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YAMATO-793592: THE FIRST ENSTATITE ACHONDRITE (AUBRITE) IN THE YAMATO METEORITE COLLECTIONS

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Abstract: The first aubrite in the Yamato meteorite collections has been identified as a result of the recent initial processing at the National Institute of Polar Research (NIPR), Tokyo. Yamato-793592 (Y-793592) is the only aubrite recovered so far among about 6000 classified specimens of the Yamato collections. Y-793592 is a friable small stone weighing 32 g, with a white interior covered by a small amount of black fusion crust. It shows the typical brecciated texture and consists mostly of larger angular, white pyroxene (enstatite), less plagioclase and traces of olivine, with some opaque grains (blackish brown color). The constituent minerals of Y-793592 are almost pure Mg-pyroxene (enstatite), pure Mg-olivine (forsterite), sodic plagioclase, and small amounts of opaque phases such as Ni-poor metal, daubreelite, and troilites with highly variable compositions.

1. Introduction

Yamato-793592 (Y-793592) has been identified and classified as the first enstatite achondrite (aubrite) among about 6000 specimens of the Yamato meteorite collections (YANAI and KOJIMA, 1991). Before Y-793592 was discovered thirty specimens of aubrites were recovered in Antarctica, and identified as three different aubrites (SCORE *et al.*, 1982; WATTERS and PRINZ, 1980; MASON *et al.*, 1989; JONSON SPACE CENTER, 1985, 1986a, b, 1988). The Y-793592 aubrite is the fourth aubrite in Antarctica and the fourteenth in the world collections (KEIL, 1989; BECK and PAPAZ, 1951; OKADA *et al.*, 1988; FOSHAG, 1940; KEIL *et al.*, 1989; GRAHAM *et al.*, 1977; LONSDALE, 1947; HEY and EASTON, 1967; NEWSOM *et al.*, 1986). Here a preliminary report is given about the recovery, processing, mineralogy, petrology, and mineral and bulk chemistry of Yamato-793592.

2. Recovery of Yamato-793592

The search party for Antarctic meteorites of the 20th Japanese Antarctic Research Expedition (JARE-20), led by the author, visited the Yamato Mountains for the second time during the 1979–1980 austral summer season, and collected over 3600 meteorites from the Meteorite Ice Field. The Yamato-793592 meteorite was found in November 1979, on the bare ice around JARE-IV Nunatak, west of the Yamato Mountains and 15 km north of Massif A. The meteorite was recognized as an unusual specimen among those in the Yamato-79 meteorite collection, and identified during preliminary examination as a kind of achondrite by the author after processing at the National Institute of Polar Research (NIPR), Tokyo.

3. Yamato-793592 Meteorite: Initial Processing

All Yamato-79 meteorites are kept in frozen condition under $-20°C$ during transport from Antarctica to NIPR. Then the meteorite was processed initially at room temperature in a clean flow bench and then returned to room temperature in a dry nitrogen-filled cabinet at the NIPR.

The specimen was named officially Yamato-793592 (abbreviation Y-793592), following the naming system of the Japanese Antarctic meteorite collections.

Y-793592 weighed 31.99 g and measured $4.5 \times 3.5 \times 2.5$ cm. The original volume of this specimen was 10.1 cm^3 and the specific gravity is 3.16 (g/cm^3). Y-793592 is an almost complete small stone (Fig. 1), showing a friable and brecciated appearance. This stone is conspicuous by its white interior and retains only a minor amount of black fusion crust. It consists mostly of coarse-grained, angular, white pyroxene with minor plagioclase, and less abundant smaller black minerals and lithic fragments. Some metal is present and oxidation (brown color) occurs around the metal grains.

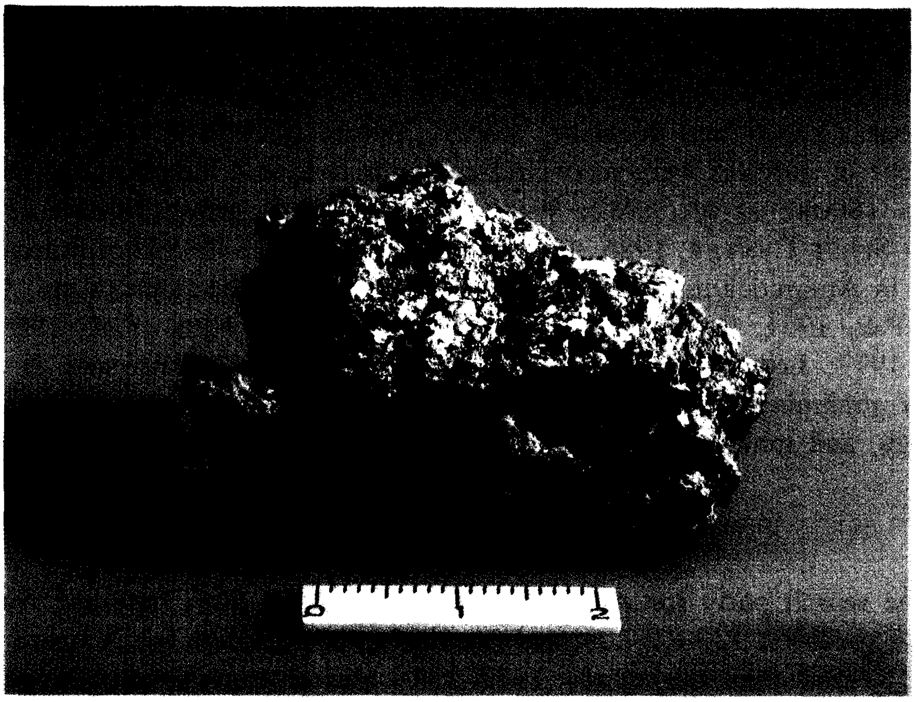

Fig. 1. Y-793592 is an enstatite achondrite (aubrite) most recently identified in the Antarctic meteorite collections, showing friable and brecciated texture with less fusion crust, weighing 32 g.

4. Materials and Analytical Methods

A small chip (0.16 g) removed from the near surface of Y-793592 was made into polished thin sections (PTS) at NIPR. Two PTS were studied under the microscope in both transmitted and reflected light. Quantitative chemical analyses of the constituent minerals were carried out by an automated electron microprobe analyzer (EPMA) JEOL JCXA 733 with five spectrometers at NIPR. The method of the EPMA is the same as that of KUSHIRO and NAKAMURA (1970). A bulk wet chemical analysis of a 0.799 g interior chip was done by H. HARAMURA.

Table 1. Microprobe analyses of silicates and opaque phases in the Yamato-793592, in weight percent. Numbers in parentheses are those of analyses averaged.

Silicates	Pyroxene (Mg-rich) (31)	Pyroxene (Ca-rich) (15)	Olivine (9)	Plagioclase (9)
SiO_2	58.97	54.94	41.42	67.66
TiO_2	0.02	0.47	0.01	0.01
Al_2O_3	0.10	0.29	0.02	19.23
FeO	0.04	0.04	0.03	0.02
MnO	0.07	0.01	0.04	0.02
MgO	39.87	20.11	57.62	0.01
CaO	0.44	23.37	0.06	0.47
Na_2O	0.02	0.28	0.02	10.95
K_2O	0.01	0.01	0.00	0.55
Cr_2O_3	0.02	0.01	0.00	0.01
Total	99.56	99.53	99.22	98.93
	$En_{99.2}$	$En_{54.4}$	$Fo_{99.98}$	$Ab_{94.7}$
	$Fs_{0.1}$	$Fs_{0.1}$	$Fa_{0.02}$	$An_{2.3}$
	$Wo_{0.8}$	$Wo_{45.5}$		$Or_{3.1}$

Opaque phases	Ni-poor metal (8)	Daubreelite (17)	Troilite average (22)	Troilite range
Ca	0.01	0.01	0.01	0.00-0.03
Fe	96.46	17.33	57.35	42.52-62.11
Mn	0.02	0.45	0.13	0.00-1.48
Cr	0.02	36.57	0.83	0.18-9.26
Ti	0.01	0.13	3.79	0.36-9.96
Zn	0.06	0.21	0.43	0.00-4.42
Mg	0.05	0.03	0.02	0.00-0.06
S	0.03	43.87	37.08	35.89-38.41
Ni	3.11	0.14	0.22	0.00-2.48
Si	0.04	0.01	0.02	0.00-0.11
P	0.10	0.02	0.02	0.00-0.08
Co	0.22	0.24	0.09	0.00-0.55
Total	100.13	99.01	99.99	

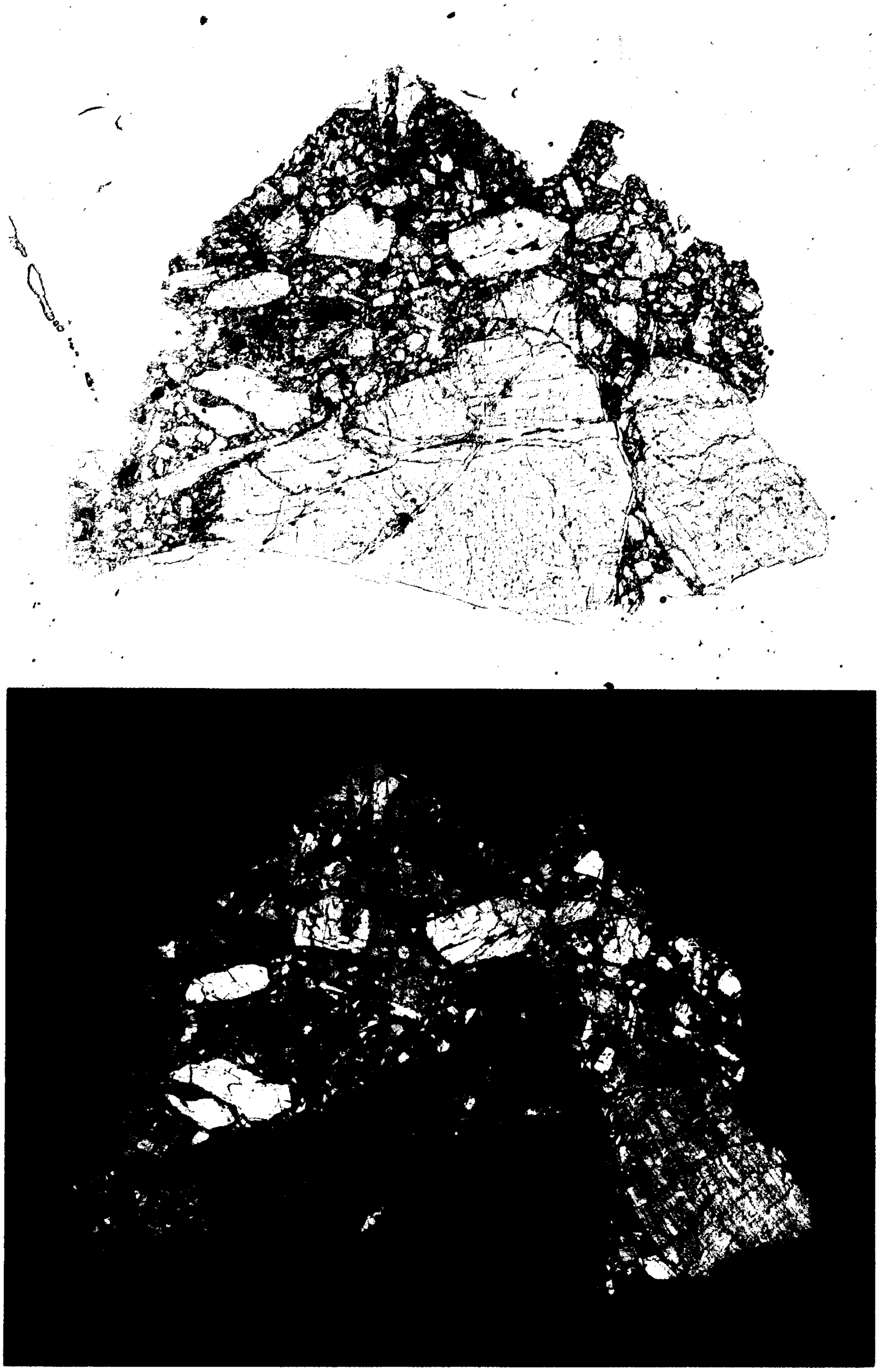

Fig. 2. Photomicrograph of thin section of Y-793592; field view is 8 mm. Plane-polarized light (upper) and crossed-polarized light (lower), showing typical brecciated texture composed mainly of coarse fragmental enstatite crystals enclosed in breccia of much smaller to fine-grained enstatite crystal with diopsidic pyroxene, sodic plagioclase, metal, opaques, and traces of olivine.

5. Petrography and Mineral Composition

Under the microscope, Y-793592 shows a typical brecciated texture, with large angular fragments of enstatite embedded in a fine-grained matrix (Fig. 2). Y-793592 consists mainly of angular enstatites (1–6 mm across), enclosed in a breccia of much smaller enstatite crystals (under 1 mm across) with minor plagioclase, metal, opaques and traces of olivine (under 0.1 mm across). Compositions of the silicates and opaque phases are given in Table 1. The iron content of the silicate phases is remarkably low and it is similar to those of known aubrites. Most of the Mg-rich pyroxenes and Mg-olivines are pure enstatite and pure forsterite, respectively. Ca-rich pyroxene is also almost iron-free diopsidic pyroxene. The feldspar is albite ($An_{0.2-3.7}$ $Or_{2.2-3.5}$) and is present in grains up to 0.1 mm across. Chemical compositions and chemical variation of the constituent minerals are given in Fig. 3.

Opaque phases are not abundant in Y-793592. Metal grains have remarkably low contents of Ni (average 3.10%, range 2.91–3.47%). The sulfides are daubreelite and troilite. Daubreelite is an Fe-Cr sulfide and is a common opaque in Y-793592. Troilite is also a common opaque and there are abundant compositional varieties among the troilite grains; notable compositional variations are represented by Fe (42–62%), Mn (0–1.5%), Cr (0.2–9.3%), Ti (0.4–10%), Zn (0–4.4%), and Ni (0–2.5%). However, their compositional variations in each grain are not large. The complex composition of troilite requires further study. Kamacite of normal Ni-content, taenite, perryite, alabandite, oldhamite, and schreibersite were looked for but not found so far in the Y-793592 aubrite.

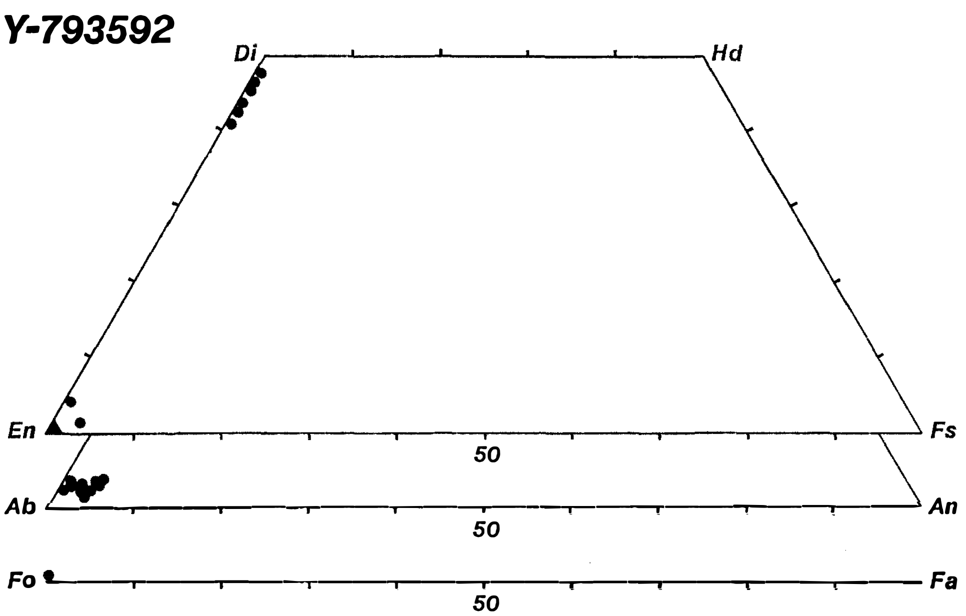

Fig. 3. Plot of Yamato-793592 pyroxene compositions on the pyroxene quadrilateral. Plagioclase and olivine compositions are also plotted in this figure.

6. Bulk Chemistry

The major element composition of Y-793592 was determined by standard wet chemical analysis by H. HARAMURA. The results are presented in Table 2, together with data for the Allan Hills(ALH)-78113 aubrite and the Yamato(Y)-691 enstatite chondrite (EH3) for comparison. The similarity in bulk composition of the two aubrites, Yamato and Allan Hills, is obvious. Contents of some oxides, Al_2O_3, CaO, and Na_2O of Y-793592 are slightly higher than those of ALH-78113, and FeO and MgO are slightly lower.

Table 2. Bulk composition of enstatite achondrite Y-793592, compared with ALH-78113 (aubrite) and Y-691 (EH), in weight percent

	Y-793592 (aubrite)	ALH-78113 (aubrite)	Y-691 (EH3)
SiO_2	56.41	57.16	36.31
TiO_2	tr.	0.02	0.08
Al_2O_3	2.20	0.18	2.93
Fe_2O_3	<0.05	0.0	0
FeO	<0.1	0.97	0.96
MnO	0.18	0.17	0.24
MgO	35.53	39.25	19.59
CaO	1.72	0.62	1.29
Na_2O	0.96	0.15	0.83
K_2O	0.11	0.02	0.07
$H_2O(-)$	0.25	0.69	0.50
$H_2O(+)$	1.41	0.0	0.5
P_2O_5	0.07	tr.	0.46
Cr_2O_3	0.025	0.06	0.45
FeS	0.97	0.77	16.31
Fe	0.0	0.0	17.8
Ni	0.32	0.055	1.71
Co	0.023	0.003	0.077
Total	100.32	100.11	100.10

7. Summary

Yamato-793592 is an enstatite achondrite and the first aubrite identified among almost 6000 specimens of the Yamato meteorite collections. This meteorite shows the typical brecciated texture consisting of large fragmental enstatite crystals in a fine-grained matrix of enstatite, minor plagioclase, metal, opaques, and traces of olivine. Orthopyroxene and olivine are pure enstatite and forsterite, respectively. Clinopyroxene is also almost iron-free diopsidic pyroxene. The feldspar is albite and K-feldspar is absent. Opaque phases are characterized by extremely Ni-poor metal ranging from 3 to 3.5% of Ni and much compositional variability in troilite grains.

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