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PETROLOGICAL VARIATION OF THE ŁOWICZ METEORITE

Absract: The Łowicz mesosiderite (3A) breccia consists of the rock fragments characterised by varied petrological composition, where orthopyroxene rocks correspond to diogenites, some fragments are enriched in a metallic phase and the others contain pyroxenes with strongly diverisfied compositions. Its current position in classification is equivocal. Locally, the Łowicz meteorite is excessively rich in Ti.

Keywords: Łowicz meteorite, mesosiderite, breccia, diogenite, ortho-, clinopyroxenes, plagioclases.

INTRODUCTION

On the 11/12 of March 1935 the meteorite shower fell southward from Łowicz. The total mass of the over 60 collected specimens exceeds 60kg. This event and subsequent mineralogical, petrographical analyses with classification of the meteorite were widely described by Kobyłecki (1938), Jaskólski (1938), Kołaczkowska (1938), Moritz (1938), Thugut (1938), Powell (1971), Karwowski (2003, 2004). Based on that the silicates present reflect a relatively basaltic composition with abundant plagioclase and clinopyroxene, and that their matrix is recrystallised (Mittlefehldt *et al.* 1998), the Łowicz meteorite has been classified as a 3A mesosiderite. Karwowski (2003) pointed on the significantly different petrographic type of this meteorite. Two samples of the meteorite corresponding to pyroxenite with melting crust, which were collected near Łowicz in 1935 have been found in the museums. These two fragments are distinguished due to their lower density. The mineralogical composition and the proportion of the metallic phases are the main features that differentiate considerably others available specimens of the Łowicz meteorite.

METHODS

The analysed material has been obtained by courtesy of Olsztyn Planetarium and Astronomic Observatory, Astronomic Observatory of the Jagiellonian University, Geological Museum of the Jagiellonian University and private collectors: M. Cimała, J. Bandurowski, S. Jachymek; one sample come from the USA (Tab. 1).

Table 1. Studied meteorites with number of fragments.

Sample	Fragments of meteorite (number of fragments)
1	Diogenitic achondrite (4)
2	Mesosiderite (1-from the USA)
3	Metal with silicates (2)
4	Mesosoderite (2)

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The petrographic studies in reflected light and treating with nital were carried out, then micro-area analyses using microscope Philips XL 30 ESEM/TMP with EDS – EDAX attachment and an electron microprobe CAMECA SX 100 were performed.

RESULTS

As the Łowicz meteorite is the mesosiderite it represents a unique type of breccia meteorite where the silica phases consist of a mixture of clasts related petrologically close to the HED suite. Observational data show that studied specimens vary significantly in colour, crystal sizes and metallic phase content. Some fragments contain more than 90% of metal. The careful investigations of the single fragments of the Łowicz meteorite contradict its recent classification.

The achondritic fragments (1) consist mainly of the anhedral orthopyroxene clasts En$_{\sim 80}$ (bronsite – hypersten) surrounded by fine-grained orthopyroxene matrix (Fig. 1 and 2). A glassy melted crust containing pyroxene (Wo$_{1.07}$ En $_{80.31}$ Fs$_{18.62}$) has been preserved on the small secondary metal veins cutting the whole rock. Silica phase and apatite are minor components. Opaque minerals are represented by kamacite, taenite, tetrataenite, troilite, chromite, schreibersyte and minute quantities of graphite (Tab.2). The rock composition corresponds to pyroxenite –the Earth magmatic cumulates– hyperstenite; while in meteorites – diogenites (Bowman *et al.* 1997) without olivines and plagioclases.

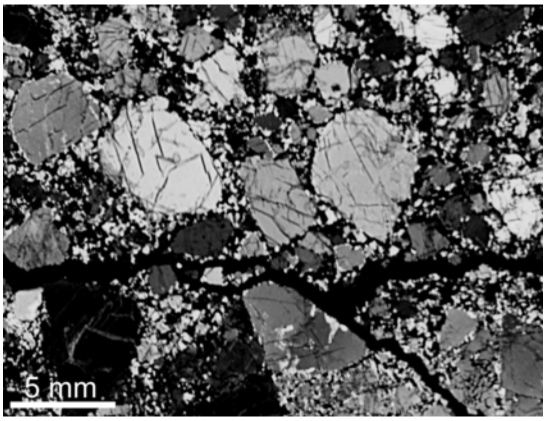

Fig. 1. Large orthopyroxene crystals surrounded by fine grained orthopyroxene matrix in diogenite (1); metal veins (black) cut the whole rock.

Table 2. Composition of diogenite (1) (vol %)

Orthopyroxene	88.14
SiO$_2$ (probably)	1.20
kamacite, taenite, tetrataenite	3.31
Troilite	6.60
Chromite	0.67
Σ: apatite, schreibersite, graphite	0.08

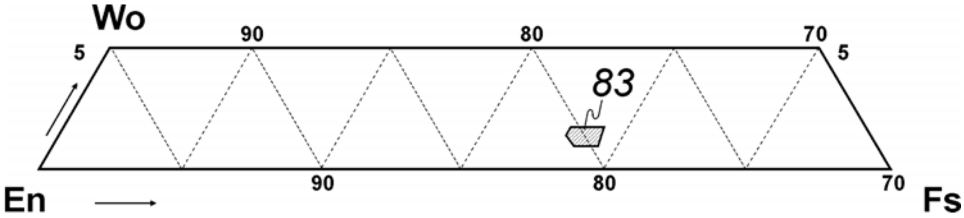

Fig. 2. Composition of orthopyroxenes from diogenite (1) plotted on En-Wo-Fs diagram.

The diogenite (1) and other fragments (2,3,4) of the meteorite differ significantly in the pyroxene chemical composition. Pyroxenes of the diogenite are twice as rich in Cr and Mn as the latter one, but contain less titanium. There occur small inclusions of silica, kamacite or chromite in the orthopyroxene.

Table 3 shows clearly that chromites from the Łowicz diogenite (1) are markedly richer in Cr than those from the samples (2,3,4), but slightly poorer in Al, Ti, Fe and V.

Table 3. Compositions of chromite grains from the Łowicz meteorite (wt%)

Component	Diogenite (1)	Samples 2,3,4
Cr_2O_3	59.59 – 63.02	50.86 – 52.18
Al_2O_3	2.89 – 8.02	12.75 – 8.72
FeO	26.23 – 27.22	27.92 - 29.55
MgO	2.44 – 3.53	2.55 – 3.13
MnO	0.91 – 1.32	0.72 – 1.13
V_2O_5	0.48 – 0.78	0.74 – 0.85
TiO_2	0.23 – 0.41	1.25 – 3.08
CaO	0.00 – 0.00	0.00 – 0.14
NiO	0.00 – 0.04	0.00 – 0.02
ZnO	0.00 – 0.03	0.00 – 0.09
SiO_2	0.00 – 0.003	0.00 – 0.03

Karwowski (2003, 2004) gives the wide characteristics of the other mineral phases. Fluoroapatite and hydroxylapatite has been found only among apatites. The cores of metallic phase grains in diogenite fragments (1) consist of kamacite, while rims are taenite and tetrataenite. Two different forms of kamacite have been found in secondary veins, and coarse crystalline form with numerous Neumann lines outside. The investigated diogenites are greatly diminished in titanium. The orthopyroxenes contain extremely low amounts of TiO_2 from 0.02 to 0.07wt%, as compared with typical diogenites (Mittlefehldt *et al.* 1998).

Silicates (orthopyroxenes, bytownite, olivine and silica phase) are located in coarse crystalline kamacite mass with taenite secretion, in the specimens (3) where the metallic phase reaches over 90% of the volume. They formed as a result of recrystallisation of silicate melt being in equilibrium with metal (Fs/Fa ~0.8). Troilite, titanium minerals and chromite coexist with silicates.

The fragment (2) obtained from the USA is rich in clinopyroxenes (pigeonite, diopside) and orthopyroxenes ($Fs_{\sim 30-40}$) with small exsolutions of orthopyroxene clasts (~1cm) ($Fs_{\sim 20}$) identical to the diogenitic ones (Fig. 3 a), as well as, smaller olivine clasts ($Fa_{\sim 26.7}$). The olivines of different compositions ($Fa_{\sim 33.6}$) occur near the outermost parts of the metallic phase. The evenly scattered rutile and plagioclase, bytownite/anortite in composition, coexist with the pyroxenes, while schreibersyte is connected with the metallic phase. This sample corresponds to 3A mesosiderite, only.

A few of the examined meteorite (4) differ slightly in composition from the described above. Silicates are represented by orthopyroxene ($Fs_{\sim 28}$, Fs_{35-37}) (Fig. 3 b), palgioclase (An_{71-73}, An_{89-92}) and rare clasts of cataclastic olivines (Fa_{26-27}). Pyroxenes of the contents above Fs_{30}, often accompanied by silica phase, were inverted from original pigeonite (Powell 1971). These meteorites contain also chromite and evenly scattered rutile and troilite. Metal content is approximately 40-60 % in volume.

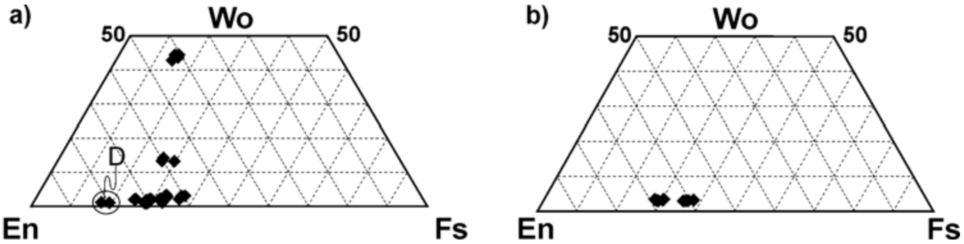

Fig. 3. Plots showing variation of pyroxene compositions in the En-Wo-Fs system; a) fragment from the USA (2); D – relates to orthopyroxene clasts from diogenite (1); b) microprobe analysis of orthopyroxenes from specimens (2,4)

Rutile dominates among the Ti-phases, which occur as secretions in studied samples (2,3), except diogenite (1). The Ti-phases contain inclusions of ortho- and clinopyroxenes as well chromites averaging 0.4-0.8 and 1.23-3.08 of wt% TiO_2, respectively. The contacts between the metal and silicate phases are characterised by high concentration of titanium minerals, in some samples. Locally, chromites contain the small lamellae of ilmenite originating from exsolution (Jaskólski 1938), in those area secretions of titanium minerals reach 30% in volume. Several oval melt inclusions representing two separate partly devitrified silica melts (Karwowski 2003), with extremely different chemical composition have been found close to secretions of titanium minerals within the kamacite area in meteorite (3) (Tab. 4). It is assumed they are relics of the impact melt.

The external melt phase corresponds to subsilicic melt significantly enriched in P, Ti and Ca, while the internal one has an acid character. According to the TiO_2/MgO and Al_2O_3/ MgO ratios the former phase is close in relations to some high-Ti moon basalts (Papike et al. 1998), but is vastly different in high content of P_2O_5 and CaO and low content of FeO. Surprisingly, inclusions are preserved in relatively coarse crystalline kamacites.

Table. 4. Composition of the exsolved silica melts in inclusions in kamacite (wt%).

Component	External alloy phase	Internal alloy phase
P_2O_5	12.65 - 13.36	0.58 – 0.80
K_2O	0.26 – 0.36	0.10 – 0.64
Na_2O	1.09 – 1.11	0.86 – 1.30
CaO	16.78 – 17.71	5.40 – 6.35
FeO	6.84 – 8.74	1.34 – 2.32
MnO	0.50 – 0.73	0.12 – 0.19
TiO_2	6.45 – 7.93	1.55 – 1.77
MgO	5.29 – 7.17	0.75 – 1.91
Al_2O_3	9.10 – 11.57	11.75 – 12.14
SiO_2	35.42 – 37.26	73.98 – 76.32

CONCLUSIONS

There are fragments of non-homogenised diogenites in the Łowicz meteorite that have been partly scattered within the meteorite leaving relics of several centimetres large fragments or single orthopyroxene grains. The investigated meteorites vary significantly in content-wise of metal and silicates (orthopyroxenes Fs_{28} and $Fs_{35\text{-}37}$ and olivines) being in balance with metal. It is believed they are the result of impact alloy recrystallisation. One specimen corresponds to the determined classification of the Łowicz mesosiderite–3A.

Hence, the genesis of the Łowicz meteorite is complex. It may be assumed that it formed as a result of collisions of two or more bodies varied significantly in phase contents. Presuming that it was an increasing collision of differentiated planetozymallae and the fragment with metal core, it resulted in mixture of various rocks originating from different depths with metallic matter. This may be proved by the general lack of equilibrium between the olivine, pyroxene and metal phases. However, locally partial melting and crystallization of pyroxene and olivine being already in equilibrium with the metal phase could have occurred.

Undoubtedly, the occurrence of the fragments extremely enriched with titanium as well as the presence of the relics of Ti-bearing impact alloy is quite interesting. Such a high concentration of titanium apart from the moon rocks is rare.

It is necessary to carry out further investigations of the museum material containing various types of rocks from that fall to obtain more reliable knowledge on petrography and origin of the Łowicz meteorite.

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