CHEMICAL COMPOSITION OF Y-793605, A MARTIAN LHERZOLITE

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Abstract: As a part of consortium study, we have analyzed the Yamato-793605 lherzolitic shergottite by instrumental neutron activation analysis (INAA), radio-chemical neutron activation analysis (RNAA) and inductively coupled plasma mass spectrometry (ICP-MS). For comparison, ALH 77005 was also analyzed by INAA and RNAA. Compositionally, Y-793605 is similar to ALH 77005 (and also to LEW 88516). REE abundances for Y-793605 are similar to but slightly lower than those for ALH 77005 and are characterized by a hump around Dy in the CI-normalized pattern. Iridium/Os ratios of Y-793605 and ALH 77005 are exactly chondritic, suggesting that the shergottite parent material had an approximately chondritic Ir/Os ratio. On the other hand, Ni/Co ratios of these two lherzolitic shergottites are lower than the CI value, with both elements being more abundant than refractory siderophiles such as Os and Ir. Presumably, both elements partly existed as oxides when the core formation occurred, but Ni was partitioned into the core more effectively than Co because of the higher stability of the Co oxide. Molybdenum and W are also largely fractionated in Y-793605 and ALH 77005, with Mo being more depleted than W. Apparently, segregation of W into the core was inefficient whereas Mo was more effectively incorporated into the metal-sulfide core. These observations suggest that the oxygen fugacity was considerably elevated when the core formed (at least at the latest stage of core formation).

1. Introduction

Yamato-793605 was originally classified as a diogenite, but later reclassified as a shergottite (Yanai, 1995). This meteorite is not a typical shergottite, but is grouped with lherzolitic shergottites, being similar to ALH 77005 and LEW 88516 (Mikouchi and Miyamoto, 1996). As Y-793605 is small (16 g) compared with ALH 77005 (482.5 g), a consortium study was organized under the direction of Hideyasu Kojima, Paul Warren, Masamichi Miyamoto, and Keizo Yanai. A piece weighing 209 mg was allocated for our proposed study. In order to compositionally characterize the meteorite, we analyzed the sample using instrumental neutron activation analysis (INAA) for major and trace elements, radiochemical neutron activation analysis (RNAA) for siderophile trace elements and inductively coupled plasma mass spectrometry (ICP-MS) for rare earth elements, Th and U. For comparison, ALH 77005 was also analyzed by INAA and RNAA.

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2. Analytical Procedures

The Y-793605 sample allocated for this consortium study is an aggregate of lithic fragments with black glasses (Kojima *et al.*, 1997). The black matter is estimated to comprise 11% by volume of consortium sample, which is considerably less than the average for the whole meteorite (about 30%) (Kojima *et al.*, 1997). The sample was easily crushed in an agate mortar. The roughly ground sample was then divided into two portions, 123 mg and 86 mg. The larger portion was used for NAA and the smaller portion was used for ICP-MS. Another lherzolitic shergottite, ALH 77005, was allocated by the Meteorite Working Group. Several chips weighing about 500 mg were carefully crushed and ground in an agate mortar. An aliquant of this powdered specimen (119 mg) was used for NAA.

2.1. INAA

The fraction assigned for NAA was doubly sealed in clean polyethylene bags, along with chemical standards and reference materials. The chemical standards were prepared from high-purity chemical reagents for the elements of interest. The Allende meteorite reference sample prepared by the Smithsonian Institution (split 11, position 11) and a Japanese standard rock sample, JB-1 (basalt) prepared by the Geological Survey of Japan were used as reference materials in this study. All the samples were successively irradiated twice (100 s and 6 h) at a neutron flux of 1.5×10^{12} cm^{-2}s^{-1} in a TRIGA-II reactor at the Institute for Atomic Energy, St. Paul's (Rikkyo) University. Following the short irradiation (100 s), Na, Mg, Al, Ca, Ti, V and Mn were determined. Following the long irradiation (6 h), Na, K, Sc, Cr, Fe, Co, Ni, Zn, Ga, Se, La, Ce, Sm, Eu, Tb, Yb, Lu, Hf, W, Ir and Au were determined by repeated counting over a period of 1 month. In order to correct for the contribution of ^{28}Si (n, p) ^{28}Al and ^{27}Al (n, p) ^{27}Mg to ^{28}Al and ^{27}Mg, from which Al and Mg contents are calculated, respectively, high-purity Si and Al metals were irradiated. More detailed INAA procedure is described by Kong and Ebihara (1996a).

2.2. RNAA

The same specimen used for INAA was reused for RNAA. After completion of the INAA, the shergottite samples were quantitatively transferred into clean, synthesized quartz tubes, which were then sealed. Chemical standard solutions were prepared from appropriate chemical reagents for the elements of interest. Known amounts of these solutions were successively pipetted into quartz tubes containing several tens mg of high-purity MgO as a diluting substance, which were then dried in an oven. Nine elements (Mo, Ru, Ag, W, Re, Os, Ir, Pt, Au) were to be determined by RNAA, so three sets of mixed chemical standards, each containing three elements, were prepared. The Allende reference sample (split 11, position 11) prepared by the Smithsonian Institution was used as a monitor. All samples were irradiated for 24 h at a neutron flux of 1×10^{14} cm^{-2}s^{-1} in the JRR-3 reactor at the Japan Atomic Energy Research Institute. The radiochemical procedure used in this work was similar to that described by Kong and Chai (1989).

2.3. ICP-MS

We determined rare earth elements (including Y), Th and U in Y-793605 by ICP-MS. To determine the precision of our data, duplicate analyses were performed using two different portions (31.3 mg and 40.7 mg) of the sample allocated for ICP-MS. Each sample was placed in a Teflon container and digested with HF and $HClO_4$ under high pressure. Measurements were carried out with dilution factors of 10000 and 1000. Yttrium was determined with a more highly diluted solution, whereas the remaining REE (lanthanoids) Th and U were determined at a lower dilution. A detailed description of the ICP-MS procedure is described by SHINOTSUKA and EBIHARA (1997).

3. Results

The INAA, RNAA and ICP-MS results are shown in Tables 1, 2 and 3, respectively. In general, our INAA data for ALH 77005 are in good agreement with literature values, suggesting that our INAA results are reliable. Y-793605 has an elemental abundance almost identical to that of ALH 77005, except for a few elements. Our Na and K values for Y-793606 are consistently lower than those for ALH 77005 by more than a factor of two. Actually, our K value of ALH 77005 is remarkably high compared with literature values. A high Hf abundance in ALH 77005 was also found.

Table 1. INAA results for Y-793605 and ALH 77005.

	weight mg	Na %	Mg %	Al %	K ppm	Ca %	Sc ppm	Ti %	V ppm	Cr %	Mn %	Fe %	Co ppm	Ni ppm
Y-793605	123	0.147	16.5	0.76	107	3.11	25.0	0.116	281	0.729	0.410	14.1	72.0	315
		(1.0)†	(5.3)	(3.9)	(22)	(3.7)	(1.0)	(11)	(5.4)	(1.0)	(4.2)	(1.0)	(1.0)	(1.0)
ALH 77005	119	0.435	15.1	1.16	490	2.82	21.6	0.24	132	0.652	0.387	15.8	77.7	338
		(1.0)	(5.2)	(3.7)	(11)	(4.1)	(1.0)	(10)	(5.0)	(1.0)	(3.4)	(1.0)	(1.0)	(1.0)
Literature*														
(1)		0.325	16.7	1.37	220	2.39	21.1	0.26		0.659	0.354	15.5	69.5	335
(2)		0.356	16.1	1.59	230	2.72	22	0.18	158	0.57	0.34	15.7	69	320
(3)		0.443			270	2.15	20.1			0.670	0.357	16.1	75.2	340
(4) (light)		0.220			170	2.4	22.2			0.81		14.3	67.4	320
(dark)		0.435				2.5	22.0			0.70		16.3	77	340

	Zn ppm	Ga ppm	Se ppm	La ppb	Ce ppb	Sm ppb	Eu ppb	Tb ppb	Yb ppb	Lu ppb	Hf ppb	W ppb	Ir ppb
Y-793605	67.3	6.7	<0.3	108	350	205	103	47	392	59.3	456	<280	
	(2.5)	(11)		(10)	(20)	(1.0)	(3.2)	(9.7)	(11)	(8.3)	(6.6)		
ALH 77005	60.7	9.3	0.37	614	1280	770	373	296	919	127	951		8.7
	(2.8)	(11)	(21)	(3.4)	(10)	(1.0)	(1.3)	(2.0)	(1.9)	(4.4)	(3.6)		(9.9)
Literature													
(1)	71	7.5	<0.4	320	1090	420	200	170	520	73	550	84	3.5
(2)	49	6.1	0.15	320	840	460	220	180	550	77	580		
(3)	62	8.9		490	1600	670	288	190	730	100	780		4
(4) (light)				210		290	134	130	400	55	420		6
(dark)			0.5	510	2600	630	890	200	710	99	810		3.3

†Figures in parentheses are errors due to counting statistics (in %; 1σ).
*Literature values for ALH 77005, including non-INAA values: (1) BURGHELE et al. (1983); (2) SMITH et al. (1984); (3) WÄNKE et al. (1986); (4) TREIMAN et al. (1994).

Table 2. Siderophile contents (in ppb) of Y-793605 and ALH 77005 determined by RNAA.

	Mo	W	Re	Ir	Os	Pt	Au	Ag
Y-793605	28.3	10		3.14	3.09	2.79	0.175	1.7
	(4.0)[†]	(14)		(1.0)	(2.8)	(4.3)	(1.0)	(13)
ALH 77005	47.3	38	0.197	9.11	8.98	3.84	0.342	4.0
	(2.5)	(13)	(2.7)	(1.0)	(2.1)	(7.3)	(1.0)	(10)
Literature*								
(1)			0.102	4.10	4.40		0.260	
(2)		84		3.5			0.3	

[†]Figures in parentheses are errors due to counting statistics (in %; 1σ).
*(1) RNAA values by Warren and Kallemeyn (1996); (2) NAA values by Burghele et al. (1983).

Table 3. Rare earth elements, Th and U contents (in ppb) of Y-793605 determined by ICP-MS.

	Sample (mg)	Y	La	Ce	Pr	Nd	Sm	Eu	Gd
Run 1	31.3	2280	80.4	192	36.2	226	156	71.5	338
		(1.6)[†]	(1.8)	(1.4)	(3.0)	(2.2)	(4.4)	(3.2)	(2.1)
Run 2	40.7	2790	111	244	47.0	267	175	—	397
		(0.9)	(0.9)	(2.1)	(1.4)	(1.8)	(2.7)		(2.0)

	Tb	Dy	Ho	Er	Tm	Yb	Lu	Th	U
Run 1	65.9	489	103	305	42.0	281	41.8	11.7	3.03
	(0.6)	(1.1)	(1.7)	(1.2)	(4.0)	(0.8)	(1.7)	(2.9)	(4.0)
Run 2	72.3	528	109	318	43.4	290	42.2	15.3	4.19
	(2.6)	(1.2)	(0.9)	(1.6)	(1.8)	(1.7)	(1.6)	(2.0)	(1.3)

[†]Figures in parentheses are relative standard deviation for five repeated measurements (in %; 1σ).

Possibly K-feldspar, in which Hf is also preferentially sited, is abundant in our sample of ALH 77005. Slightly but distinctly lower values of Al, Ti and Hf were also found in Y-793605.

Although duplicate analyses by ICP-MS yield highly consistent results for REE, Th and U, the data from run 1 are systematically higher than those from run 2. It appears that the difference between two runs is higher for light REE than for heavy REE. Interestingly, Th and U show a trend similar to that for the light REE. The difference in relative abundance between two runs is apparently related to ionic radius. Some REE were determined by both INAA and ICP-MS, so their values can be compared. From Tables 1 and 3, it can be seen that the ICP-MS data are systematically lower than the INAA data. Because we did not thoroughly grind the sample, it must not have been completely homogenized. Treiman et al. (1994) analyzed dark (glass-rich) and light (glass-poor) portions of ALH 77005 and found that REE are relatively enriched in the dark portion by a factor of two. Because we did not compare the relative abundance of dark and light portions between the two Y-793605 specimens

analyzed by INAA and ICP-MS, we are unable to confirm the conclusion of TREIMAN *et al.* (1994). In spite of the difference in absolute contents, both INAA and ICP-MS data yield essentially the same CI-normalized REE abundance patterns within experimental error. Few Y data have been determined in SNC meteorites. Our Y value is essentially the same as that for Ho in the CI-normalized data for Y-793605, implying that both Y and Ho behaved similarly during igneous processes (partial melting and/or fractional crystallization) on the shergottite parent body. Thorium and U do not seem to be fractionated from each other, with their CI-normalized abundances being similar to those of light to middle REE (such as Nd). Our U value for Y-793605 is 10 times smaller than literature values for shergottites (MA *et al.*, 1981; SMITH *et al.*, 1984); such a small value for U has not been found for any Martian meteorites.

Some comparable data for siderophile elements are available for ALH 77005; the Re, Ir, Os and Au values determined by WARREN and KALLEMEYN (1996) are lower than our values but the difference is systematic by a factor of 1.5 to 2, suggesting that refractory siderophile elements are heterogeneously distributed as a group in the meteorite. Indeed, a large variation in the Ir content of more than a factor of 50 was observed in Shergotty (0.0285 ppb *vs.* 1.55 ppb) (TREIMAN *et al.*, 1986; LAUL *et al.*, 1972). This difference may be due to the difference in the size of the meteorites (~5 kg for Shergotty *vs.* 482 g for ALH 77005, 17 g for Y-793605 and 13 g for LEW 88515). Our Y-793605 values are even smaller than the WARREN and KALLEMEYN data for ALH 77005, but the difference is again systematic. Because of the large contribution of ^{75}Se to the 137 keV ^{186}Re photopeak, Re could not be reliably determined for Y-793605.

4. Discussion

4.1. Similarities in the chemical compositions between Y-793605 and other lherzolitic shergottites

Let us discuss the general features of the chemical composition of Y-793605, especially in comparison with those of the other lherzolitic shergottites, ALH 77005 and LEW 88516. Elemental abundances of REE and siderophiles will be discussed later. Figure 1 shows the relative abundance of 17 elements including most major elements for Y-793605 and ALH 77005. Literature values for ALH 77005 are also plotted for comparison. As clearly observed, Na and K are largely depleted in our Y-793605 sample compared with those in ALH 77005. These elements are sited in plagioclase (maskelynite in Y-793605), implying that Y-793605 slightly lacks plagioclase. This is consistent with the observation by KOJIMA *et al.* (1997) that Y-793605 has a slightly higher pyroxene/olivine ratio and a lower maskelynite content compared with ALH 77005 (TREIMAN *et al.*, 1994). In contrast to Na and K, Al, another plagiophile element, is not similarly depleted in our sample, possibly because Al is partly distributed in chromite, which is not depleted at all in our sample, as implied by its slightly high Cr abundance. Titanium is also slightly depleted in Y-793605 compared with that in ALH 77005. As Ti is mostly sited in ilmenite in Martian lherzolites (TREIMAN *et al.*, 1994), our Y-793605 specimen must have a slightly lower modal abundance of ilmenite. Except for the aforementioned elements, both Y-793605 and
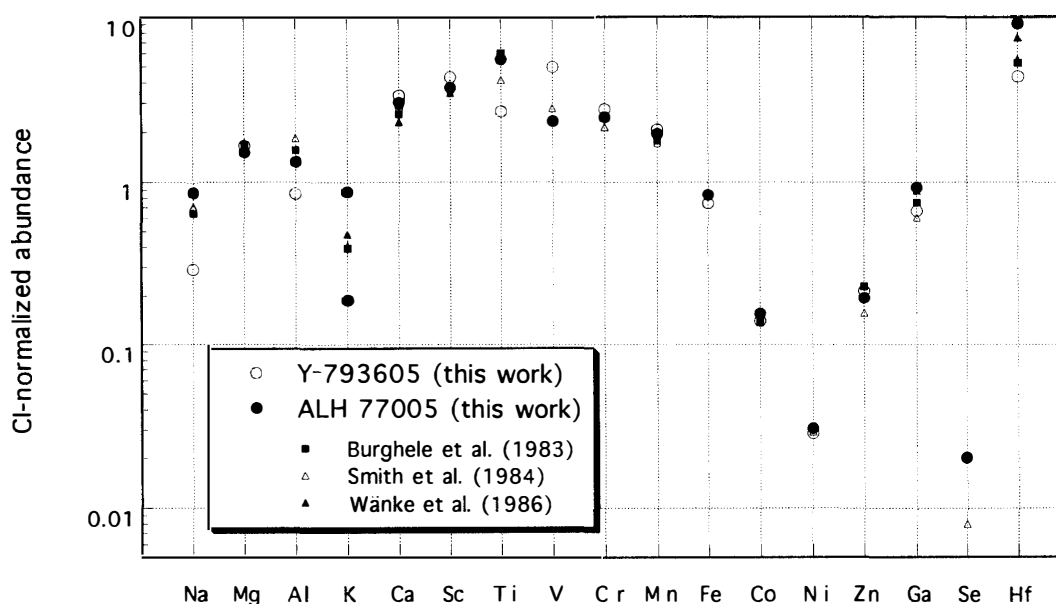
Fig. 1. CI-normalized abundances of 17 elements including most major elements for Y-793605 and ALH 77005. Literature values for ALH 77005 are also plotted for comparison. Generally, Y-793605 and ALH 77005 have essentially identical chemical compositions, suggesting a genetic link between them.

ALH 77005 have nearly identical elemental abundances as plotted in Fig. 1.

It is worth noting that Na, K and Ga (another plagiophile element; WARREN and KALLEMEYN, 1997) have very similar CI-normalized abundances in ALH 77005. Though, Al has a slightly higher abundance. As all these plagiophile elements must have behaved similarly during igneous differentiation, the slightly higher abundance of Al reflects its refractory nature. The small differences in volatility among remaining three plagiophiles caused no significant change in their relative abundances. Zinc is an order of magnitude higher in abundance than Se, which is contradictory to their relative volatility. Apparently, Se was depleted during core formation due to its chalcophile nature. As shown in Fig. 1, Co and Ni are largely fractionated relative to one another in both Y-793605 and ALH 77005. Cobalt and Ni cannot be fractionated by nebular condensation processes. Thermal processes in ordinary chondrites also cause little relative fractionation between Co and Ni (KONG and EBIHARA, 1997). Melting experiments on a metal-silicate system, however, show that Co can be fractionated from Ni, with Ni more preferably entering the metal phase; the degree of fractionation of Co and Ni is highly dependent on the oxygen fugacity involved in the melting (SCHMITT et al., 1989; HOLZHEID and PALME, 1996). The CI-normalized abundance of Ni is slightly but consistently higher than those of typical refractory siderophiles such as Os and Ir. Presumably, Ni was partitioned into silicates to a greater extent than refractory siderophiles, possibly due to a slightly elevated oxygen fugacity. This issue will be discussed later in more detail.

Both Y-793605 and ALH 77005 have a fairly high abundance of Hf. Hafnium is a typical refractory lithophile, so it tends to remain in the liquid phase during igneous fractionation processes. Although this liquid phase was partly trapped in the Y-793605

and ALH 77005 cumulates, the amount was not very high, as suggested by the deplet-ed REE abundance. LAUL et al. (1986) determined elemental abundances in separat-ed mineral phases from Shergotty and observed that Hf was enriched in a K-rich phase and in Ti-magnetite. Considering that K is depleted while Ti is enriched in these two lherzolitic shergottites, magnetite must be responsible for the high abundance of Hf (and possible V). As suggested by LAUL et al. (1986), the refractory lithophile ele-ments such as REE (especially light REE), Hf and Ti are enriched in the crust of the shergottite parent body (presumably Mars), but the degree of enrichment must be vari-able among these elements.

4.2. Detailed abundances of rare earth elements in Y-793605

In Fig. 2, REE (including Y), Th and U abundances in Y-793605 are compared with those in ALH 77005. All data for ALH 77005 are from the literature and were determined by RNAA. Our ICP-MS values for Y-773605 are systematically lower than the literature data for ALH 77005. The abundance patterns are very similar for both meteorites at a glance, but a slight systematic difference can be observed; light REE are more depleted in Y-793605 compared with those in ALH 77005, with the relative difference between two meteorites decreasing with increasing the atomic number of REE. As already pointed out, such a trend can also be found between the two ICP-MS data (or even between the ICP-MS and INAA data) obtained in this study. WADHWA et al. (1994) determined REE abundances in several constituent mineral phas-es of ALH 77005 and found that whitlockite was the most enriched in REE. WÄNKE et al. (1986) conducted a leaching experiment on the ALH 77005 meteorite and found that about 80% of the light REE and about 50% of the heavy REE were leached out
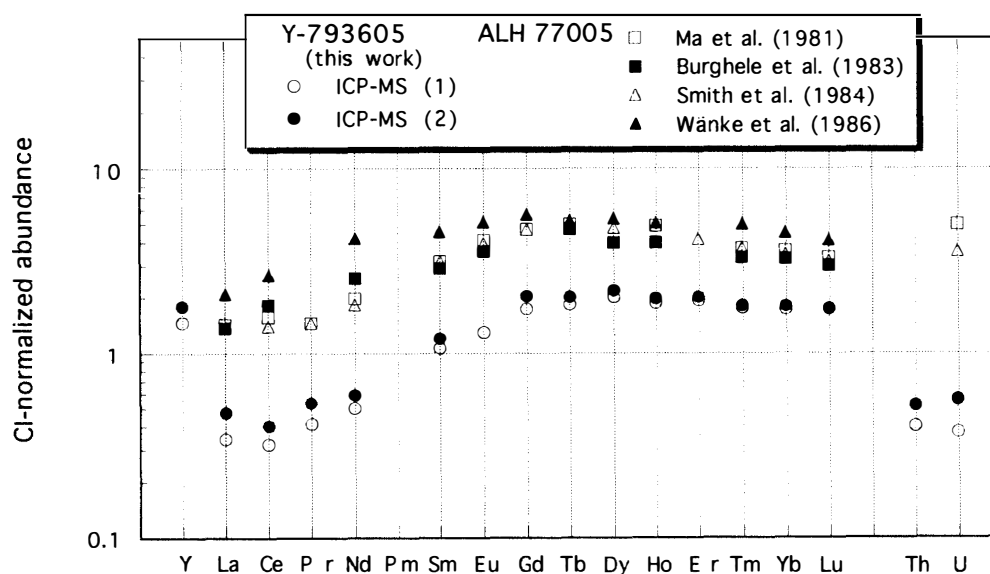

Fig. 2. CI-normalized abundances of REE, Th and U for Y-793605 determined by ICP-MS. Literature values of REE abundances for ALH 77005 are also shown for compari-son. Our ICP-MS values for Y-793605 are systematically lower than those for ALH 77005, but the abundance patterns are very similar. They are characterized by a grad-ual increase through the light REE span and a decrease through the heavy REE span.

by acid, possibly due to the selective dissolution of Ca-phosphate, mainly whitlock-ite. The lower abundance of REE and the more light REE-depleted abundance pattern obtained by our ICP-MS analysis suggest that our Y-793605 specimen used for ICP-MS was not representative of the meteorite, being enriched in cumulative mineral phas-es but poor in the trapped liquid containing Ca-phosphate (whitlockite) which carries most of the REE, Th and U. Indeed, the Y-793605 sample was not thoroughly ground before sampling in this study. Wänke et al. (1986) also noticed a heterogeneous dis-tribution of REE-containing phases in ALH 77005, which explains the fairly large variation of REE abundances in ALH 77005, as shown in Fig. 2.

Bulk samples of Y-793605 and ALH 77005 have no Eu anomaly in the CI-nor-malized REE abundance patterns. Yet, the ion probe study on ALH 77005 revealed that whitlockite has a negative Eu anomaly whereas maskelynite has a positive Eu anomaly (Harvey et al., 1993). This suggests that whitlockite and plagioclase were crystallized after the parental material for both meteorites was isolated from the par-ent magma and further suggests that plagioclase separation didn't occur in the parent magma on a large scale, from which the source material (melt) for the ALH 77005 (and also Y-793605) cumulates was produced. Rare earth and other incompatible lithophile elements were largely present in the melt phase and were mechanically trapped rather than incorporated into the cumulate phase and were partitioned into their constituent, non-cumulate minerals during the later stages of crystallization of the meteorites.

The most characteristic feature of the REE abundance patterns of Y-793605 (and of ALH 77005) is the presence of a hump in the middle to heavy REE span (around Dy for Y-793605); in the lighter REE span, the abundances increase, whereas the abun-dances decrease in the heavier REE span. Similar patterns can also be observed for other shergottites such as Zagami (Shih et al., 1982), EET 79001, Shergotty (Laul et al., 1986) and QUE 94201 (Dreibus et al., 1996) but the REE abundance for Y-793605 (and ALH 77005) is slightly different from those of the other shergottites in that the REE abundance in Y-793605 is lower and has a slightly steeper inclination in the light REE region. It may be noted that the REE abundances for LEW 88516 (Dreibus et al., 1992; Treiman et al., 1994) resembles those of Y-793605 and ALH 77005. Apparently, this difference must be related to a difference in the genesis of the lher-zolitic shergottites and the other shergottites.

As stated above, Ca-phosphate (mainly whitlockite) is a major carrier phase for REE, especially light, more incompatible REE. As Ca-phosphate was presumably crys-tallized from the trapped liquid, this liquid phase must have had a REE abundance pattern similar to Ca-phosphate and further bulk shergottites in a relative sense. It is quite impossible to produce the REE abundance pattern with a hump at the middle REE range by a single process from material having unfractionated REE abundances. Wadhwa et al. (1994) presented a model for the genesis of shergottites, which starts with a partly depleted mantle, in which light REE are relatively depleted compared with heavy REE. Then, partial melting of the partly depleted mantle increased the light REE relative to heavy REE in the melt, and part of this melt was trapped with the cumulative crystals, forming a crystal mush layer. Thus, a two-staged differentia-tion could produce the REE abundance patterns observed for shergottites. Because

these two processes, which either decrease the light REE or heavy REE, occur independently, the center of the REE abundance hump can shift towards either the light or heavy REE ends of the pattern. It should also be pointed out that Y-793605 has a peak in the CI-normalized REE abundances at Dy whereas ALH 77005 has it at Gd-Tb (Fig. 2). Because we have ICP-MS data only for Y-793605, detailed discussion of that data cannot be made here.

4.3. Siderophile element abundances in Y-793605 and ALH 77005 and their implications for the redox conditions during the formation of the lherzolitic shergottites

Siderophile abundances normalized to CI values for Y-793605 and ALH 77005 are shown in Fig. 3. Although Ga is thought to be plagiophile in Y-793605 (WARREN and KALLEMEYN, 1997) and plotted in Fig. 1, it is also plotted in Fig. 3, because Ga is present in the metal phase in ordinary chondrites (KONG and EBIHARA, 1997) and is thought to have behaved as a siderophile element during core formation in the moon and the eucrite parent body (DRAKE *et al.*, 1984). In general, siderophile abundances for ALH 77005 are systematically higher than those for Y-793605, but the relative abundance patterns are very similar for Y-793605 and ALH 77005. WARREN and KALLEMEYN (1996) discussed the Re abundances in some SNC meteorites and eucrites and came to the conclusion that the oxygen fugacity of the SNC parent magma increased after the late accreting materials were mixed into the source region of SNC meteorites. Indeed, Mo and, in particular, W have relatively high abundances in Y-703605 and ALH 77005, just like as Ga, suggesting that these elements were mostly
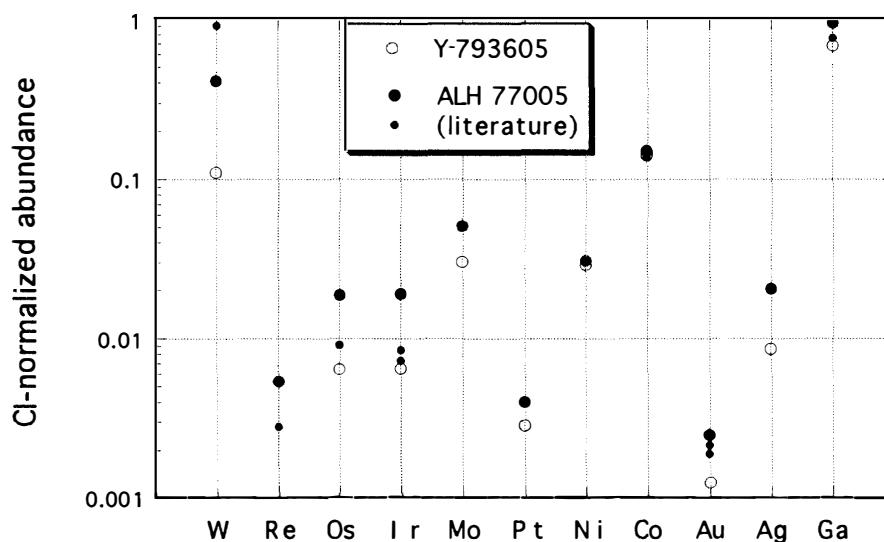

Fig. 3. *CI-normalized abundances of siderophile elements. Siderophile abundances are quite variable compared with CI abundances; only the Os/Ir ratios are exactly chondritic. Nickel is more depleted than Co, possibly due to a preferential uptake of Ni into the core. Gallium and W are very abundant compared with the other siderophile elements, suggesting that these elements did not behave as siderophiles when the parental material for Y-793605 and ALH 77005 formed. Again, Y-793605 bears a close resemblance to ALH 77005 in siderophile abundances.*

present as oxides rather than in metallic form during the formation of the (young) SNC parent magma.

Iridium/Os ratios of Y-793605 and ALH 77005 are exactly chondritic (1.03). Previously, TREIMAN et al. (1986) were troubled by an anomalously low value for Os in Shergotty. No new data for siderophiles (or at least Os) are available for Shergotty, but new data for the other shergottites (mostly from Antarctica) appear to support their conclusion that the shergottite parent material had an approximately chondritic Ir/Os ratio, as did the earth (MORGAN et al., 1981; CHOU et al., 1983). It should be noted that the lherzolitic shergottites (Y-793605, ALH 77005 and LEW 88515) all have a Ir/Os ratio very close to the CI chondritic ratio. Silver also appears to behave like Ir and Os in lherzolitic shergottites (or at least for Y-793605 and ALH 77005) in Fig. 3, but this cannot be said for the other SNC meteorites (or even the other shergottites).

Like other shergottites, Y-793605 and ALH 77005 have Ni/Co ratios lower than the CI value. According to experimental partitioning coefficient data, Ni is partitioned more into solid metal and sulfide liquid than Co (JONES and DRAKE, 1986; SCHMITT et al, 1989). This implies that the mantle became depleted in Ni relative to Co if equilibrium partitioning of Ni and Co occurred between a metal-sulfide melt (which presumably corresponded to the core of the shergottite parent body, probably Mars) and silicate material (corresponding to the mantle, from which the shergottites were derived). Nickel is considered a compatible element, while Co is an indifferent element during mantle genesis in the shergottite parent body (TREIMAN et al., 1986). Nevertheless, Ni is more depleted than Co in the shergottite parent body mantle, suggesting that Ni was partitioned into the core much more efficiently than Co. Because the Co and Ni abundances in lherzolitic shergottites are higher than refractory siderophiles, partitioning of Co and Ni into the metal-sulfide core was likely hindered due to an increased stability of oxide species (NiO and CoO), especially during the late stages of accretion.

Tungsten and Mo are generally modeled as siderophile elements in cosmochemistry, following their condensation behavior from a nebula of solar composition. Geochemically, Mo and W behave as incompatible elements, with Mo being more siderophile and chalcophile than W (NEWSOM and PALME, 1984; LODDERS and PALME, 1991). Therefore, the partition coefficient of W into metal decreases greatly with increasing oxygen fugacity. On the other hand, Mo is more easily sulfurized than W and a significant amount of Mo exists in sulfides in ordinary chondrites, especially equilibrated ordinary chondrites (KONG and EBIHARA, 1996b). Our observation of Mo and W in Y-793605 and ALH 77005 suggests that segregation of W into the core was insufficient, whereas Mo was efficiently partitioned into the metal-sulfide core. A more quantitative discussion will be presented elsewhere including a larger set of data.

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