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THE ASUKA-87 AND ASUKA-88 COLLECTIONS OF ANTARCTIC METEORITES: PRELIMINARY EXAMINATION WITH BRIEF DESCRIPTIONS OF SOME TYPICAL AND UNIQUE-UNUSUAL SPECIMENS

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Abstract: Preliminary examinations were carried out of over 2400 pieces of the new Asuka meteorites after the initial processing at the NIPR. According to the initial processing, the Asuka-87 meteorite collection consists of one iron, one stony-iron, 9 achondrites, 3 carbonaceous meteorites and over 300 chondritic specimens. The Asuka-88 meteorites collection comprises 7 irons, 5 stony-irons, over 50 achondrites, 31 carbonaceous meteorites and over 2000 chondritic specimens.

Through preliminary examinations with a polarizing microscope and electron microprobe, one mesosiderite, 2 ureilites, 2 diogenites (possibly paired) and 2 eucrites were identified in the Asuka-87 collection. In the Asuka-88 collection, one unbrecciated gabbro and one olivine-fassaite basalt were examined. These unique-unusual specimens were determined to be a lunar mare gabbro and an angrite-type achondrite. Diogenites, ureilites, and one fine-grained, one coarse-grained and one porphyritic eucrite were also newly identified in the Asuka-88 collection, together with a pallasite, a mesosiderite and CM, CV, CO chondrites. Some of the typical and unique-unusual specimens of the Asuka-87 and Asuka-88 collections are briefly described here.

1. Introduction

The Asuka-87 and Asuka-88 meteorites were recently collected by the 29th Japanese Antarctic Research Expedition (JARE-29, 1987–89) on the bare icefield around the Sør Rondane Mountains in Queen Maud Land, East Antarctica (YANAI, 1989; YANAI and THE JARE-29 ASUKA PARTY, 1989; NARAOKA *et al.*, 1990). Over 2400 new specimens were recovered by the expedition and were initially processed at the National Institute of Polar Research (NIPR) in 1989–1992 (YANAI, 1991a; YANAI and KOJIMA, 1992).

According to the initial processing, the Asuka-87 meteorite collection comprises one iron, one stony-iron, 9 achondrites, 3 carbonaceous meteorites and over 300 chondritic specimens including a number of low petrologic types. The Asuka-88 collection consists of 7 irons, 5 stony-irons, over 50 achondrites, 31 carbonaceous meteorites and over 2000 chondritic specimens (YANAI *et al.*, 1993).

Preliminary studies using the polarizing microscope and electron microprobe analyzer resulted in the discovery of one mesosiderite, 2 ureilites, 2 diogenites (possibly paired) and 3 eucrites in the Asuka-87 collection. In the Asuka-88 collection, two unique-unusual specimens, one very coarse-grained and unbrecciated gabbro and one olivine-fassaite-plagioclase achondrite were discovered and examined. The unbrecciated gabbro was identified as a lunar meteorite and determined to be a lunar mare gabbro of a type unknown among lunar rocks (YANAI, 1991d). The other achondrite consists of olivine, fassaite and plagioclase and was identified as an angrite-type meteorite, but the specimen is fairly different from the original angrite, Angra dos Reis (ADOR). Diogenites, ureilites and fine-grained, coarse-grained and porphyritic eucrites were also newly examined, together with one pallasite, one mesosiderite and CM, CV, CO chondrites. More detailed examinations for identification and classification are being continuously carried out by the author.

2. Material and Analytical Methods

Small fragments (about 0.5 g) chipped from the exteriors of the meteorites were made into polished thin sections at the NIPR. The sections were studied under the microscope in transmitted and reflected light. Quantitive elemental analyses of the constituent minerals were carried out using an automated JEOL JCAA733 electron microprobe analyzer (EPMA) with five spectrometers at NIPR. The analytical procedures of the EPMA are the same as those of KUSHIRO and NAKAMURA (1970).

About 50 thin sections were made from typical and unique-unusual specimens of the Asuka-87 and Asuka-88 collections for preliminary examination. A few grams of interior chips were used for standard wet chemical analyses. Nearly ten of the unique-unusual meteorites were chemically analyzed by H. HARAMURA at the NIPR. The analyses will be published in the catalog of the Antarctic meteorites, NIPR.

3. Asuka Meteorites: Initial Processing and Brief Identification

All the Asuka meteorites were processed following the procedures initiated for all Antarctic meteorites in the NIPR. The Asuka meteorites have been listed in the meteorite catalogs and are stored at the NIPR for detailed identification and classification after the initial processing. Together with the Asuka-86 collection, the Asuka-87 and Asuka-88 meteorites processed initially are shown in Table 1 with numbers, total weights and

Table 1. The Asuka meteorite collections.

Name (year)	Asuka-86 (1986/87)	Asuka-87 (1988)	Asuka-88 (1988/89)
Total	3	352	2124
Irons	—	1	7
Stony-Irons	—	1	5
Achondrites	—	9	53
Carbonaceous meteorites	—	3	31
Chondrites	3	338 (Chondrites and Doubtful combined)	2028 (Chondrites and Doubtful combined)
Doubtful	—		
Total weight	2.2 kg	120.1 kg	394.0 kg

meteorite types. This collection also includes 13 doubtful pieces which appear black and dark brown in color, like deeply weathered H-group chondrites. The total number of specimens in the Asuka-87 collection is 352 meteorites and/or meteorite fragments, weighing 120 kg in total. The largest, an LL-group chondrite (Fig. 4a) weighs 46 kg and there is a 5.7 kg crystalline eucrite that is covered completely with shiny-black fusion crust (Fig. 5a).

The Asuka-88 collection numbers 2124 meteorites and/or meteorite fragments including deeply weathered or doubtful specimens. Total weight of this collection is almost 400 kg, the average being 200 g, which is grater than that of the average Yamato meteorite of about almost 100 g (YANAI and KOJIMA, 1987).

4. Preliminary Examination and Classification for the Asuka-87 and Asuka-88 Collections

According to the initial processing, all specimens were tentatively identified and classified. Then some typical and unique-unusual specimens were chosen for more detailed examination. Together with the Asuka-86 collection, the Asuka-87 and Asuka-88 meteorites were examined and tentative classifications were made as shown in Table 2.

Table 2. The tentative classifications of the Asuka meteorites.

Type\Name	Asuka-86	Asuka-87	Asuka-88
Total number	3	352	2124
Irons	—	1	7
Stony-Irons	—	1	5
Pallasite		0	1
Mesosiderite		1	1
Achondrites	—	9	53
Lunar Gabbro		0	1
Angrite		0	1
Diogenites		2	12
Eucrites		3	33
Howardites		1	2
Ureilites		2	4
Carbonaceous meteorites	—	3	31 CM, CV, CO CI(?)
Chondrites	3	325	over 2000 (Chondrites and Doubtful)
Doubtful	—	13	

5. Brief Descriptions of Typical Asuka-87 Meteorites

Asuka(A)-87001 to A-88113 were collected in the Mt. Balchen area. The others were collected at the Nansenisen Icefield.

A-87031 ureilite: A-87031 is a small fragmental piece, 15 grams, covered partly with a dull-black fusion crust and showing a coarse-grained, darker interior. In thin section it consists mainly of darker material (possibly carbon matter) and coarser-

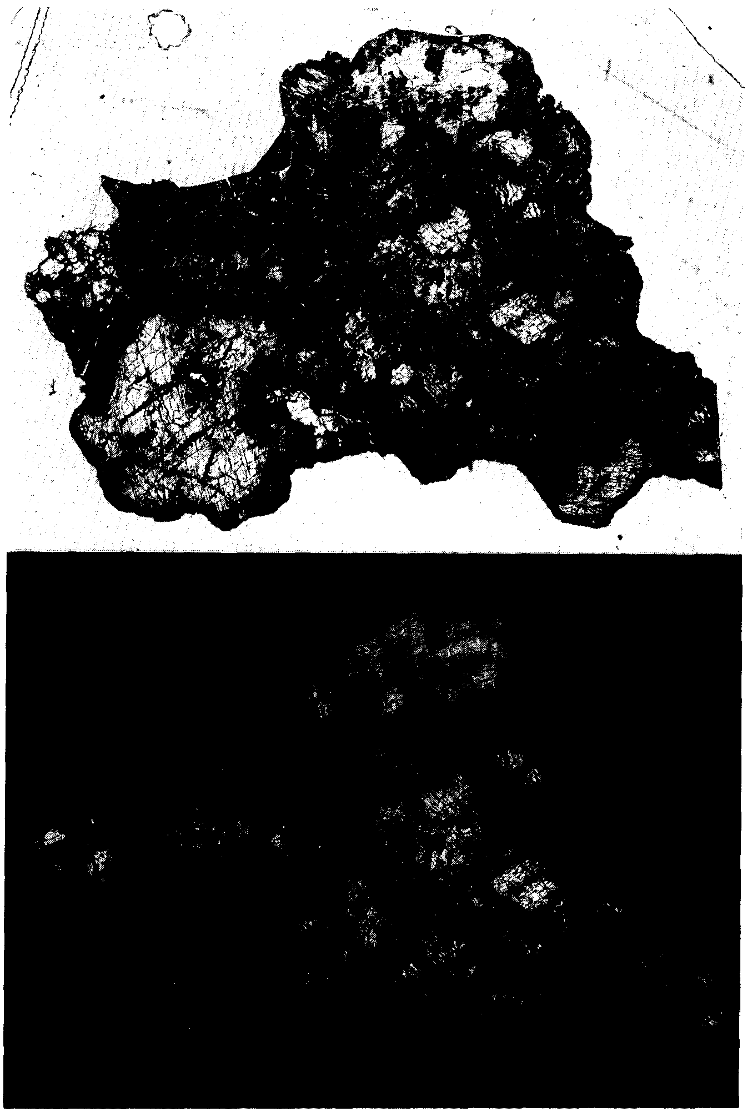


Fig. 1. *Photomicrographs of A-87031, ureilite, composed of coarse-grained olivine in a large amount of darker material. Width is 9 mm. (a) Plane polarized light. (b) Crossed polars.*

grained olivine, with traces of pyroxene (Fig. 1). Olivine is a high magnesian variety ($Fo_{98.6-79.5}$) and shows compositional variation, and pyroxene is a low-Ca pigeonite ($En_{75.1}Fs_{17.3}Wo_{7.5}$).

A-87034 L4 chondrite: A-87034 is a 19 kg, complete angular stone with a dull, black fusion crust (Fig. 2a). This stone is the largest specimen recovered from the Mt. Balchen area. The thin section shows that A-87034 is a typical chondrite, consisting of many well-rounded chondrules, chondrule fragments, mineral fragments, metallic iron and troilite in the matrix (Fig. 2b). Chondrules occur in a variety of types such as porphyritic olivine, porphyritic olivine-pyroxene, barred olivine, radial pyroxene and granular olivine-pyroxene. Some of the pyroxene is polysynthetically twinned clinobronzite. Microprobe analyses give the following average compositions; olivine $Fa_{22.9}$ and pyroxene $Fs_{19.3}$.

A-87106 mesosiderite: A-87106 is a 35 g fragmental specimen without fusion crust. It is brown in color and covered by a limonitic stain, indicative of heavy

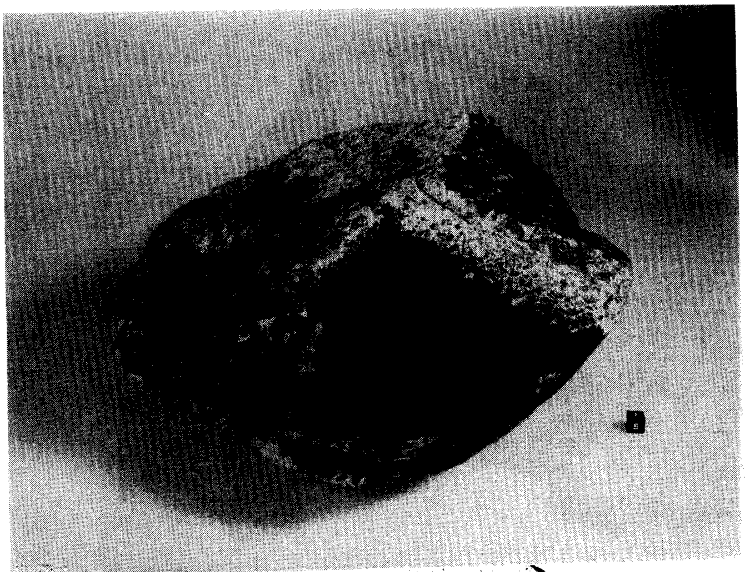


Fig. 2a. Photograph of A-87034 (19 kg), L4 chondrite, an almost complete angular stone covered by dull black fusion crust. This is the largest stone from the Mt. Balchen area. Scale cube is 1 cm.

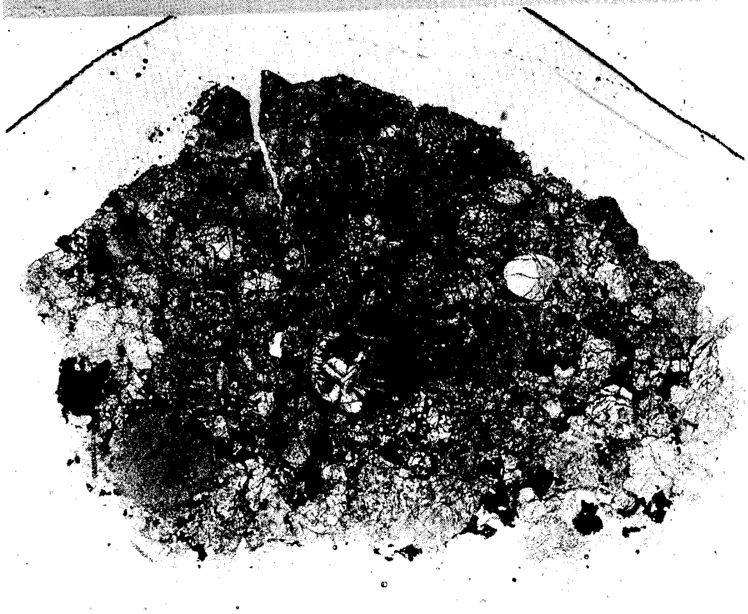


Fig. 2b. Photomicrograph, showing typical chondritic texture. Width is 11 mm, plane polarized light.

weathering. The thin section shows a typical brecciated texture (Fig. 3) and the rock consists mainly of pyroxene, plagioclase and Fe-Ni metal with troilite. Pyroxene is low-Ca orthopyroxene ($En_{71.5-59.9}Fs_{36.6-26.1}Wo_{4.7-1.7}$), and plagioclase is Ca-rich ($Ab_{10.8-4.5}An_{95.5-88.7}Or_{<1.0}$). The texture, mineral assemblage and abundant metallic iron of A-87106 indicate that it is a mesosiderite, and its silicates are similar to those of typical howardite achondrites.

A-87251 LL5 chondrite: A-87251 is a complete, round stone of over 46 kg. It has a dull-black fusion crust covering a gray, friable interior (Fig. 4a). This is the largest specimen in the Asuka collections of over 2000 individuals. The thin section shows that the chondritic structure is poorly developed, but most chondrules are fragmental, which consist mainly of olivine and pyroxene, with minor amounts of plagioclase, Fe-Ni metal and troilite, and accessory chromite (Fig. 4b). The meteorite has a brecciated structure

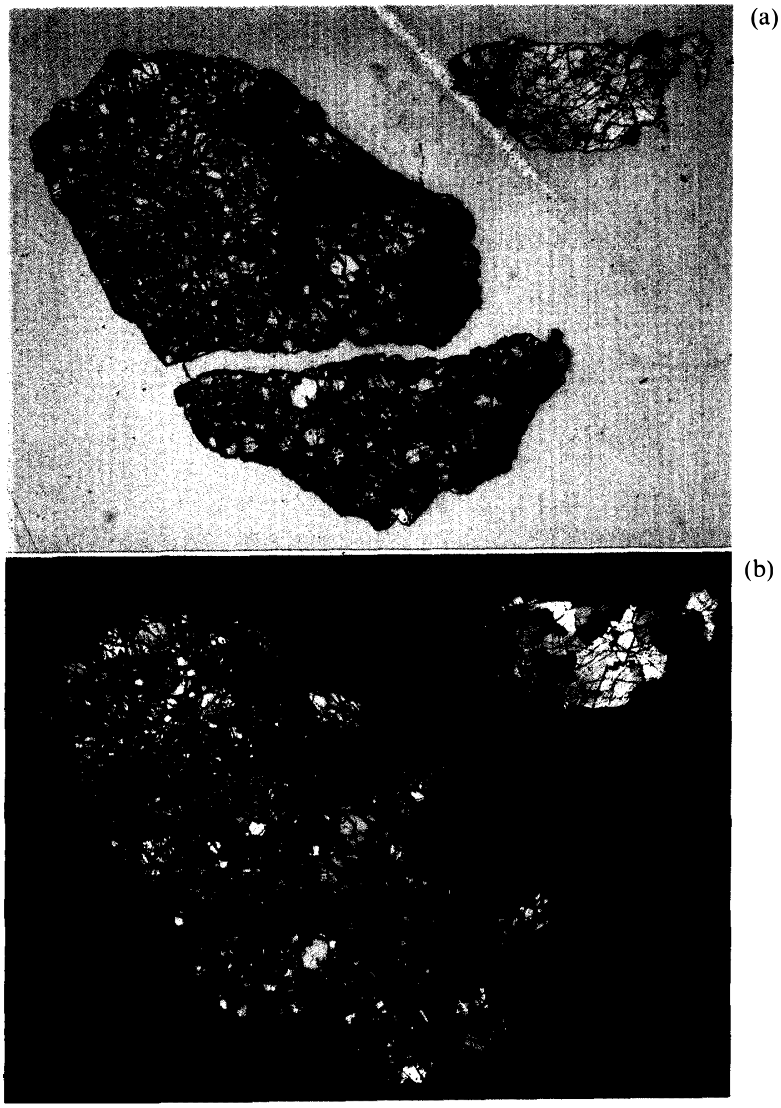


Fig. 3. Photomicrograph of the A-87106 mesosiderite, with typical brecciated texture. Width is 7 mm. (a) Plane polarized light. (b) Crossed polars.

with a network of black, glassy veinlets and fine troilite grains. Microprobe analyses give the following average compositions: olivine Fo_{70}, pyroxene Fs_{24}.

A-87272 eucrite: A-87272 is a 5.7 kg angular, almost complete stone with a shiny-black fusion crust (Fig. 5a). It has a light gray and almost crystalline interior of white plagioclase and pale-gray pyroxene with fine-dark spots (possibly troilite). This complete stone is the largest achondrite collected in the Sør Rondane region so far. The thin section shows that A-87272 is a moderately brecciated and coarse-grained eucrite, consisting mainly of pyroxene and plagioclase with a trace of troilite (Figs. 5b, c). Microprobe analyses give the following composition: pyroxene $En_{42.3-27.6}Fs_{63.2-25.0}Wo_{46.9-1.6}$, plagioclase $An_{72.4-89.3}Or_{0.7-0.1}$. The bulk analyses are given in Table 3.

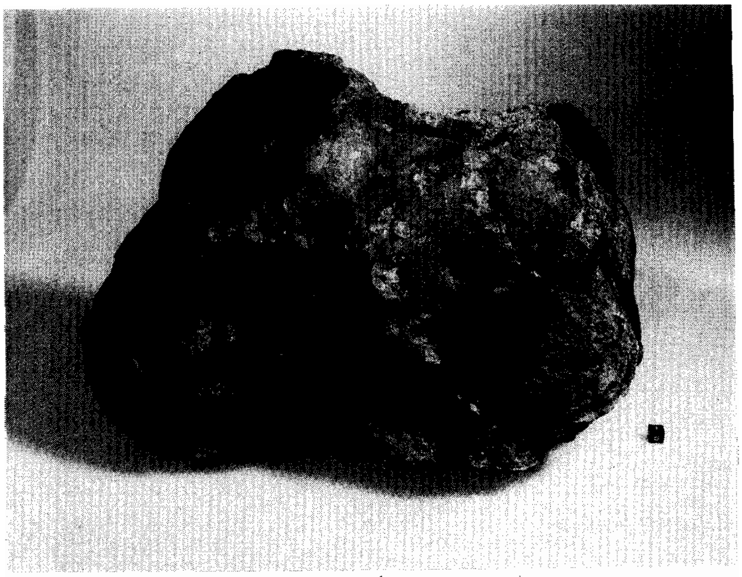


Fig. 4a. Photograph of A-87251 (46 kg), LL5 chondrite, an almost complete rounded stone covered by dull black fusion crust. This is the largest specimen of all the Asuka meteorites collected. Scale cube is 1 cm.

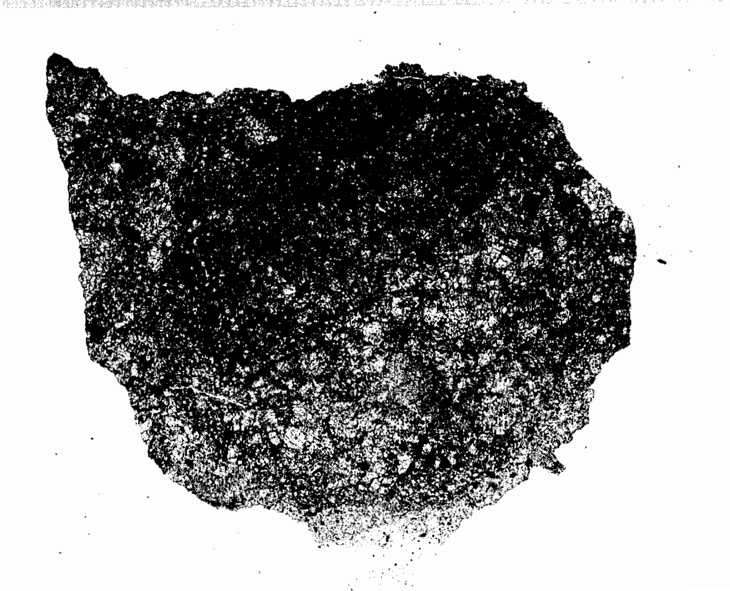


Fig. 4b. Photomicrograph showing brecciated texture with chondrules. Width is 12 mm, plane polarized light.

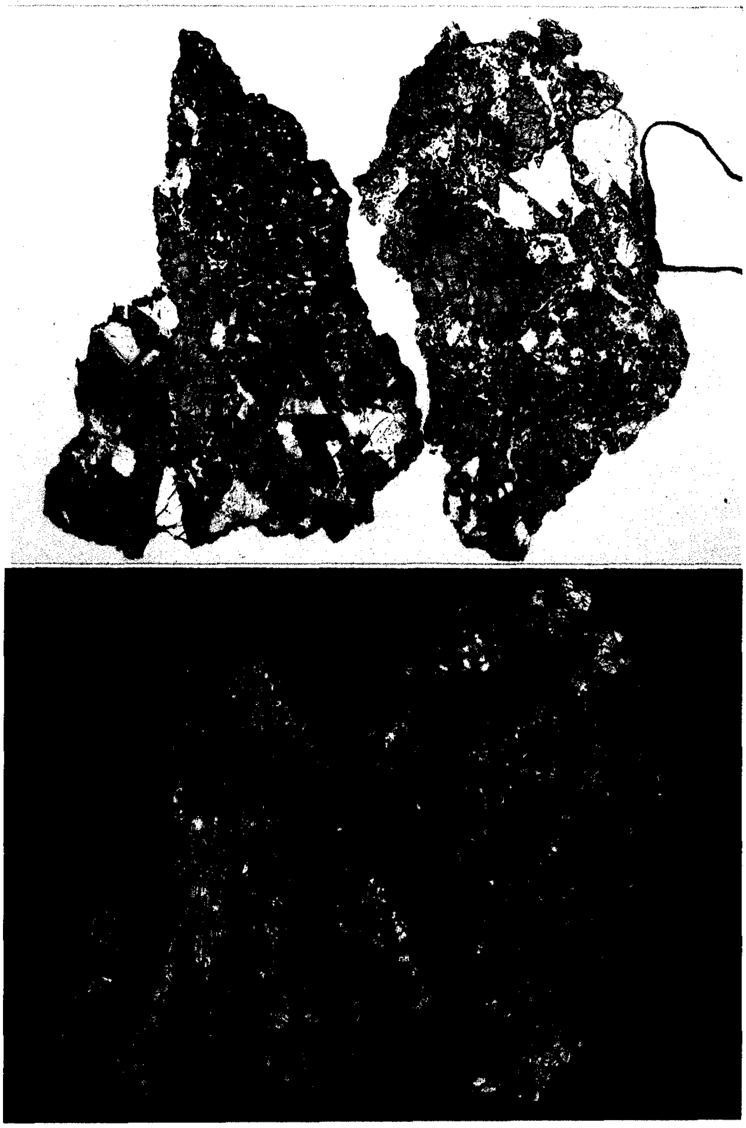
6. Brief Descriptions of Asuka-88 Achondrites and Mesosiderite, Together with Unique and Unusual Meteorites

A-881371 olivine-fassaite basalt: A-881371 is one of the most unusual specimens among the 2000 meteorites collected from the new site of the Asuka region, East Antarctica.

A-881371 consists mainly of olivine, fassaite and plagioclase, with accessory spinel (YANAI, 1991b). This specimen is a rounded stone of 11 grams, almost completely covered with a dull-black fusion crust (Fig. 6a). Pale green, relatively coarse porphyritic olivine crystals are seen on the exposed interior. The photograph of the section (Figs. 6b, c) shows an unbrecciated and typically ophitic (doleritic) texture with euhedral plagioclase, intergranular fassaite and relatively coarse-grained porphyritic olivine, and

(a)

Fig. 5a. Photograph of A-87272 (5.7 kg), eucrite, a complete angular stone covered by shiny-black fusion crust. This is the largest achondrite in the Asuka collections. Scale cube is 1 cm.



(b)

(c)

Figs. 5b, c. Photomicrographs showing a coarse-grained and moderately brecciated texture. Width is 12 mm. (b) Plane polarized light. (c) Crossed polars.

(a)

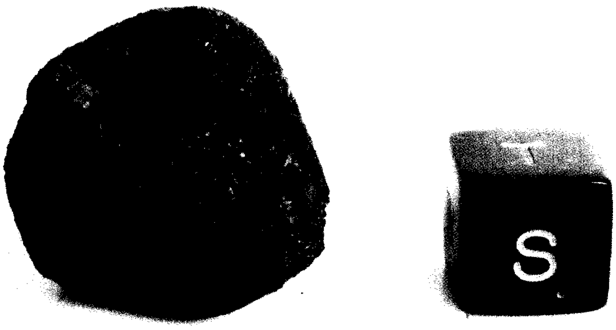
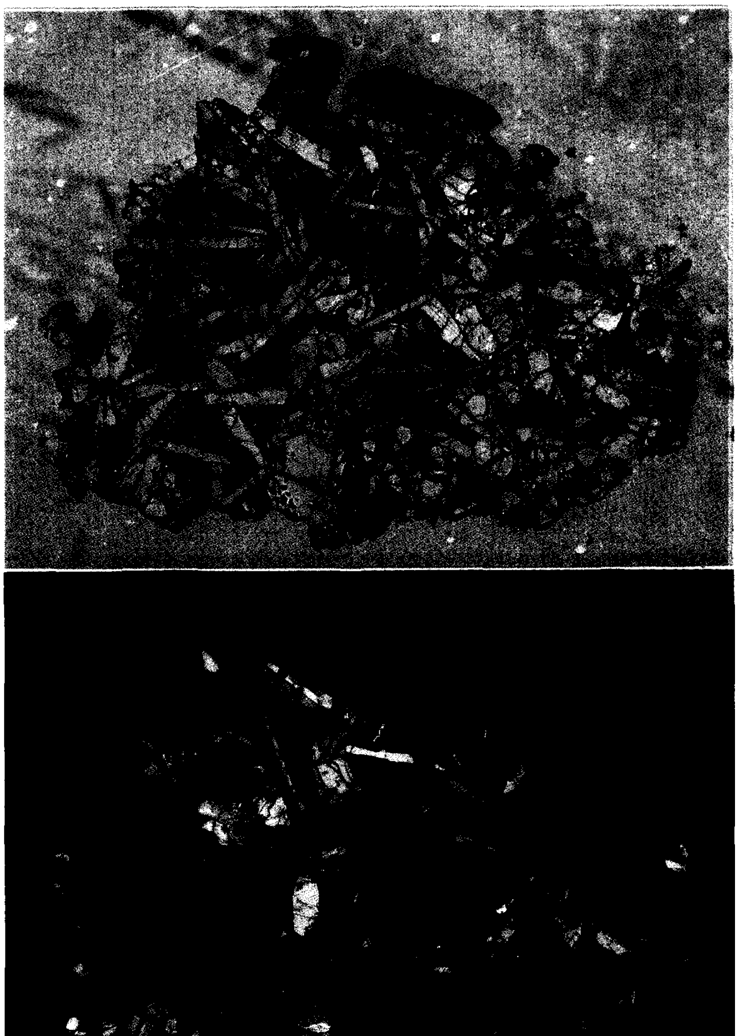


Fig. 6a. Photograph of A-881371, angrite, an almost complete rounded stone covered by black fusion crust. Some green-colored, large olivine grains can be seen. Scale cube is 1 cm.

(b)

(c)



Figs. 6b, c. Photomicrographs showing ophitic texture of plagioclase, fassaite pyroxene and coarser olivine with fusion crust at the top. Field of view is 3.5 mm wide. (b) Plane polarized light. (c) Crossed polars.

opaques and spinel. From its texture, it is clear that this meteorite originated from igneous activity on the surface or near surface of its parent body.

Pyroxene is the most abundant mineral and is strongly pleochroic, from nearly colorless in the core to brown in the rim. Pyroxene is extremely high in CaO (over 22%) and variable in Al_2O_3 (3.5–9.9%). Most pyroxenes have uniform CaO, but show zoning from Mg-rich cores to Fe-rich rims, which corresponds to their pleochroic features. The pyroxene is fassaite, but only a few of the pyroxenes plot in the pyroxene quadrilateral where all known pyroxenes in lunar basalts plot. The pyroxenes have a remarkably high FeO/MnO ratio, and several grains lie within the range of average lunar pyroxenes, but most are clearly different from pyroxenes of lunar and basaltic achondrites.

Olivine shows a very wide compositional range of $Fo_{2.8-90}$ and crystals are zoned over the range Fo_{58-85}, with Fe-rich rims and extremely Mg-rich cores. Most olivines lie in the restricted ranges of Fo_{55-73} and Fo_{84-90}, but some are very Fe-rich, $Fo_{2.8}$. Plagioclase is remarkably homogeneous and is virtually pure anorthite of An_{99}. It is more calcic than that found in all known achondrites (except angrites) and in lunar basalts. No evidence of zoning and maskelynitization is found.

The bulk analyses are given in Table 3. The results of the oxygen isotopic analysis differ from previous analyses of lunar rocks (R. CLAYTON, personal communication, 1989). Three meteorites; Angra dos Reis, LEW86010 and LEW87051 are already known as fassaite achondrite or angrites. A-881371 is an unusual achondrite and texturally similar to the LEW87051 angrite, but texturally distinct from Angra dos Reis and LEW86010, and chemically different from LEW87051 (PRINZ *et al.*, 1977; MASON, 1987, 1989; KALLEMEYN and WARREN, 1989; WARREN and KALLEMEYN, 1990).

A-881377 diogenite: A-881377 is an almost round stone of 214 grams, with a shiny-black fusion crust showing a light gray to pale greenish interior (Fig. 7a). In the thin section, this fresh specimen shows a typical brecciated texture consisting almost entirely of magnesian orthopyroxene with olivine and traces of troilite and metallic iron (Figs. 7b, c). A large orthopyroxene grain shows undulatory extinction and 3 parallel cracks through the whole grain. Microprobe analyses give the following compositions: pyroxene $En_{74}Fs_{23}Wo_3$ (average), and olivine Fa_{26-28}.

The bulk analyses are given in Table 3.

A-881388 fine-grained eucrite: A-881388 weighs 16 g and appers to be half of the original stone. It has a broken very fresh surface without fusion crust (Fig. 8a) and the remainder has a smooth, well rounded surface covered by a shiny-black fusion crust. This tiny fresh specimen is an unbrecciated, fine-grained crystalline eucrite, consisting mostly of pyroxene (pigeonite) and plagioclase and traces of troilite, chromite and a silica mineral (Figs. 8b, c). Microprobe analyses give the following compositions: low-Ca pyroxene ($En_{34.8-37.5}Fs_{51.2-61.0}Wo_{3.0-14.0}$), Ca pyroxene ($En_{29.4-30.2}Fs_{28.3-30.0}Wo_{40.2-41.9}$) and plagioclase ($An_{88-91}$). The bulk analyses are given in Table 3.

A-881394 coarse-grained eucrite: A-881394 weighs 70 g, and is a somewhat elongated, angular stone with approximetely 3% shiny-black fusion crust and a coarse-grained interior (Fig. 9a). The stone appears as a granular aggregate of light brown spotted pyroxene grains within a white plagioclase basis. The thin section shows

Table 3. Major-element chemical analyses of the Asuka-87 and Asuka-88 meteorites in weight percent.

	A-87272 Eucrite	A-881371 Angrite	A-881377 Diogenite	A-881388 Eucrite	A-881394 Eucrite	A-881467 Eucrite	A-881526 Diogenite	A-881757 Gabbro	A-881931 Ureilite	A-882023 Mesosiderite
SiO_2	46.98	37.30	50.35	46.80	49.92	46.45	52.99	45.36	37.70	27.93
TiO_2	0.18	0.88	0.13	0.42	0.20	0.53	0.03	1.66	0.03	0.04
Al_2O_3	13.27	10.07	2.29	13.86	15.39	14.24	0.99	11.49	0.51	4.88
Fe_2O_3	0.0	0.63	0.95	0.76	0.67	0.74	2.06	0.60	3.56	1.79
FeO	19.57	23.43	15.72	18.06	12.74	18.69	14.72	21.18	16.20	8.80
MnO	0.36	0.20	0.36	0.29	0.29	0.29	0.32	0.25	0.32	0.28
MgO	7.29	14.81	27.86	7.02	9.45	6.25	27.19	6.41	35.26	10.01
CaO	11.02	12.51	1.27	11.13	11.53	10.73	1.21	11.99	1.34	4.39
Na_2O	0.42	0.03	<0.02	0.45	0.07	0.52	0.03	0.50	0.21	0.27
K_2O	0.05	<0.02	<0.02	0.03	<0.02	0.05	<0.02	0.04	0.02	<0.02
$H_2O(-)$	0.05	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.05	0.00
$H_2O(+)$	0.1	0.0	0.2	0.19	0.0	0.54	0.05	0.0	3.8	0.1
P_2O_5	0.27	0.17	trace	0.31	0.03	0.24	trace	0.05	0.20	0.53
Cr_2O_3	0.13	0.13	0.54	0.15	0.33	0.15	0.62	0.17	0.20	0.30
FeS	0.80	—	—	—	—	—	—	—	0.89	0.49
Fe	0	—	—	—	—	—	—	—	0	38.70
Ni	78 ppm	233 ppm	62 ppm	18 ppm	53 ppm	13 ppm	62 ppm	29 ppm	0.11	1.96
Co	<30 ppm	<30 ppm	<30 ppm	<30 ppm	<30 ppm	<30 ppm	<30 ppm	<30 ppm	0.007	0.12
S		0.59	0.14	0.19	0.08	0.74	0.17	0.19		
Total	100.49	100.77	99.85	99.86	100.72	100.16	100.40	99.89	100.40	100.61

Analyst: H. HARAMURA.

(a)

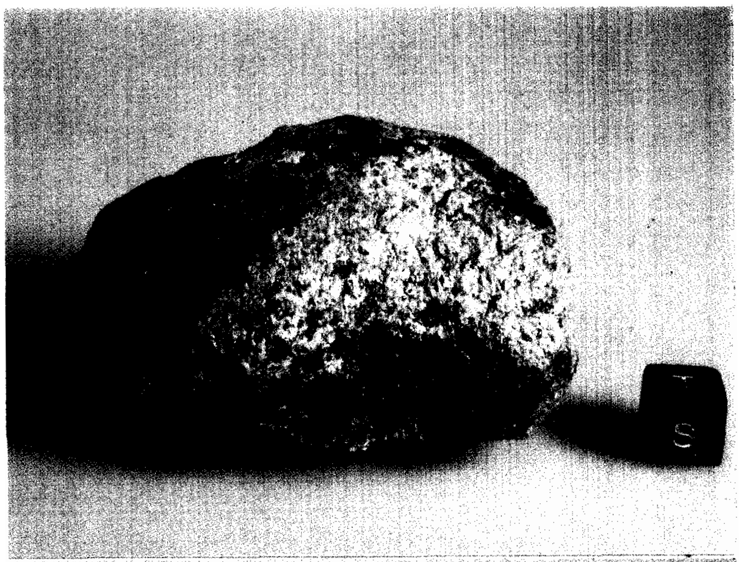
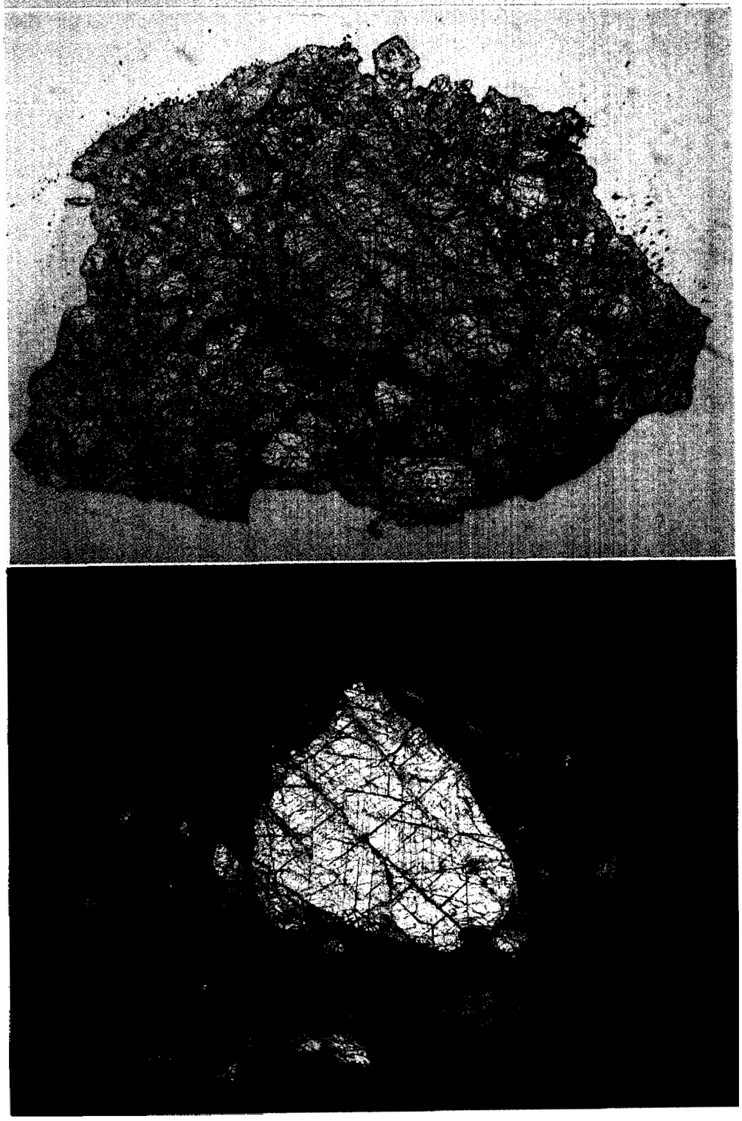


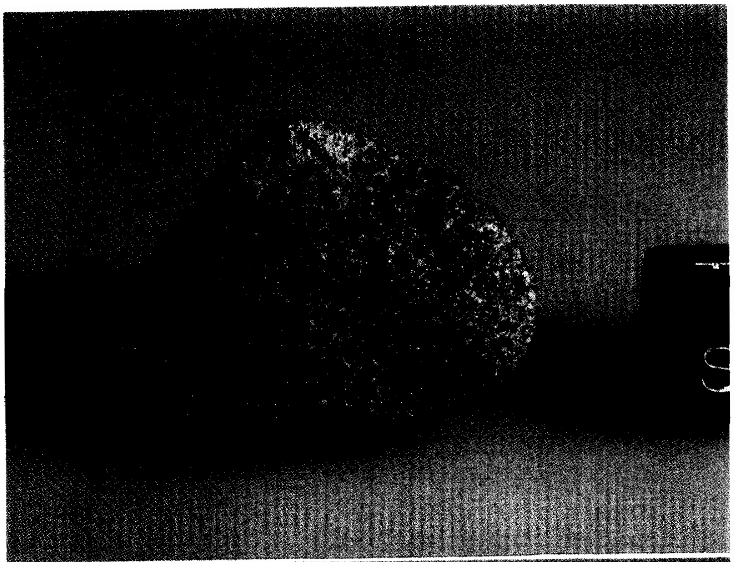
Fig. 7a. Photograph of the A-881377 diogenite, covered by shiny-black fusion crust with pale greenish interior. Scale cube is 1 cm.

(b)

(c)

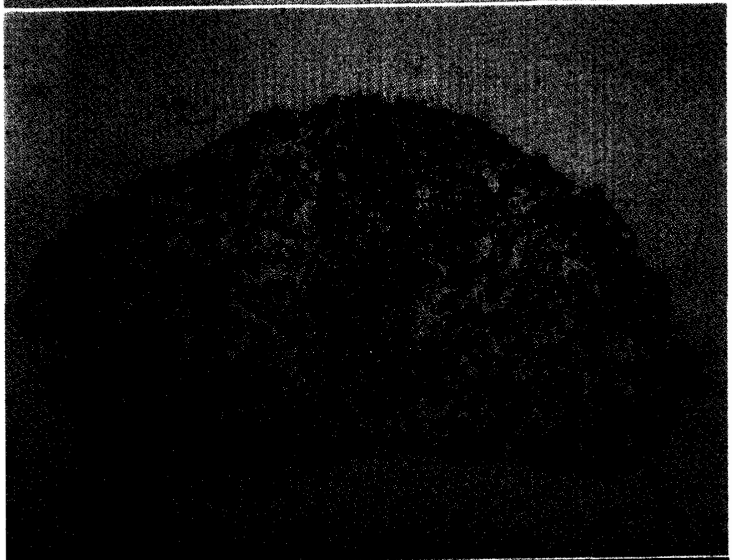


Figs. 7b, c. Photomicrographs showing typical brecciated texture, consisting almost entirely of magnesian orthopyroxene. Width is 9 mm. (b) Plane polarized light. (c) Crossed polars.

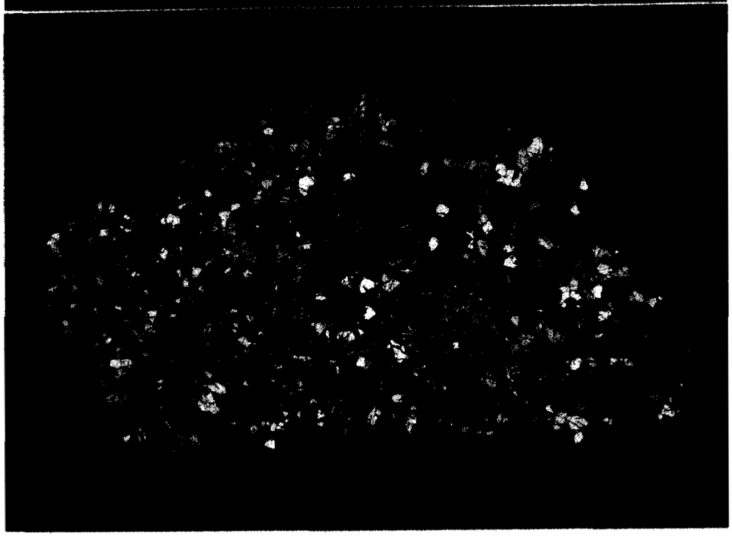


(a)

Fig. 8a. Photograph of the A-881388 fine-grained eucrite, almost half with shiny-black fusion crust. Scale cube is 1 cm.

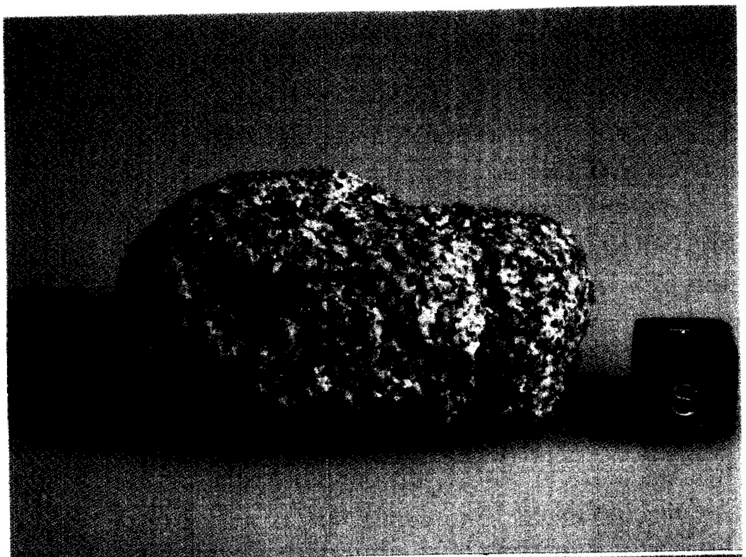


(b)



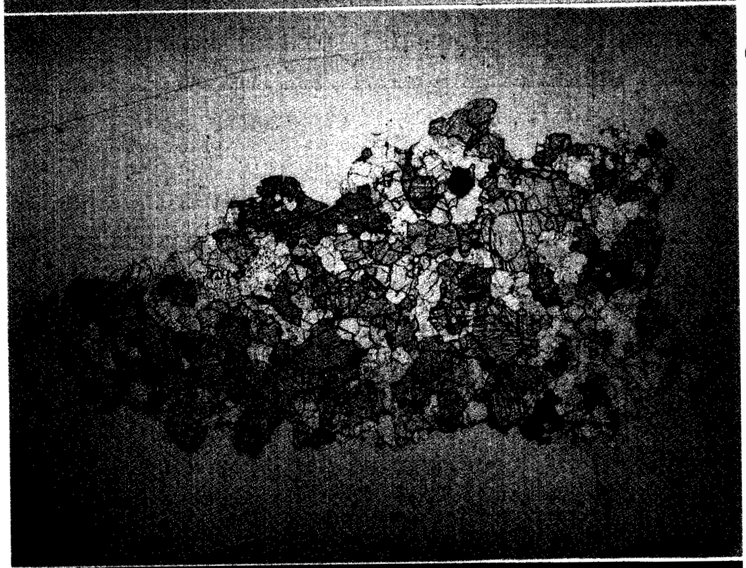
(c)

Figs. 8b, c. Photomicrographs showing fine-grained texture of pyroxene and plagioclase. Width is 6.5 mm. (b) Plane polarized light. (c) Crossed polars.



(a)

Fig. 9a. Photograph of the A-881394 coarse-grained eucrite, with completely ablated fusion crust, showing coarse-grained interior. Scale cube is 1 cm.



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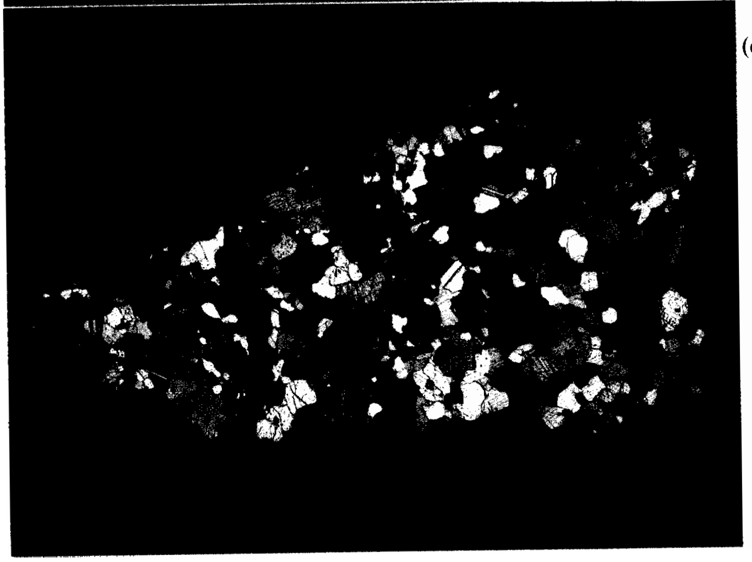


(c)

Figs. 9b, c. Photomicrographs showing a granular texture of coarse-grained pyroxene and plagioclase. Width is 11 mm. (b) Plane polarized light. (c) Crossed polars.

that A-881394 is an unbrecciated, coarse-grained crystalline eucrite (Figs. 9b, c) consisting mainly of pyroxene and plagioclase with traces of troilite. Mineral compositions give the following: low-Ca pyroxene ($En_{54}Fs_{43}Wo_3$)–Ca pyroxene ($En_{39}Fs_{18}Wo_{43}$) on average, and plagioclase ($Ab_2An_{98}Or_0$, average). The bulk analyses are given in Table 3.

A-881467 medium-grained eucrite: A-881467 (previously named A-15) is an unbrecciated, porphyritic eucrite which is one of the unique achondrites from the Asuka region (YANAI, 1991c). The specimen weighed 38 g and measured 4.2 × 2.6 × 2.2 cm. It is a round and seemingly almost complete stone, but less than 1% of its shiny-black fusion crust remains (Fig. 10). The exterior shows nearly homogeneous plagioclase (white) and granular pyroxene (yellowish-pale brown) with fine opaques (black).

A-881467 is characterized by porphyritic plagioclase (1.5–2 mm), with lots of inclusions and elongated, an euhedral silica minerals in a fine-grained groundmass of pyroxene, inclusion-free plagioclase (0.1–0.3 mm), silica minerals and troilite, ilmenite and apatite. Pyroxene is as abundant as plagioclase. It is colorless to pale brown and occurs as subhedral grains (0.1–0.5 mm) showing exsolution in some. Ca-pyroxene has an almost uniform composition, $En_{30}Fs_{30}Wo_{40}$, but low-Ca pyroxene ranges slightly in Ca, $En_{31}Fs_{51-61}Wo_{3-14}$. Plagioclase varies in size from porphyritic crystals (1.5–2 mm) to fine grains (0.1–0.3 mm) in the groundmass, in which composition ranges from An_{83-90}. The silica mineral is possibly cristobalite, as suggested by its low refractive index and weak birefringence. Some silica crystals are elongated up to 2 mm and they often cross-cut porphyritic plagioclases and pyroxenes.

The bulk analyses are given in Table 3. Al and Fe are high, but Si and Mg are low compared with cumulate eucrites.

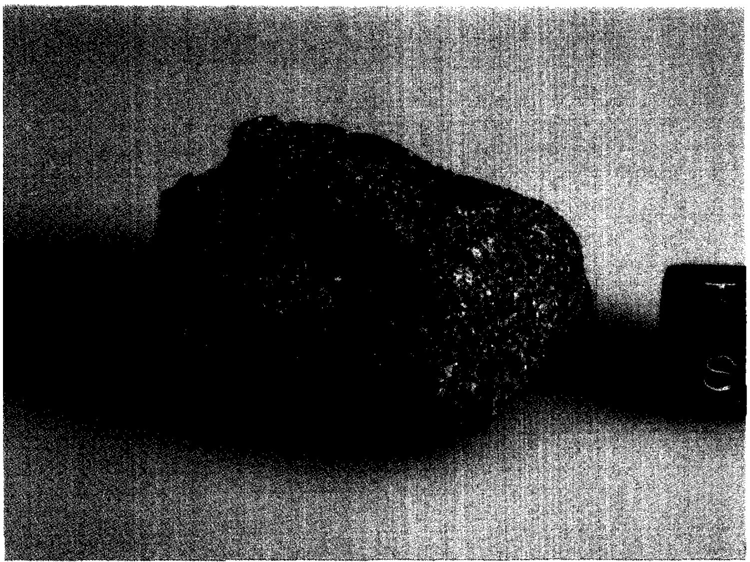
A-881526 diogenite breccia: A-881526 is a 480 g, extremely ablated and quite fragile stone with a trace of a black fusion crust. It is very coarse-grained, with large pyroxene clasts in a fine-grained pyroxene matrix. It is a very fresh specimen in spite of the weathering (Fig. 11a). The thin section shows that it consists of an extremely simple mineral assemblage made almost entirely of orthopyroxene clasts and matrix, with traces of troilite, metallic iron and chromite (Figs. 11b, c). Microprobe data of pyroxene give an average $En_{74}Fs_{23}Wo_3$, with a small compositional range.

The bulk analyes are given in Table 3. A-881526 is similar to the Johnstown diogenite in its texture, mineral assemblage and chemical composition.

A-881757 lunar mare gabbro: A-881757 (previously named Asuka-31) is one of the most unusual specimens among the Asuka meteorites. This specimen was found on December 20, 1988, at the northeastern end of the Nansenisen (Nansen Icefied) approximately 130 km south of the Japanese Antarctic Base "Asuka Station" (71°32′S, 24°08′E), Sør Rondane Mountains in Queen Maud Land, East Antarctica.

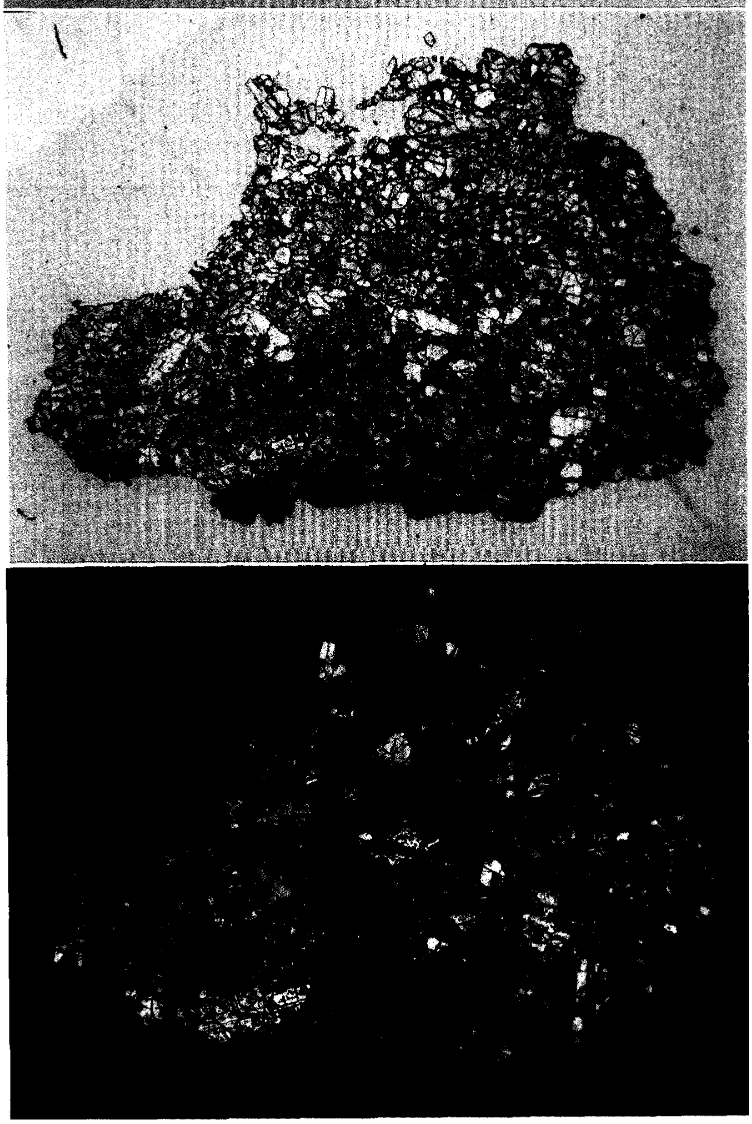
The meteorite appears to be half of the original stone and has a broken surface without fusion crust, and the remainder has a very smooth, well rounded surface covered by shiny-black fusion crust (Fig. 12a). A-881757 weighed 442.12 g and measured 8.0 × 8.0 × 5.8 cm. The original volume of the specimen is 130.8 cm^3 and the specific gravity is 3.38 (g/cm^3). These values were obtained by the Air Comparison Pyconometer Model 930 (made by Beckman Instrument, Inc., Canada), without water or any liquids.

Preliminary descriptions and photography of the specimen were carried out by the



(a)

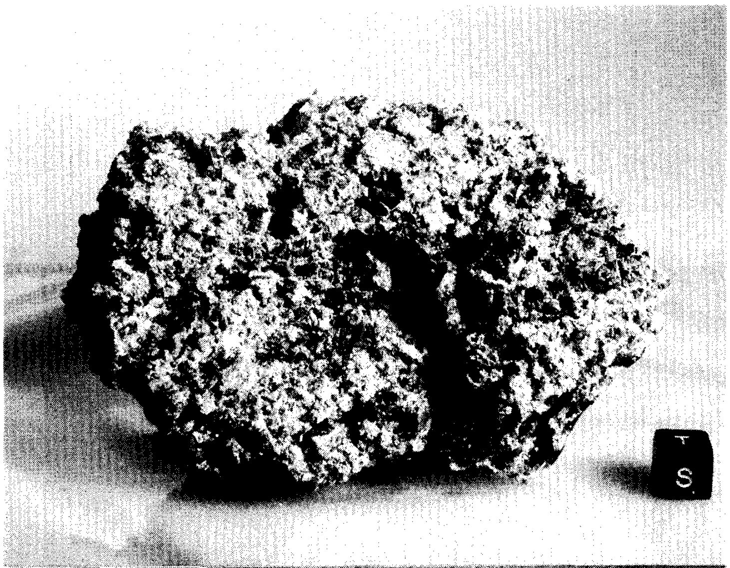
Fig. 10a. Photograph of the A-881467 medium-grained eucrite, with traces of a shiny-black fusion crust. Scale cube is 1 cm.



(b)

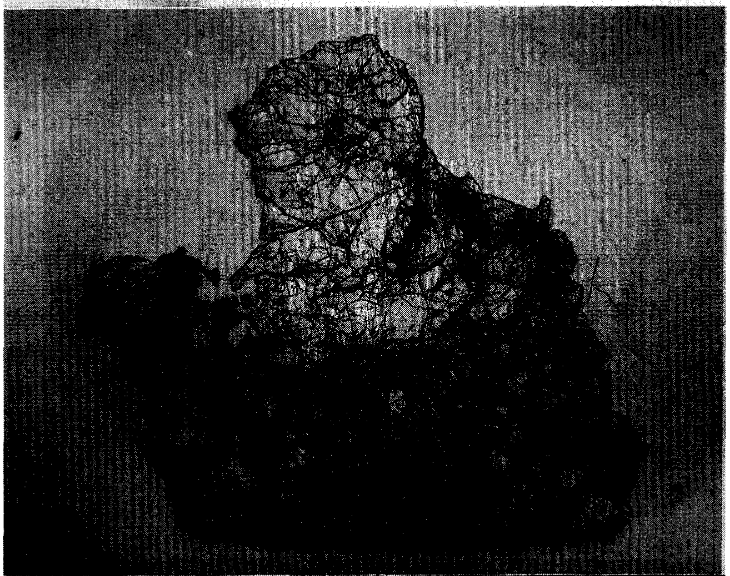
(c)

Figs. 10b, c. Photomicrographs showing the unbrecciated and porphyritic texture consisting of porphyritic plagioclase, granular pyroxene and an elongated silica mineral. Width is 10 mm. (b) Plane polarized light. (c) Crossed polars.

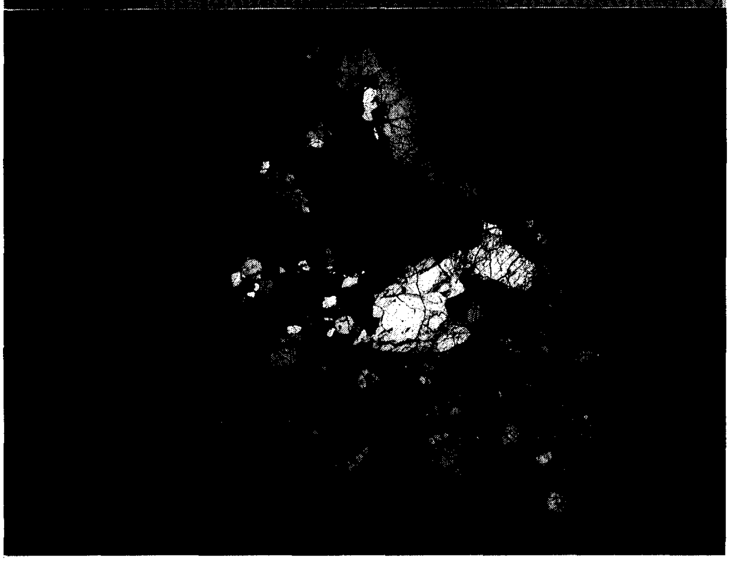


(a)

Fig. 11a. Photograph of the A-881526 diogenite breccia, scale cube is 1 cm.



(b)



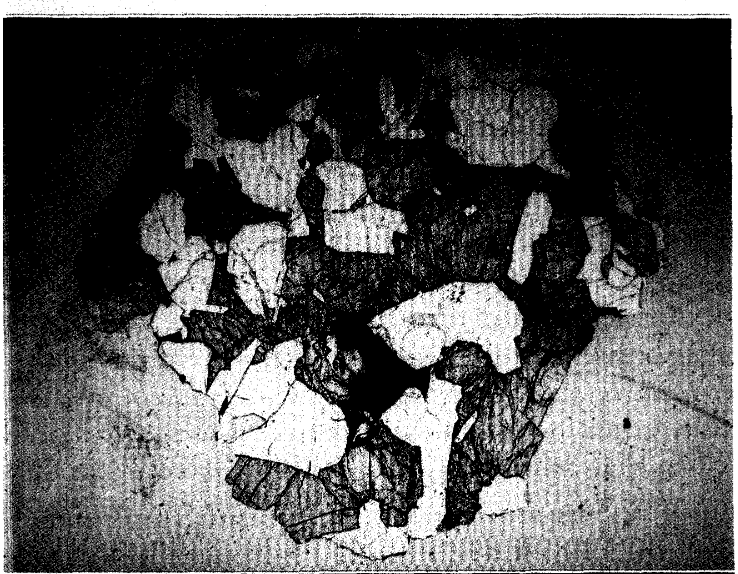
(c)

Figs. 11b, c. Photomicrographs showing the typical brecciated texture, consisting entirely of orthopyroxene clasts and matrix, with fusion crust at the bottom. Width is 9.5 mm. (b) Plane polarized light. (c) Crossed polars.

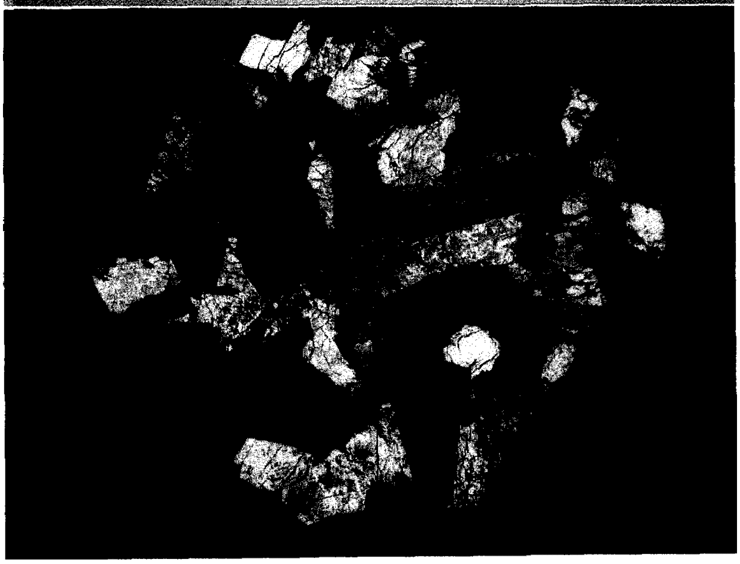
(a)

Fig. 12a. Photograph of the A-881757 (previously named Asuka-31) lunar mare gabbro, almost half of a specimen showing the interior composed of coarse-grained, brown pyroxene and translucent plagioclase (maskelynite), with black ilmenite and black glass veinlets, covered with shiny-black fusion crust at top of the stone. Scale cube is 1 cm.

(b)



(c)



Figs. 12b, c. Photomicrographs of gabbro consisting of very coarse-grained pyroxene and isolated plagioclase (maskelynite), with ilmenite and with fusion crust on the left edge. Field view is 9 mm. (b) Plane polarised light. (c) Crossed polars.

author (YANAI, 1990, 1991d). It has a coarse-grained, unbrecciated interior composed of pale flesh-colored to brown pyroxenes and translucent plagioclases with black glass veinlets and black ilmenites. The stone has the general appearance of a very coarse-grained cumulate eucrite or ureilite.

The thin sections show that A-881757 is a very coarse-grained and unbrecciated rock, consisting mainly of pyroxene and plagioclase (completely maskelynitized) with ilmenite and troilite, and traces of olivine, apatite, a silica phase (quartz?) and Ni-Fe metal (Figs. 12b, c). A-881757 typically has a subhedral granular texture consisting of chains of pyroxene and isolated plagioclase crystals, ranging from 2 to 4 mm, and from 1 to 3 mm respectively. The mode is roughly 59% pyroxene, 30% plagioclase, 6% ilmenite and 5% other phases, including troilite and coronas of symplectite around opaque minerals.

Pyroxene is the dominant mineral. It occurs in transparent and almost colorless, apparently twinned subhedral grains showing slight cracking and wavy extinction caused by shock. The composition of the pyroxene is remarkably heterogeneous, ranging from $En_{7.8}$ to $En_{43.6}$, $Fs_{30.7}$ to $Fs_{68.2}$, $Wo_{11.6}$ to $Wo_{40.7}$. The pyroxenes of A-881757 have an average FeO/MnO = 61, within the range of lunar pyroxenes and clearly different from pyroxenes of basaltic achondrites. The range of FeO/MnO (40 to 100) is typical of lunar pyroxene.

The olivine is Fe-rich, ranging from $Fo_{5.4}$ to $Fo_{13.4}$; its FeO/MgO ratio is very high, 73 to 105, and characteristic of lunar material. Most olivines are very small crystals ($<10\,\mu m$) in contact with opaque minerals or rimmed by symplectites, in which the olivines formed around opaque minerals.

Plagioclases are completely maskelynitized and occur as isolated grains in chains of pyroxene crystals. Twinning and zoning are not observed under the microscope, but relatively clear compositional zoning of Ca-rich cores ($Ab_{3.8}An_{96.1}Or_{0.1}$), sodic and potassium-rich rims ($Ab_{22.6}An_{75.1}Or_{2.3}$) is recognized, with a strong mode at approximately $An_{90\text{-}95}$. Among several dozens of plagioclases analyzed, only the rims of a few large grains were as sodic as $Ab_{22.8}An_{73.8}Or_{3.4}$.

Several grains of ilmenite with chromian ulvöspinel were found as one of the minor components in each of the thin sections. Ilmenite grains are subhedral, isolated from each other, and range from 2 to 3 mm. Some are surrounded by symplectite. Troilite is fine-grained (10–30 μm), and there are two different occurrences; one as isolated grains mostly rimmed by symplectite, and the other are sporadic very tiny grains (under 10 μm) in most of the symplectites.

Symplectite is not a rare occurrence in the specimen and surrounds the opaque minerals (ilmenite and troilite) as halos. It consists mainly of very fine-grained olivine, pyroxene, apatite, plagioclase (anorthite), Fe-Ni metal(?) and a silica phase (quartz?). The worm-like texture is composed mainly of an olivine-pyroxene-plagioclase intergrowth.

The major element composition of A-881757 was determined by standard wet chemical analysis by H. HARAMURA (YANAI, 1991c, Table 3.). The bulk chemical data of A-881757 are in the range of lunar mare basalts, which differ from all highland rocks and terrestrial basalts. Therefore, A-881757 might have originated from a lunar mare region.

(a)

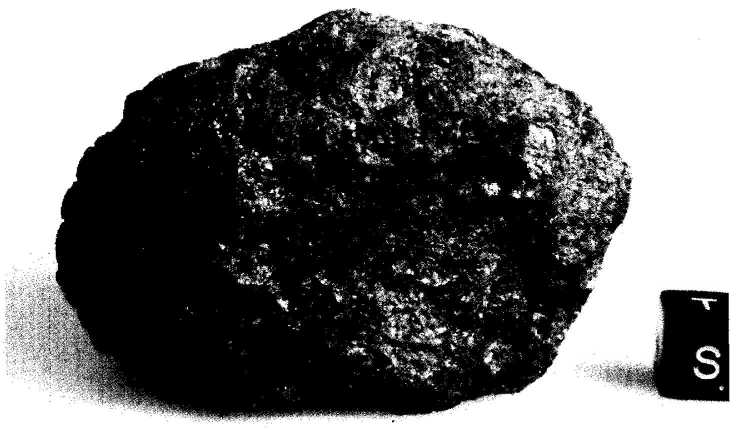
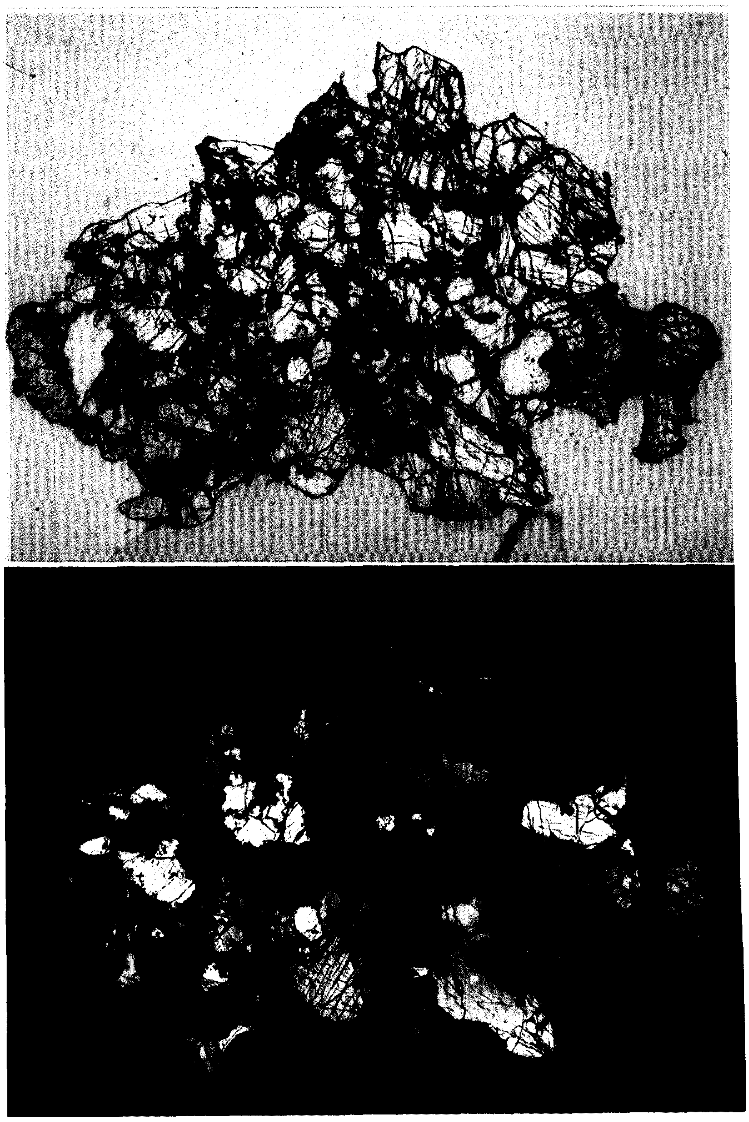


Fig. 13a. Photograph of the A-881931 ureilite, a coarse-grained and almost complete, angular stone covered by dusty-dark gray fusion crust. Scale cube is 1 cm.

(b)



(c)

Figs. 13b, c. Photomicrographs showing a coarse-grained texture of olivine and pyroxene with darker material along grain boundaries. Width is 7.5 mm. (b) Plane polarized light. (c) Crossed polars.

(a)

Fig. 14a. Photograph of the A-882023 mesosiderite, a complete angular specimen covered by dusty black fusion crust. Scale cube is 1 cm.

(b)

(c)

Figs. 14b, c. Photomicrographs showing a brecciated texture of metallic clasts and crushed pyroxene and plagioclase. Field view is 10 mm. (b) Plane polarized light. (c) Crossed polars.

The oxygen isotopic signature of mineral fractions in A-881757 has recently been determined by R. CLAYTON. The results are in exact agreement with previous analyses of lunar rocks, and are unlike any other non-lunar meteorite type. The oxygen isotope data strongly support a lunar origin for A-881757 (R. CLAYTON, personal communication, 1989).

A-881757 is an unbrecciated and very coarse-grained meteorite showing gabbroic texture. Its lithology is similar to some cumulate eucrites and ureilites, but compositionally distinct from them. The bulk chemistry and mineral composition of A-881757 are consistent with those of lunar mare basalts and differ from basaltic achondrites. A-881757 appears to be closely related to the low-titanium and the very-low-titanium (VLT) lunar mare basalts.

The Apollo and Luna samples contain coarse-grained gabbroic rocks as tiny fragments in soil and small clasts in breccias, but hand specimens have not yet been sampled. All lunar meteorites collected previously, except Y-793169 (YANAI and KOJIMA, 1991), are breccias (YANAI and KOJIMA, 1984), and a gabbroic type like A-881757 was unknown. Asuka-881757 is a new type of lunar gabbro which might have originated from a lunar mare region. It is similar to Apollo 15 pigeonite basalts, Luna 24 and Apollo 17 VLT basalts in bulk chemistry and mineral compositions in spite of their quite different lithology.

A-881757 suggests that there is a great possibility of the existence of more unsampled rock types on the Moon, and that there are new types of meteorites to be found in Antarctica.

A-881931 ureilite: A-881931 is a 150 g, almost complete subangular stone, approximately 60% being covered with dull, black fusion crust. The interior is dark gray and shows a medium to coarser-grained granular texture with darker material (Fig. 13a). The thin section shows that the meteorite is a ureilite consisting almost entirely of anhedral to subhedral olivine and pyroxene with carbonaceous material which is concentrated at the grain baundaries (Figs. 13b, c). Trace amounts of troilite and nickel-iron also occur along grain boundaries. Microprobe analyses give olivine of variable compositions (Fo_{84-78}) and low-calcium clinopyroxene with almost uniform composition ($En_{73-74}Fs_{17-19}Wo_{8-9}$).

A-882023 mesosiderite: A-882023 is a complete specimen of over 1.1 kg. It is rounded to subangular with fairly smooth surfaces covered with dull-dark brown to black fusion crust, approximetely over 90% (Fig. 14a). Some light brown silicate inclusions are obvious on the crust-free surface. The thin section is dominated by metal clasts in a groundmass consisting largely of crushed pyroxene, olivine, plagioclase and metallic iron with troilite (Figs. 14b, c). Microprobe analyses give the following compositions; Olivine is almost uniform Fo_{67-65}, pyroxene is a little variable $En_{67}Fs_{30}Wo_{3}$ (average) with some Ca-pyroxene, and plagioclase is almost pure anorthite An_{88-96} with $Or_{0.1-0.4}$.

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