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New Saharan Find: Arondrite of Lunar Origin

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Introduction

Over twenty meteorites have been identified as being of lunar origin. The find site in the Libyan Sahara is one of the richest lunar meteorite locality in recent time. We report on the recovery of a new achondrite from Libya. This stone (6 g) was collected in the wadi Zam Zam area in year 2000. It is a dark grey unbrecciated basaltic stone with incomplete fusion crust. We present here the first results of mineralogical and petrological studies.

Mineralogy, Petrology and Composition

A small piece of the original meteorite was studied by mineral analysis (quantitative analyses and backscattered electron images – BSE were obtained using CamScan S4 electron microscope with Link ISIS 300 analytical system at Charles University, Prague) and bulk chemistry was studied using compositional methods (INAA, fused-beam EMP). The meteorite is a ***low-Ti olivine mare basalt*** with crystalline porphyritic texture. The modal mineralogy, as determined by EMP mapping and point counting, is: 25.3 % olivine, 52.2 % pyroxene, 17.4 % feldspar (maskelynite), 3.1 % opaques (mainly ilmenite and spinel), <1 % silica, <1 % impact melt.

Olivine occurs in anhedral to subhedral grains ranging up to 300 μm across with composition from Fa_{38} to Fa_{62}, mean Fa_{47}, commonly with ilmenite and chromian-spinel inclusions. Matrix is composed of coarse-grained pyroxene, which varies in composition from pigeonite Wo_{11-20} En_{2-70} to augite Wo_{25-38}

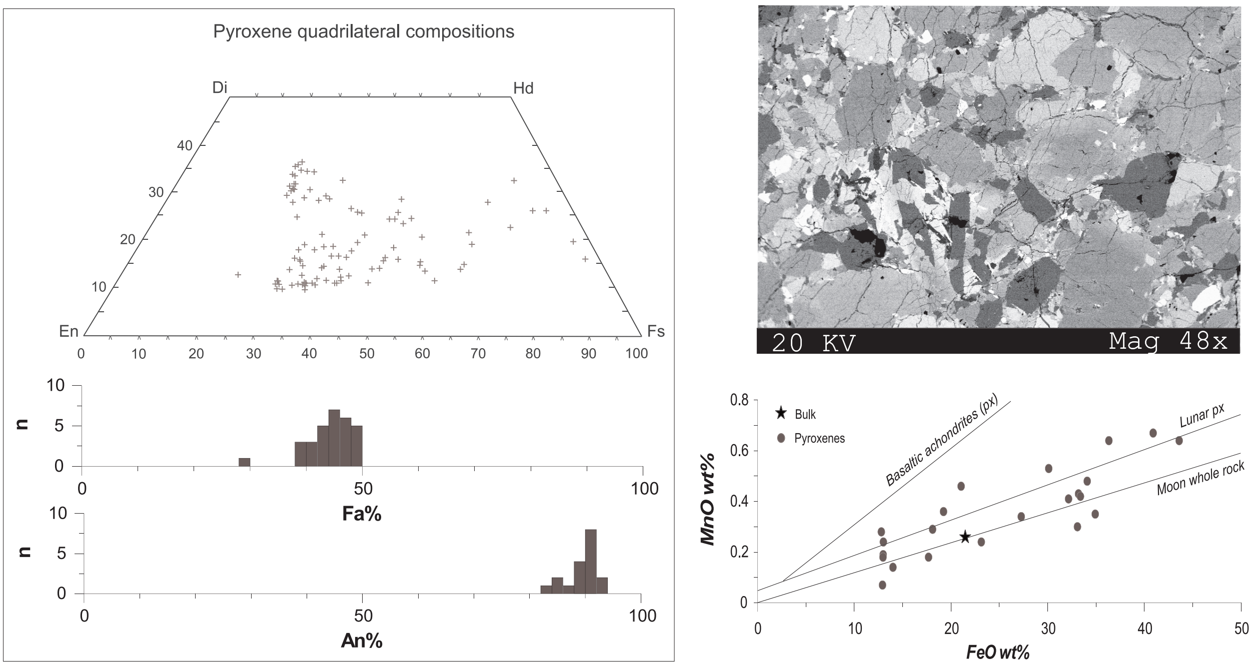

Fig. 1. Major element composition of pyroxenes plotted onto pyroxene quadrilateral and composition diagrams for olivine and plagioclase (left). FeO/MnO ratio of pyroxenes and bulk sample (right). BSE image displaying the porphyritic texture (upper right).

En_{2-50}; Fe-rich pyroxene Wo_{15-25} En_{2-20} and plagioclase (An_{85-92}) are also present. Minor phases include ilmenite (1–3 wt% MgO) and chromian ulvöspinel, accessory minerals are troilite, silica and K-Ba-rich glass. From the observed texture we can reconstruct the crystallization sequence for major phases: olivine + spinel → pigeonite → augite → plagioclase → ilmenite.

The bulk composition, estimated from planispheric EMP analyses, is: 44.5 SiO_2, 1.6 TiO_2, 8.9 Al_2O_3, 0.49 Cr_2O_3, 21.6 FeO, 0.35 MnO, 12.9 MgO, 9.2 CaO, 0.07 K_2O (wt%). REE abundances and the REE pattern will be determined using NAA methods.

Shock effects include impact-melt veinlets localized along olivine and plagioclase grain boundaries (2-10 µm wide), undulatory extinction and presence of planar features in olivine, suggesting shock pressures >20 GPa (S4) (Stoeffler et al., 1991). The evidence of strongly shocked nature is supported by almost complete conversion of plagioclase to maskelynite. Terrestrial weathering feature – oxidation of opaque phases – indicates weathering grade W1 (Wlotzka, 1993).

Conclusions

From the bulk chemical composition, mineralogical description and analyses of major phases (MnO/FeO ratio), presence of troilite (indicator of prevailing reduction conditions) and the total lack of minerals containing water, it can be inferred that the sample is of lunar origin. The porphyritic texture and zoning of pyroxene indicate relatively slow crystallization and cooling of the basalt. Mineral chemistry (e.g., pyroxenes) and textures together with major element composition resemble olivine basalts collected during Apollo 12 (Taylor, 1975; Papike et al., 1998). Based on spectral reflectance measurements taken by Clementine mission (1994) we can define the source areas of the meteorite mass: the meteorite may have been a part of lava flows filling the margins of large impact basins at near side of the Moon. The new Saharan meteorite is unique among lunar meteorites in terms of lithology, which is distinctly different from the formerly described mare basalts NWA 032, NWA 773 or Dhofar 287.

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Dip-Slip Tectonics in the Lower Devonian Rocks of the NW Edrengyin Nuruu, SW Mongolia

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Edrengyin Nuruu is a NW–SE-tending mountain range composed of Lower Devonian to Carboniferous volcanosedimentary complexes intruded by Variscan granitic bodies. Central part of the mountain range is formed by slightly metamorphosed Lower Devonian Ulgii Fm. It is generally composed of flysch-like volcaniclastic rhythmites in the southern part, altered basaltic tuffs and agglomerates in the central part and massive basalt of alkaline composition in the north.

Mylonitized phyllite schists and green schists with folded bodies of rhyolite and limestone represent the Ulgii Fm. in the NW termination of the Edrengyin Nuruu. Contacts with undeformed and unmetamorphosed Carboniferous volcanics in the NE and granodiorite of the Devonian Tsakhirt intrusive complex in the SW are of tectonic character.

Subvertical NW–SE-striking mylonitic foliation strongly overprinted the bedding which is preserved in relics only. Rare small-scale folds have limbs parallel to foliation and steeply plunging axes, they are tight to isoclinal. Two generations of lineation have been identified. The older one is subvertical aggregate lineation. Asymmetrical structures indicate subsidence of the northern block. Dextral shearing is related to younger striae and furrowing plunging to the SE.

Normal faulting tectonics in the Ulgii Fm. should be pre-Carboniferous and could reflect the emplacement of the granitic massif exposed in the south, although the primary contact is masked by a younger fault today. Relation to breaking-up and rifting (Voznesenskaya, 1989) of a pre-collisional volcanic arc is speculative only. The youngest dextral shearing is connected with the late Variscan movements along the boundaries between different accreted blocks.

The studied section was situated in the vicinity of a base camp of the Czech–Mongolian geological expedition in the year 2002 (International Development and Assistance Project of the Czech Republic); its position is defined by coordinates 44°36.7 N and 96°55.0´ E.

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