Miller Range 05035

Unbrecciated basalt

142 g

Figure 1: MIL 05035 as found in the ice in the Miller Range.

Introduction

Miller Range 05035 (Fig. 1) was found during the 2005-2006 ANSMET field season (Fig. 2), and was announced in the August 2006 Antarctic Meteorite Newsletter (Figs. 3 and 4). The exterior has about 95% black, shiny fusion crust. The interior is pinkish-tan in color with no rusting. The rock is moderately hard and has an unusual granular texture with a vague resemblance to granite. There are numerous inclusions; linear white features a few mm in length, melted appearing black, glassy inclusions with an iridescent "peacock ore" opalescent sheen, a transparent, glass like mineral, and a few clay-like powdery areas. Initial results of studies of this meteorite were reported at the 2007 Lunar and Planetary Science Conference, and are summarized below.

Mineralogy and Petrography

The section exhibits an unbrecciated texture of coarse-grained (several mm) pyroxene and maskelynite (Fig. 5, 6) with interstitial sulfides, iron-titanium oxides, intergrowths of fayalite-silicate-augite (Fig. 6, 7a), and other late-stage glasses (Fig. 7b) and minerals (including BaO-enriched potassium feldspar). Pyroxenes contain fine exsilution lamellae (Fig. 6, 7c), and are overall are strongly zoned and include pigeonites and augites with a range of compositions (Fig. 8). The zoning is very reproducible from section to section, and along with minor elements defines a fractionation trend (Fig. 8, 9). Plagioclase (maskelynite) is $An_{83-92}Or_{0-2}$(Joy et al., 2007; Liu et al., 2007; Arai et al., 2007).

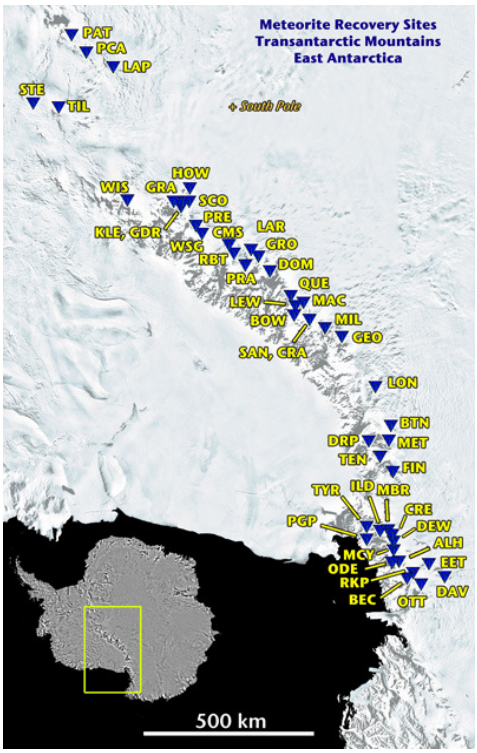

Figure 2: The Miller Range region of Antarctica (where MIL 05035 was found), is near the center of the map at the edge of the Trans Antarctic Mountains.

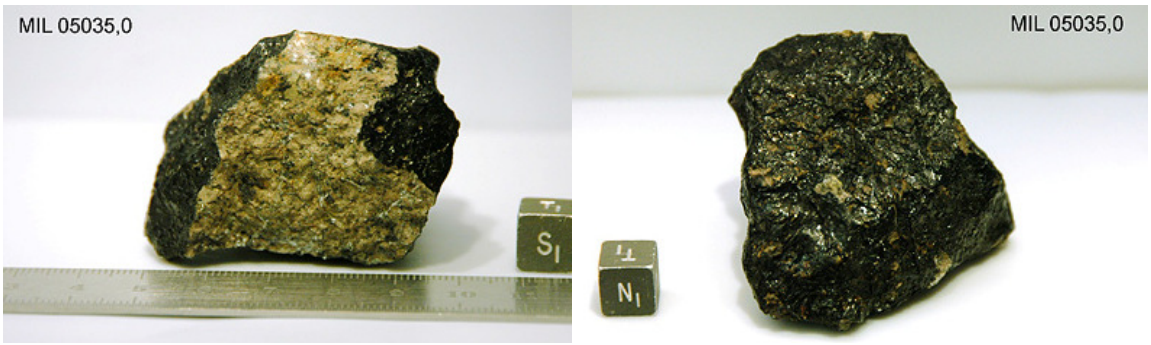

Figure 3: Photos of MIL 05035 taken in the Antarctic Meteorite Processing Lab at NASA-JSC.

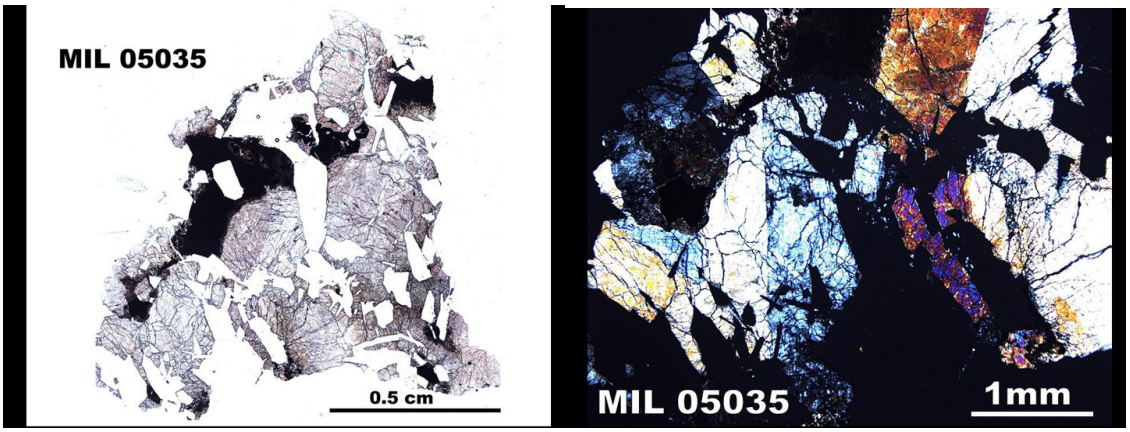

Figure 3: Low magnification plane polarized light images of section MIL05035 ,4.
Figure 4: Higher magnification crossed nicols image of a different region of MIL05035 ,4.

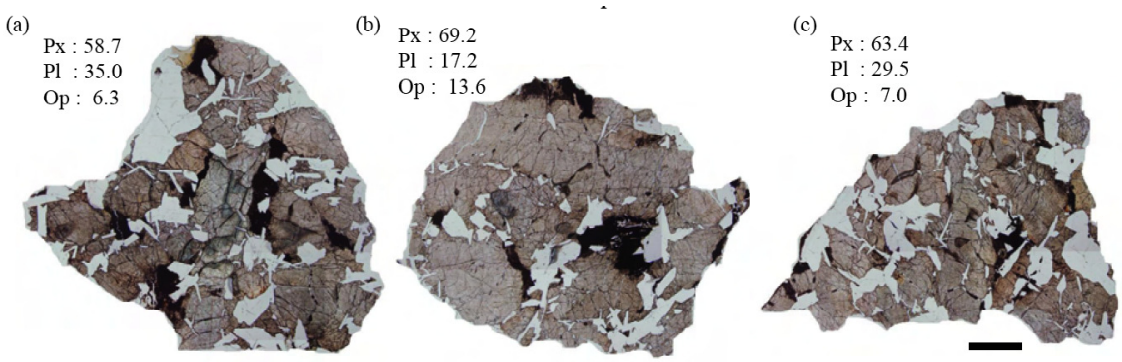

Figure 5: three different sections and subsamples of MIL 05035, illustrating the variation in modal mineralogy given the coarse-grained nature of the sample (from Arai et al., 2007).

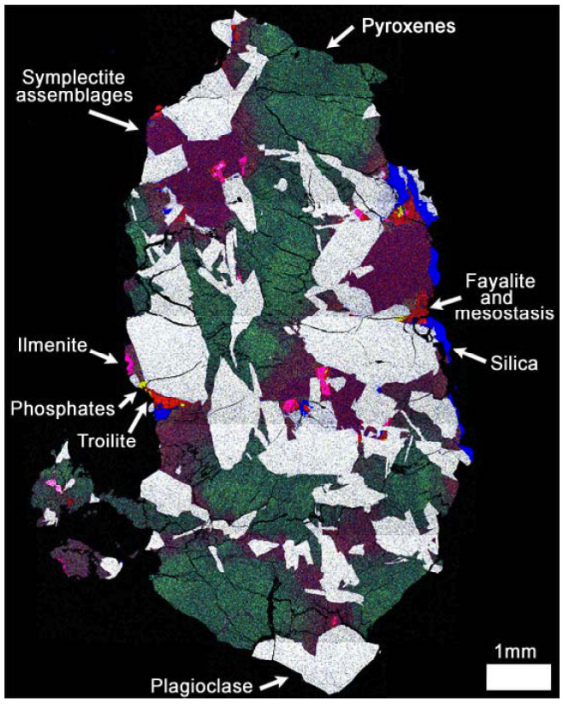

Figure 6: X-ray map of split of MIL 05035 showing major phases of pyroxene (green), maskelynitized plagioclase (white) and symplectites (dark purple), as well as minor silica (blue), troilite (red), phosphates (yellow) and ilmenite (light purple) (from Joy et al., 2007).

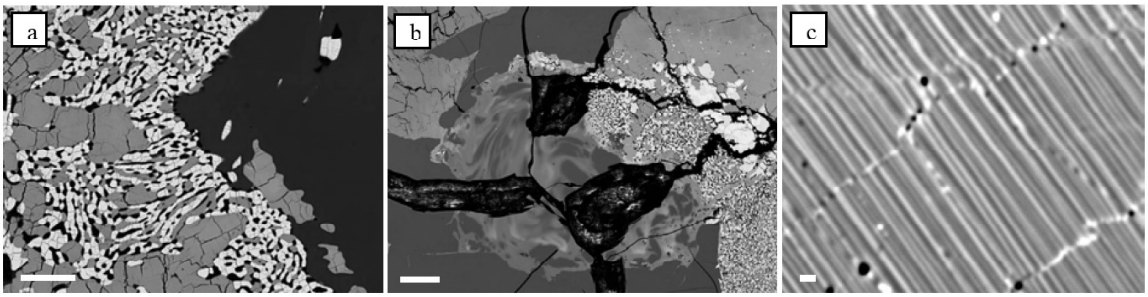

Figure 7: BSE images of three different textures in MIL 05035: a) symplectitic texture at grain boundary between pyroxene and maskelynite – phases are hedenbergite, ferrosilite and SiO_2 (30 μm scale bar), b) heterogeneous shock melt glass (100 μm scale bar), and c) fine grained exsolution lamellae in pyroxene (1 μm scale bar) (from Arai et al., 2007).

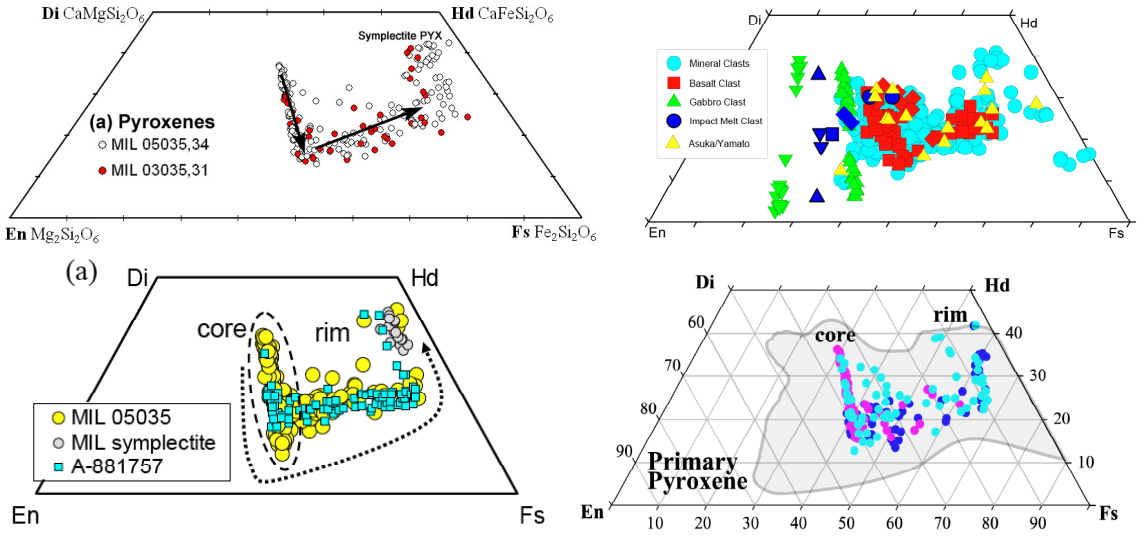

Figure 8: Pyroxene compositions from MIL 05035 taken from four different studies illustrating the same trend of compositional variation from augite to ferroaugite. From the studies of (clockwise from upper left) Joy et al. (2007), Zeigler et al. (2007), Arai et al. (2007) and Liu et al. (2007).

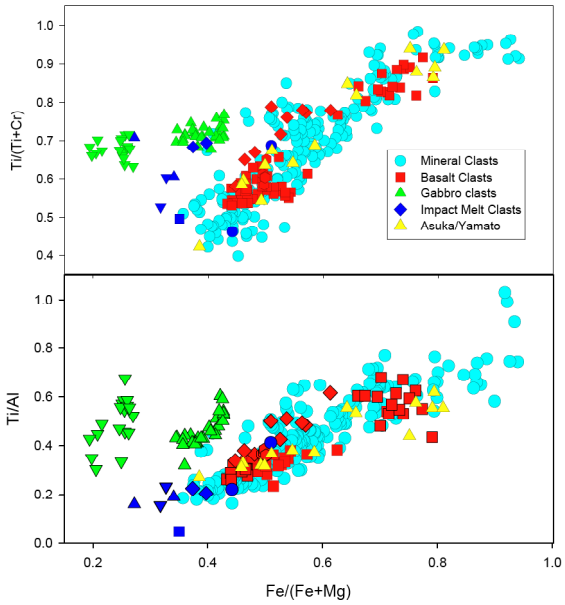

Figure 9: Pyroxene minor element variation – Ti, Al and Cr – measured in MIL 05035 pyroxenes (from Zeigler et al., 2007).

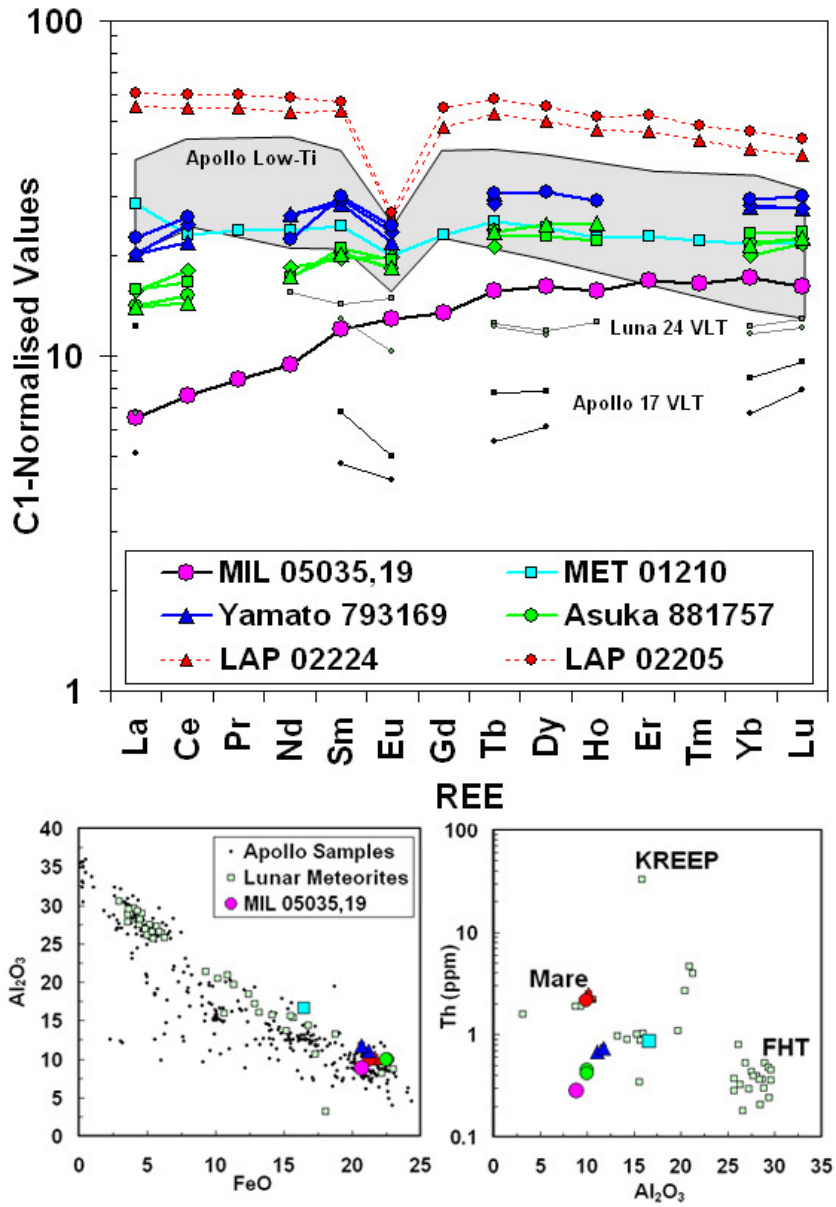

Figure 10: Whole rock composition of MIL 05035 demonstrates it similarity to other mare basalts with high FeO contents (~21 wt%), low Al_2O_3 (~8 wt%), and LREE depletion compared to other Apollo and lunar basaltic meteorite samples (from Joy et al., 2007).

Chemistry

Compositionally, MIL 05035 is somewhat typical of low Ti basalt, containing high FeO (near 21 wt%), low Al_2O_3 (~ 8 wt%), and low Th (0.3 ppm). It has low light REE compared to many other lunar basalts (Fig. 10), and based on composition, texture, age and mineralogy, some have argued that MIL 05035 is launch paired with Asuka 881757 and Yamato 793169 (Zeigler et al., 2007; Arai et al., 2007).

Isotopic studies

Initial studies of the Sr and Nd isotopic systems have shown that MIL 05035 is an old low Ti basalt, similar in age to the Asuka 881757 gabbro (Figs. 11-12).

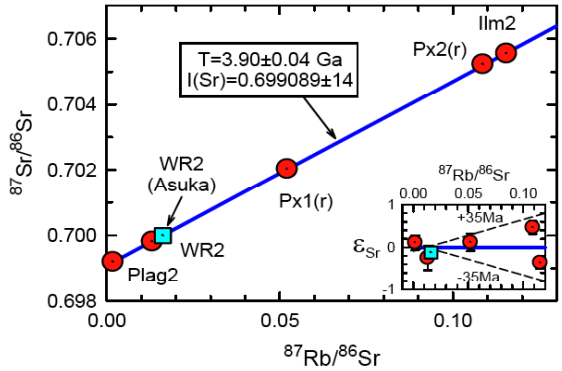

Figure 11: Rb-Sr mineral and whole rock isochron yielding an age of 3.90 Ga for MIL 05035 (Nyquist et al., 2007).

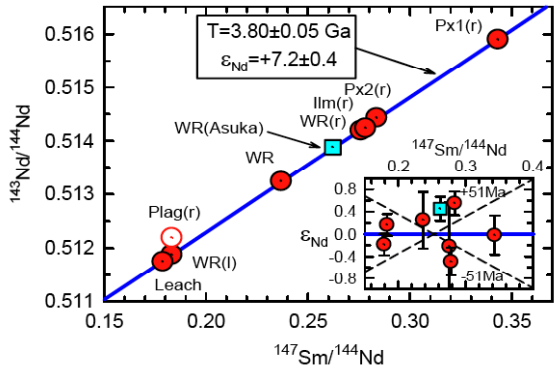

Figure 12: Sm-Nd mineral and whole rock isochron yielding an age of 3.80 Ga for MIL 05035 (Nyquist et al., 2007).

Table 1a. Chemical composition of MIL 05035

reference	1	2
weight	140	
technique	a,b	c
SiO2 %	48.39	47.2
TiO2	0.9	1
Al2O3	8.85	10.5
FeO	20.68	20.7
MnO	0.33	
MgO	7.79	5.9
CaO	12.13	13.7
Na2O	0.21	
K2O	0.01	
P2O5	0.02	
S %		
sum	99.31	
Sc ppm	108.98	
V	106.69	
Cr	513	
Co	28.07	
Ni	10.98	
Cu	9.64	
Zn	16.91	
Ga	2.96	
Ge	0.12	
As		
Se		
Rb	0.49	
Sr	105.2	
Y	22.08	
Zr	36.38	
Nb	1.15	
Mo	0.02	
Ru		

Rh	
Pd ppb	
Ag ppb	
Cd ppb	
In ppb	
Sn ppb	410
Sb ppb	160
Te ppb	
Cs ppm	0.03
Ba	25.76
La	1.54
Ce	4.58
Pr	0.75
Nd	4.24
Sm	1.77
Eu	0.72
Gd	2.65
Tb	0.56
Dy	3.93
Ho	0.68
Er	2.66
Tm	0.39
Yb	2.78
Lu	0.39
Hf	1.03
Ta	0.06
W ppb	0.01
Re ppb	
Os ppb	
Ir ppb	
Pt ppb	
Au ppb	
Th ppm	0.28
U ppm	0.07

technique (a) ICP-AES, (b) ICP-MS, (c) EMPA - modes

Table 1b. Light and/or volatile elements for MIL 05035

Li ppm	9.63
Be	0.26
C	
S	
F ppm	
Cl	
Br	
I	
Pb ppm	0.39
Hg ppb	
Tl	0.01
Bi	0.02

References: 1) Joy et al. (2007); 2) Liu et al. (2007).

K. Righter, 2008