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NEW FINDS IN THE MORASKO METEORITE PRESERVE, POLAND

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Abstract: In result of searching in the Morasko preserve for the documentary series *Meteorite Men* two irons were found below ground. A 544-g shrapnel-like with weak shock deformations, mildly weathered, at low depth, and 34-kg individual, with its upper surface 156 cm deep, with a thick shell of clay and weathering minerals. Of particular interest is presence of chukanovite, a mineral discovered in the Dronino iron meteorite. Morasko is the second meteorite, where chukanovite could be found.

The recovery of a new specimen so much deeper than the previous depth record, suggests that further, more detailed surveys should be conducted in the future with improved metal detecting equipment. Moreover, the larger specimen was found embedded in a Miocene clay, which demonstrates that it fell from the sky at that exact spot and was not deposited in glacial terminal moraine.

Keywords: iron meteorite Morasko, new finds, strewnfield

INTRODUCTION

The Morasko iron meteorite has been known since 1914, when a mass of iron, 77.5 kg, was found while digging trenches at the town of Morasko near the Poznan city (Grady, 2000). Later a few more irons were recovered, and in late 1950 Jerzy Pokrzywnicki found evidence of multiple fall in Morasko, and noticed eight pits that could be meteorite craters (Pokrzywnicki, 1964). His efforts resulted in the formation of the Morasko meteorite preserve in 1976 in order to protect the area around the craters.

In the 1970s, research on Morasko was continued under direction of Hieronim Hurnik from Adam Mickiewicz University and resulted in publications on the strewnfield, and composition of the meteorite (Hurnik, 1976; Dominik, 1976).

In the last two decades, access to better equipment resulted in the recovery of hundreds of iron meteorites by private meteorite hunters in the fields and forests mostly north and east of the craters, and outside of the protected area. At the same time, comprehensive research in the Morasko area were made by scientists and students of the Geological Institute of Adam Mickiewicz University in Poznań (Stankowski, 2001). In 2005 the University was granted permission to search for meteorites in the Morasko preserve over a two-year period (permission SR.III-2.6630-89/04/05). The search was conducted on behalf of the university by Krzysztof Socha, an experienced meteorite hunter who had previously found hundreds of Morasko irons outside the preserve. As a result, 13 meteorites larger than 1 kg were found, including the largest specimen ever recovered (164 kg after cleaning), plus many smaller irons (Muszyński et al., 2007). Because of snow or dense vegetation searching

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[1] Permission SR.III-2.6630-89/04/05

was only possible during early spring and late autumn. Moreover, the preserve was full of scrap iron and lead bullets, which made working with metal detectors slow and laborious. As the result of these obstacles, the two-year season turned out to be too short, and part of the preserve area was left unsearched.

The results of research on the Morasko iron were summarized by Wojciech Stankowski (2008). After a few reclassifications the Morasko iron was finally classified as IAB-MG (Wasson & Kallemeyn, 2002).

An opportunity to continue searching presented itself in 2011, when Discovery Science and LMNO Cable Productions applied for permission to film an episode of the documentary series, *Meteorite Men,* at Morasko. As part of a joint research project with Adam Mickiewicz University, the permission – WPN-II.6205.43.2011.MM – was given for a five-week season that would include searching and filming. Due to the limitations of participants, searching was done in two short periods: June 28–29 and July 18–21, 2011.

METHODS

Two metal detectors were used in the search: a hand detector, which employed VLF (very low frequency) technology and another hand detector, which employed the pulse induction (PI) technology, with an 18-inch coil, which was replaced during the second search season with a 2-meter coil for deeper targets.

Finds were ground or cut to unveil metal and then the metal surfaces were etched with nital.

Loose clay was cleaned off from the second specimen, and part of the weathering crust was removed for analyses. Then an end piece was cut and etched for examination under an optical microscope, and another slice was cut and prepared for analysis. Mineral phases were investigated using a scanning electron microscope equipped with EDS (EDAX) detector and an X-ray diffractometer X'Pert Philips PW 3710 at the Faculty of Earth Sciences, University of Silesia and an electron microprobe CAMECA SX 100 at the Faculty of Geology, Warsaw University.

FINDS

The northwestern part of the preserve was chosen to begin the search, an area that had not been extensively covered by Krzysztof Socha. From among many iron fragments found, two pieces were proven to be real meteorites. The first meteorite was found on July 29 by Andrzej Pilski (Fig. 1). A 544-g piece of iron with a thin weathered crust, it was found about 30 cm below ground, among stones of similar size or larger, with sand between them. The find was cut in half and etched. Its etched surface shows an irregular, coarse Widmanstätten pattern with Neumann lines in kamacite (Fig. 2). Both the Widmanstätten pattern and Neumann lines are distorted in places because of shock influence. There are no larger inclusions visible. Schreibersite appears in form of rhabdite, and in some places between kamacite bars replacing taenite.

The second meteorite was located on July 19 by Steve Arnold using a PI detector with a 2-meter coil. Because of its great depth, and without the ability to use mechanical devices for excavation, the iron could

Fig. 1. The 544 g iron found on June 29, 2011 in the Morasko preserve

Fig. 2. Etched cross section of the 544 g find

Fig. 3. The 34 kg Morasko iron seen from two sides. Dimentions: 28 × 24 × 18 cm. It is shown upside down relative to its position in the clay.

only be uncovered at the end of next day. Its upper surface was 156 cm below ground, buried in the colorful Poznan clay (Miocene in age). After preliminary cleaning its weight was determined to be 34 kg, and size 28×24×18 cm. Despite cleaning the iron was still covered with clay tightly attached to the meteorite itself.

During examination, an attempt was made to first remove the attached clay and unveil crust or metal. The result was a large end piece of totally weathered rock that was chipped out, plus a few other fragments of minerals from the weathering crust. It was discovered that the lump of iron was deeply weathered and it was hard to uncover clean metal. In order to determine the depth of the weathering crust, a larger end piece was cut. After cutting and etching the cut surface, it was found that weathering was irregular. Some areas were deeply affected and in other places nickel iron alloy was intact even at shallow depths (Fig. 5).

PETROGRAPHY AND MINERALOGY OF THE LARGE FIND

On the meteorite cross section two different areas are clearly visible. About one half of it (lower on Fig. 5) is rich in cohenite, grains of which mimic the Widmanstätten pattern, and being situated between kamacite

Fig. 4. Deeply weathered section after removing an end piece from the upper right side on Fig. 3, left.

Fig. 5. Etched cross section of the 34 kg find. There are many cohenite inclusions in the lower part and two elongated, horizontal schreibersite inclusions below center; the lower one is rimmed with cohenite. Part of a troilite inclusion rimmed with schreibersite is seen at the upper edge

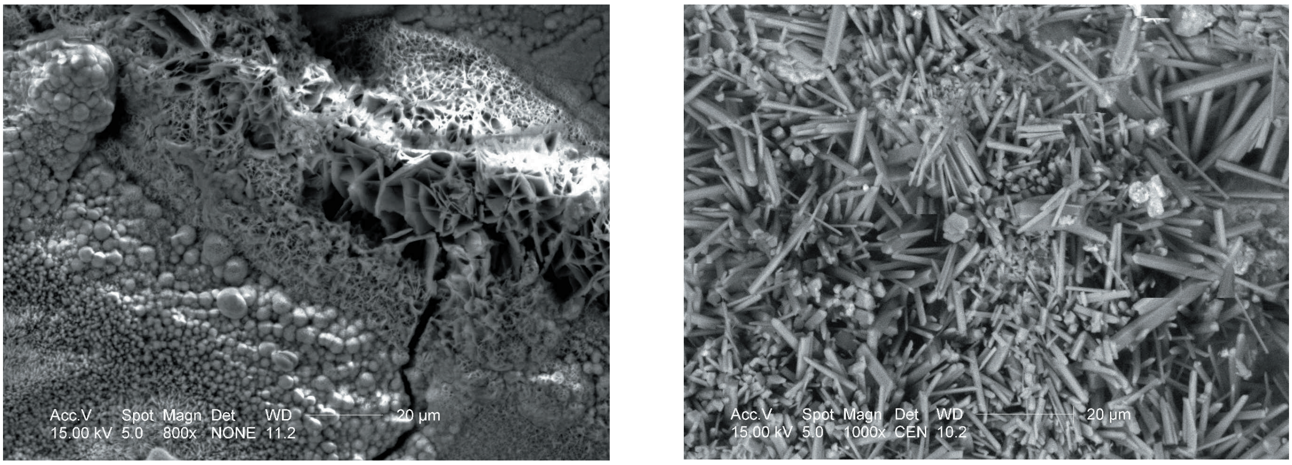

Fig. 6. Minerals in the external layer. Left: iron hydroxides. Right: a druse of aragonite. SEM image

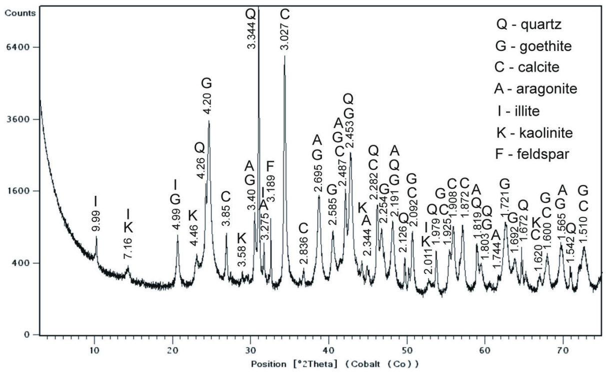

Fig. 7. X-ray diffraction pattern of minerals in the most external part of weathering crust

plates or inside them. The cohenite pattern continues into a deeply weathered area (lower right on Fig. 5), where the kamacite is completely weathered out into hydroxides, but cohenite seems to be intact. The second half (upper on Fig. 5) is cohenite-free and texturally resembles the first iron find, except there are no signs of shock influence. Generally the unweathered part of the specimen seems to be typical of Morasko, the petrology of which was described in detail by B. Dominik (1976), Karwowski & Muszyński (2008), Karwowski et al. (2009).

The most external layer of the meteorite is not its real weathered section, but the attached clay, cemented with some iron oxides. In the case of our specimen the cementing mineral is goethite. Its origin is debatable, but most likely the iron in goethite is a result of clay coming in contact with the meteorite. Usually an iron meteorite will act as a strong reducing agent and attract iron and manganese from its surroundings. Goethite is associated with calcite and aragonite; the last mentioned often forms tiny druses within the crust (Fig. 6). The cemented material comprises of small grains of quartz, muscovite, kaolinite with some addition of feldspar (Fig. 7). It seems that the meteorite, when penetrating the clay, some surface material (soil) adhered to its front.

The weathered meteorite forms the next layer beginning with a relatively homogenous layer of iron

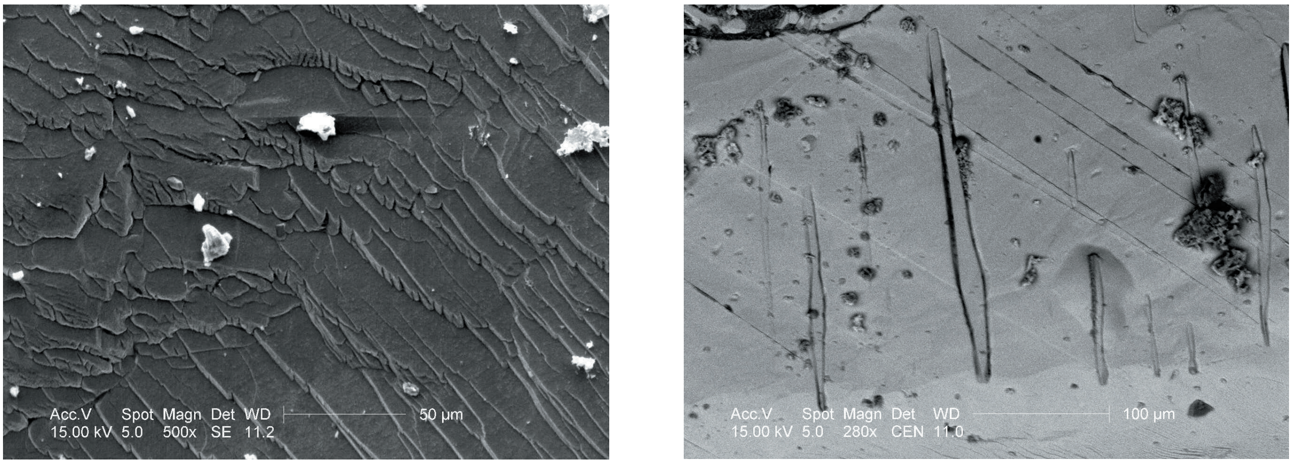

Fig. 8. Taenite. Left: surface with growth steps. Right: elongated exsolutions of nickelsulphide on the surface of a taenite lamelle. SEM image

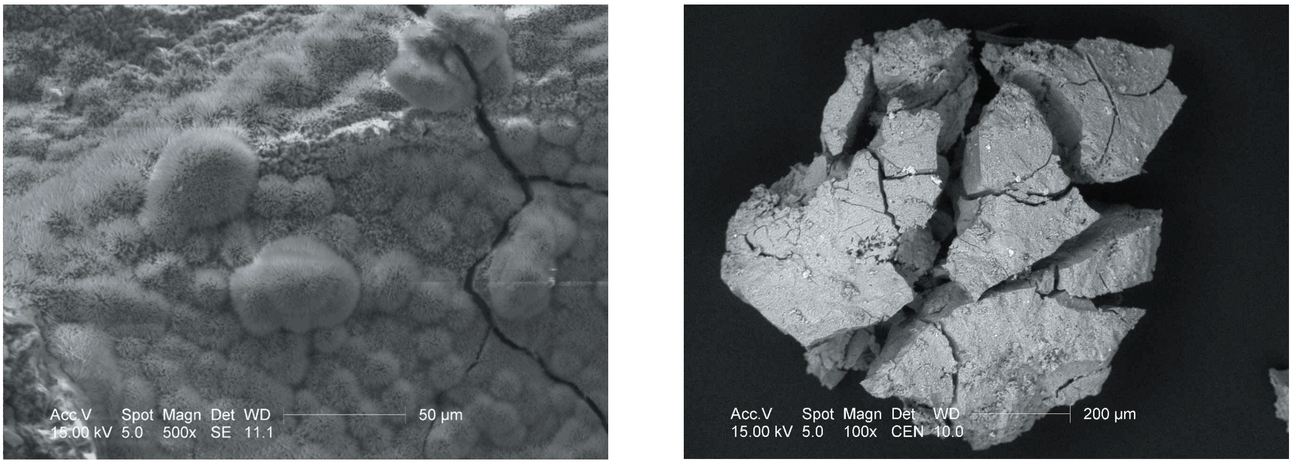

Fig. 9. Left: a microdruse of chukanovite. Right: a desintegrating grain of helleyrite. SEM image

hydroxide, mainly goethite, with lepidocrockite in places. After cutting and polishing, the layer shows conspicuous luster. The next layer contains tiny metal phases, represented mainly by taenite in the form of thin plates with distinct surfaces (Fig. 8). In some places elongated grains of nickelphosphide are attached to taenite plates.

Spaces between taenite plates are filled with hydroxides and carbonates together with aggregates of an emerald-green substance. In some places there is a dark gray substance with romboedric cleavage. After a detailed examination it was found that it is the pseudomorph after kamacite and its cleavage comes from Neumann lines. The substance is composed mainly of chukanovite (Fig. 10) with minor taenite and small addition of siderite, where some Fe is replaced by Ca and Mg. These elements were probably absorbed from outside with carbon dioxide. In some places small microdruses of green chukanovite can be seen.

Additionally, small amounts of goethite and hellyerite ($NiCO_3.6H_2O$) could be seen. The last mineral is emerald-green and unstable. In a laboratory it disintegrates quickly into an amorphous, greenish mass. Hellyerite was discovered on SEM images and its presence was confirmed with EDS analysis.

In the unweathered, internal section of the meteorite, the cohenite zone ends with a conspicuous, elongated inclusion of schreibersite rimmed with cohenite. A nearby, elongated schreibersite inclusion with no cohenite rim, is the beginning of the cohenite-free zone. There can be seen a schreibersite inclusion inside the kamacite crystal, some elongated schreibersite inclusions replacing taenite between kamacite plates, and a schreibersite rim around the troilite inclusion on edge, which continues into the weathered part.

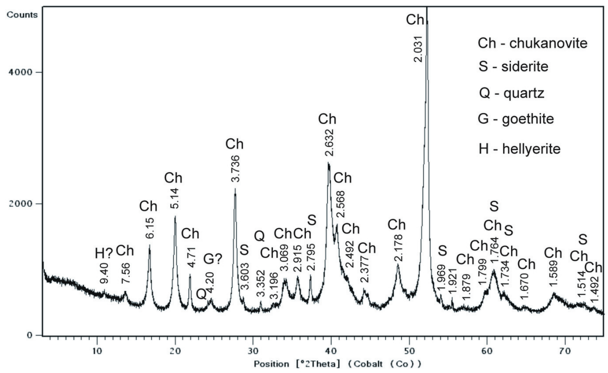

Fig. 10. X-ray diffraction pattern of chukanovite

DISCUSSION

The search was very limited, due to time constraints. Sampling was carried out in different areas, but unfortunately neither a survey of the entire area, nor a controlled exhaustive in very defined areas could be completed.

A comparison of both finds confirms once again that the weathering grade may depend more on terrestrial environment than on the terrestrial age of a meteorite. The smaller specimen was found in a slightly elevated place, cut with trenches, among stones, where water had no chance to accumulate for any length of time. The larger meteorite was found in the clay, which can retain water for long time, as was demonstrated when rain fell during the excavation. As both

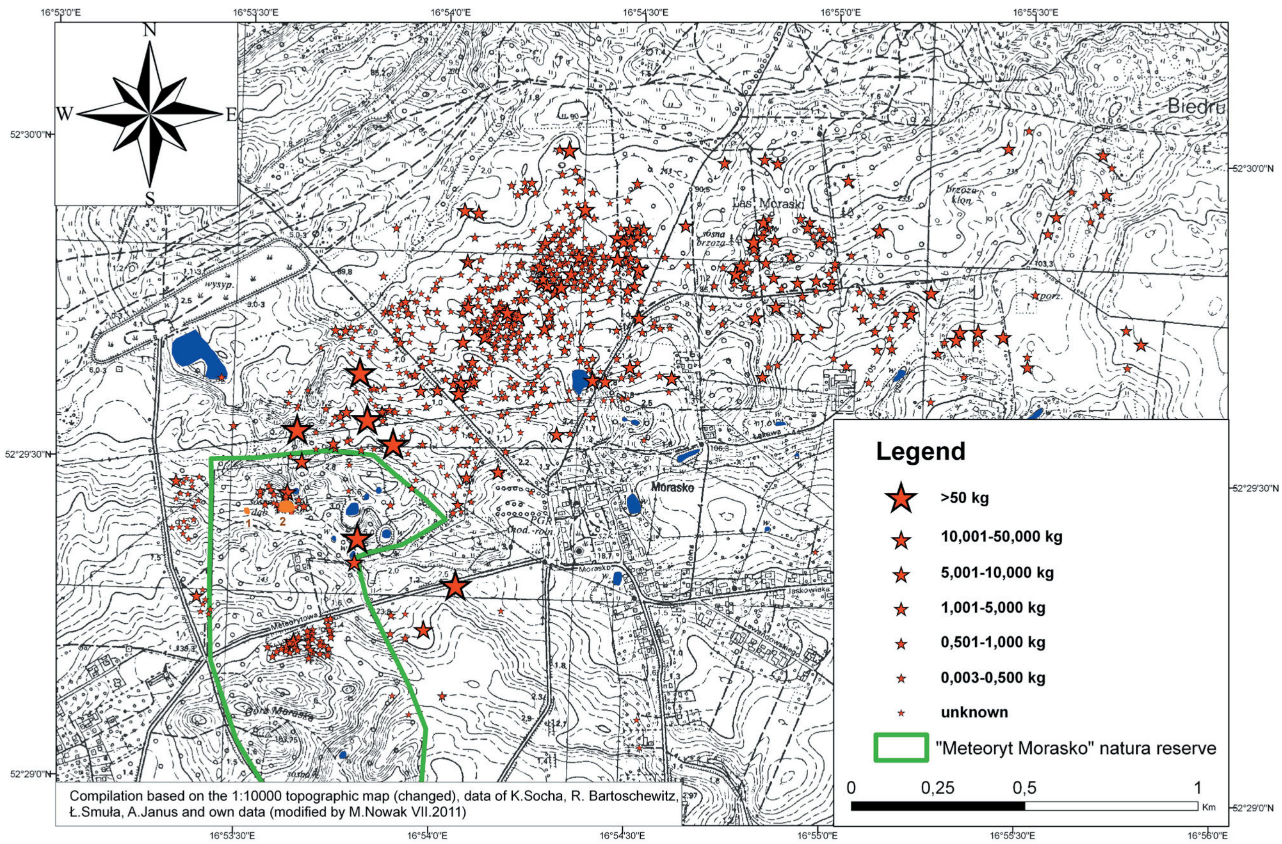

Fig. 11. The orange spots mark locations of the new finds: 1 = 544 g and 2 = 34 kg. Map from Muszyński et al., 2012

finds belong to the same meteorite shower, their terrestrial age is the same, but their weathering grades are entirely different.

Characteristic of the Morasko strewnfield are numerous finds confined to relatively small area on the northern slope of a terminal moraine. This gave reason to a supposition, that possibly meteorites showered onto a glacier during the most recent period of glaciation, and then they were transported by the glacier and deposited in terminal moraine. If this is correct, all meteorites should be found in relatively shallow depths and in strata deposited during the last glaciation. Until now all finds were buried at relatively shallow depths suggesting that this supposition may be accurate. The 34-kg find, embedded in the Poznan clay with an age of more than 5 million years, obviously had to penetrate the clay rather than being deposited. It seems the only reason for relatively shallow finds is that less sensitive detectors were unable to locate the deeply-buried irons.

A characteristic of the external layer of the 34-kg specimen is the presence of substantial amounts of carbonates. The outer part of the meteorite coating consists of relatively light colors, and contains kaolinite, minerals from the mica group, both light and dark, goethite, quartz as well as aragonite and calcite. The presence of aragonite clearly distinguishes this find from Morasko specimens that were found at shallower depths. In those specimens calcium carbonates were rare and sometimes only occurred on the bottom faces of meteorites, due to the crystallization of oozing solutions from moraine formations. They only appeared in the form of calcite. In the analyzed find aragonite clearly dominates and it forms tiny druses on the sides of cracks. Most often aragonite crystals form distinctive triplets of pseudohexagonal morphology (Fig. 6, right).

Another distinctive feature that makes the specimen under consideration of particular interest, is the presence of chukanovite ($Fe_2(CO_3)(OH)_2$) as a dominant mineral phase in pseudomorphs after kamacite with distinctive quasi-cleavage as a relic after Neumann lines in kamacite, as well as the presence of emerald-green, unstable in room conditions, hellyerite ($NiCO_3{\cdot}6H_2O$). The authors are of the opinion that the presence of chukanovite and hellyerite is a result of a specific stability of climatic conditions (temperature, constant humidity, limited accessibility of oxygen) existing at a depth of 1.5–2 meters below the ground in this region.

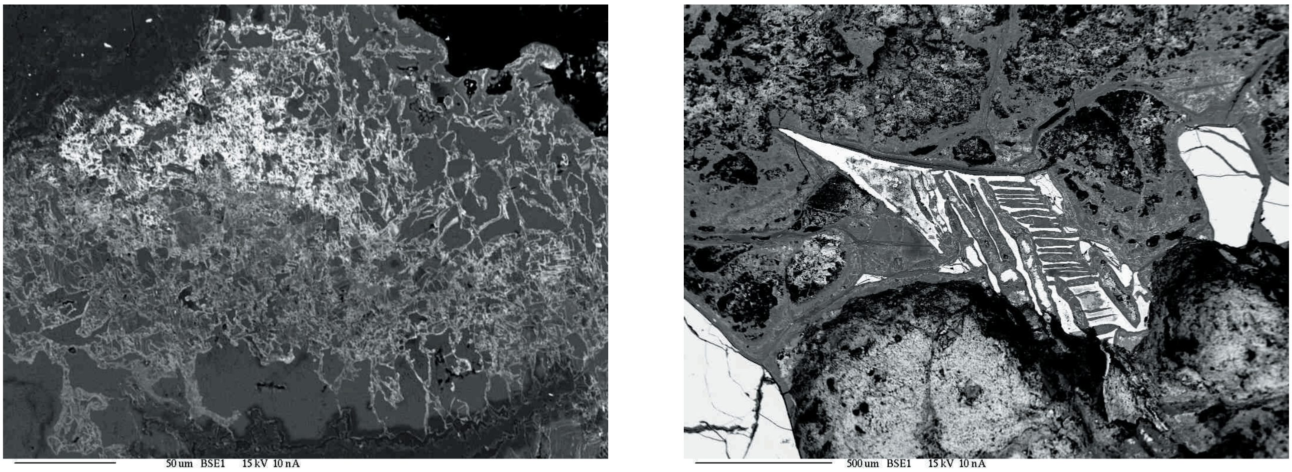

Fig. 12. Left: nickel exsolutions. Right: weathering of taenite. BSE images

Weathering acted most quickly on metal phases: mainly kamacite and to a lesser extent, taenite and tetrataenite. Kamacite was nearly completely transformed into a mixture of chukanovite and iron hydroxides. Inside this mixture tiny druses appeared, filled with greenish needles of chukanovite or, less often, with dripstones of clear, colorless iron hydroxides (Fig. 6, left), which quickly turned yellow (a rusty color), and became turbid and dehydrated. In the most external layers of the meteorite only iron hydroxides – mainly goethite – could be seen.

Weathering resulted in the separation of nickel from iron. Nickel is concentrated among secondary carbonates and hydroxides as a separate mineral phase of native nickel (Fig. 12, left). The secondary exhalations of nickel are enriched with germanium and, in the analyzed specimen, they contained up to 2.56 wt% Ge, which means a 60-times enrichment relative to typical Ge content in Morasko meteorites. The highest Ge contents appear in the most external appearances of the secondary Ni. A still higher Ge content in the secondary Ni metal was measured by Karwowski & Gurdziel (2009).

Weathering of taenite depends upon nickel content (Fig. 12 right), and low-Ni phases are destroyed first. The most resistant are high-Ni phases and tetrataenite. In the most external layers of a weathering iron meteorite only relics of tetrataenite may be seen (Fig. 13). The minerals most resistant to weathering are schreibersite and nickel phosphide. Characteristic of schreibersite inclusions in the specimen under consideration is a high Ni content: nearly 1:1 relative to Fe content, whereas the nickelphosphide contains more nickel, from 39.78 to 42.31 at% of Ni. These phases seem not to be affected by secondary processes.

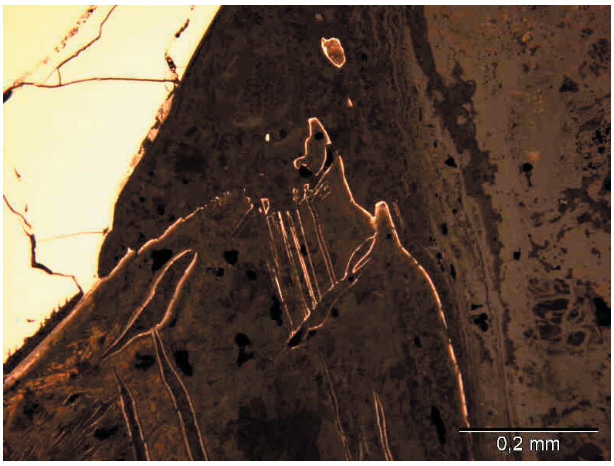

Fig. 13. Tetrataenite left after taenite totally weathered out. BSE image

Slightly less resistant is cohenite, in which iron hydroxides grow along cracks. Low-Ni kamacite from a cohenite decomposition and secondary graphite were not observed.

Cleaning finds and removing dirt and rust crust to expose metal or at least a crust on the metal is a common practice among iron meteorite hunters. This can result in the removal of all weathering minerals before a meteorite is examined by scientists. Due to a different approach with the larger find, a rare mineral, chukanovite, was discovered first time in Morasko specimens and only the second time in any meteorite, the first being the iron meteorite Dronino (Pekov et al., 2007). As the 34-kg find is not the first Morasko specimen to be so highly weathered, it seems possible that the mineral could have been detected earlier if other finds were not so thoroughly cleaned.

CONCLUSIONS

Applying new detecting techniques to the Morasko strewnfield resulted in the discovery of a Morasko specimen with its upper surface buried 156 cm below the ground, deeper than any previous Morasko find. It seems possible that more irons exist that could not be located until now because detectors were not sensitive enough to locate deeply-buried specimens. More detailed surveys should be conducted in the future with the improved equipment available today.

These new finds confirm, once again, that weathering grade is a poor indicator of the terrestrial age of an iron meteorite and depends mainly on conditions in the soil around a meteorite specimen. Moreover, composition of the soil is an important factor that helps determine both the type and the rate of weathering.

The find of the 34-kg Morasko specimen in Poznan clay is evidence that the Morasko meteorites fell in situ and were not transported by glaciers. The idea that the meteorites might have been deposited by glacier on the terminal moraine "Moraska Góra" has been proven incorrect.

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