent the freshly accreted parent body embedded in a plastic matrix. Within these fragments all coarse-grained components are rimmed by fine-grained phyllosilicate-rich dusty materials. These components include chondrules, chondrule fragments, CAIs, and mineral clasts (troilite, pentlandite, olivine, pyroxene, spinel). Fine-grained rims within the mm-sized fragments were also found surrounding PCP-rich objects and calcite. These observations indicate that PCP-rich objects and calcite had to be present prior to the aggregation of the dusty materials and prior to the parent body accretion. In the accretionary dust mantles we found fresh (unaltered) Fe,Ni-particles and olivines that should have been affected by aqueous processes on the parent body. Metzler and Bischoff (1, 2) and Metzler et al. (3) stated based on their investigations of CM-chondrites that phyllosilicates had to be already present in the solar nebula prior to the accretionary processes. Although hydration of preexisting anhydrous silicates is difficult to achieve (4), Keller and Busck (5) could demonstrate that some water-bearing minerals (micases) probably formed by gas/solid reactions in the solar nebula prior to accretion. Recently, Zolensky et al. (6) asked based on their mineralogical studies if really all of the aqueous alteration processes occurred on (or in) the meteorite parent body.

Within the dark inclusions from Allende similar textures can be studied that clearly must have been formed by accretionary processes. Larger components, primarily olivine aggregates, are rimmed by fine-grained lath-like olivine grains (compare 7).

Grossman (8) suggested that the fragmentation of many CAIs may have occurred during collisions of aggregates in the nebula. We have studied various CAIs from Allende and Arch and observed very similar effects. We identified inclusions that have lost part of the surrounding Wark-Lowering rims. We also found objects with small impact craters or inclusions that were in part heavily brecciated. These processes must have taken place after the formation of the Wark-Lowering rim and definitely prior to the parent body accretion. Collisions among objects in the nebula are also confirmed by the existence of fragmented chondrules in unbrecciated chondrites and compound chondrules, which have to be formed directly after chondrule formation (9).


In addition to shocked quartz and feldspars, K/T boundary distal ejecta deposits also contain the trace minerals zircon and chromite that display effects of shock metamorphism. Multiple planar deformation features (PDF) are usually not visible on untreated zircon surfaces, but can be revealed by etching in alkalies. Following treatments to remove other minerals, immersion in concentrated NaOH for 1½ hours at 70°C usually is sufficient to reveal multiple intersecting sets of PDF on shocked zircon surfaces. Single crystal X-ray precession camera photographs of one of the shocked grains, with μ = 0 (Laue configuration), showed extreme broadening and streaking of diffraction maxima (astematism), confirming its shocked state. Previously, investigators have reported phase changes and melting of zircons exposed to shock pressures, but have not mentioned PDF.

Chromite is another trace mineral from K/T boundary target rocks evidencing shock as PDF. We have previously shown that some chromite grains from K/T boundary claystones show PDF, and that these same grains display asterism on their Laue and non-rotated Gandolfi patterns (1). We plotted chemical compositions of both shocked and unshocked chromite grains in K/T ejecta layers from marine and non-marine sites. Chromites from the fireball layer of nonmarine sites plot as a single group, but the majority of chromite grains from marine sites plot in a different grouping, indicating that they are derived from detrital contamination; none of these detrital grains displayed PDF. The contaminant chromites in marine sites have a higher Fe and Ti content than the shocked nonmarine chromites derived from the target rocks. The spinell-group minerals from the target rock population approximate a chromite-hematite (picroite) composition, with the formula (Fe,Mg) (Cr,Al,Fe)O. This composition should be indicative of the basic and ultrabasic target rocks sampled by the impact. Reference: (1) Bohor B. F., Foord E. E. and Betterton W. J. (1989) Meteoritics 24, 233.

The K/T Impact: A Cuban Connection. Bruce F. Bohor1 and Russell Seitz.2 U.S. Geological Survey, Box 25046, MS 972, Denver, CO 80225, USA. 1Dept. of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA.

A location for the K/T impact crater has been sought for more than a decade. In the past few years, mineralogical and sedimentological data from several sources have indicated a locus south of the North American continental land mass. Recently, the reinterpretation as impact ejecta of a 50-cm layer at the K/T boundary in Haiti (1, 2), previously described as a volcanogenic turbidite, directed our attention to the Caribbean area. A search of the geological literature on the Greater Antilles revealed the presence of thick K/T boundary deposits in Cuba containing large boulders of exotic rock types and huge transported blocks of limestone. These unusual deposits had been described either as regoliths shed from the south side of the Caribbean, or derived from the southernmost olistoliths. We tentatively have interpreted these deposits as proximal continuous ejecta blankets from a large impact crater lying off the southern coast of western Cuba (3). The locus of this putative crater is some
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1350 km north of the crater site in the Colombian basin proposed by Hildebrand and Boynton (1, 2).

The geology of Cuba is extremely complex. We suggest that much of this complexity can be explained by plate tectonic modification of an impact crater and its environs. The area of Cuba was once attached to the Caribbean microplate, but now is accreted to the North American plate and can be considered part of the continent. Cuba is one of the longest islands in the world and its shape has not been well explained. We postulate that the arcuate shape of the western end of the island may represent the original uplifted rim of a crater centered near the Isle of Pines. The central and eastern portions of Cuba may also include parts of the crater rim, translocated northeastward from their original positions surrounding the crater by plate tectonic movements along the known transcurrent fault zones that have cut the eastern portion of the island into blocks (4). Jamaica also may be a translocated part of the crater rim, and may contain K/T boundary deposits similar to those on Cuba.


Inhomogeneities in the molavdites of the Southern Bohemia strewn field. V. Bouška. Faculty of Science, Charles University, Albertov 6, Praha 2, 128 43, Czechoslovakia.

The appearance and chemical composition of the molavdites which in the Badenian (Mioocene) fell in Southern Bohemia and Southwestern Moravia were not uniform. Major differences remained preserved between the molavdite localities in spite of several redepositions during the Pleistocene. The whole molavdite strewn field can be divided into three subfields. The subdivision is based on the colour distribution, maximum projection sphericity, lechatelierite content, bubble frequency, and chemical composition (Bouška, 1968, 1972; Konta, 1971): a) Molavdites from the area surrounding Radomilice (in Southern Bohemia), b) the other occurrences in Southern Bohemia, c) the Moravian molavdites.

From these subfields especially the group sub b), i.e., the other occurrences in Southern Bohemia, is quite heterogeneous. Only from this group the molavdites are rich in bubbles. The layered molavdites and/or Muong Nong type were described by Rost (1972), Glass et al. (1989), Koeberl et al. (1989) and some of them we have found between the specimens from the locality Janov. The two-coloured molavdites come mostly from this group (Bouška and Konta, 1980). All the mineral inclusions known from molavdites belong to this Southern Bohemian group—the molavdites rich in lechatelierite grains, contain magnetic spherules (Kleinnmann, 1969), there the quartz grain was identified by Barnes (1963), as well as coesite by Wisskirchen (1962), the baddelylite is known from Jakúle (Glass et al., 1989). Recently we have found the baddelylite or zircon grains in layered molavdites from Vrábce and Janov.

Delano et al. (1988) distinguished the HCa/Mg ratio molavdites with the sum of CaO + MgO equals ~8.0 wt% in this group. Then the molavdites exist here with high content of FeO (w-SiO₂, 72.67 wt%), TiO₂ 0.64, Al₂O₃ 13.94, FeO 4.33, MnO 0.09, CaO 1.92, MgO 1.95, Na₂O 0.33, K₂O 3.39; Jankov-SiO₂, 70.90 wt%, TiO₂ 0.68, Al₂O₃ 14.47, FeO 4.26, MnO 0.07, CaO 2.43, MgO 2.45, Na₂O 0.46, K₂O 3.58.


Iron meteorites are, when counted in number of events, rarer than stony meteorites, however, when counted in tons they are much more impressive. Iron meteorite falls are most uncommon, the total number on record since 1751, when Hrasschina was seen to fall in Croatia, being 35. In this number are omitted a few falls, which have been accepted by the British Museum Catalogue (e.g., Majorca and Patti), but which are rather uncertain, either because we have no reliable documentation, or because the material has been lost before it could be adequately studied. The three newest falls of iron meteorites are, as far as the author is oriented, Juromenka (1968, Portugal, 25 kg, A III), Ningbo (1975, China, 14 kg, IV A), and Akyumak (1981, Turkey, 50 kg, IV A), and Sobolimak (1990, Russia).

With this extremely limited influx of new material the research laboratory would soon be out of work, if it were not for the zeal and energy of the numerous field parties which have skimmed the Nullarbor Plain, the Campo del Cielo region and, in particular, the Antarctic Blue Ice. From the Antarctic we had two iron meteorites (Lazarev and Neptune Mountains) before the concerted effort of Japanese and U.S. sponsored field parties since the late 1970s resulted in a systematic exploration of the Blue Ice field beds. There has been a yield of about 35 new iron meteorites. The cautious "about" refers to the uncertainty about a few possible pairings.

Some of the Antarctic iron are preserved very well. Lewis Cliff (1954) is, e.g., a perfect example of the development of a button-type flight sculpture, very similar to the rimmed buttons of many Australian tektites. Other iron is less well preserved. A close study of many Antarctic irons, and of metal inclusions in the chondrites, has revealed that corrosion has taken its toll, even under these low-temperature conditions where liquid water is absent. Apparently, given sufficient time, on the order of 10,000 years (?), the iron-nickel alloys are attacked under the simultaneous influence of chlorine, oxygen and ice, forming — by solid-state diffusion—metastable akaganeite, which is theoretically Fe₆Ni₂O₁₆(OH)₂[C(OH)]. Present research shows this to be a monoclinic mineral, related to hollandite, and responsible for the aggravating and destructive corrosion that often takes place on meteorites removed to indoor conditions. Lawrencite is out, akaganeite is in.

With this information, a more realistic approach may be made to protect meteorites in storage. The chlorine was not in the meteorite from the beginning, but was introduced from the terrestrial environment in which it was lying many years before being recovered. Therefore, methods should be developed to gain access the chlorine and create the stable iron oxides, goethite and maghemite, e.g., by electrolyzing the meteorite in a soda solution, or subjecting it to slight reheating in a hydrogen plasma, applying methods similar to those already in use when protecting iridescent objects.


In November 1989 a new meteorite was brought to the attention of the Geological Museum of Copenhagen. Negotiations between the curator, Dr. P. Graaff-Petersen, and the finder, farmer Peter Jessen-Jülicher, Felsted, went smoothly and rapidly led to the acquirement of the 13.5 kg block. In December, the meteorite was cut on a reciprocating saw with a HSS blade. Two end pieces and three thin slices were produced.