XXVII. Yamato 980459

Olivine-phyric Basalt
82.46 grams

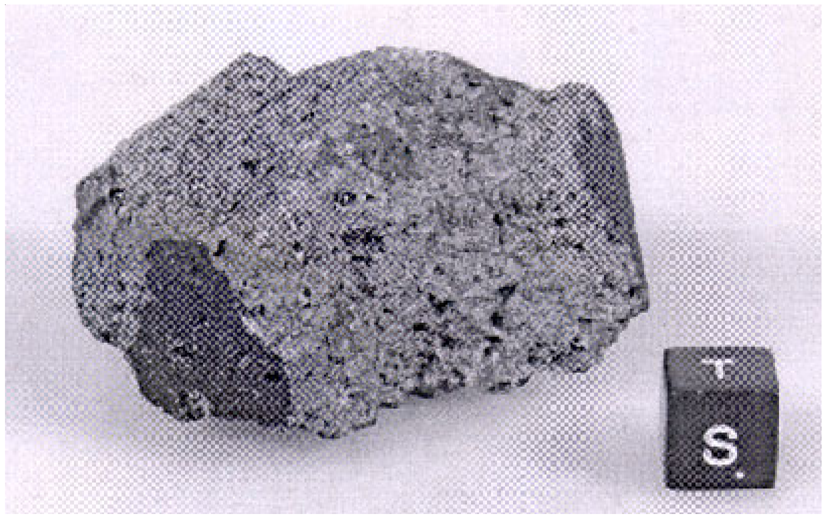

Figure XXVII-1: Martian meteorite Y980459 found in Antarctica (photo courtesy Keiji Misawa). Note the fusion crust and the yellow olivine. Cube is 1 cm.

Introduction

Martian meteorite Y980459 was collected near Minami-Yamato Nunataks by the Japanese field party in 1998 (figure XXVII-1). Y980459 was initially announced in Japanese Meteorite Newsletter #11 (2002) and is listed in Meteoritical Bulletin 87, appendix 2 (Russell *et al.* 2003). Y980459 is currently the subject of an integrated consortium study (Misawa 2003).

Y980459 is an olivine shergottite like EETA79001, DaG476 and SaU005, but it appears to have an exposure age more like that of regular shergottites (*see below*). It is depleted in light rare-earth-elements, has the most magnesian olivine megacrysts and apparently lacks plagioclase (Greshake et al. 2004).

Petrography

Y980459 is a porphyritic basalt with devitrified glassy matrix and no plagioclase (or masklynite). Yellow olivine phenocrysts are apparent in hand specimen and prominent in thin section (figure XXVII-2). Y980459 is not only very mafic in composition, but also appears to be very reduced and perhaps "primitive" (McKay et al. 2004).

Olivine megacrysts contain magmatic melt inclusions (Ikeda 2003) and chromite grains (Mikouchi *et al.* 2003; Greshake *et al.* 2003). Where olivine, and/or pyroxene phenocrysts are touching, Fe-enrichment of the rims is less pronounced.

Mineralogical mode

	Ikeda 2003	Greshake *et al.* 2003	Mikouchi *et al.* 2003	Greshake (CIPW) et al. 2004
Olivine	8.7 vol. %	15.7	26	19.4
Plagioclase				12.6
Pyroxene	52.7	52.6	48	63.4
Chromite	0.7	0.5		0.5
Pyrrhotite	0.4	0.3		0.3
Glass	37.4	30.9	25 % mesostasis	
Phosphates				0.5
SiO2 polymorphs				2.7
Melt inclusions		0.1		

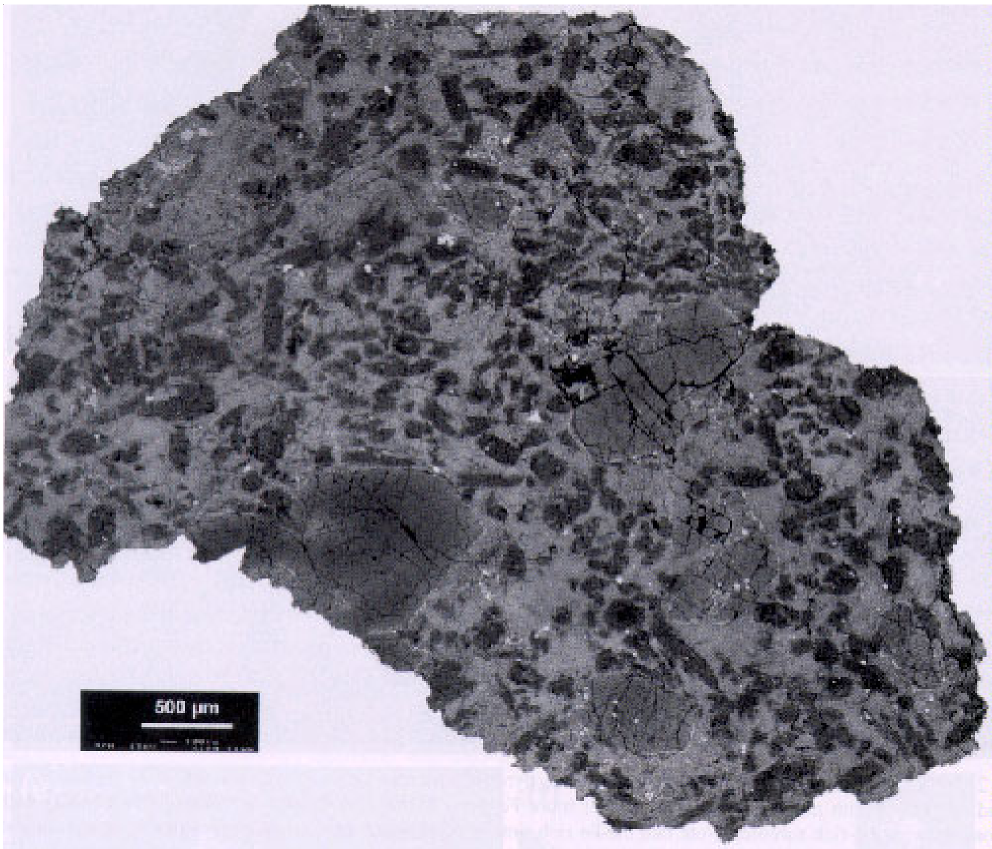

Figure XXVII-2: *Back-scattered-electron (BSE) image of Yamato 980459 showing large olivine megacrysts and smaller pyroxene phenocrysts embedded in fine-grained groundmass (from Greshake et al. 2004).*

Olivine megacrysts show undulatory extinction. Ikeda (2003) and Mikouchi *et al.* (2003) report shock-melt pockets. Greshake *et al.* (2003, 2004) estimate peak shock pressure 20-25 GPa.

Mineral Chemistry

Olivine: Large olivine crystals (up to 2 mm) are chemically zoned (Fo_{84-33}) and frequently form glomerophyric "clumps" (Greshake et al. 2004). Koizumi et al. (2004) report olivine as magnesian as Fo_{86}. Smaller olivine crystals are Fe-rich (Fo_{44}). Feathery olivine dendrites in the quenched residual material are Fo_{29}.

Pyroxenes: Pyroxene is zoned from an orthopyroxene core (En_{82}), to pigeonite ($En_{78}Wo_5$), with finally a thin augite rim ($En_{70}Wo_{35}$) (figure XXVII-3). Greshake *et al.* (2003, 2004) find that the Al_2O_3 content of the pyroxene continuously increases out to the rim where it can be as high as 8.5 wt % *(plagioclase apparently forgot to nucleate)!*

Maskelynite: none

Glass: This sample has a glassy residual matrix that is quenched with feathery microlites of sulfide, opaques, olivine and pyroxene (McKay *et al.* 2003).

Chromite: Chromite in Y980459 is Ti-poor (Ti<0.4%) (Greshake et al. 2004). Careful analysis of chromite and comparison with chromite formed in reducing conditions, shows that the oxygen fugacity of Y980459 was very low (reduced) (McKay et al. 2004).

Sulfide: Sulfide is identified as pyrrhotite with up to 2 wt. % Ni.

Whole-rock Composition

The chemical composition of Y980459 has been determined by Haramura (reported in Misawa 2003) and Dreibus *et al.* (2003) (Table XXVII-1). Trace elements have been reported by Shirai and Ebihara (2003) and Nakamura *et al.* (2003) (figure XXVII-4). Note that Y980459 is extremely depleted in LREE.

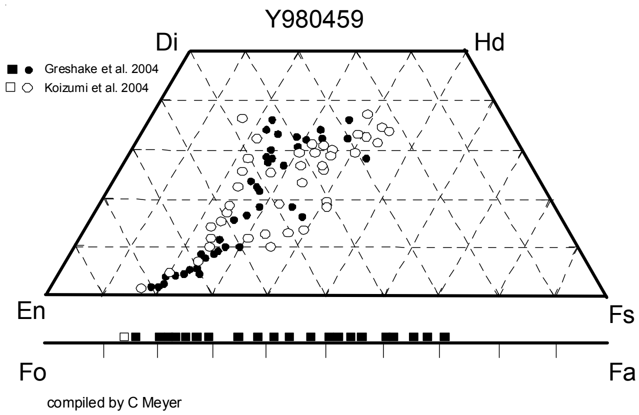

Figure XXVII-3: *Pyroxene and olivine composition of Y980459 (from Gresheke et al. 2004, Koizumi et al. 2004).*

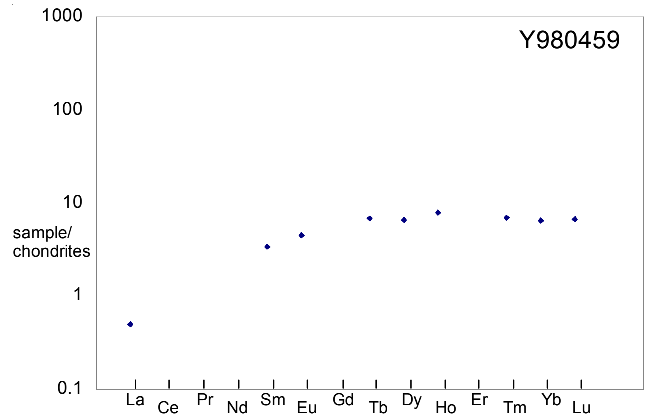

Figure XXVII-4: *REE diagram for Y980459 from Dreibus et al. (2003).*

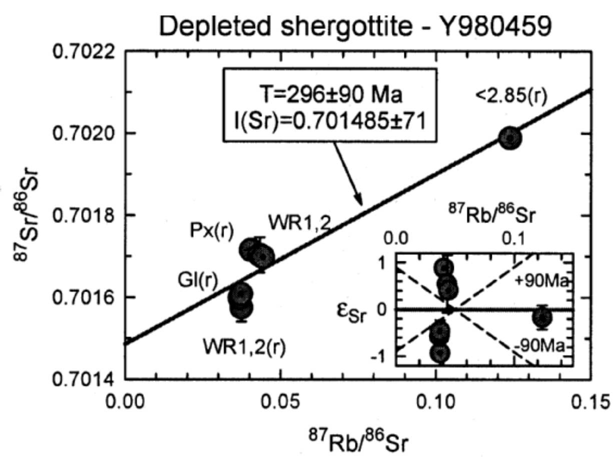

Figure XXVII-5: *Rb-Sr isochron for Y980459 (from Shih et al. 2004).*

Radiogenic Isotopes

Shih *et al.* (2004) determined a Rb-Sr isochron age of 296 ± 90 Ma with I(Sr) = 0.701485 ± 0.000071 (figure XXVII-5). They also determined a concordant age of 290 ± 45 by Nd-Sm.

Cosmogenic Isotopes

The cosmic-ray exposure ages calculated from ^{3}He, ^{21}Ne and ^{38}Ar are 1.6, 2.5 and 2.1 m.y., respectively (Nagao and Okazaki 2003). Christen et al. (2004) also found disagreement between these methods and suggest that the average is 2.5 m.y. However, the exposure age determined by ^{10}Be is 1.1 ± 0.2 m.y. (Nishiizumi and Hilgonds 2004). They suggest that this difference might be attributed to a pre-exposure history (while on Mars ?).

Other Isotopes

Oxygen isotopes determined by Clayton are ä^{17}O = 2.52 ‰, ä^{18}O = 4.31 ‰; with Ä^{17}O = +0.28 ‰. The activity of ^{26}Al and ^{41}Ca was determined by Nishiizumi and Hilgonds (2004).

Processing

The processing and distribution of Y980459 is described in Misawa (2003).

Table XXVII. Chemical composition of Y980459.

reference	Haramura (d)		Dreibus 03		Shirai 03	Greshake 04		Nakamura 03
weight	1.4 g				2.585 g			see dia.
SiO2	48.7	(a)				49.4	(c)	
TiO2	0.54	(a)				0.48		
Al2O3	5.27	(a)				6		
FeO *	17.53	(a)	18.24	(b)		15.8		
MnO	0.52	(a)	0.49	(b)		0.43		
CaO	6.37	(a)	5.88	(b)		7.2		
MgO	19.64	(a)				18.1		
Na2O	0.48	(a)	0.68	(b)		0.8		
K2O	<0.02	(a)				0.02		
P2O5	0.29	(a)				0.31		
sum								
Li ppm			1.3	(b)				
F			86	(b)				
Cl			57	(b)				
Sc			36.4	(b)				
V								
Cr	4858	(a)				4858		
Co	70	(a)	56.2	(b)				
Ni	270	(a)	240	(b)				
Cu								
Zn			76	(b)				
Ga			11	(b)				
Ge								
As			<0.2	(b)				
Se			<0.9	(b)				
Br			0.205	(b)				
Rb								
Sr								
Y								
Zr								
Nb								
Mo								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								
Sb ppb								
Te ppb								
I ppm								
Cs ppm								
Ba			<30	(b)				
La			0.12	(b)				
Ce			<0.7	(b)				
Pr								
Nd								
Sm			0.498	(b)				
Eu			0.25	(b)				
Gd								
Tb			0.25	(b)				
Dy			1.6	(b)				
Ho			0.44	(b)				
Er								
Tm			0.17	(b)				
Yb			1.05	(b)				
Lu			0.164	(b)				
Hf			0.49	(b)				
Ta								
W ppb								
Re ppb								
Os ppb								
Ir ppb			<5	(b)				
Au ppm			1.5	(b)				
Tl ppb								
Bi ppb								
Th ppm			<100	(b)				
U ppm			<20	(b)				

technique: (a) wet, (b) INAA, (c) Mode and elec. Probe, (d) in Misawa 03

* recalculated