IMPACT HISTORIES OF INCOMPLETELY COMPACTED ORDINARY CHONDRITES FROM PETROGRAPHIC EXAMINATION AND ^{40}Ar/^{39}Ar ANALYSIS.

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Introduction: Incompletely compacted equilibrated ordinary chondrites [1,2] are chondrites that have experienced very mild degrees of impact-related compaction and shock loading. They generally possess unusually high (10-20%) porosity. More importantly, the porosity is located primarily within intragranular regions (Fig. 1), some reaching scales of several mm^3, rather than in shock-induced cracks, as is the case for well-compacted samples [3]. Previous workers [1,2] described the nature of the porosity in six incompletely compacted samples: Baszkówka (L5), Miller (Arkansas) (H5), Mount Tazerzait (L5), NWA 2380 (LL5), Sahara 98034 (H5) and Tjerebon (L5). We have also examined MIL 99301 (LL6) and identified it as having high intragranular porosity.

Sasso et al. [2] argued that these samples were not “fluffed” on the parent body, but that the porosity is a remnant of accretional and heating processes acting during the early stages of chondritic parent-body metamorphism [e.g. 4]. Herein, we investigate the impact histories of these unusual chondrites.

Methods: *2D and 3D petrographic examination.* We examined each of the chondrites in petrographic thin section to verify their shock stages according to [5]. We also examined each sample for relict petrographic indicators of shock and annealing [6-8]. Synchrotron x-ray microtomography (μCT) was previously used to examine these samples. Details of μCT results and discussion can be found in [1-3].

^{40}Ar-^{39}Ar analysis. Samples were irradiated with neutrons at the CLICIT facility at Oregon State University. Corrections for decay, reactor interferences and spallation were applied. This was followed by a correction for a trapped component when such a component could be identified from an isochron. Baszkówka and NWA 2380 showed little evidence for any trapped Ar; the trapped component was assumed to be terrestrial atmosphere for Sahara 98034, but, in almost all cases, the correction for the trapped component was minor except for the lowest-temperature extraction. The K-Ar age (based on a summation of all the extractions, with no correction for any trapped component) and our best estimate of the age of major thermal events are also given. All uncertainties cited in the text are 1 sigma.

Results: The original shock classification [5] of these samples [1,2] indicated either shock-stage S1 or S2. Our reanalysis of their shock stages indicate that they are all S1.

Relict shock indicators. All samples contain chromite veinlets in olivine and exhibit silicate darkening. All samples except Baszkówka contain chromite-plagioclase assemblages. Baszkówka and Miller contain metallic Cu. Martensite/plessite was observed only in Baszkówka. Irregular FeS in metal and polycrystalline FeS were each observed in Miller, Mount Tazerzait, Sahara 98034, and Tjerebon.

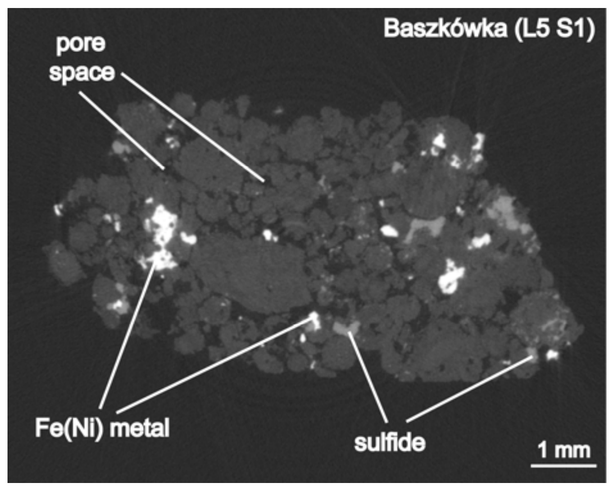

Figure 1. μCT “slice” of the Baszkówka L chondrite. The total porosity of 19.0% is primarily located within intragranular spaces indicating a very mild impact history [1,3]. Nevertheless, some relict petrographic shock indicators are apparent (see text).

^{40}Ar-^{39}Ar results. Ages for the chondrites are as follows: Baszkówka: 4526 ± 17 Ma, Miller: 4437 ± 33 Ma, Mount Tazerzait: 4372 ± 70 Ma, NWA 2380: 4481 ± 15 Ma, Sahara 9803: 4220 ± 25 Ma, Tjerebon: 4407 ±15 Ma. Except for Sahara 98034, all samples suggest that the last substantial thermal event was 4400 Ma ago or more (after uncertainties are considered). Tjerebon appears to have experienced an event at ~4400 Ma, but also seems to have suffered partial resetting <~1250 Ma ago (based on the minimum apparent age, after correction for a trapped component).

Sahara 98034 displays a release pattern indicative of partial resetting in a relatively recent (<700 Ma) event. Dixon et al. [9] examined the ^{40}Ar-^{39}Ar release profile of MIL 99301 and inferred an impact event at 4520 ± 80 Ma as well as a later impact at 4230 ± 30 Ma.

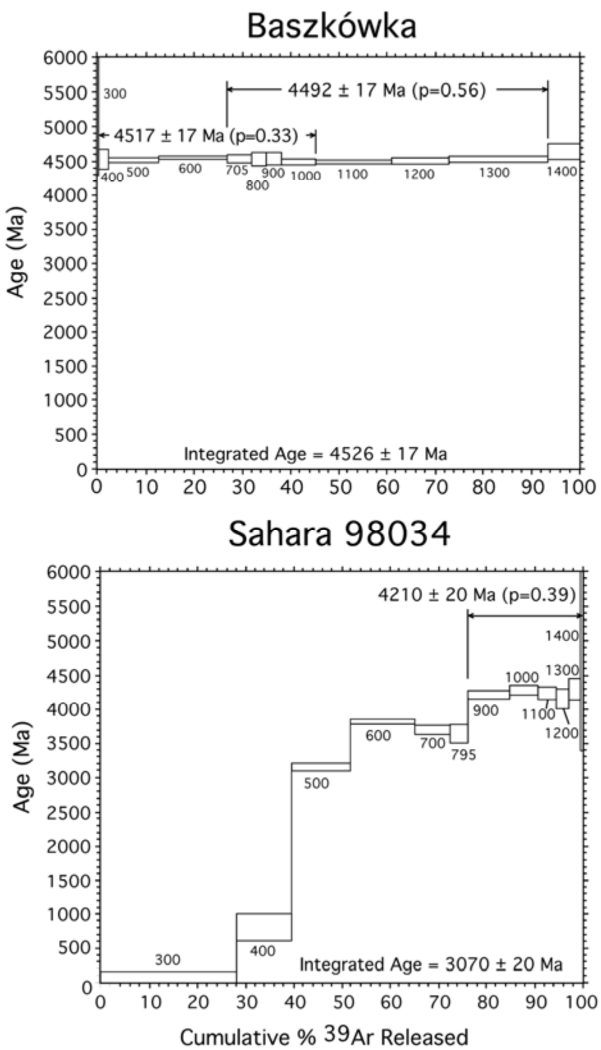

Figure 2. Release spectra for the Baszkówka and Sahara 98034 chondrites. Baszkówka has an age old enough to represent radiogenic heating, while Sahara 98034 shows resetting of the K-Ar system in a recent event (<700 Ma). Baszkówka and NWA 2380, among the least compacted and most porous chondrites studied, have ages old enough to represent radiogenic heating. In the case of these two samples, annealing of relict shock features could have been caused by radiogenic heating. Annealing of petrographic shock features in all other samples, including Sahara 98034, could have also involved impact-related heating.

Discussion and Conclusions: All of the samples investigated here show petrographic evidence for moderate shock (≥S3) followed by annealing back to the S1 shock stage. We suggest that the relict shock indicators are remnants of very early impacts on the parent body, perhaps those responsible for the compaction of the materials from a high initial porosity (>30%) to their present values. We can rely on Ar-Ar data to place some constraints on the nature of the heat source for the annealing.

Baszkówka (4526±17 Ma) and NWA 2380 (4481±15 Ma) have ^{40}Ar-^{39}Ar ages old enough to be consistent with radiogenic heating; they show no evidence for later reheating. These samples are also among the least compacted samples of the suite [1,2,3]; they have significant porosity and the largest intragranular pores.

Miller, Mount Tazerzait, Tjerebon, Sahara 98034, and MIL 99301 [9] have slightly younger plateau or total ages and provide some evidence of a more recent thermal event. They might have experienced radiogenic heating followed by impact heating, impact heating alone, or a late low-level shock event that caused minor loss of ^{40}Ar leading to lower apparent ages. Given their lack of compaction, an impact heating event that caused annealing of shock features would likely have been peripheral, such as heating by conduction by neighboring impact ejecta, but a major impact on these porous samples can be ruled out because of their incompletely compacted nature.

How can materials that have experienced such little compaction possess relict shock indicators suggesting shock stages up to S3 or higher? Impacts into initially heated materials may be one possibility [e.g. 10, 11].

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