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SECONDARY MINERALS IN MORASKO AND PUŁTUSK METEORITES

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Morasko and Pułtusk meteorites represent two different types of interplanetary matter – iron and stony chondrite adequately. Both underwent weathering in similar conditions, with predominance of soil and atmosphere influence. In both meteorites the weathering of kamacite and taenite was observed. Goethite and lepidocrochite enriched in Ni as well as iron carbonate – siderite enriched in Ni are the main products of weathering. In the external parts of weathered meteorites the high-Ni metallic and sulphide phases precipitated. The metallic phases resemble the Ni-alloys with admixture of several per cent of Fe. Sulphides are represented by non-stoichiometric Ni,Fe phases and millerite (NiS). The secondary high Ni metallic compounds, stated in Morasko meteorite, showed also unusually high Ge concentration: up to 5% at. That might be interpreted in terms of strong siderophile tendency of Ge in hypogene conditions.

Key words: Morasko and Pułtusk meteorite, weathering, secondary minerals, Ni-secondary minerals, Ge-concentration.

Morasko and Pułtusk meteorite represent two different types of interplanetary matter. Morasko meteorite is classified as iron-type meteorite (IAB), while Pułtusk represent the stony meteorite, in particular ordinary chondrite H5 (brecciated)[1, 5]. The source area for Morasko meteorite is most probably the planetoid 4 Westa type, while Pułtusk meteorite comes from 6 Hebe planetoid. Morasko meteorite was discovered in 1914, and his fall is estimated for 3 500–5 000 years ago. Pułtusk meteorite had fallen down 140 years ago. On the Earth's surface both meteorites existed in absolutely different physical and chemical conditions. However, the both underwent the weathering in similar climatic and soil conditions in different time periods. The primary mineral phases of Morasko meteorite are as follows: kamacite (α – Fe,Ni), taenite (γ – Fe,Ni), cohenite (Fe,Ni)₃C, schreibersite (FeNi)₃P, tetrataenite, troilite FeS, sphalerite ZnS, graphite, daubreilite FeCr₂S₄, altaite PbTe. Meteorite contains also rare silicates (pyroxenes, olivine, feldspars), phosphates, oxides (rutile, and chromite) and copper [1, 2, 3]. Pułtusk meteorite showed different mineral composition. Main groundmass is formed by silicates (olivines, pyroxenes, feldspars). Iron is represented by both kamacite, taenite and tetrataenite which form about 16–18% vol. Troilite, chromite – FeCr₂O₄, apatite and copper – are subordinate mineral phases [4].

Meteorites found in the last years near Morasko near Poznań and those coming from meteorite “rainfall” from Pułtusk were investigated. Part of the material investigated were specimens collected just after the fall (1868), part of the specimens come from the museum collections (collected by J. Samsonowicz in the 30s of XX c.) as well as the specimens collected in the years 2007 and 2008. Petrographical investigations were carried out using both reflected and transmitted microscopy and mineral phases were identified both optically and using X-ray diffraction. Chemical composition of minerals was determined using scanning electron microscope equipment of EDS (EDAX) detector (in Scanning Microscopy Laboratory at the Faculty of Earth Sciences, University of Silesia, Sosnowiec) and Electron Microprobe Cameca SX 100 in the Inter-Institutional Laboratory of Microanalysis of Minerals and Synthetic Substances at the Faculty of Geology, Warsaw University.

In both meteorites, only metallic phases: kamacite, taenite, tetrataenite and in small extent troilite, underwent weathering. In case of Morasko meteorite also schreibersite and cohenite showed weathering. Zones of weathering in both meteorites are not reaching deeply, in case of Morasko – weathering reach up to some cm, while in Pułtusk meteorite changes are observed up to 1,5–2,0 cm.

Factors of weathering are similar in case of both meteorites. Main factors are oxygen and CO₂ from the atmosphere, solutions and soil. Water plays an important role and is connected to atmospheric water, soil humidity and humic and humin acids. Sulphate ions, formed inside both meteorites as a result of sulphide oxidation, could play an important role, also. The interactions with sulphate ions from the soil cannot be excluded. Phosphate ions, in case of Morasko meteorite, originated from the oxidation of Fe,Ni₃P–schreibersite. Chlorine ions are fully of soil origin.

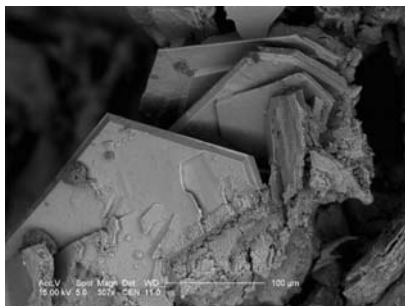


Fig. 1. Crystals of goethite in Morasko meteorite. SEM micrograph

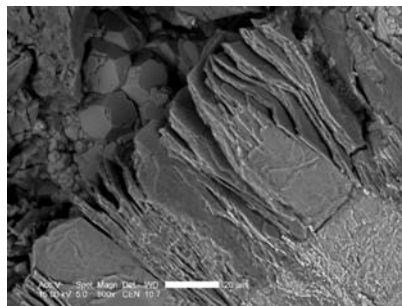


Fig. 2. Lepidocrocite from Morasko meteorite. SEM micrograph

In both meteorites secondary minerals are formed at the cost of kamacite and taenite only. The most common secondary mineral phases are polymorphic varieties of Fe³⁺-hydroxides: goethite (α -Fe³⁺O(OH)), lepidocrocite (γ -Fe³⁺O(OH)) (fig. 1 and 2) and akaganeite (β -Fe³⁺O(OH,Cl)) showing different admixtures of Ni. Near the surface of weathering meteorite the reduction conditions were formed, which allowed to crystallize the iron carbonate – siderite FeCO₃ (fig. 3 and 4). This mineral also contains the important admixture of Ni. In both weathered meteorites carbonates crystallized in pores and cavities formed after the kamacite removal.

In both meteorites in near surface zones among the Fe³⁺-hydroxides the secondary high Ni-metallic phases occurred. They represent native nickel or awaruite Ni₃Fe

(fig. 5 and 6). Rarely non-stoichiometric Ni-sulphides with Fe admixture are formed. Only in small cavities in Pultusk meteorite millerite NiS was found (fig. 8). Awaruite or native nickel is usually found as thin coverings in the vicinity of small rhabdite crystals (rhabdite=schreibersite variety), occurring in (Fe, Ni) phosphates and chlorides (fig. 7).

In both meteorites in their the weathering crusts the strong Ni concentration occurred. In the primary metallic phases Ni is contained mostly in kamacite. Higher Ni contents could be found also in taenite, tetrataenite and rhabdite. However, the high-Ni minerals do not prevail in the mineral composition and total mean Ni-content in metallic phases and phosphates is 6,76%wt [5]. In iron hydroxyoxides the strong secondary concentration of Ni is observed, up to 13,27% wt., with the drop of Fe content in relation to not weathered part of meteorite.

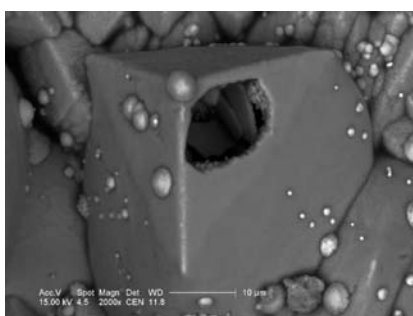


Fig. 3. Rhombohedron of siderite from Morasko meteorite. SEM micrograph

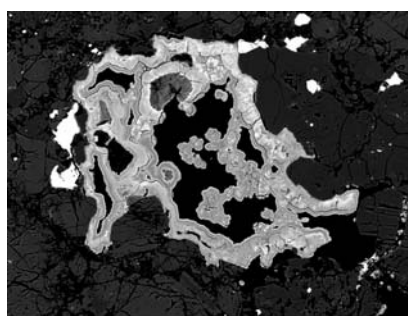


Fig. 4. Colomorphic exsolution of siderite in Pultusk meteorite. BSE image

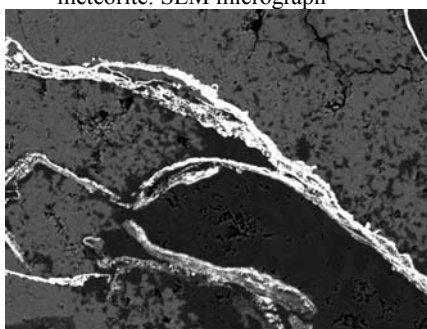


Fig. 5. Secondary exsolution of native nickel bearing c. 5%at of Ge. Morasko meteorite. BSE image

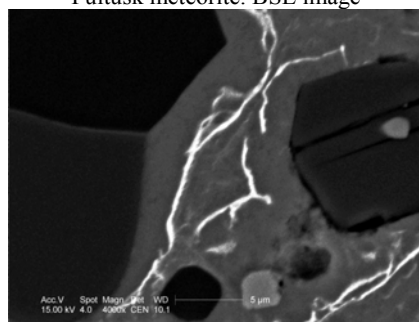


Fig. 6. Secondary metallic nickel or awaruite in Fe-hydroxide. Pultusk meteorite. BSE image

Small amount of Ni could migrate to soil solutions, and are mostly stopped in iron crust formed in the outer parts of meteorite. In that crust iron coming from internal part of meteorite and from the soil envelope concentrate. Both stony meteorites (with iron phases also) and iron meteorites are active in the soil environment as the reductive factors. That could cause the concentration of iron compounds cementing detrital minerals from the soil. The reductive interaction of iron mineral phases caused the delay in meteorite weathering in mild climate conditions.

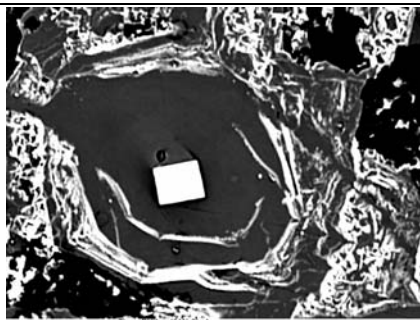


Fig. 7. Awaruite or nickel found as thin coverings in the vicinity of rhabdite. Morasko meteorite. BSE image

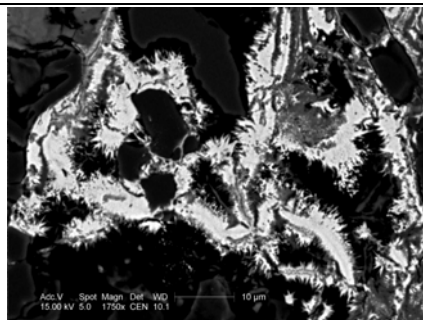


Fig. 8. Secondary exsolutions of millerite in Pułtusk Meteorite. Scanning microscope, BSE image

In the internal part of meteorite, below the melted crust, the exsolution of secondary high-Ni phases occurred. In most cases they are metals (alloys) sulphide minerals. That zone could be interpreted as a specific cementation zone, with secondary Ni- and partly Co- and Fe-sulphide precipitation occurred. The secondary metallic phases, enriched in Ni in relation to primary ones, are locally formed. Those mineral phases contain from 75 to 89% at Ni (table 1). Small size of secondary high-Ni minerals do not allow for their structural investigations. They could be identified as awaruite (Ni_3Fe) or native nickel with some percent of Fe as admixture. Secondary metallic high-Ni minerals are characterized by strong Ge concentration, from 0,n to about 5% at. (table 1). Such concentrations are very high in relation to mean Ge content in Morasko meteorite, which is about 500 ppm [5]. Ga is also concentrated in the secondary high-Ni minerals, but not so strongly (from 0,0n to 0,29% at Ga with mean value for Morasko meteorite at 100 ppm [5]).

Table 1
Chemical composition of secondary, high-Ni metallic phases from Morasko meteorite in % at. (without S, Si, Mn which are meaningless)

Elements/no	Ni	Fe	Co	Ge	Ga	P
1	85,72	12,80	0,28	0,73	0,04	0,15
2	80,42	14,74	0,11	3,91	0,00	0,75
3	86,56	9,29	0,06	3,14	0,04	0,82
4	78,58	15,31	0,18	5,05	0,10	0,69
5	89,22	9,58	0,32	0,72	0,00	0,05
6	88,93	9,68	0,32	0,88	0,02	0,07
7	83,36	15,04	0,34	0,17	0,05	0,36
8	88,83	10,34	0,22	0,05	0,05	0,14
9	82,16	13,01	0,14	4,01	0,29	0,55
10	86,34	10,03	0,12	3,31	0,02	0,10

In mild climate conditions the slow weathering of iron and stony (ordinary chondrite) meteorites. In the soil environment meteorite presence could cause locally reductive conditions. During oxidation of metallic phases the meaningful Ni concentration took place in a form of metal and sulphide minerals. Main products of

weathering – iron hydroxyoxides and partly carbonates – are enriched in Ni in relation to primary metallic phases. In secondary high-Ni metallic phases the strong enrichment in Ge and partly in Ga occurred. That might be an evidence for strong siderophile tendency of the mentioned elements in hypogene conditions.

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ВТОРИННІ МІНЕРАЛИ В МЕТЕОРИТАХ МОРАВСЬКО І ПУЛТУСЬК

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Метеорити Моравско і Пултуск є двома різними видами міжпланетної речовини – залізний і кам'янистий хондрит, відповідно. Вони піддаються ерозії в подібних умовах з переважанням на початкових умовах ґрунтового та атмосферного впливів. Основними продуктами ерозії є збагачений Ni гетит та лепідокрокит, а також збагачений Ni залізний метеорит. У поверхневих частинах метеоритів виділяються металічні та сульфідні фази Ni. Металічні фази нагадують сплави Ni з незначними додатками Fe. Сульфідні представлені нестехіометричними фазами Ni₃S₂, Fe та міллериту (NiS). Вторинні металічні композити з високим вмістом Ni, які названі метеоритами Моравсько, містять до 5% Ge.

Ключові слова: метеорити Моравсько і Пултуськ, ерозія, вторинні мінерали, вторинні мінерали Ni, концентрація Ge.

ВТОРИЧНЫЕ МИНЕРАЛЫ В МЕТЕОРИТАХ МОРАВСКО И ПУЛТУСК**Л. Карвовский, А. Гурdziель**

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Метеориты Моравско и Пултуск являются двумя разными видами межпланетного вещества – железного и каменистого хондрита, соответственно. Они поддаются эрозии в подобных условиях с преобладанием в начальных условиях грунтового и атмосферного влияний. Основными продуктами эрозии являются обогащенный Ni гетит и лепидокрокит, а также обогащенный Ni железный метеорит. В поверхностных частях метеоритов выделяются металлические и сульфидные фазы Ni. Металлические фазы напоминают сплавы Ni с незначительными дополнениями Fe. Сульфиды представлены нестехиометрическими фазами Ni, Fe и миллерита (NiS). Вторичные металлические композиты с высоким содержанием Ni, которые названы метеоритами Моравско, содержат до 5% Ge.

Ключевые слова: метеориты Моравско и Пултуск, эрозия, вторичные минералы, вторичные минералы Ni, концентрация Ge.

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