Hydrogen isotopic composition of the Tagish Lake meteorite: comparison with other carbonaceous chondrites

Conference or Workshop Item

HYDROGEN ISOTOPIC COMPOSITION OF THE TAGISH LAKE METEORITE: COMPARISON WITH OTHER CARBONACEOUS CHONDRITES. V.K. Pearson, M.A. Sephton, I. Gilmour and I.A. Franchi, Planetary and Space Sciences Research Institute, The Open University, Milton Keynes MK7 6AA, United Kingdom. (v.k.pearson@open.ac.uk)

Introduction: Boato [1] carried out the first study on the bulk hydrogen abundance and isotopic compositions of the carbonaceous chondrites and noted that they were enriched in deuterium. The deuterium is believed to be indigenous [2], although identification of its carrier phase has proven difficult.

Boato [1] also noted variations in hydrogen isotopic compositions between chondrite groups, with the CI chondrites being appreciably more D-enriched than the CM chondrites. These variations may be attributed to the mixing and processing of hydrogen-bearing components.

This study presents data from a suite of whole rock carbonaceous chondrites, analysed for their hydrogen abundance and isotopic compositions. In addition, the Tagish Lake meteorite has also been analysed to attempt to assign it a specific chondrite group.

Methods: 44 whole-rock samples of carbonaceous chondrites, in powder or chip form were analysed. Samples of both non-Antarctic and Antarctic origin were chosen from all carbonaceous chondrite groups. Sample size varied between 7.2 and 21.9 mg, depending on the availability of the meteorite. Sampling strategy involved sub-samples of all meteorites to enable intrameteorite variations to be observed. The high number of analyses required for this were achieved by using an elemental analyser coupled to an isotope ratio mass spectrometer (Europa ANCA-SL).

Results: *Hydrogen Abundance:* Hydrogen contents for the entire data set ranged from 0.01 to 1.75 wt% (Table 1). No significant differences were observed between the hydrogen contents of non-Antarctic and Antarctic samples, although no Antarctic CI chondrites and only a single sample of one Antarctic CR and one non-Antarctic CH chondrite were analysed. Tagish Lake had a similar hydrogen abundance to the CI, CM and CR chondrites (1.37 wt%)

Hydrogen Isotopes: Isotopic compositions for the entire sample set ranged from –156.20 to +644.35‰. Antarctic chondrites are apparently more D-enriched than non-Antarctic samples. The CR chondrites studied gave gave the most D-enriched values, up to +644‰. Tagish Lake also gave a D-enriched isotopic composition of +374.18‰. No significant correlation between isotopic composition and yield was observed.

Discussion: *Intrameteorite Heterogeneity:* Subsamples of individual meteorites did, in some instances, show evidence for intrameteorite heterogeneity. In particular, Kakangari (CH), Renazzo (CR), ALH85085 (CH) and EET96286 (CV) showed variations in isotopic composition of greater than ±30‰. This intrameteorite heterogeneity has been noted in previous studies [2,3,4] and has been attributed to the various components present in the meteorites and the effects of secondary processing.

Antarctic vs. non-Antarctic: There were no obvious differences observed between Antarctic and non-Antarctic samples. This was quantified with unpaired t-test (2 tailed) statistical analyses. The null hypothesis for the t-tests was that hydrogen abundance and isotopic compositions are the same in Antarctic and non-Antarctic samples (μ_1-μ_2=0, α=0.05). It might be expected that Antarctic samples would display a more negative δD values due to the addition of terrestrial hydrogen in the Antarctic environment. However, the only possible evidence of terrestrial weathering we observed was an increase in variance in the Antarctic samples. This may reflect selective degradation during weathering of different H-bearing components.

Intrameteorite Heterogeneity: Only the CR chondrites could be fully differentiated from the other groups on the basis of their hydrogen isotopic compositions. The other chondrite groups could be placed in two regions based on hydrogen abundance: a high hydrogen region consisting of the CI and CM chondrites and a low yield region comprising all other groups. These differences were supported by statistical analyses (t-tests). All groups, with the exception of the CR chondrites have similar δD values, although the CI chondrites are marginally heavier.

Tagish Lake: The Tagish Lake meteorite displayed a hydrogen abundance similar to the CI and CM chondrites and to the CR chondrite Al Rais. Its δD value resembled that of the CR chondrites and Antarctic samples of the CV and COs. Tagish Lake is known to have fallen onto a frozen lake, which may have made it susceptible to terrestrial weathering, however, the prompt collection of the sample used for this study would presumably reduce this risk. However, no Antarctic samples display this effect leading to difficulty in establishing the extent of terrestrial weathering. It is also known to contain substantial amounts of organic matter and phyllosilicate minerals [5] known to be possible deuterium carriers.

Comparison with Carbon and Nitrogen: The majority of meteoritic C and N in carbonaceous chondrites is tied up within the organic matter, a known deuterium carrier. It would therefore be expected that these elements might show a correlation with hydrogen abundance. A good positive correlation was seen between H and C abundance, the C data being obtained through similar analytical techniques [6]. This indicates that some hydrogen is organic. δD and $\delta^{15}N$ values [6] also show a correlation. $\delta^{15}N$ enrichments are thought to be produced by ion-molecule reactions in interstellar space, a process also believed to be responsible for δD enrichments [7] However, the original $\delta^{15}N$ values may have been disturbed by secondary alteration.

Conclusions: No significant differences have been observed between whole rock Antarctic and non-Antarctic samples analysed for bulk hydrogen abundance and isotopic compositions. Intrameteorite variations are significant and may be caused by the varying distribution of H-bearing components within the meteorites and any secondary processing that may have affected them.

The Tagish Lake meteorite is similar to the CI and CM chondrites and the CR chondrite Al Rais with respect to hydrogen yield. With regards to its hydrogen isotopic composition, it resembles the CR chondrites.

References: [1] Boato G. (1954) *GCA*, 6, 209-220. [2] Becker R.H. and Epstein S. (1982) *GCA*, 46, 97-103. [3] Kerridge J.F. (1985) *GCA*, 49, 1707-1714. [4] Kolodny *et al*. (1980) *EPSL*, 46, 149-158. [5] Brown P.G. *et al*. (2000) *Science*, 290, 320-325. [6] Pearson V.K. *et al*. (2000) *LPS XXXI* , 1823. [7] Geiss J. and Bochsler P. (1982) *GCA*, 46, 529-548.

Table 1. Hydrogen abundance and isotopic compositions of a suite of carbonaceous chondrites.

METEORITE	TYPE	wt% H	δD
Allende (n=4)	CV	0.02±0.01	-31.39±18.02
Grosnaja (n=2)	CV	0.53±0.01	-24.51±0.14
Vigarano (n=2)	CV	0.32±0.02	-28.40±4.31
EET96286 (n=2)	CV	0.60±0.08	281.97±140.90
ALH84028 (n=2)	CV	0.01±0.00	-45.86±22.56
Bali (n=2)	CV	0.05±0.01	-70.46±26.46
Kaba (n=2)	CV	0.24±0.06	-66.35±50.24
Renazzo (n=2)	CR	0.43±0.26	428.77±174.97
Al Rais (n=2)	CR	1.43±0.01	644.35±31.97
EET87770 (n=2)	CR	0.47±0.08	366.60±16.48
Lance (n=2)	CO	0.28±0.02	-87.59±5.17
Colony (n=2)	CO	0.92±0.02	-54.94±24.13
Ornans (n=2)	CO	0.06±0.00	-58.11±0.68
Kainsaz (n=2)	CO	0.07±0.01	-40.20±0.52
Warrenton (n=3)	CO	0.08±0.00	-83.43±2.85
Y791717 (n=2)	CO	0.34±0.00	-49.76±2.27
FRO95002 (n=2)	CO	0.14±0.00	-70.57±0.77
ALH82101 (n=2)	CO	0.11±0.00	-78.25±5.25
ALHA77003 (n=2)	CO	0.15±0.00	-71.85±4.69
Y790112 (n=2)	CO	0.77±0.03	421.78±21.59
Mighei (n=2)	CM	1.21±0.17	-91.87±0.19
Murray (n=2)	CM	0.96±0.01	-79.29±2.51
Murchison (n=2)	CM	1.01±0.01	-53.25±2.63
Cold Bokkeveld (n=2)	CM	1.59±0.21	-91.00±12.32
Nogoya (n=2)	CM	1.59±0.08	-96.56±0.79
ALH83100 (n=2)	CM	1.60±0.03	-156.20±5.18
Y791824 (n=2)	CM	1.39±0.00	-129.91±3.08
EET83334 (n=2)	CM	1.51±0.01	-188.37±3.8
Banten (n=2)	CM	1.35±0.32	-28.52±2.88
Pollen (n=2)	CM	1.52±.0.32	-75.64±2.77
Y791198 (n=2)	CM	1.61±0.02	26.11±1.88
LEW90500 (n=2)	CM	1.73±0.01	-47.36±1.26
ALH85004 (n=2)	CM	0.36±0.09	23.14±19.39
Karoonda (n=2)	CK	0.01±0.00	-83.44±1.04
Maralinga (n=2)	CK	0.16±0.02	-82.24±3.31
Orgueil (n=2)	CI	1.62±0.08	-30.16±2.14
Alais (n=2)	CI	1.71±0.15	20.73±6.53
Ivuna (n=2)	CI	1.75±0.16	53.30±8.44
LEW87232 (n=2)	CH	0.54±0.07	-92.72±4.18
Kakangari (n=2)	CH	0.19±0.03	-69.30±43.75
ALH85085 (n=2)	CH	0.24±0.01	104.17±21.02
ALH84025 (n=2)	CH	0.07±0.01	-96.71±6.74
Coolidge (n=2)	C1	0.40±0.03	-77.02±4.93
Tagish Lake (n=2)	?	1.37±0.07	374.18±18.98