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Polish scientists in studies of extraterrestrial matter; past, present, reminiscences

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The contributions of Polish scientists to studies of extraterrestrial matter are described, and a history of investigations into the Pułtusk, Łowicz, Morasko and Baszkówka meteorites is given. Opinions expressed in Polish journals on the structure and genesis of chondrules are discussed, together with the results of X-ray structural research of graphites. Polish papers devoted to the studies of cosmic dusts, particularly of their aluminosilicate glass, are summarized. In this context the use of the infrared method in distinguishing terrestrial and cosmic glasses is stressed.

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The first papers Polish scientists on meteorites date back to the beginning of the 19th century (Kortum, 1805; Jundziłł, 1805, 1821; Drzewiński, 1819, 1820, 1825; Makólski, 1820; Śniadecki, 1822; Wolski, 1822; Kratter, 1825*b* in: Pokrzywnicki, 1964). Makólski, writing in Polish, wrote what was probably one of the first Ph.D. dissertations in meteoritics in the world (Fig. 1). I. Domeyko (1802–1889), a Polish mineralogist active for years in Chile, was also a researcher and collector of meteorites.

On 30 January, 1868, a shower of stony meteorites, i.e. chondrites, fell in the vicinity of Pułtusk in Poland. The descriptions of the fall and the preliminary of investigations of the Pułtusk meteorite were published in French by Wawnikiewicz (1868) in a booklet of the Warsaw Central School. The booklet, alongside with the specimens of the meteorite (!!), were sent out to universities, research units and some scientific associations in Paris, London, Copenhagen, Stockholm, Prague, Wrocław (then Breslau), Królewiec (then Königstein), Kraków and Lvov as well as to universities and scientific institutes in the area of the then tsarist Russia. The booklet and the specimens were also passed on to selected professors in mineralogy and chemistry. This action aroused interest in the Pułtusk meteorite within the European scientific community. As a result, 16 papers on this meteorite in question were published in the same year, followed by 36 more by the end of the 19th century. For many years the strewn field of the Pułtusk fall was debated. Eventually, Samsonowicz (1952) determined the shape of the ellipse, calculating the longer and shorter axes at 18 and 9 km respectively, and the area of dispersion at 127 km^2. He also estimated the total number of fragments of this meteorite at *ca.* 68,870 pieces. I carried out mineralogical investigations of the Pułtusk meteorite 20 years later (Manecki, 1972*b*). Beautifully developed, diversified textures of chondrules from this meteorite inspired me to provide a tentative classification of chondrules (Fig. 2) and consider their genesis in the paper entitled "Chondrites and chondrules" (Manecki, 1972*a*). The following classification of chondrules according to their textural features was proposed:

A. Criterion — the degree of crystallisation of components:

I. Chondrules displaying holocrystalline texture:

1. Excentroradial structure:

a — monospherolitic, consisting of plates and rods (Fig. 2a),

b — polyspherolitic, consisting of plates and rods (Fig. 2b).

2. Centroradial structure.

3. Parallel structure (barred chondrules).

II. Chondrules showing hypocrystalline texture:

1. Excentroradial structure:

a — monospherolitic, consisting of platy and rodlike minerals cemented with glass (Fig. 2c),

b — polyspherolitic, consisting of rodlike or platy minerals cemented with glass (Fig. 2d).

2. Centroradial structure (Fig. 2e).

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DESZCZU KAMIENNYM

podana

Wydziałowi Filozoficznemu Sekcyi Matematyczno – Fizyczney Uniwersytetu Jagiellońskiego

przez

Franciszka Makólskiego

Nauczyciela Fizyki i Zoologii Szkoły Woiewódzkiey w Kielcach

W celu dostąpienia zaszczytu Doktora Filozofii.

w KIELCACH

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Fig. 1. The cover of Makólski's Ph.D. dissertation (1820) „Treatise on aerolites, i.e. stone shower"

3. Parallel structure (barred chondrules) (Fig. 2f and 3b).

B. Criterion — relations of grain size:

I. Chondrules displaying porphyritic texture and massive structure (Fig. 2g).

II. Chondrules showing granular, equigranular and inequigranular textures and massive structure (Fig. 2h).

C. Criterion — occurrence of individual grains or their aggregates:

I. Chondrules consisting of individual grains (Fig. 2i).

II. Chondrules composed of numerous grains showing mixed structures and textures (Fig. 2j).

Chondrites generally contain chondrules exhibiting granular and excentroradial structures. Those consisting of individual grains are rare whereas chondrules displaying porphyritic or centroradial structures occur only sporadically. The latter structures, described in the Saratov meteorite, are rare. Chondrules showing porphyritic texture were found in the Chainpur meteorite. The matrix embedding chondrules in this meteorite consists of glass including euhedral olivine crystals and dendritic pyroxenes. The occurrence of chondrules displaying barred structures is problematic. Nevertheless, they were reported by numerous authors. They are mostly thought to represent intersections of chondrules displaying excentre-radial structures (Figs. 3 and 4). The person who turned my attention to this fact was Prof. Grigoriev from Petersburg, longstanding chairman of the IMA Commission on Cosmomineralogy.

In the same paper I gave my opinion on the genesis of chondrules, joining the heated discussion on the matter (the debate remains heated even now, especially as much new information, e.g. on planetoids, has become available). The following conclusion was expressed:

"The processes of formation of low-temperature silicates and chondrules were closely connected spatially, since chondrites occur (carbonaceous variety of the IIIrd type) in which a dark matrix of low-temperature silicates cements chondrules. Thus, crystalline aggregates of high-temperature silicates (chondrules) coexist with a groundmass composed of hydrated silicates formed at temperatures below 100°C. Using the nebular hypothesis we may assume that in the outermost cold zones of primitive solar matter low-temperature silicates could form, whereas in deeper zones, silicate melt took the form of dispersed particles. Hot nebulae consisting of droplets of this melt could be ejected outwards into cooler zones, where they collided with aggregates of unconsolidated matter composed of low-temperature silicates of the serpentine-chlorite type. The latter silicates were thus subjected to thermal alteration and recrystallised in a solid state — at higher temperatures into pyroxenes (the alteration: serpentine → olivine → pyroxene) and at lower temperatures into olivine (the alteration: serpentine → olivine). These newly formed crystal nuclei initiated crystallisation. The process started from the margins of these droplets (chondrules) and depending on the form of the crystallites of the nuclei (clinochrysotile — rods; antigorite and chlorite — plates) there developed rodlike, platy excentroradial or parallel aggregates of pyroxenes and olivines. In the case of a single crystallite aggregate, a monospherulitic chondrule was formed, while if numerous aggregates were available, a polyspherolitic chondrule originated. Initial accumulation of chondrules and their subsequent cementation with a matrix consisting of low-temperature silicates took place in the cold outer zones of primitive solar matter."

In the text a review of various hypotheses concerning the origin of chondrules and chondrites was given.

The Pułtusk meteorite requires further studies, as inspection of the numerous specimens shows a heterogenous structure (Pilski, pers. comm.).

In the night of 11/12 March 1935, a mezosiderite fell in Poland near the town of Łowicz. Its description was published in German in 1938 in the volume XIVth of *Archiwum Mineralogiczne* "Meteorit von Łowicz in Polen" by six authors (Kobyłecki, Jaskólski, Kołaczkowska, Thugutt, Moritz, Cichocki). Jaskólski described ilmenite in the Łowicz meteorite, a mineral rare in meteorites (though common in lunar basalts). His finding is probably the first identification of this mineral in meteorites.

In the year 1964 Pokrzywnicki published in English his *Catalogue of meteorites in the Polish collections*. Pokrzywnicki, an amateur-scientist, recorded all the meteorites present in Polish collections, and devoted a substantial part of his paper to the meteorites that had fallen in Poland. He gathered information on these meteorites not only from scientific descriptions (reaching back to the earliest papers), but also from old journals, chronicles and other written records. In the year 1971 Manecki presented the development of mineralogical research on bodies of extraterrestrial origin, conducted in a period from 1749 to 1969.

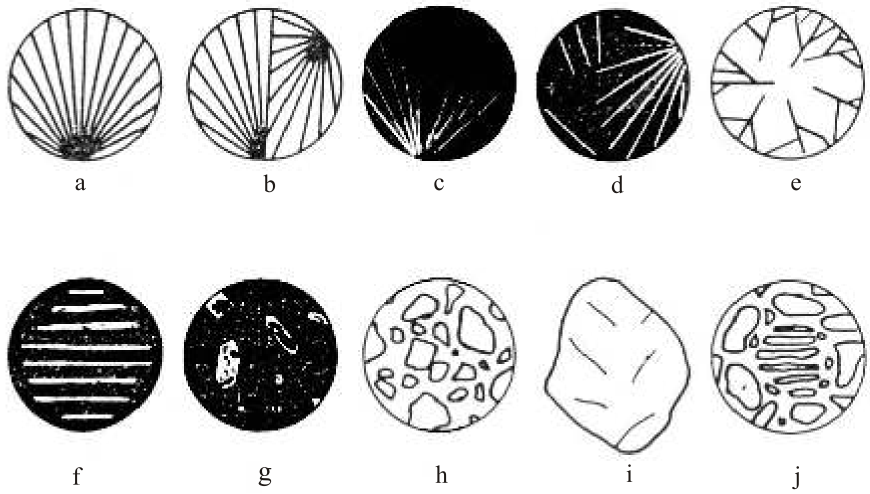

Fig. 2. Structural and textural types of chondrules (after Manecki, 1972*a*)

a–j — explanations in the text

Another interesting story relates to the finding of and then research into, an iron meteorite — the Morasko octahedrite. It was during World War I, on 12 November, 1914, that in the course of digging trenches at Morasko near Poznań, soldiers discovered, at a depth of 0.5 m below the ground surface, a meteorite with a weight of 77.5 kg, and in the following years further fragments of this meteorite. The total weight of the fragments unearthed to date exceeds 300 kg. In the area where the meteorite was found, circular forms with diameters of 60–70 m are characteristic morphological features, considered to be small craters resulting from the fall of the Morasko meteorite fragments. Mineralogical and chemical investigations of the Morasko meteorite, as some years before with the Pułtusk meteorite, were carried out at the Department of Mineralogy and Petrography of the University of Mining and Metallurgy in Kraków. B. Dominik devoted several years to studies of the Morasko meteorite, and presented her results in English in a monograph (Dominik, 1976). She found nickel iron (kamacite — 90%, taenite — *ca.* 0.5%) to be dominant in the Morasko meteorite, being accompanied by troilite, graphite (Fig. 5), cliftonite, schreibersite, rhabdite, cohenite, sphalerite and whitlockite. Numerous graphite-troilite nodules and rare troilite ones with diameters of 2.5–20 mm were also found, often covered with schreibersite rims, as well as the effects of mechanical deformation of these minerals (Dominik, 1976). The structure of the graphite from the Morasko meteorite was studied using X-ray methods and compared to that of terrestrial graphite from Ceylon (Dominik *et al.*, 1974). The graphite filling the nodules in the Morasko octahedrite differs from the Ceylon graphite in:

— the shape of crystallites — a more distinct lamellar structure (a higher L_a/L_c ratio),

— a larger size of crystallites but a lower degree of three-dimensional ordering of the layers,

— a higher content of rhombohedral structure,

— the presence of cliftonite.

The data obtained indicate that the Morasko graphite was subject to destructive forces (shock metamorphism) that caused an increase in the content of rhombohedral structure and a deterioration in three-dimensional ordering. These processes, however, were not accompanied by high temperatures (higher than about 1250^{o}C) as this would have resulted in a decrease in the content of rhombohedral graphite. The susceptibility of graphite to structural changes under the influence of pressure and high temperature makes this mineral an important indicator of the processes of shock and thermal metamorphism in meteorites. Those were then the first such thorough investigations into meteoritic graphite.

A small and portable X-ray fluorescence spectrometer with a radioisotope source constructed in Poland was used in initial,

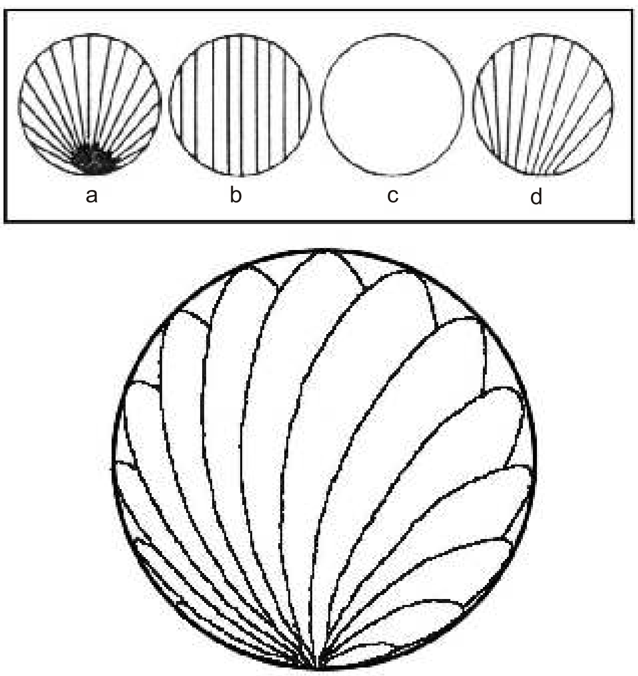

Fig. 3. Schematic presentation of a chondrule displaying excentroradial structure, consisting of platy olivines (lower), and of this chondrule in thin sections a–d (upper)

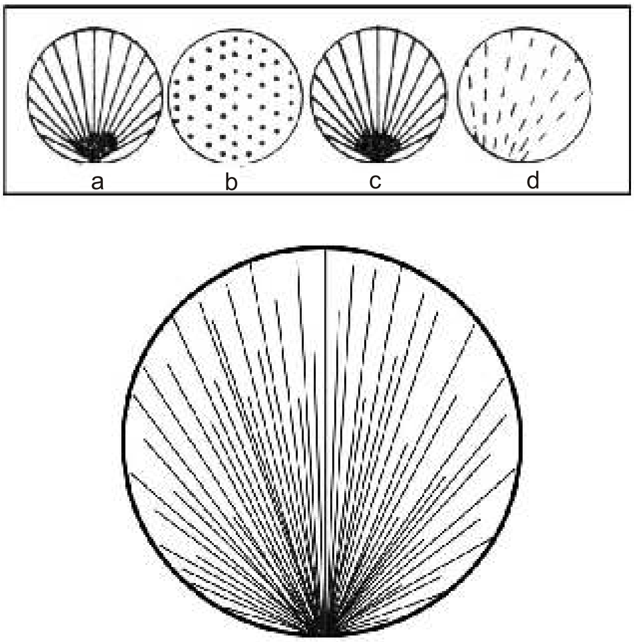

Fig. 4. Schematic presentation of chondrule displaying excentre-radial structure, consisting of rodlike pyroxenes (lower), and of this chondrule in thin sections a–d (upper)

field analyses of meteorites (Niewodniczański *et al.*, 1974). In 1974–1988, I was the representative of Poland on the Commission on Cosmomineralogy of the International Mineralogical Association. It was following an initiative of this Commission that the International Symposium "Problems of cosmomineralogy and cosmochemistry" was held in Kraków in November 1973. The symposium was organised at the Department of Mineralogy and Petrography of the University of Mining and Metallurgy to commemorate the 500th anniversary of the birth of Nicolaus Copernicus, the Polish astronomer. A series of investigations of the Pułtusk meteorite using an optical ultramicroscope was carried out and the results were published by Waleńczak (1977). Having published the monograph on the Morasko meteorite, B. Dominik next joined the group of P. Ramdohr in Germany, studying meteorites and lunar rocks (Dominik and Jessberger, 1978; Dominik *et al.*, 1978). She currently continues her research on meteorites in Switzerland (Dominik and Bussy, 1994*a–c*; Dominik *et al.*, 1994), where also she co-authored a catalogue of meteorites at the Museum of Natural History in Geneva (Dominik and Deferne, 1992).

In 1979, a Polish monograph was published, describing the field of cosmochemistry (Kuchowicz, 1979). Then, in the 1980s, investigations of meteoritic and lunar matter were made by researchers from Warsaw University: they focussed on studies of porosity in stone meteorites and impactites (Żbik, 1982; Żbik and Stein, 1983; Żbik and Florenski, 1984) and structural features of the lunar regolith (Grabowska-Olszewska and Żbik, 1984). M. Żbik continues his studies on meteorites in Australia (Żbik, 1994*a*, *b*; Żbik and Gostin, 1995), has taken part in discussions on the Tunguska explosion, and published numerous popular articles. A. Pilski, an astronomer of Frombork, another outstanding popularizer of meteorites and their collectors, is the founder and editor of *Meteorite*, the *Bulletin of Meteorite Amateurs*. Employing his contacts with professionals in the field, mainly with mineralogists, A. Pilski has so thoroughly mastered the science of extraterrestrial matter that he is frequently invited as a co-researcher, e.g. he took part in the studies on the Baszkówka meteorite. A. Pilski has also authored in Polish the catalogue *Meteorites in Polish Collections* (Pilski, 1995). B. and H. Hurnik, living in Poznań, should also be mentioned; they wrote, in Polish, a monograph on meteoroids, meteors and meteorites (Hurnik and Hurnik, 1992).

The fall of a meteorite in Baszkówka near Warszawa on 28th of August, 1994, provided new stimulus to the studies of cosmic matter in Poland. A series of papers ensued (Stępniewski, 1995; Stępniewski *et al.*, 1996, 1998*a*, *b*; Wlotzka *et al*., 1997; Gałązka-Friedman *et al.*, 1998*a, b*; Pilski and Walton, 1998; Siemiątkowski, 1998; Dybczyński *et al.*, 1999; Maruyama *et al.*, 1999, Przylibski and Zagożdżon, 1999). Further investigations of this extremely porous chondrite, with beautifully developed chondrules, are detailed in a joint monograph on this meteorite in the *Geological Quarterly* (this issue). The Baszkówka meteorite, with its beautiful regular shape and characteristic morphology, formed as an effect of ablation in the Earth atmosphere, remains enigmatic, for example as regards its high porosity.

A further Polish contribution to cosmomineralogical and cosmochemical research is represented by analyses of an iridium geochemical anomaly in Middle/Upper Jurassic boundary strata in southern Poland (Brochwicz-Lewiński *et al.*, 1984, 1986, 1988*a*, *b*, 1989).

Fig. 5. Hexagonal-shaped plates of graphite and fine idiomorphic blocks of crystallites in the matrix of the Morasko coarse octahedrite; SEM, x 1000 (*fide* Dominik *et al*., 1974; Dominik, 1976)

First detailed photographs of the lunar surface revealed a large number of circular, shallow craters. Photographs of other planets in our solar system and, lately, of planetoids (e.g. of the Eros surface) confirm that such cratering is widespread. Polish contributions include numerical modelling of collision processes in cosmic objects associated with cratering (Jach *et al.*, 1999).

Light-emitting objects in the Earth atmosphere are always interesting, especially when they cause visible effects. Bolides and ball lightning are two such phenomena. Many papers describe the trajectories, origin, optical and acoustic effects, and interaction of bolides with the Earth surface. Less known is ball lightning, the trajectories in the atmosphere and explosion effects of which are difficult to predict. Usually it is easy to distinguish a bolide from ball lightning, but in certain circumstances this cannot be done due to common optical, electrical, acoustic and impact effects of both phenomena. Such a case happened on 14 January, 1993 in Jerzmanowice near Kraków, prompting, much scientific discussion. The press, too, reported on the destruction wrought by this object in the village. In an issue of *Review of Geophysics* several papers describing this unusual phenomenon were published (Bąk *et al.*, 1995; Kułak, 1995; Manecki and Manecki, 1995; Mazur, 1995; Mietelski and Włodarczyk, 1995; Morawska-Horawska *et al.*, 1995; Ścieżor and Płeszka, 1995). The two hypotheses regarding this phenomenon — meteorological and astronomical ones — both remain possible. The third explanation, involving the simultaneous flight of a bolide and the generation of ball lightning, may also be considered. The issue also contains reports of eye-witnesses of the Jerzmanowice phenomenon, collected by members of the Kraków section of the Polish Society of Amateur Astronomers.

The "Jerzmanowice puzzle" requires further study. The damage caused may relate to the explosion of powerful ball lightning or the sonic boom of a supersonic bolide. Can the Jerzmanowice phenomenon be compared to the Tunguska explosion, but on a micro-scale?

In the 1960s and 1970s a number of papers on cosmic dust were published in Poland. These were initiated by Wieser (1963), and followed by Mazur (1969, 1973), an astronomer from Toruń. The latter studied cosmic dust separated out from various rocks in Poland and described, among others, spherules of native nickel from the salt mine in Wieliczka. In the 1970s, during investigations of Carboniferous bentonites from the underground Milowice coal mine in Upper Silesia, several hundred cosmic spheres were separated out. Detailed investigations focussed on those composed of glass (Manecki and Skowroński, 1970*a*, *b*). The aim of these studies was to provide additional criteria to help differentiate natural glass of terrestrial origin (i.e. volcanic glass) from cosmic glass, as not all of the spheres in question contain elevated amounts of nickel. Therefore, the authors (*op. cit.*) applied infrared absorption spectroscopy, for the first time in studies of cosmic bodies. It is worth summarizing these investigations, as IR spectroscopy is seldom used in research of extraterrestrial matter.

The examinations were performed with a *C. Zeiss UR-10* infrared spectrometer in the range 400–1800 and 3000–3600 cm^{-1}. Samples were prepared as homogenised KBr pellets,

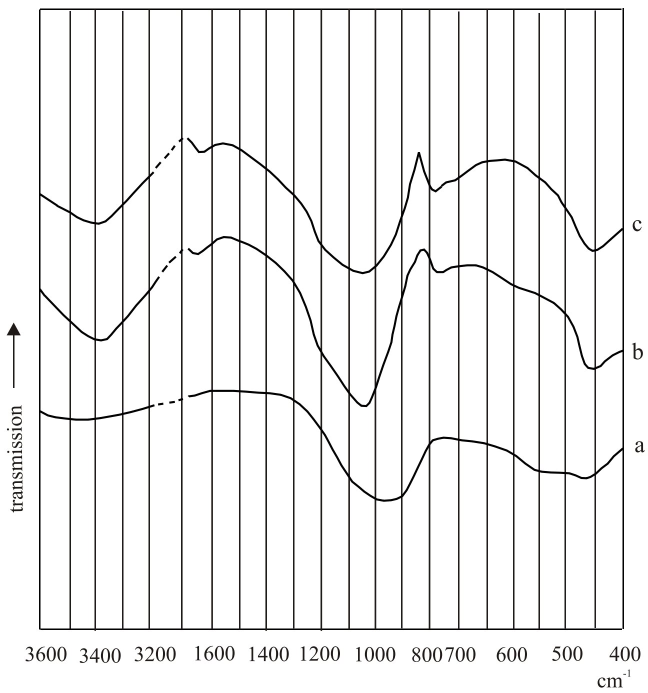

Fig. 6. Infrared absorption curves (after Manecki and Skowroński, 1970*a*, *b*)

a — glass of cosmic spherules from montmorillonite rocks of the Upper Silesian Carboniferous from Milowice Mine, Poland; b — pitchstone from Meissen, Germany; c — obsidian from Lipari Island, Italy

pressed in vacuum after thorough dehydration of the KBr. Infrared spectra recorded no absorption bands at 1640 cm^{-1} and in the range 3200–3800 cm^{-1}. The spectra were compared with those reported in the literature: of high-silica glass and fused silica. These two substances contain traces of water in the form of OH groups, and manifest their presence as two absorption peaks, at 3660 and 1600 cm^{-1}, due to the OH stretching vibrations and the O-H-O bending vibrations, respectively. The authors also studied typical volcanic glasses: a green pitchstone (Meissen, Germany) and a black obsidian (Lipari Islands, Italy), in which vibrations of H_2O at 3420 and 1640 cm^{-1} were found (Fig. 6). This highlighted the anhydrous nature of the spherules from Milowice and, thus, identified them as cosmic dust.

Manecki (1976) proposed the term „aeromineralogy" as a new class of mineralogical study concerning atmospheric dust, and in its classification distinguished cosmic spherules. Cosmic dust from Cenozoic sediments in the vicinity of Głogów was described by Wagner (1978).

A new challenge faces Polish scientists: this is the Zaklodzie stony meteorite, probably related to a bolide passage, reported a hundred years ago. A preliminary report on the Zaklodzie find was published last year (Stępniewski and Jachymek, 2000), and a small fragment of this meteorite already rests next to my microscope. So, we can expect a further "cosmic feat" in mineralogy.

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