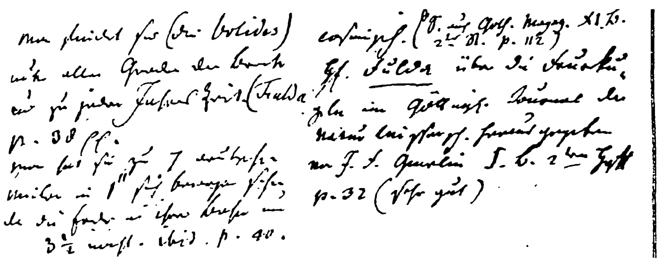

**Fig. 1.** Cut from Lichtenberg's notes concerning Fulda (with personal remark "sehr gut").

supplements the text with his extensive commentaries. Lichtenbergs' editions also document the theoretical change from a Newtonian science system into the romantic science of the early German Idealism (Schlegel).

Fortunately, Lichtenbergs' working exemplars survived three revolutions, two world wars, and one "Bücherraub" in the Forschungs-und Landesbibliothek Gotha/Thuringia [1, Fig. 1]. The recovery is described in [2]. In paragraph 758 of his working exemplar concerning the falling stars (Sternschnuppen), in the sixth edition of 1794, Lichtenberg made several notes. The date of inception can be estimated between December 1796 and May 11, 1798. These handwritten notes are the first authentical documentation of Lichtenberg's change from opposition to Chladnis theses to a moderate agreement.

Out of his handwritten notes, we can see that Lichtenberg was recommending the hard core of Chladni's extraterrestrial theory of meteorites, but was also avoiding a radical break from the Newtonian system. He consequently follows a phenomenologically stated argument, much like that of Fulda [3]. This argument structure avoids the exclusive interplanetary origin of meteorites that Chladni postulated, but also concedes the possibility of origin from lunar volcanism [4]. This ambiguity is typical of Lichtenberg ("a doctrine of scattered ocassions," states J. P. Stern).

The citation of a rare book in Lichtenberg's unpublished notes and Benzenberg [5] suggests a closer influence on the research of his students than is documented in the Briefwechsel [6]. In a retrospective view, the actions of Lichtenberg's students Fulda (1796/1798) and Benzenberg/Brandes (1798/1799) on a theoretical and empirical validation of Chaldnis theses needs to be reinterpreted.

**References:** [1] Lichtenberg G. C. (o.A. [Dez 1796?/1798]) handwritten remarks of G. C. Lichtenberg to *J. C. P. Erxleben (1794): Anfangsgründe der Naturlehre 6. Aufl.* Forschungs- und Landesbibliothek Gotha, (Sig.: N 413 Rara), 730–731. [2] Czegka W. (1997) *Abstr. Geschichte der Geowissenschaften und Recherchemöglichkeiten im deutschen Bibliothekswesen,* 24–26. [3] Fulda F. C. (1798) *Göttingsches J. Naturwissensc., 1, 2H.,* 32–49. [4] Czegka W. (1998) this volume. [5] Benzenberg (1802) *Ueber die Bestimmung der geographischen Lange durch Sternschnuppen.* [6] Joost and Schöne, eds. (1992) *G. C. Lichtenberg-Briefwechsel IV.*

**HOLOCENE METEOR CRATERS IN CENTRAL AND NORTH-EAST-CENTRAL EUROPE.** W. Czegka[1] and R. Tiirmaa[2], [1]Karlsbader Ring 7, D-68 782 Brühl, Baden, Germany (czegka@gfz-potsdam.de), [2]Technical University Tallinn, Estonia Pst 7, EE 0001 Tallinn, Estonia (vaher@gi.ee).

European Holocene impact structures are not very well known. We want to introduce the six quaternary impact craters in Europe that have already been documented and one structure that is still in discussion (Fig. 1) (the numbers shown in parentheses in the text refer to the numbets shown on Fig. 1). Four of these Holocene structures are found in Estonia (in an area of ~45,000 km$^2$). This is where, in 1927, A. Wegener, R. Meyer, and I. Reinwaldt began contemporary impact research in Europe [1]. Two of the Estonian structures are crater groups (Kaali (1) [2,3] and Ilumetsa (2) [4,5]); the others represent single craters (Tsõõrikmäe (3) [4]

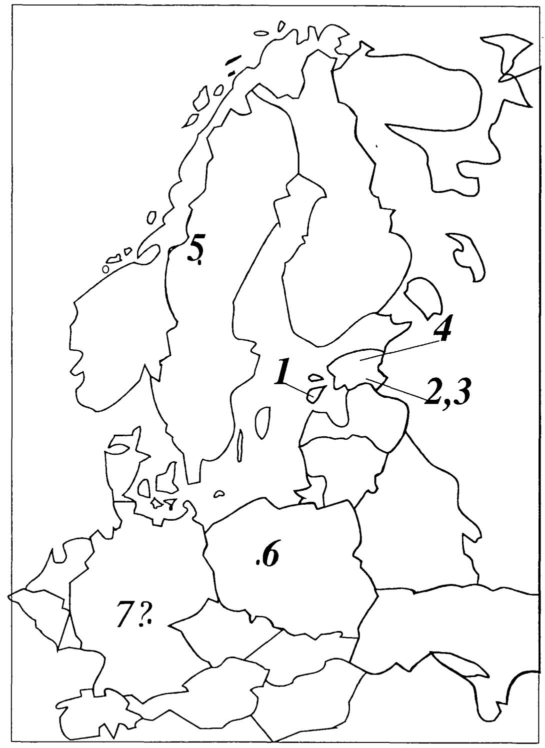


**Fig. 1.** Map of the documented Holocene impact structures in Europe (numbers are shown in parentheses in the text).

and Simuna (4) [6]). Outside Estonia, only Morasko (5) [7], near Posen/Poznan (Pl), and Tor (6) [8], near Härjedalen, Sweden, are documented. A suggested and highly possible structure in Central Germany (7) is still under investigation [9]. The differences in crater density between Estonia and the rest of the circumbaltic area is obvious. Not presented are structures that are highly doubtful, such as the Frauenburg/ Frombork [10] kettle hole in Prussia (Pl).

**References:** [1] Czegka W. (1996) *Meteoritics & Planet. Sci., 31,* A33–A34. [2] Tiirmaa R. and Czegka W. (1996) *Meteoritics & Planet. Sci., 31,* A142–A143. [3] Raukas A. et al. (1995) *Proc. Est. Akad. Sci. Geology, 44,* 178–183. [4] Pirrus E. and Tiirmaa R. (1990) *Symp. Fennoscandian Impact Structures,* pp. 51–52, Espoo Geol. Surv. Finn. [5] Czegka W. (1997) *Aufschluss, 48,* 200–210. [6] Pirrus E. and Tiirmaa R. (1991) *Eesti Loodus,* 210–214. [7] Czegka W. (1996) *Meteoritics & Planet. Sci., 31,* A34. [8] Henkel H. et al. (1997) *Tritia Geofoto 1996, 7,* 59 pp. [9] Auth R. et al. (1998) *Terra Nostra,* in press. [10] Korpikiewica H. (1980) *Meteoritics, 15,* 63–67.

**POLYTYPE VARIATIONS IN PRESOLAR SILICON CARBIDE GRAINS: MICROSTRUCTURAL CHARACTERIZATION BY TRANSMISSION ELECTRON MICROSCOPY.** T. L. Daulton[1], R. S. Lewis[2], and S. Amari[3], [1]Argonne National Laboratory, Material Science Division, Argonne IL 60439-4838, USA, [2]Enrico Fermi Institute, University of Chicago, Chicago IL 60637-1433, USA, [3]McDonnell Center for the Space Sciences, Washington University, St. Louis MO 63130-4899, USA.

**Introduction:** Microstructures produced during the formation of any material are highly dependent on both the conditions imposed during formation and the atomic-scale mechanisms of formation. Therefore, fossil microstructures of presolar grains archive valuable information concerning grain condensation mechanisms and the conditions within circumstellar grain-forming regions.

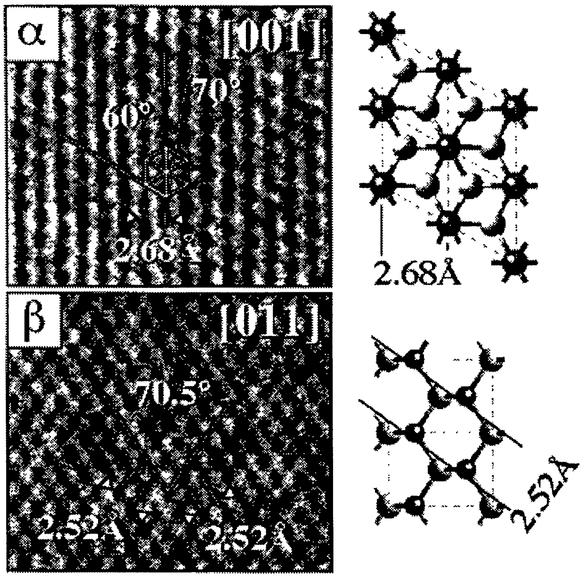


**Fig. 1.**

An important component of presolar dust is SiC, which appears to contain several distinct grain populations. For example, Si- and C-isotopic compositions of the very largest SiC grains fall into several discrete clusters [1], while the isotopic compositions of trapped N show a grain-size dependence [2].

The crystallographic structure of SiC can adopt a range of polytype forms depending on the formation conditions. A characterization of the distribution of polytypes, stacking faults, twin planes, dislocations, phase intergrowths, and morphologies of presolar SiC can place constraints on their formation parameters. These parameters include the growth rates, temperatures, and pressures at which SiC grains condense from circumstellar outflows.

In this work, the microstructures of presolar SiC grains isolated by acid dissolution from the Murchison meteorite are studied by transmission electron microscopy. Preliminary results of this study are reported here.

**Experiment:** Silicon carbide isolated in the KJ series Murchison separates are distributed between nine size fractions (KJA through KJI) [3]. Based on SEM measurements, 80% of the SiC grains are between 0.3 and 0.7 µm in diameter [3]. This corresponds to the size range in which the greatest overlap between the nine size fractions occurs. The KJB separate has been reported to contain the highest SiC abundance (1.91 ppm of the bulk meteorite), highest purity (97% SiC), and grain sizes characteristic of the total population (90% between 0.3 and 0.7 µm) [3].

In this work, the structure of (≈0.3 µm) SiC grains contained in KJB was identified by selected area diffraction and lattice imaging. A roughly equal abundance of the cubic (β) and hexagonal (α) polytypes were observed (cf. Fig. 1). Recent C- and N-isotopic analyses of individual SiC grains (mean diameter 0.67 µm) in the KJC separate revealed they are predominantly presolar in origin [4]. A similar result was found for the SiC in the KJE separate [2]. Since the SiC populations in KJB-KJE overlap significantly, our TEM observations suggests that α-SiC is also a presolar dust component. This is in contrast to earlier work on individual large grains (>2 µm), where every isotopically anomalous SiC grain whose structure was identified by Raman spectroscopy was cubic [1]. Since rapid growth has been shown to favor the cubic SiC polytype [5], the large, solely cubic SiC grains may have formed under different circumstellar conditions than those of α-SiC.

**References:** [1] Virag A. (1992) *GCA, 56,* 1715–1733. [2] Hoppe P. et al. (1996) *GCA, 60,* 883–907. [3] Amari S. et al. (1994) *GCA, 58,* 459–470. [4] Hoppe P. et al., this volume. [5] Gmelin L. (1986) *Handbook of Inorganic Chemistry,* p. 165, Springer-Verlag.

**HYDROGEN, NITROGEN, AND NEON ELEMENTAL AND ISOTOPIC CONSTRAINTS ON COMETARY AND METEORITIC FLUXES.** N. Dauphas[1], F. Robert[2], and B. Marty[1], [1]Centre de Recherches Pétrographiques et Géochimiques, Centre National de la Recherche Scientifique, Rue Notre-Dame des Pauvres, BP 20, 54501 Vandoeuvre Cedex, and École Nationale Supérieure de Géologie, Rue du doyen Marcel Roubault BP 40, 54501 Vandoeuvre Cedex, France (dauphas@crpg.cnrs-nancy.fr), [2]Laboratoire de Minéralogie, Muséum National d'Histoire Naturelle, 61 Rue Buffon, 75005 Paris, France.

The flux of matter falling on terrestrial planets was heavier in the past than at present, as shown by the lunar cratering record [1]. The late bombardment of extraterrestrial matter rich in volatiles [i.e., comets and carbonaceous chondrites, VRM (volatile rich matter)] could have contributed to the Earth's atmosphere (as a whole). Such extraterrestrial contribution would have left its isotopic fingerprint in the Earth's isotopic record (e.g., cometary water is enriched in D relative to the oceans by a factor 2 [2 and references therein]). Here, we develop an isotopic and chemical approach that allows us to estimate the flux of VRM that fell on Earth throughout its history (Md) as well as the relative fraction of comets in the VRM (f = comets/VRM).

The Earth presents an isotopic disequilibrium between the atmos-phere and the mantle; the surface reservoirs are depleted in light isotopes relative to the mantle (i.e., the $^{22}Ne/^{20}Ne$, $^{15}N/^{14}N$ are higher in the atmosphere than in the mantle [3–5]). Such disequilibrium cannot simply be accounted for by isotopic fractionation during subduction-zone metamorphism [5,6]. In addition, rare gases (e.g., Ne) are unlikely to be quantitatively recycled via subduction [7]. So far, two explanations were envisioned to account for this disequilibrium: (1) The early atmosphere (primary or secondary) endured a period of fractional loss of its volatiles, or (2) the Earth endured a period of heavy bombardment (i.e., addition of a late veneer).

Here, we assume that the Earth's isotopic disequilibrium (at least for Ne and N) arises from the late bombardment of VRM, the primitive Earth being isotopically homogeneous. In this frame, the lowest D/H [8], $^{15}N/^{14}N$ [9], and $^{22}Ne/^{20}Ne$ [3,4] ratios reported so far in the Earth's mantle could represent the primitive Earth values.

The extraterrestrial flux is in large measure composed of carbonaceous matter, as shown by the Moon trace-element pattern [10] and by the present-day asteroid-belt population [11]. Among carbonaceous chondrites, CI and CM match best the spectra of C-type asteroids [12]. At first sight, the flux of VRM that fell on the Earth throughout its history can be seen as a mixture of comets and carbonaceous chondrites (i.e., CI/CM).

Erosion of the Earth's atmosphere by impacting bodies is highly model-dependent. We will follow Walker [13] in considering that the Earth retained all incident volatiles. If we assume the Earth to be conservative, we can draw an isotopic (iE) and an elemental (iiE) mass balance for any element E (subscripts p, i, o, and c refer to the present-day Earth, the primitive Earth, comets, and carbonaceous chondrites respectively). α and β are two isotopes of E. $M_\oplus$ is the mass of the Earth. $\delta^{\beta\alpha}E_{SAMPLE} = [(^{\beta}E/^{\alpha}E)_{SAMPLE}/(^{\beta}E/^{\alpha}E)_{STD}-1] \times 1000$, $\Delta^{\beta\alpha}E_{mn} = \delta^{\beta\alpha}E_m - \delta^{\beta\alpha}E_n$. $C^{\alpha}E_m$ is the concentration of the α isotope of E in m). ($S_E$) system (unknown parameters are in bold):

$$^{(iE)}\,Md = \frac{M_\oplus.C^{\alpha}E_p.\Delta^{\beta\alpha}E_{ip}}{C^{\alpha}E_o.\Delta^{\beta\alpha}E_{io}.f + C^{\alpha}E_c.\Delta^{\beta\alpha}E_{ic}.(1-f)}$$

$$^{(iiE)}\,M_\oplus.C^{\alpha}Ei = M_\oplus.C^{\alpha}E_p - Md.(f.C^{\alpha}E_o + (1-f).C^{\alpha}E_c)(\geq 0)$$

Recent measurements of cometary D/H [2] and $^{15}N/^{14}N$ [14] ratios make it possible to solve $S_E$ system (two unknowns — f, Md — with two equations — iH, iN).

The mass (Md) of impacting bodies (VRM) that fell on Earth since 4.5 G.y. is set within ~$1 \times 10^{21}$ kg–$1 \times 10^{22}$ kg, which is in remarkably good agreement with time-integrated fluxes derived on physical grounds by Chyba [1]. In addition, the relative fraction of comets (f) cannot ex-