HALOGENS IN NAKHLITES: STUDIES OF PRE-TERRESTRIAL AND TERRESTRIAL WEATHERING PROCESSES. G. Dreibus, W. Huisl, B. Spettel, and R. Haubold, Max-Planck-Institut f. Chemie, P.O. BOX 3060, D-55020 Mainz, Germany, (dreibus@mpch-mainz.mpg.de).

Introduction: Nakhlites, a 1.3 Ga old subgroup of the martian meteorites, are augite and olivine cumulates from a single lithologic unit on Mars and were all ejected from the planet ~ 10.75 Ma ago. These meteorites are the only SNCs that contain iddingseite, attributed to aqueous alteration on Mars [1, 2, 3, 4]. From the 7 known nakhlites, we have analysed Nakhla, Lafayette, the paired Y-000593 and Y-000749, NWA 998 and MIL03346. We have measured halogens, C, S, and major, minor and trace elements using INAA, RNAA, a C-S analyzer and an ion selective electrode. The only observed fall of all Nakhlites is Nakhla and a terrestrial weathering is not expected. However, a terrestrial weathering of the other meteorite finds from cold and hot dessert cannot be excluded. The comparison of halogen, C and S contents with those of trace elements like La, Ba, Th and U allows us to distinguish between terrestrial and martian weathering processes.

Results: Table 1 shows the results of our measurements for halogens, S, and C in the Nakhlites. Because of the unusually high Cl and Br concentrations of Nakhla, samples from three different Nakhla specimens were analysed. Nakhla (E) was obtained from A. El Goresy, Nakhla (K) and (G) were received from Natural History Museums of Vienna and London (Dreibus, 1999).

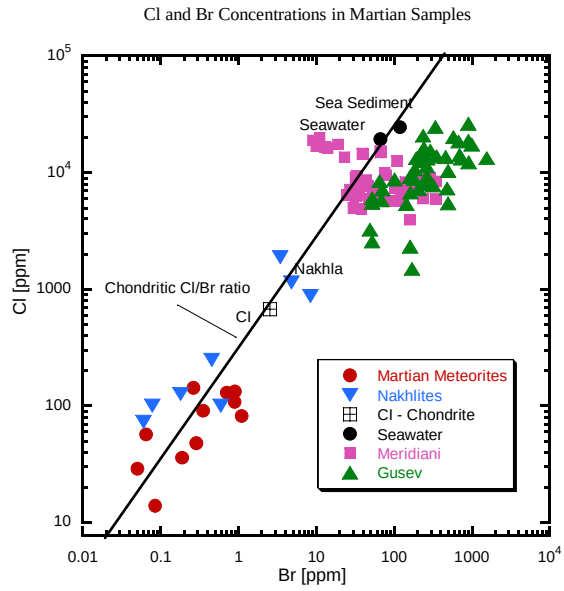
Table 1: Analytical results in ppm

Nakhlite	F	Cl	Br	I	S	C
Lafayette	74	101	0.59	0.054	340	673
Nakhla (E)	57	1890	3.46	0.017	670	696
Nakhla (K)	57	1145	4.3	<0.01	250	700
Nakhla (G)	69	876	8.45	0.026	320	270
NWA 998	88	127	0.18	0.281	230	1324
Y-000593	264*	101	0.08	0.378	280	489
Y-000749	67	73	0.060	0.682	170	305
MIL03346	147	248	0.45	1.59	610	315

Analytical uncertainty: 5 %, except 40 % for F in Y-000593.

A pre-terrestrial origin of the high Br and also unusually high Cl contents in Nakhla is debated since many years [1, 5, 6, 7]. The presence of water-soluble phases in Nakhla could suggest exposure on Mars to a solution containing high concentrations of sulphate, Cl and Br. The recent results from the MER (Mars Exploration Rover) missions reveal Br contents up to 1000 ppm in some subsurface soils and outcrops and an enrichment of Br over Cl relative to the chondritic Cl/Br ratio (Fig. 1) [8, 9, 10]. Our data in Table 1 from the three different Nakhla samples show the highest Cl and S contents in Nakhla (E). Nakhla (G), which was a sample free of crust and cut under clean conditions by the NASA Meteorite Sample Curator, has lower Cl concentration and the S content is half of Nakhla (E), but slightly more than found in Nakhla (K). Carbon in this pristine sample is also by more as a factor of 2 lower indicating a lower terrestrial contamination.

Fig. 1

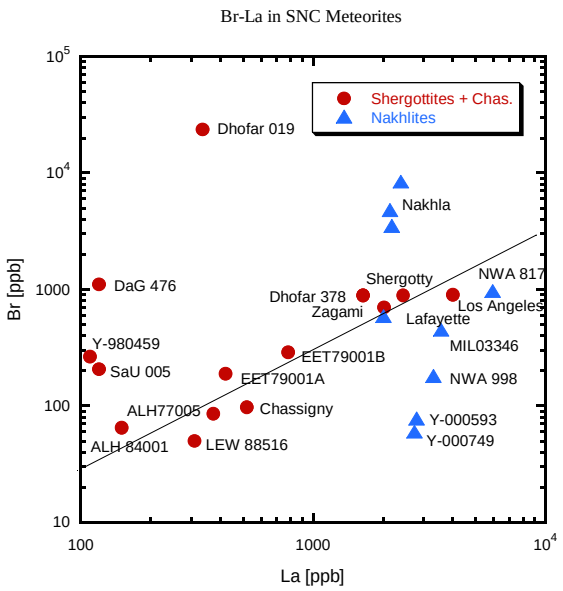


However, a part of the organic carbon in this sample is terrestrial [11, 12]. Also, the low I content of 26 ppb relative to the high Cl cannot exclude a contamination of fragments of the Nakhla meteorite shower before their recovery by salts originating from terrestrial brine. On the other hand, the enrichment of Br in the pristine sample by a factor of two as well as the substantial enhancement of Br over Cl, reported for fracture-filling aqueous alteration products in Nakhla olivine [6, 13] point to pre-terrestrial weathering processes. On Mars, an excess of Br was observed in alteration veins of the primitive olivine-rich basaltic rock, Mazatzal, in Gusev Crater [8]. High Br concentration and low Cl/Br ratio may be indicative of alteration in an aqueous martian environment. Precipitation of chlorides after reaching saturation decreases the Cl/Br ratio in residual brines [8, 13].

All other investigated Nakhlites have lower Cl and Br concentrations (Fig. 1). Except for Lafayette all other Nakhlites were collected in cold (Y-000593, Y-000749, and MIL03346) or hot (NWA998) deserts and terrestrial weathering products cannot be ruled out. All Antarctic Nakhlites have a terrestrial enrichment of iodine caused by aerosols [14]. In the hot deserts, an enrichment of I together with C in olivine-phyric shergottites was attributed to a contamination with organic material or precipitation of carbonates in cracks or veins of the meteorites. The high C content of 1324 ppm and the high Ba content of 110 ppm in NWA 998 must be referred to terrestrial weathering. Barium is probably atmospherically-derived because it is a common constituent of desert varnish, which can coat the surfaces of hot desert meteorites [15]. Uranium and Th seem to be not affected by this weathering process.

The highest Cl and S concentrations next to Nakhla were measured in MIL03346 collected in Antarctica. MIL03346 with a high portion of mesostasis contains gypsum in a similar setting [16] as found for Nakhla by Bridges and Grady [5, 17] and postulated as martian weathering product.

Fig. 2



The La versus Br plot in Fig. 2 demonstrates the deviation of Br in nakhlites from the Br-La correlation line found for shergottites and Chassigny, which are igneous rocks and experienced no terrestrial contamination. The correlation is the consequence of similar behaviour of the two incompatible elements Br and La during magmatic fractionation processes.

The deviation from the correlation line is in the case of excess Br either caused by terrestrial weathering of the individual samples in hot deserts as discussed above or derived partly from an infiltration of a Br-rich aqueous phase on Mars. The depletion of Br could be the result of an extraction of highly soluble bromine-salts by martian weathering, although a dissolution of Br during the storage in the Antarctic ice cannot completely be excluded.

Conclusion: The non-magmatic behaviour of La and Br together with the non-chondritic Cl/Br ratio found in nakhlites could originate from their contact with fluid phases on Mars, which could supply or extract Br, depending on their compositions. Especially in the case of Nakhla, an additional terrestrial contamination by halogens originating from brine seems to be plausible.

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