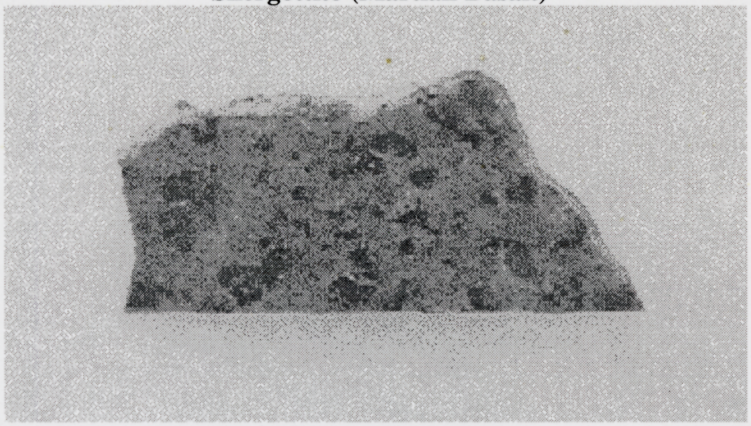
DAR AL GANI 476

Shergottite (Martian Basalt)



Found May 1, 1998
27° 21.16' N., 16° 12.04' E.

Dar al Gani 476, also known as "Lucky 13", is a basaltic shergottite found in the Libyan Sahara desert, the first Martian meteorite recovered from a hot desert environment. The brown, loaf-shaped mass measuring ~15 x 10 cm and weighing 2,015 g was analyzed and classified at Germany's Max-Planck-Institut für Chemie in Mainz. This is very appropriate since this institute also developed the APXS instrument used during the Mars Pathfinder Mission aboard the Sojourner Rover to analyze surface rock compositions. Three separate basaltic shergottites designated DaG 489, DaG 670, and DaG 735 weighing 2,146 g, 1,619 g, and 588 g respectively were recovered in the same area. Petrographic and mineralogical features and noble gas abundances are indistinguishable from those of DaG 476 and all four meteorites are likely paired. After thousands of years of desert exposure (85 +/-50 k.y.), DaG 476 has completely lost its fusion crust and developed cracks and veins that are filled with carbonate and other terrestrial weathering products. DaG 735 has experienced less weathering and has no carbonate-filled veins.

The Martian shergottite group was divided into two distinct subgroups:

1. A basalt subgroup comprising those meteorites with a volcanic origin derived from a fractionated magma and consisting primarily of the clinopyroxenes pigeonite and augite, in addition to having a high abundance of feldspathic glass.
2. A lherzolite subgroup comprising those meteorites with a plutonic origin and a cumulate texture that were derived from the original magma, consisting primarily of olivine, chromite, and orthopyroxene.

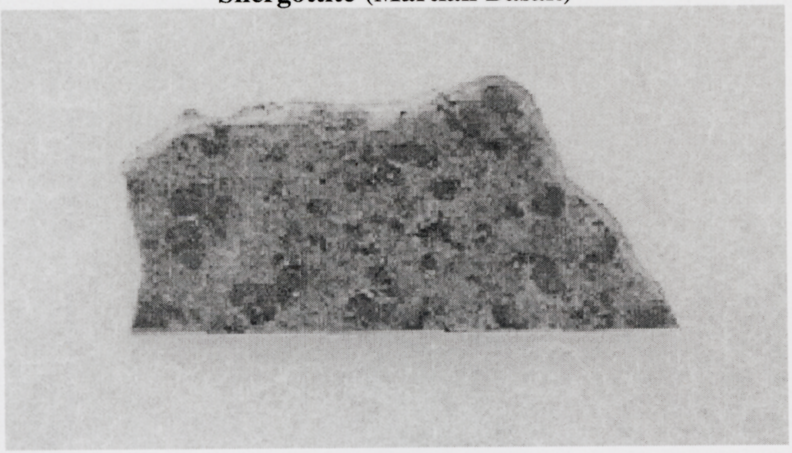
DaG 476 contains an unusually high abundance of olivine (15-17 vol%) in the form of xenocrysts embedded in a fine-grained groundmass composed mostly of Ca-poor pigeonite and feldspathic glass with minor Ca-rich augite. Chromite grains and other minor phases are present. The olivine xenocrysts in this meteorite show close mineralogical, petrological, and trace element similarities to lithology A of the basaltic shergottite EETA79001, and has experienced similar cooling rates. The REE pattern and Sm-Nd systematics of DaG 476 imply that a close relationship once existed with the basaltic shergottite QUE94201, as well as to Nakhla and Chassigny. Conversely, the bulk chemistry of DaG 476 is very similar to that of the lherzolitic shergottites. The conditions under which DaG 476 crystallized were more reducing than those of other basaltic shergottites, and it is the most magnesian member of the basalt subgroup. Overall, its mineralogy and bulk chemistry indicate it is a distinct shergottite intermediate between the basaltic and lherzolitic subgroups.

Comparisons with Viking inert gas measurements as well as results from chemical, mineralogical, petrographic, and oxygen isotopic studies clearly identify DaG 476 as Martian. Combining the 21Ne-based CRE age of ~1.17 m.y. and the calculated terrestrial age of ~85 k.y., a Mars ejection age of ~1.35 m.y. ago is derived. This represents a unique ejection event from that of other members of either the basaltic or lherzolitic subgroups (~2.8 and ~3.8 m.y. ago respectively). However, it is close to that of the basaltic shergottite EETA79001 which has a CRE age and terrestrial age consistent with its ejection close to the time of DaG 476. Based on cosmogenic Ne isotopic ratios it is estimated that the preatmospheric radius of DaG 476 was only ~20 cm.

DaG 476 has a crystallization age of 800 m.y., and the cooling rates are consistent with a burial depth during crystallization of less than 1 m. The texture of olivine xenocrysts and pyroxene crystals are indicative of flow alignment within an extruded lava flow near the surface. Shock features in the meteorite include twinning of clinopyroxene, mosaicism of olivine, and plagioclase converted to feldspathic glass, as well as abundant impact melt pockets. The above specimen is a 0.7 g partial slice in which dark olivine xenocrysts are seen throughout the greenish pyroxene matrix.

DAR AL GANI 476

Shergottite (Martian Basalt)



Found May 1, 1998
27° 21.16' N., 16° 12.04' E.

Dar al Gani 476, also known as "Lucky 13", is a basaltic shergottite found in the Libyan Sahara desert. The brown, loaf-shaped mass measuring ~15 x 10 cm and weighing 2,015 g was analyzed and classified at Germany's Max-Planck-Institut für Chemie in Mainz. This is very appropriate since this institute also developed the APXS instrument used during the Mars Pathfinder Mission aboard the Sojourner Rover to analyze surface rock compositions.

At least three other separate basaltic shergottites designated DaG 489, DaG 670, and DaG 735, weighing 2,146 g, 1,619 g, and 588 g respectively, were recovered in the same general area as DaG 476. Petrographic, mineralogical, textural, and shock features, as well as noble gas abundances, are indistinguishable from those of DaG 476 and all four meteorites are likely paired. After thousands of years of desert exposure (85 ±50 k.y.), DaG 476 has completely lost its fusion crust and developed cracks and veins that are filled with carbonate and other terrestrial weathering products. Although likely falling at the same time, DaG 670 is much more highly weathered than DaG 476. On the other hand, DaG 735 has experienced less weathering than DaG 476 and has no carbonate-filled veins. Although it was the last mass to be officially classified, DaG 735 was actually the first of the four masses to be found; it was recovered during the Winter 1997/98.

Another Martian basaltic shergottite was recovered in Oman in 1999 and given the name Sayh al Uhaymir 005. Together with a paired mass named Sayh al Uhaymir 008, the two have a total combined weight of 9,923 g. SaU 005 shows very close similarities to DaG 476 in bulk chemical composition, and texture, although it shows mineralogical evidence of having experienced slower cooling rates. Noble gas and radiometric age data place the cosmic-ray exposure age at 1.5 ±0.3 m.y., indicating an ejection age from Mars similar to that of DaG 476 (see below). The preatmospheric diameter of SaU 005 was determined to be ~24 cm. Unlike DaG 476, SaU 005 is very fresh, retaining a partial fusion crust and exhibiting few terrestrial weathering products. SaU 005 and Dag 476 are likely comagmatic rocks from the same igneous region on Mars.

Also in 1999, two paired stones totaling 698 g were found in, and given the name of Los Angeles, California. This unique basaltic shergottite is the most differentiated of any Martian meteorite found so far. Los Angeles crystallized in a lava flow or shallow intrusion, and experienced a slower cooling rate than other shergottites, resulting in a coarser-grained texture. A cosmic-ray exposure age of ~3.0 m.y. is similar to that of the Shergotty and Zagami shergottites, implying a common ejection event.

To add to this staggering number of recent Martian meteorite recoveries, a 1,056 g basaltic shergottite found in Oman in January, 2000, named Dhofar 019, has provided a further window on Martian igneous petrogenesis. This meteorite has features quite similar to those of DaG 476 including an abundance of olivine phenocrysts, but with a lower magnesium content. A 21Ne- and 38Ar-based CRE age of ~20 m.y. has been calculated. This is a third longer than any other Martian meteorite, and four times longer than any other shergottite. This extremely long CRE age is at the theoretical limit of the calculated delivery time of material to Earth from Mars.

The Martian shergottite group was divided into two distinct subgroups:

1. A basalt subgroup comprising those meteorites with a volcanic origin derived from a fractionated magma and consisting primarily of the clinopyroxenes pigeonite and augite, in addition to having a high abundance of feldspathic glass.
2. A lherzolite subgroup comprising those meteorites with a plutonic origin and a cumulate texture that were derived from the original magma, consisting primarily of large olivine and chromite crystals, and enstatitic pyroxene. They also contain magnesium-rich pigeonite, augite, merrilite, and ilmenite.

DaG 476 contains an unusually high abundance of olivine (~20 vol%) in the form of phenocrysts embedded in a fine-grained groundmass composed mostly of Ca-poor pigeonite and feldspathic glass with minor Ca-rich augite. Micron-sized chromite grains and other minor phases are present within the olivine, giving it a speckled appearance. The olivine phenocrysts in this meteorite show close mineralogical, petrological, and trace element similarities to the lherzolitic shergottites, and in particular to EETA79001 lithology A. While the bulk chemistry of DaG 476 is closer to that of the lherzolitic shergottites, the REE pattern and Sm-Nd systematics imply that a close relationship once existed with the basaltic shergottite QUE94201, as well as to Nakhla and Chassigny. The conditions under which DaG 476 crystallized were more reducing than those of other basaltic shergottites, and it is the most magnesian member of the basalt subgroup. Overall, its mineralogy and bulk chemistry indicate that it is a distinct shergottite intermediate between the basaltic and lherzolitic subgroups.

DaG 476 has a young crystallization age of ~474 m.y. (Sm-Nd), with cooling rates that are consistent with a burial depth during crystallization of less than 1 m. It is thought to have formed through a high-degree of partial melting of a lherzolite-like source material, followed by segregation of a melt containing unmelted phases of olivine, enstatite, and chromite. Furthermore, a residue containing a fraction of the unmelted phases was removed from this "crystal mush", leaving behind the fraction that would eventually form DaG 476. The texture of olivine phenocrysts and pyroxene crystals are indicative of flow alignment within an extruded lava flow near the surface. High shock features including twinning of clinopyroxene, mosaicism of olivine, and plagioclase converted to feldspathic glass, as well as abundant impact melt pockets, correspond to a shock stage of at least S5.

Comparisons with Viking inert gas measurements as well as results from chemical, mineralogical, petrographic, and oxygen isotopic studies clearly identify DaG 476 as Martian. Combining the 21Ne-based CRE age of ~1.17 (±0.09) m.y. and the calculated terrestrial age of ~85 k.y., a Mars ejection age of ~1.35 m.y. ago is derived. Exposure ages of all members of both the basaltic and lherzolitic subgroups represent only a few ejection events from Mars; shergottites correspond to ejections at ~1.5, ~2.8, and ~20 m.y., and lherzolites at ~3.8 m.y. As a result of the uncertain terrestrial age for the basaltic shergottite EETA79001, which has a CRE age of ~0.6 m.y., its ejection age may either be similar to that of DaG 476, or represent a unique ejection event.

Based on cosmogenic Ne isotopic ratios, it is estimated that the preatmospheric diameter of DaG 476 was only ~40 cm. The above specimen is a 0.7 g partial slice in which dark olivine phenocrysts are seen throughout the greenish pyroxene matrix. The photo below shows the *in situ* mass of DaG 476 as it was found in the desert.