by some species such as C, P, S, *etc.* A lower limit for the temperature of the reducing event is provided by Ca-zoning in ol which develops below 650 °C (Köhler *et al.*, 1991). Since strong FeO zoning in ol is absent reduction of FeO in ol should have occurred above 650 °C, assuming similar diffusion coefficients for Ca and Fe in ol.

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Boron, samarium, gadolinium, lithium and hydrogen abundances in Antarctic meteorites. Denis M. Shaw, Patti L. C. Smith and Mingzhe Zhai. Department of Geology, McMaster University, Hamilton, Ontario, Canada L8S 4M1.

The boron concentrations in 13 Antarctic meteorite specimens were published in 1988 (Shaw *et al.*, 1988). Here we report B, Sm, Gd and some H abundances in 27 additional chondrites and 14 achondrites, all measured by prompt gamma neutron activation analysis: some Li analyses are also made, using AAS.

The accuracy and precision of analysis are particularly important for B, Sm and Gd, whose abundance levels in meteorites can be 1 ppm or less, so multiple analyses of Reference Materials DTS-1, PCC-1, BHVO-1 and JG-1 were made for controls. The results showed good agreement with recommended values for B and H (expressed as H_2O); the results were good also for Sm and Gd but at concentrations $10\times$ meteorites. Precision was adequate, averaging 10 to 15 percent (1 SD) of amount present.

TABLE 1.

	B ppm	Sm ppm	Gd ppm	H_2O %	Li ppm
Mean of 6 analyses of 3 C.C.	0.93	0.36	0.39	0.94	4.3
Mean of 42 analyses of 37 CH	0.78	0.35	0.30	0.97	5.8
Mean of 7 eucrites, howardites	2.7	1.1	1.9	0.75	—

Stringent precautions against contamination were maintained during handling and analysis. Natural mobilisation of B in the Antarctic weathering environment is however known to take place (Shaw *et al.*, 1988). The results are summarised in Table 1.

The principal observations are that: (a) B and Li abundances in CH and C.C. resemble earlier estimates, (b) Sm and Gd in CH and C.C. are markedly higher than expected, (c) B, Sm and Gd are significantly higher in eucrites and howardites than in other meteorites (including aubrites, diogenites and ureilites) and (d) estimates of H_2O on individual meteorites agree quite well with published results by conventional methods.

These observations form the basis for further interpretations.

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⁶⁰Fe—Light my fire. A. Shukolyukov and G. W. Lugmair. University of California, San Diego, La Jolla, California 92093-0212, USA.

We have previously reported on the first long-sought evidence for live ^{60}Fe in the early solar system (Shukolyukov and Lugmair, 1992). ^{60}Fe decays with $T_{1/2} = 1.5$ My (Kutschera *et al.*, 1984), and forms, via ^{60}Co, the stable nuclide ^{60}Ni. The importance of the ^{60}Fe-^{60}Ni system is determined by the fact that it could serve as a sensitive chronometer for early solar system events and, if ^{60}Fe was present in sufficient amounts, as a heat source for melting and differentiation of early formed planetesimals.

To search for the presence of ^{60}Fe in the early solar system we have chosen the relatively unbrecciated eucrite Chervony Kut (CK), whose igneous origin is well established (Gooding *et al.*, 1979). Their extremely high Fe/Ni ratio clearly suggests that eucrites are the basaltic products

of planet-wide melting and differentiation and, together with an old age, are prerequisites for the detection of effects from the decay of ^{60}Fe and for the demonstration of its large scale occurrence.

The first analysis of a fine grained 'bulk' sample of CK with $^{56}Fe/^{58}Ni = 3.4 \times 10^4$ revealed a distinct and well resolved excess on ^{60}Ni of 6.6 $\pm$ 0.6 ϵ units (Shukolyukov and Lugmair, 1992). Considering several potential sources for this effect, it has been concluded that this excess is due to the decay of ^{60}Fe and represents the first clear evidence for the existence of live ^{60}Fe in the early solar system. We calculated the $^{60}Fe/^{56}Fe$ ratio at the time of Ni depletion as $\sim 7.5 \times 10^{-9}$. It was also shown that the decay of ^{60}Fe could provide considerable amounts of heat within planetesimals during the very early stages of accretion.

After this original discovery we set out to a) provide corroborating evidence from other samples of CK and b) ascertain whether ^{60}Fe was still alive at the time of solidification of CK and, if so, attempt to determine the $^{60}Fe/^{56}Fe$ ratio at that time. It was found that Ni is very heterogeneously distributed within the meteorite and may reside mainly within tiny metal grains rather than within the major mineral phases. For example, several 'bulk' samples had Ni concentrations ranging from >6 ppm down to 0.5 ppm. Mild HCl washes of Px separates contained more Ni than the actual Px fractions. Nevertheless, all samples with sufficient amounts of Ni for isotopic analysis showed excess ^{60}Ni ranging from 2 to about 14 ϵ units, clearly confirming the earlier result. However, no correlation exists between excess ^{60}Ni and Fe/Ni.

If we assume that CK represents a closed system with respect to Ni and ^{60}Fe was 'dead' at the time of solidification we should expect *the same* ^{60}Ni excess in all samples analyzed regardless of Fe/Ni, which is obviously not the case. Different ^{60}Ni excesses can be understood only if some ^{60}Fe was still alive at the time of crystallization of CK. Post-crystallization mobilization of Ni caused redistribution of Ni relative to Fe at a later time and, thus, obliterated any correlation of ^{60}Ni excesses with Fe/Ni. A metamorphic event is also indicated by earlier Rb-Sr and $^{40}Ar/^{39}Ar$ results (Wooden *et al.*, 1979). Unfortunately, the incompatibility of Ni and its mobility during metamorphic disturbances may hamper the future usefulness of the ^{60}Fe-^{60}Ni system as a chronometer.

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Evidence for changes in redox state during crystallization of Allende type B1 inclusions. S. B. Simon,[1] A. M. Davis[2] and L. Grossman.[1,2] [1]Dept. of the Geophysical Sciences, 5734 S. Ellis Avenue, The University of Chicago, Chicago, Illinois 60637, USA. [2]Enrico Fermi Institute, 5640 S. Ellis Avenue, The University of Chicago, Chicago, Illinois 60637, USA.

Because the fassaite/liquid distribution coefficient for Ti^{3+}, $D_{Ti}^{fas/l}$, is ~ 3 and $D_{Ti}^{fas/l}$ is ~ 1, Ti^{tot} ($Ti^{3+} + Ti^{4+}$) contents and Ti^{3+}/Ti^{tot} ratios in fassaite should decrease from core to rim in fassaite crystals in Type B CAIs if the residual liquid did not maintain equilibrium with the reducing, solar nebular gas. As reported previously (Simon and Grossman, 1991), such trends have been observed in fassaite crystals in Allende Type B CAIs, as have sharp increases (spikes) in Ti^{tot}, Ti^{3+}/Ti^{tot} and V near the rims of the same crystals in TS34 (Type B1). We attributed those spikes to changes in liquid composition caused by incoming of anorthite, and to reaction of the Ti^{4+} component in fassaite with anorthite (Beckett, 1986). We undertook the present study to test this theory.

The Ti^{3+}-rich fassaite overgrowths are discernible in backscattered electron images because of their higher Ti^{tot} relative to their Ti^{tot}-poor fassaite substrates. We found such fassaite in two more CAIs, TS23 and TS33. The boundaries between Ti^{3+}-poor and Ti^{3+}-rich fassaite are sharp and irregular, scalloped or embayed. We conducted electron probe traverses (~ 3 μm between analysis spots) and coarser ion probe traverses across the spikes. If the spikes were caused by anorthite crystallization we would expect to see, in the fassaite, sharp increases in elements that are compatible in fassaite and incompatible in anorthite (*e.g.*, Ti^{tot}, V, Sc).

The results do not support the previous conclusions of Simon and Grossman (1991): we do not see evidence of the incoming of anorthite.

Calculations which take into account the different fassaite/liquid Ds for Ti^{3+} and Ti^{4+} show little or no increase in the Ti^{tot} contents of the liquids in TS33 and TS34. We observe small increases or continued decreases in Sc, and ion probe data across nine spikes reveal none of the changes that would be consistent with anorthite crystallization, e.g., increased Sm/Eu, sharp increases in trivalent REE content. Because the only elements which consistently show spikes, Ti and V, are also the only elements in fassaite with multiple oxidation states at the range of T-f_{O_2} conditions under which refractory inclusions crystallized (Beckett, 1986), we now believe that the spikes reflect redox reactions which increased the Ti^{3+} and V^{3+} contents of the residual liquids.

Gradual decreases in Ti^{3+}/Ti^{tot} from core to rim in fassaite in TS33 and TS34 and before the spikes in TS23 indicate that the residual liquids did not reequilibrate with the reducing, solar nebular gas throughout most of the interval of fassaite crystallization. Late reequilibration, perhaps by entry of the solar gas via cracks in the cooling CAI, would increase the Ti^{3+}/Ti^{tot} of the liquid. The Ti^{3+}-poor rims of fassaite crystals would then be out of equilibrium with the liquid. Resorption of the rims may have occurred, followed by deposition of relatively Ti^{3+}-rich fassaite. This is consistent with the observations of sharp, irregular low-Ti/high-Ti boundaries.

Of the V species presumed to be present in the CAIs, V^{3+} should be favored in fassaite over V^{2+}, based on its ionic radius. Increasing the V^{3+} content of the liquid is a problem, however, because this requires oxidation of V^{2+} when Ti is being reduced. Perhaps, prior to reequilibration, the internal f_{O_2} of the inclusions became high enough to stabilize V^{4+}, which was reduced to V^{3+}.

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Characteristics of impact diamonds. R. Skála[1] and V. J. Bouška.[2] [1]National Museum, Václavské nám. 68, Praha, Czechoslovakia. [2]Faculty of Science, Charles University, Albertov 6, Praha, Czechoslovakia.

Having studied two Czech diamonds in UV light ($\lambda = 366$ nm), they appeared an extraordinary dirty orange color (Bouška and Skála, 1992), the same as in the case of Popigai and ureilites impact diamonds (ID) (Masaitis et al., 1990). There is evident a thatch-like shaped surface on SEM images of them which is very similar to that of the Abee chondrite (Russell et al., 1991). Commonly, the ID contain microscopic black plates which are formed by graphite or a carbon matter with indefinite structure, and they are always associated with hexagonal moissanite (Masaitis et al., 1990; Bauer et al., 1963). One unexplained fact is connected with a fabric of the ID aggregates, i.e., both Czech diamonds are single crystals; otherwise other ID form polycrystalline strongly textured aggregates.

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Hydrogen and oxygen isotope exchange in hydrated carbonates from an H-5 chondrite: Clues to the formation of weathering products on LEW85320. R. A. Socki,[1] C. S. Romanek,[2] E. K. Gibson, Jr.[2] and J. H. Allton.[1] [1]LESC and [2]SN4, NASA-JSC, Houston, Texas 77058, USA.

Terrestrial weathering is an important process that can significantly alter the elemental and isotopic character of meteorites (e.g., Socki et al., 1991). Jull et al. (1988) demonstrated that alteration and subsequent formation of the hydrated Mg-carbonates, nesquehonite and hydromagnesite, can occur in geologically short time frames (<40 A). Karlsson et al. (1991) showed that a large portion of the carbonate material in seven Antarctic meteorites either underwent extensive isotopic exchange with atmospheric CO_2 or formed recently in the Antarctic environment. To further constrain the effects of terrestrial weathering on Antarctic meteorites, we have characterized isotopic exchange equilibria

for the hydrated Mg-carbonate nesquehonite [$Mg(HCO_3 \cdot OH) \cdot 2H_2O$]. To this end, mineralogically-pure nesquehonite was grown from fixed-temperature solutions under controlled isotopic composition to monitor the partitioning of hydrogen and oxygen isotopes during the growth of the solid phase. These results are used to interpret the isotopic composition of water extracted from nesquehonite occurring on the surface of LEW85320.

Following the procedures of Ming and Franklin (1985), mineralogically-pure nesquehonite was synthesized at 10 °C and 25 °C from solutions of constant hydrogen and oxygen isotopic composition. After filtration, the mineralogy of oven-dried precipitate was confirmed by X-ray diffraction (XRD) to be pure nesquehonite. Differential scanning calorimetry (DSC) heating curves from the synthetic product match those of the salt scraped from LEW85320. This salt was identified by XRD as nesquehonite by Gooding et al. (1988). Approximately 250 μl of water was extracted from synthetic nesquehonite by cryogenic trapping during heating of the solid to 625 °C in vacuum. The $\delta^{18}O$ of extracted water was determined following the procedure of Socki et al. (1992). A second water extraction was condensed into a pyrex tube containing zinc. The tube was heated to 450 °C for one half hour, and the resultant H_2 was analyzed for D/H. Solution water was also analyzed for hydrogen and oxygen isotopes. Hydrogen isotope data for water extracted from synthetically grown nesquehonite (−29‰ SMOW) is virtually identical to the isotopic composition of the precipitating solution at both 10 °C and 25 °C, suggesting that structural water can be used as a proxy for the ambient solution in which the hydrated carbonate formed.

This observation has important ramifications for the study of meteorites and associated weathering products. For example, debate exists as to the processes responsible for the isotopic modification of solution water which formed nesquehonite on LEW85320 (Gooding et al., 1988). Grady et al. (1989) suggest that nesquehonite formed from a water enriched in ^{18}O (−17‰) compared with the ambient environment (~ −30‰). This ^{18}O-enriched water cannot be generated in the Antarctic environment without significant exchange of oxygen with silicates in underlying bedrock, or by extensive evaporation of ambient waters. D/H isotopes, extracted from the hydration water of alteration products, can be used to distinguish between these two processes as they relate to the origin of weathering products on Antarctic meteorites.

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Chemical composition of carbonaceous chondrites from Sahara and Null-arbor Plains. B. Spettel,[1] H. Palme,[1] F. Wlotzka[1] and A. Bischoff.[2] [1]Max-Planck-Institut für Chemie, Saarstrasse 23, D-6500 Mainz. [2]Institut für Planetologie, Universität Münster, 4400 Münster.

A comparatively large number of carbonaceous chondrites was recovered from Antarctica and the African and Australian deserts during the last years. Selected elements (INAA) of ten carbonaceous chondrites from Sahara and Nullarbor Plains are listed in Table 1. Data on Allende and two ordinary chondrites from desert areas are given for comparison. Petrologic information on Acfer carbonaceous chondrites of types 2 and 3 is given by Geiger and Bischoff (1992).

The distinction between ordinary and carbonaceous chondrites is not in all cases easy. Petrological indicators include higher matrix/chondrule ratios and the presence of Ca, Al-inclusions in the carbonaceous chondrites. Chemical differences involve: Lower contents of refractory elements in ordinary chondrites. Higher concentrations of some moderately volatile elements (Na, K, Mn and Au) in ordinary chondrites. As