

large bulk heavy isotope enrichments of 3–13‰ [3].

Volatile depletion is a feature of the bulk composition of chondrites, achondrites, and planets, and so reflects a process that has occurred on a scale of the inner solar system. Since partial devolatilization can be eliminated as a possible cause, it is required that a substantial fraction of presolar condensed matter accreting to the nebular disk must have been heated to temperatures ≤ 1200 – 1400 K on comparable scales. This is consistent with models of the nebular disk that attain temperatures “thermostatically regulated” by the condensation of Fe-Ni grains [4]. It should be noted that such models do not destroy all presolar dust, and allow for thermal heterogeneity [5] and the survival of isotopic anomalies and presolar grains. It cannot be claimed that there are no instances of volatilization of moderately volatile elements, just that these cannot constitute a mass fraction of chondrites sufficient to control the chemical composition. Thus, the observed chemical compositions of chondrites and other solar system materials must be attributed to incomplete condensation of volatile elements from an initially hot solar nebula [4,6].

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NITROGEN ISOTOPES IN SILICON CARBIDE: STELLAR NUCLEOSYNTHESIS? G. R. Huss, R. H. Nichols Jr., and G. J. Wasserburg, Lunatic Asylum, Division of Geological and Planetary Sciences, Mail Stop 170-25, California Institute of Technology, Pasadena CA 91125, USA.

Nitrogen in presolar SiC varies over a wide range of concentrations and is typically ^{14}N -rich relative to solar N, consistent with ^{15}N being consumed during CNO processing in stellar envelopes [e.g., 1]. Although C is also heavily processed in the envelopes [1], no clear isotopic correlation exists between C and N [e.g., 2], making N compositions difficult to interpret. Although the same general N features are seen in SiC from many meteorites, clear differences between meteorites have also been observed. In particular, Murchison SiC appears to have systematically higher $^{15}\text{N}/^{14}\text{N}$ ratios than Orgueil SiC [2,3]. Among ^{15}N -poor SiC grains for both meteorites, $^{15}\text{N}/^{14}\text{N}$ and $^{28}\text{Si}/^{14}\text{N}$ exhibit a positive correlation (Fig. 1). This indicates that a ^{15}N -

rich component has been added in roughly constant abundance (relative to Si), affecting the low-N grains most. The slope of the line bounding the field of Murchison SiC data is $\sim 10\times$ greater than that for Orgueil SiC (Fig. 1), implying that Murchison grains carry on average $\sim 10\times$ more of the ^{15}N -rich component.

If both meteorites sampled the same presolar SiC reservoir, as indicated by isotope systematics of other elements [3], then the ^{15}N -rich component could not have been acquired at the stellar source or in interstellar space. Spallation in the early solar system can also be excluded. Although the pre-compaction exposure age for Murchison (≥ 145 Ma [4]) is considerably longer than the total exposure history of Orgueil (~ 25 Ma [5]), ^{15}N production rates [6] are 500 – $2000\times$ too low to explain the data. A more likely scenario is that terrestrial N ($^{15}\text{N}/^{14}\text{N} \approx 0.0037$) has been acquired by the grains during sample processing. Measured $^{15}\text{N}/^{14}\text{N}$ ratios seldom exceed that of terrestrial N (Fig. 1). A minimum of $\sim 2.5 \times 10^{-5}$ atoms of $^{14}\text{N}_{\text{terr}}$ per ^{28}Si atom (0.01%–0.1% of the ^{14}N in a grain) is required to produce the correlation observed for Orgueil; $\geq 10\times$ more is required for Murchison. Systematic differences between SiC grain-size fractions in Murchison SiC (Fig. 1) may reflect different processing histories [2]. Also, aggregates of tiny SiC grains, which have very large surface areas, exhibit higher $^{15}\text{N}/^{14}\text{N}$ ratios than single grains.

Do measured $^{15}\text{N}/^{14}\text{N}$ ratios reveal anything about N in the stellar sources? The lowest measured $^{15}\text{N}/^{14}\text{N}$ ratios in SiC from Orgueil, Murchison, Semarkona, and Qingzhen lie between 0.0001 and 0.0002, and the lines bounding the data fields on Fig. 1 intersect the ordinate at ~ 0.0001 . This suggests that the intrinsic $^{15}\text{N}/^{14}\text{N}$ ratios in the most ^{15}N -poor grains is ~ 0.0001 , very close to the predicted ratio for the stellar envelope [e.g., 1]. Grains with $^{15}\text{N}/^{14}\text{N}$ ratios higher than solar and grains with moderate ^{15}N depletions, but very high N abundance, probably also reflect the stellar source.

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A SURVEY OF LARGE SILICATE OBJECTS IN ORDINARY CHONDRITES. R. Hutchison and J. C. Bridges, Mineralogy Department, Natural History Museum, London SW7 5BD, UK.

We present the results of a survey of large silicate objects in ordinary chondrites (OCs) from the collection of the Natural History Museum, London; 390 H group, 386 L group, and 57 LL group meteorites were examined. A total of 61 objects were identified (Table 1). Meteorites with light and dark, brecciated fabrics were excluded from our survey. Following Weisberg et al. [1], large silicate objects are taken to be $\geq 5\text{mm}$ in size. Macrochondrules have rounded outlines and textures—porphyritic, barred olivine, radiating pyroxene—that are indistinguishable from normal chondrules in OCs [1]. In addition, we also recognize igneous clasts and chondritic clasts. The largest macrochondrule in the collection is 4 cm in diameter, with a microporphyritic texture [2]. Igneous clasts are those objects whose properties indicate that they originated through melting and differentiation on a planetary body. Examples include a 2-cm-diameter clast in Ness County (L6), that contains large (2-mm) olivine and enstatite grains set in a plagioclase + olivine groundmass, cristobalite- and tridymite-rich clasts [3], and the FELINE feldspar-nepheline clast [4]. Chondritic clasts comprise a diverse group including a 1-cm clast from Barwell (L6) that contains apparently remelted chondrules, microporphyritic clasts with K-rich mesostasis, e.g., in Quenggouk (H4), and a 1-cm single olivine grain with minor inclusions of anorthite and enstatite in Julesburg (L3). The K-rich objects are similar to others described from a survey of LL chondrites and may have an impact origin or have undergone exchange with a K-rich vapor [5].

Abundances of the three types of large silicate objects (Table 1) reflect the relative numbers of H, L, and LL meteorite samples in the collection, although LL-group-hosted clasts are overrepresented as our work concentrated on sections of LL chondrites. In total, 46% of the objects are

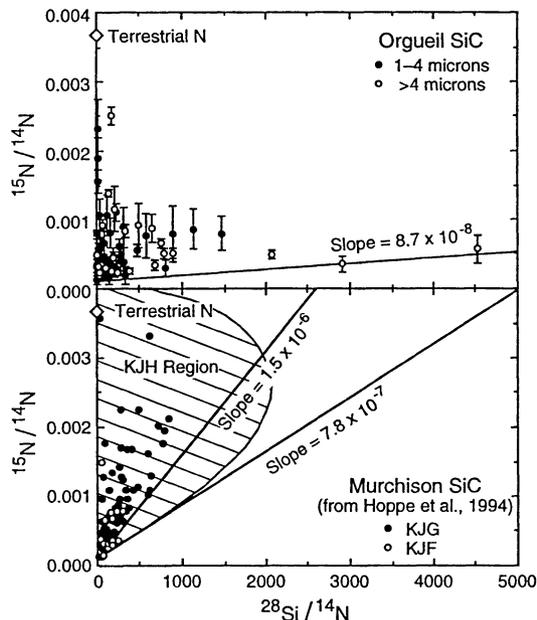


Fig. 1.

TABLE 1. Large silicate objects in the OCs studied.

Host	Macrochond.		Igneous		Chond. Clast 5		Total	
	No.	%	No.	%	No.	%	No.	%
H	7	25	0	0	7	32	14	23
L	15	54	2	18	11	50	28	46
LL	6	21	9	82	4	18	19	31
Total	28	100	11	100	22	100	61	100

macrochondrules, 18% are igneous clasts, and 36% are in the indeterminate chondritic clast group. All three types of object occur in petrographic types 3–6, but none was found in H3 meteorites. Mineral compositions in large silicate objects in hosts of petrographic types 4–6 are usually equilibrated, although enstatite in H4-hosted samples and the cristobalite-rich igneous clasts from Farmington (L5) [3, 6] are exceptions to this. Clasts and chondrules from the same host meteorite sometimes belong to different shock stages.

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SHOCK EFFECTS IN OLIVINE FROM MOCS CHONDRITE.

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The Mocs (syn. Moci) meteorite, classified as L6 chondrite by Van Schmus and Wood [1] and recently reclassified as L5-6 by Miura et al. [2], fell on February 3, 1882, 16.00 hr, over a large area (15 km × 3 km) in Transylvania (Cluj District). Olivine from six fragments of the Mocs chondrite was analyzed by optical microscopy, scanning electron microscopy with energy dispersive X-ray analysis, and X-ray powder diffractometry. Olivine occurs as grains in matrix or chondrules: barred olivine chondrules, composed of parallel sets of prismatic olivine crystals and devitrified glass and porphyritic olivine chondrules, which consist mainly of fine-grained olivine crystals and glassy materials of feldspar composition. In order to determine the mineralogical and chemical effects of shock metamorphism (induced by collisions in space of the Mocs chondrite parent body), in every thin section, 10–20 of the largest, randomly distributed olivine single crystals were examined by optical polarizing microscope with 20× or 40× objectives [3] and with a JEOL JSM-5400 scanning electron microscope for higher magnifications. The mineralogical effects observed are undulatory extinction, irregular fractures, planar fractures, mosaicism, and planar deformation features. These, correlated with the presence of small amounts of maskelynite (An_{12–19}), indicate that the maximum shock degree this meteorite experienced was S-5 [3]. The quantitative chemical analysis of 77 olivine grains in matrix from all thin sections [6], determined by a JEOL JSM-5400 scanning electron microscope with JED 2001 energy dispersive X-ray analysis at the Yamaguchi University, shows a variation in composition from Fa₂₃ to Fa₂₇ mol% fayalite (avg. Fa₂₅; PMD 2.3%), indicative of the L group. The Fayalite content of olivine from chondrules ranges from Fa₂₃ to Fa₂₇ (avg. Fa₂₅; PMD 1.74%). According to Deer et al. [4], olivine composition can be measured also by X-ray powder diffractometry as Fa (mol%) = 100 – (4233.91 – 1494.59 × δ¹³O). By using a RIGAKU computer-assisted diffractometer (radiation Cu Kα = 1.54059) at the Yamaguchi University, the δ¹³O value of olivine from Mocs meteorite was calculated as 2.781 ‰ and the fayalite content as Fa₂₃ mol% fayalite (forsterite-ferroan as of IMA files, 1993) consistent also with the L group. The cell parameters and density determined from the X-ray diffraction pattern are a = 4.779; b = 10.297; c = 6.032; V = 296.857, and Dx = 3.446 g/cm³.

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TITANIUM-IRON-SULFUR-BEARING COMPOUNDS IN KAIDUN.

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The Kaidun meteorite is a unique breccia that contains a set of different types of carbonaceous and enstatite chondrite clasts as well as an enstatite achondritelike clast [1, 2]. Kaidun also contains some rare and new minerals, e.g., Ti-Fe and Cr-Fe phosphides [3]. Here we present the results of a study of Ti-Fe-S-bearing compounds that were found in the polished section of fragment #53.09.

The main part of the fragment is a carbonaceous C1-2 breccia that also contains large grains of enstatite, forsterite, and olivines. Grains of metal (Si < 0.1 wt%) are also present. No opaque minerals that can be apparently connected with E meteorites were found in the section.

Titanium-iron-sulfur-bearing compounds are present as rare, discrete, anhedral grains up to 50 μm in maximum dimension. The grains have a stripped structure and consist of subparallel thin (up to a few micrometers) light (LB) and dark (DB) bars. IDX data show a high O content in DB and only a small O content in LB. The compositions of LB and DB are variable; the representative compositions (average of four analyses for each, wt%) are presented below in elementary (LB) and oxidized (DB) forms in accordance with IDX data. LB: S 36.7, Ti 33.7, Cr 2.0, Fe 14.7, Mg 0.1, Na 0.3, total 87.8. DB: SO₃ 36.9, TiO₂ 41.6, Cr₂O₃ 2.4, FeO 14.7, MgO 1.7, Na₂O 1.1, total 98.4.

Taking into consideration the stripped structure of the grains and IDX data, we consider the LB a mixture of a certain sulfide and DB. The composition of a sulfide after subtraction of DB admixture (S 45.3, Ti 36.7, Cr 2.2, Fe 16.0) can be approximated by the formula (Fe,Cr)_{0.93}Ti_{2.17}S₄. It is very close to the formula of heideite (Fe,Cr)_{1+x}(Ti,Fe)₂S₄, the only Ti-Fe sulfide known to date, found in the Bustee aubrite [4]. Thus, this is the second finding of heideite in nature. We consider the DB to be a product of aqueous alteration of heideite. The similar Ti/Cr ratio in heideite and in its alteration product (16.7 and 15.6 respectively) may indicate that the alteration was accompanied by removal of S and Fe while Ti and Cr were stable in the process. The stripped structure of the partly altered grains may be mainly connected with a peculiarity of the primary structure of heideite.

The discovery of heideite in the Kaidun complex breccia does not appear to clarify the genesis of this mineral, which is also unclear from the thermodynamic point of view [5].

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PUCHEZH-KATUNKI IMPACT CRATER: PRELIMINARY DATA ON RECOVERED CORE BLOCK STRUCTURE.

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Previous investigations of impact crater formation mechanics show that the late stage—a transient cavity collapse in a gravity field—may be modeled with traditional rock mechanics if one ascribes very specific mechanical properties of rock in the vicinity of a crater: An effective strength of rock needs is around 30 bar [1], an effective angle of internal friction is below 5° [2]. Rock media with such properties may be called “temporary fluidized” (see the review of this hypothesis by [3]). Melosh [4, 5] suggests an acoustic (vibrational) nature to this fluidization. This model now seems to be the best