Acta Geologica Polonica, Vol. 61 (2011), No. 1, pp. 115–124

The age of the Przełazy (Seeläsgen) meteorite fall in the light of the metallic spherule content

WOJCIECH T.J. STANKOWSKI AND GRZEGORZ UŚCINOWICZ

Institute of Geology, Adam Mickiewicz University, Maków Polnych 16 Str., PL-61-606 Poznań, Poland.
E-mails: stawgeo@amu.edu.pl; guscin@amu.edu.pl

ABSTRACT:

Stankowski, W.T.J. and Uścinowicz, G. 2011. The age of the Przełazy (Seeläsgen) meteorite fall in the light of the metallic spherule content. *Acta Geologica Polonica*, **61** (1), 115–124. Warszawa.

Based on a study of the frequency and composition of the fine-grained magnetic fraction of peat profiles, the age and possible location of the Przełazy (Seeläsgen) meteorite fall have been established. The impact took place at the site of the present peat-bog, south-west of the village of Przełazy. The date of the fall was estimated as the end of the Late Glacial and the beginning of the Holocene.

Key words: Impact; Przełazy (Seeläsgen); Great Poland Lowland.

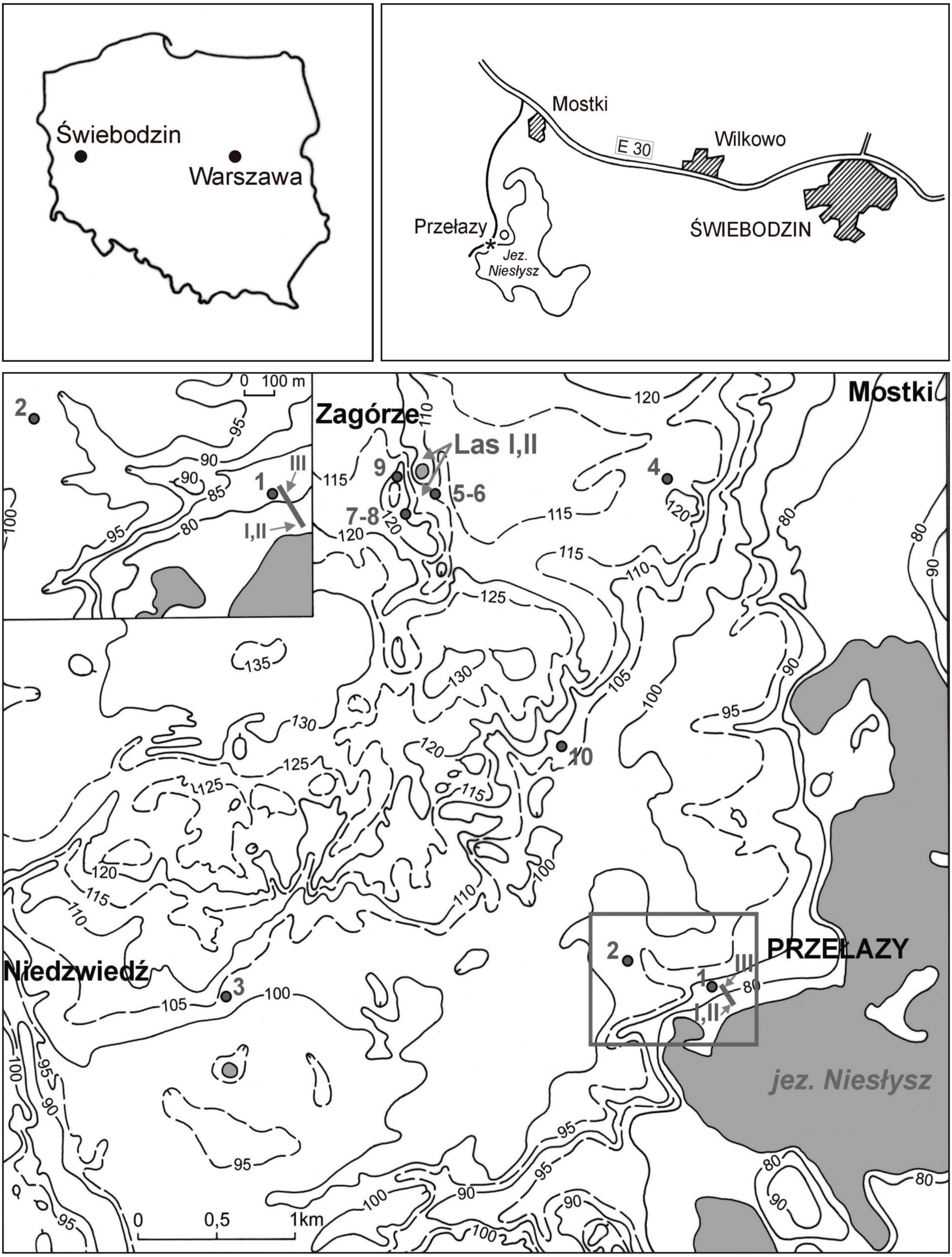
INTRODUCTION

The Przełazy meteorite was found a few years before 1847, near the village of Przełazy in western Poland. The precise date of the find is unknown. The lump of extraterrestrial metal weighing c. 102 kg was excavated from a depth of c. 4 m (6–7 ells) by a farmer who was digging a drainage ditch on a "wet meadow" towards the nearby Lake Niesłysz. It is not clear for how long the metallic lump was stored in the farmer's garden before it was first investigated (Pokrzywnicki 1964). Pokrzywnicki's brief report of the find does not provide sufficient data for establishing the date or the place of the fall.

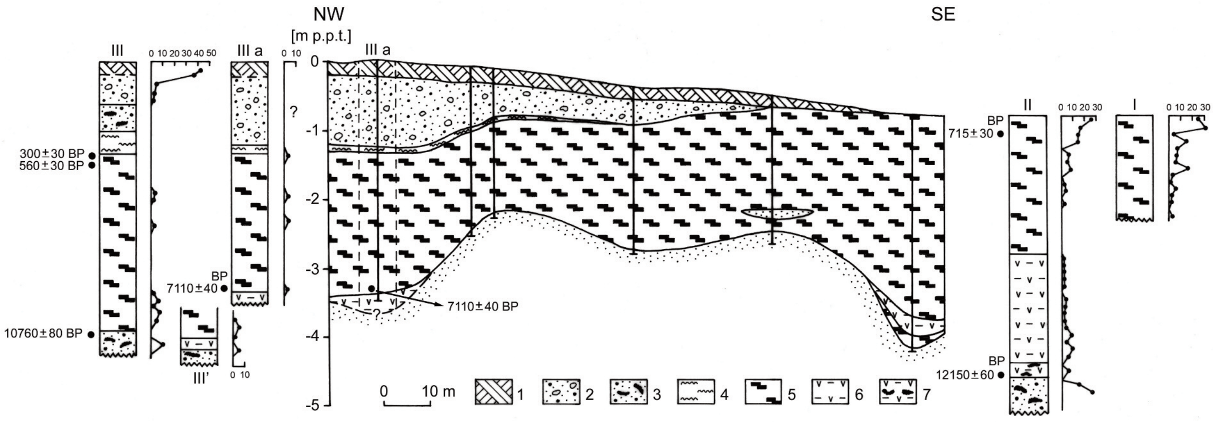
The small village of Przełazy is situated about 11 km SSW of the town of Świebodzin located c. 110 km west of Poznań, 6 km south of Mostki on the Poznań–Berlin road (cf. Text-fig. 1).

The present authors searched in the vicinity of Lake Niesłysz for traces of a fall or falls of meteorites, and specifically for impact and/or explosive craters, unfortunately in vain. Although several symmetrical oval hollows are present in this area, they lack the characteristic circumferential rims of a crater. As the morphometric criterion for identifying the site of the impact turned out to be useless, a lithological and mineralogical study was conducted instead. This followed the procedure applied in establishing the date of the fall of the Ilumetsa meteorite in Estonia (Liiva *et al.* 1979; Raukas *et al.* 2001). In the latter case, the date of the formation of the typical crater with clearly delineated rims was determined on the basis of the presence of a fine-grained magnetic fraction in a particular layer in the nearby peat-bog whose age was known.

In the present study area, there are numerous peat-bogs with well-developed organic successions. One would expect that these would yield evidence of the fall of the meteorite, in the form of a stratified concentration of fine-grained magnetic matter. The nearest "wet meadow" with drainage ditches is located immediately south-west of the village of Przełazy, where a pilot study was undertaken. Initially, this study consisted of drilling two cored boreholes, a shallow one, c. 150 cm deep (cf. Text-fig. 2, section I), and another one reaching the sandy substrate of the organic sediments (cf.



Text-fig. 1. The topography of the area near Przełazy with the location of the sites studied. Profiles/sections of organic sediments are marked with Roman numbers I–III; profiles of mineral deposits sites with Arabic numbers 1–10. In the upper left corner the main research area enlarged (sections I–III and penetration borings, soil profiles 1, 2)



Text-fig. 2. Przełazy site: main borings sections (I, II and III) with fine magnetic grains and the cross-section in between. 1 – Organic soil horizon; 2 – Sand with gravel and pebbles; 3 – Sandy materials with dispersed organic matter; 4 – Loamy strata; 5 – Peat; 6 – Gyttja; 7 – Gyttja with dispersed organic matter and thin organic layers

Text-fig. 2, section II). In both cases, the expected magnetic fraction was identified (cf. Text-fig. 2). The third borehole was done subsequently on the peat-bog mineral bank (cf. Text-fig. 2, section III with the checking ones IIIa and III'). The magnetic matter was found there too. Its distribution, in the shape of isolated layers enriched in the magnetic fraction, warrants more general conclusions on the origin of this material. Many authors have emphasized the difficulty of establishing whether a magnetic object is of extraterrestrial, volcanic, biogenic or anthropogenic origin. Thus, it must be mentioned that the profiles obtained in our study featured magnetic objects of two types: natural (extraterrestrial, volcanic and biogenic) and artificial (anthropogenic). Theoretically, the latter might have infiltrated the peat-bog downward from the surface (in practice difficult to believe), or even from the surrounding sediments. Nevertheless, the number of magnetic objects ought to display a diminishing tendency. This issue was raised by Magiera (2004) in his study of peat and soil profiles of clastic sediments throughout the territory of Poland. He demonstrated that industrial dust remains permanently in a position close to the surface, at depths of up to as little as 10–15 cm. Accordingly, any deeper layer enriched in a magnetic fraction and separated from the surface layer or another layer by a "non-magnetic layer" cannot be interpreted as the effect of a secondary contamination progressing from the surface. Such is also the essential premise of the interpretation adopted herein, as stated previously (Stankowski 2006, 2008; Uścinowicz 2008). Therefore, if a deeper layer of peat or gyttja contains a higher proportion of small magnetic objects, one may expect bodies of natural, mainly extraterrestrial origin. Their occurrence is related to the rate of sedentation (deposit-forming process which generate peat; Tobolski 2005) and accordingly may indicate the date of the arrival of the foreign matter and, in this case, the date of the fall of the Przełazy meteorite. Following the success of the pilot study, which provided evidence of layers enriched with magnetic matter, the authors extended their work outside the peat-bog and to the nearby moraine plateau, where a magnetic fraction was also expected to occur in soil profiles. The ultimate aim of the study was to ascertain a possible trajectory of the fall of the Przełazy meteorite, similar to the trajectory established for the Morasko meteorite (Hurnik 1976; Hurnik, Hurnik 1997, 2005).

THE PRZEŁAZY METEORITE

According to the Polish Meteorite Society (www.ptmet.org.pl), the metal lump from Przełazy (Seeläsgen) was taken soon after its discovery to Wrocław, where a preliminary analysis of its chemical composition determined its meteorite origin. After the discovery of the Morasko meteorite, it appeared that these two metallic lumps showed considerable similarity and both were classified as belonging to the same meteorite shower. A reclassification of the Przełazy meteorite in 1995 included it in type IIICD, and a new analysis in 2002 resulted in its being transferred to group IAB-MG.

Comparative studies of the meteorites of Morasko, Przełazy and Tabarz (Thuringia) revealed marked similarities. Puzzlingly enough, these three locations lie on a virtually straight line which may be further extended to the area of Gniezno – Jankowo Dolne in detail (Karwowski 2004). This line may be construed as the trajectory of a multiple fall of a propagation of some

470 km (Bartoschewitz 2001) and, if the meteorite discovered in Jankowo Dolne (near Gniezno) is also taken into account, of as much as ~520 km.

METALLIC SPHERULES IN GEOLOGICAL SECTIONS IN THE AREA OF PRZEŁAZY

The study of the metallic spherules was carried out in a relatively extensive area around the village of Przełazy (cf. Text-fig. 1). The sections investigated were: a) on the peat-bog south-west of Przełazy (sections I, II, III, IIIa), these being the key sections; b) penetration boreholes in between the key sections (cf. Text-fig. 2); c) shallow soil sections on the moraine plateau north-west of Przełazy (sections 1, 2, 3, 4, 10); d) sections located in and around the spectacular evorsive gully near the village of Zagórze. Two types of sections were excavated: sections in the small oval depressions filled with organic sediments (sections Las I, II), at the base of the evorsive gully; and sections in the clastic sediments from the surroundings of the evorsive gully (sections 5–9).

The studies undertaken in the peat-bog, south-west of Przełazy (sections I, II, III) and in the Zagórze sections Las I, II, consisted of several completely-cored boreholes, using the INSTORF equipment, as well as follow-up penetration cores to provide more accurate data on the local depth of the peat-bog base (Text-fig. 2, cores in between sections II and III). The cores were divided into 10-cm segments, from which the mineral matter was removed and the magnetic fraction separated manually by means of a strong magnet. From that material the spherules were selected under a microscope. Two groups of spherules were distinguished: regular/very spherical and irregular ones (see Table 1). The total number of spherules obtained from the Przełazy I and II sections are listed in Table 1 and shown on Text-figs 2, 3. While regular spherules constitute a minority, the changes in their numbers relative to the total number of spherules display a uniform tendency. The regular spherules were submitted to SEM analysis and microprobe analysis. It should be stated that all examined magnetic material is nickel-free, what make difficult to easy classified its extra-terrestrial origin (cf. Table 3).

In the upper parts of the two Przełazy sections (I and II), obtained from sites only a few metres apart, there is a marked concentration of spherules. Below the topmost 20 cm thick layer rich in spherules (some of them possibly formed of anthropogenic matter, Magiera 2004), there are two layers, at 25–45 cm and 70–80 cm depth intervals, clearly enriched in spherules. It is highly unlikely that these spherules are of industrial origin, especially those from the deeper layer. The radiocarbon date of a sample of peat from 25 cm depth is 715 ±30 BP (Poz-15605).

In the Przełazy II section, the magnetic spherule content decreases markedly beneath 80 cm. In the Przełazy I section, the same is observed beneath the 100–110 cm layer. The lowermost parts of the peat and gyttja in both sections contain only rare spherules. Conversely, the number of spherules increases markedly in the bottom part of the gyttja and in the underlying layers of sand with dispersed organic matter, at 300–340 and 385–400 cm depths. The radiocarbon date of the deepest layer studied herein (393–400 cm) is 12150 ±60 BP (Poz-15604). As we can see, the fine-grained magnetic fraction was developing before a lake environment appeared at this site, and later, during the first stages of the existence of a lake. The authors are convinced that the occurrence of the fraction cannot be explained by secondary pollution, while it may well have been caused by a fall of extraterrestrial dust.

A further study of the peat-bog border concerned the topography and the mineral composition of its side and bottom. Two boreholes (Przełazy III, IIIa) were drilled close to the peat bank at the vaguely delineated shelf, which was initially assumed to be a lake terrace, built up entirely of clastic sediments. Penetration boreholes between the sections Przełazy I, II and Przełazy III, IIIa established the peat-bog bed relief (cf. Text-fig. 2). In fact, highly compressed peat was identified under a thin layer of sand with an admixture of gravel, pebbles and cobbles; the alleged lake shelf proved to be a recent debris fan. The sedimentary cover which compressed the peat was apparently composed of coarse gravels and pebbles occurring in the sand fractions, accumulated during the Little Ice Age. This is evidenced by the radiocarbon dates of the upper layers of the fossil peat: 300 ±30 BP at ~125 cm depth (Poz-26006) and 560 ±30 BP at ~150 cm depth (Poz-26326). The radiocarbon date in the bottom part of the section (~390 cm depth), at the boundary between the organic and clastic sediments gave the age 10760 ±80 BP (Poz-25552). Data from two other boreholes made within a distance of a few metres of the Przełazy III section confirmed the considerable differences between the highest and lowest levels of the lake bottom and the differences in the dates of the beginning of sedentation in various locations. An instance of this diversity is the date of 7110 ±40 BP in section IIIa (Poz-27484).

Virtually throughout the thickness of the layer of fossil peat, only individual spherules appear (cf. the graphs of the frequency of objects in Przełazy III and

IIIa sections). This case is similar to that of the 110–300 cm depth interval in the Przełazy II section. Conversely, the numbers of spherules increases above the boundary between the peat and the sandy substrate, as well as in the actual sandy substrate in Przełazy III and III', which again seems to be correlated with the changes in the concentration of magnetic spherules in section Przełazy II (cf. the depth interval of 300–340 cm).

A study of the frequency of spherules in the fine-grained magnetic fraction in the section of peat from

Depth in cm	Spherules total numbers		Regular spherules		Irregular spherules	
	Profile I	Profile II	Profile I	Profile II	Profile I	Profile II
0-10	25	26	9	3	16	23
10-20	31	17	12	6	31	11
20-30	3	15	2	4	1	11
30-40	15	15	1	1	14	14
40-50	6		1		5	
50-60	5	6		2	5	4
60-70	5	5	2		3	5
70-80	18	8	10		8	8
80-90	2	1			2	1
90-100	1	1			1	1
100-110	5	3			5	3
110-120		1				1
120-130	1	1			1	1
130-140						
140-150	1				1	
150-160						
160-170						
170-180						
189-190						
190-200		1				1
200-210		1				1
210-220		1				1
220-230		1				1
230-240		1				1
240-250		1				1
250-260						
260-270		2				2
270-280		1				1
280-290		1				1
290-300		3				3
300-310		9				9
310-320		5				5
320-330		10		1		9
330-340		7		1		6
340-350						
350-365		6		2		4
365-384		1				1
384-393		16		4		12
393-400		26		6		20

Based on analytical data: Jopek 2006.

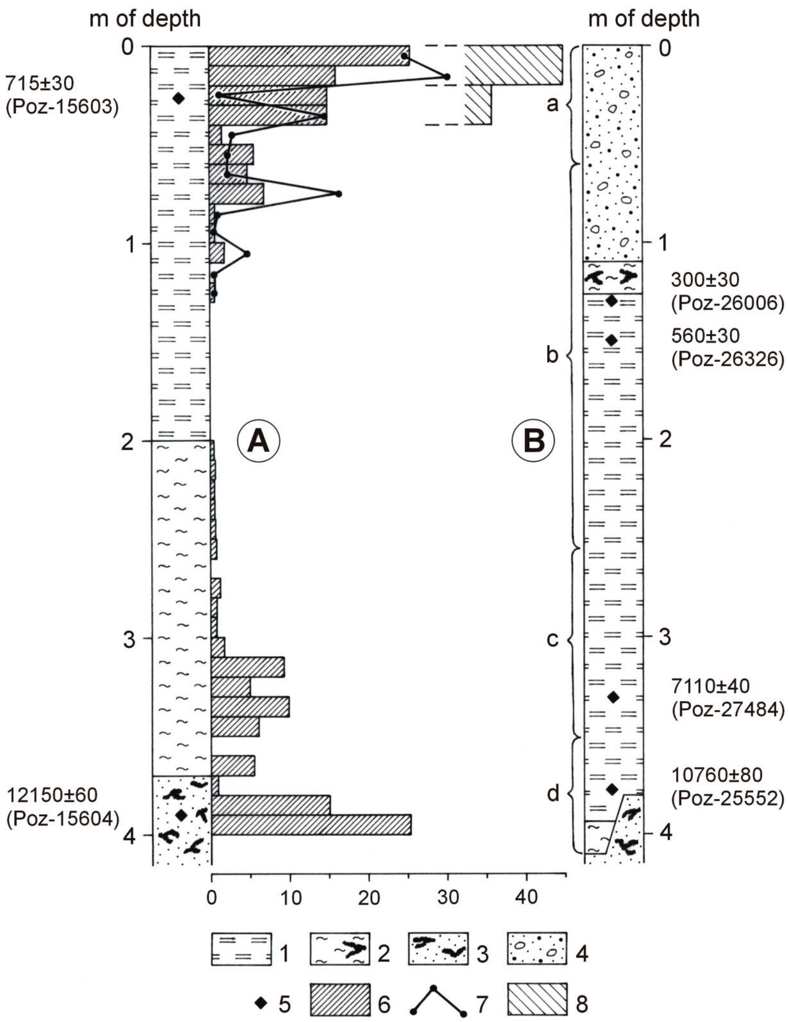
Table 1. The numbers of spherules at 10-cm depth intervals in the Przełazy sections I and II

the immediate surroundings of Przełazy (open and fossil peat bed), as well as in the overlying sediments indicates certain distinct periods of the arrival of these objects. The earliest interval may be dated for c. 7000 years BP and earlier (with a noticeable leap in the frequency at c. 11000 years BP); an intermediate interval is dated at 3000 to 2000 years BP; and the most recent one is not older than 300 years.

A comparative study, whose results were juxtaposed with those of the study of the immediate environs of Przełazy, concerned small peat-bogs in the base of a subglacial evorsive gully near the village of Zagórze. In the two profiles – Las I and Las II (cf. Text-fig 1 and Table 2), obtained at the latter place, spherules were encountered at the base of the peat, in thin layers of gyttja and at the top of the sandy substrate with dispersed organic matter.

At the Las I profile, under a thin organic cover up to 110 cm thick, there is water. Peat is present in the depth interval 110–257 cm, with an 11-cm substrate of gyttja. Generally, no spherules were found in the peat, except not very spherical magnetic material at its bottom part. Four spherules (one regular and three irregular ones) were found in the gyttja, and 65 magnetic spherules (15 regular and 50 irregular ones) were documented in the topmost 4-cm thick part of its sandy substrate. The lower layers of sand had a high percentage of spherules with a large carbon content. Genetically, these spherules may be classified as of organic origin, albeit bodies of this type are also interpreted as extraterrestrial (Firestone *et al.* 2007). The radiocarbon date of a sample of the dispersed organic matter in the sandy substrate is 3330 ± 35 BP (Poz-16596).

In the Las II profile, below a thin layer of vegetation and a layer of water up to c. 100 cm thick, interbeds of peat, gyttja and a silty-sandy sediment with dispersed organic material and small fragments of plants and shells were documented to 175 cm depth,



Text-fig 3. Correlation of main Przełazy sections – lithology, radiocarbon dating, spherule content. A – composite section I-II; B – composite section III-IIIa-IIIa'. 1 – peat; 2 – gittja with organic matter; 3 – sands with organic matter; 4 – sands with cobbles and pebbles; 5 – places of radiocarbon data; 6 – spherule numbers in section II; 7 – spherule numbers in section I; 8 – spherule numbers in section III. Letters at the left of the composite section III: a – uppermost part, rich in spherules; b – spherules absent; c – individual spherules; d – increase in spherule content

<table>
<tr><th rowspan="2">Depth within the profile</th><th colspan="12">Studied sites</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>Las I</th><th>Las II</th></tr>
<tr><td>0–20 cm</td><td>45</td><td>11</td><td colspan="2"></td><td>1</td><td colspan="3"></td><td>1</td><td>16</td><td colspan="2">no magnetic particles in peat or gyttja</td></tr>
<tr><td>20–50 cm</td><td>40</td><td>2</td><td colspan="7"></td><td>7</td><td colspan="2"></td></tr>
<tr><td>50–100 cm</td><td colspan="10"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">> 100 cm</td><td colspan="4"></td><td>10</td><td colspan="5"></td><td colspan="2">in the bottom part of the organic sediments and in the top of underlying mineral material</td></tr>
<tr><td colspan="10"></td><td>69</td><td>4</td></tr>
</table>

Analytical data: successions of sites 1–9 and Las II after Filipek 2008; Las I after Jopek 2006; site 10 by the present authors.

Table 2. The numbers of particles of magnetic matter/spherules in soil profiles from the moraine plateau north-west of Przełazy and in the Las I and Las II sections

overlying a substrate of sand with thin organic interbeds. The radiocarbon date of a sample from one of the organic interbeds in the substrate was determined as 2260 ±35 BP (Poz-25551). Generally no spherules were found in any of the peat sections examined, however, the topmost part of the sandy substrate is enriched in magnetic spherules. Among the spherules there were numerous iron (nickel-free) spherules. Firestone *et al*. (2007) also interpreted such objects as extraterrestrial.

The age of the sandy substrate of the peat and gyttja containing a magnetic fraction at the Las profiles turned out to be similar to the estimated time of the sedentation in the Przełazy II section (70–80 cm below surface; 2000–3000 years BP). Accordingly, increased arrival of magnetic matter, possibly of extraterrestrial origin, might have taken place while the peat layer was developing and while the bottoms of the cavities at the Las site, at that time still composed of clastic material, constituted the surface of the ground.

We emphasize that metallic spherules were almost not found in the organic parts of the two Las profiles. This signifies that during the last 2000–3000 years or more conditions for the generation of such objects, including fall of magnetic matter, did not occur in this particular area. The absence of metallic spherules from the surface layer of organic filling in the two oval cavities at the bottom of the evorsive gully contrasts with the presence of a magnetic fraction not only at the principal site near Przełazy, but also in soil profiles from the moraine plateau between the villages of Przełazy, Niedzwiedź and Zagórze. In almost half of the ten selected locations, the occurrence of a fine-grained magnetic fraction was recorded, and in four, a markedly increased amount of it (cf. Table 2, Text-fig. 1). These locations are: the principal site near Przełazy (No. 1, with the highest number of objects); then sites located west and north-west thereof, the nearer one (No. 2, less than 1 km), and the farther one (No. 3, c. 3.5 km away); and finally sites at distances of, respectively, c. 4 km (No. 4) and 2.5 km (No. 10). Thus, the proportion of the magnetic fraction is clearly augmented in the soil profiles from the immediately west and north-west of Przełazy. This may be interpreted as evidence of the trajectory fall of the Przełazy meteorite. The unexpected enrichment of the bottom of the soil profile from site 5 (cf. Table 2) in a magnetic fraction is apparently not related to the Przełazy meteorite fall under discussion. Can the observed distribution of the fine-grained magnetic fraction (except site 5 data) be indicative of the trajectory of the fall of the Przełazy meteorite, or of a fall of dust during the alleged flight of the meteorite(s) of Tabarz, Przełazy, Morasko/Oborniki and Jankowo Dolne (Bartoschewitz 2001; Karwowski 2004)? Unfortunately, as no data from locations farther away from Przełazy are available, including an area east and north of the lake (where iron meteorites have been found as well: Prof. Karwowski's personal communication), any answers to the above question must be merely tentative.

CHARACTERISTICS OF THE REGULAR MAGNETIC SPHERULES IN THE PEAT PROFILES FROM PRZELAZY

The chemical composition of the regular spherules separated from peat and gyttja in the Przełazy sections varies from one part of the profile to another and

	Sample No.	Principal components of the spherules [Wt%]											
		Fe_2O_3	Al_2O_3	SiO_2	Na_2O	K_2O	MgO	CaO	TiO_2	ZnO	CuO	P_2O_5	MnO
Spherules of variety “A”	11–1	98.48	0.27	0.19	–	–	–	–	–	0.52	0.54	–	–
	11–2	97.31	0.71	0.59	–	–	–	–	–	0.71	0.67	–	–
	42–1	88.82	2.17	2.11	2.79	0.98	0.35	0.51	–	–	0.72	0.42	–
	7–1	75.13	5.32	5.92	–	–	0.25	12.13	0.32	–	0.94	–	–
	7–2	99.36	–	0.37	–	–	–	–	–	–	–	0.27	–
	9–1	91.95	2.33	3.02	–	0.16	0.29	0.75	–	0.70	0.80	–	–
	9–2	84.94	2.61	11.95	–		–	0.28	0.22	–	–	–	–
	37–1	73.62	2.29	7.10	–	–	–	9.27	–	1.67	1.75	2.17	1.43
	37–2	97.54	0.74	0.38	–	–	–	–	–	–	0.71	0.28	0.35
Spherules of variety “B”	PY–Ia	48.47	4.63	33.39	–	–	1.99	8.76	1.44	0.62	0.52	–	–
Spherules of anthropogenic variety	8	15.68	13.57	58.32	1.64	2.04	2.30	5.52	0.73	–	–	–	–
	18	11.08	21.10	49.35	2.51	2.63	4.60	6.28	2.45	–	–	–	–
	19	10.10	26.13	52.62	1.24	2.65	3.46	2.36	1.43	–	–	–	–
	24	23.36	5.41	54.07	–	0.46	–	15.91	0.79	–	–	–	–
	28	7.52	18.01	59.23	2.14	4.33	2.72	4.04	2.00	–	–	–	–

Table 3. The chemical composition of spherules subdivided into varieties (as described in the text)

within a single “layer” (cf. Table 3). This considerably complicates the determination of the origin of these bodies. While most objects in the layers of peat close to the surface are presumably anthropogenic, the magnetic particles in the lower parts of the profiles are of natural origin. It is the authors’ belief that, of the latter, extraterrestrial spherules constitute a significant proportion. When meteorites pass through the atmosphere, they heat up, melt and evaporate. Simultaneously, the processes of condensation produce spherules, which fall down to the surface of the Earth (Raukas 2004; Hurnik and Hurnik 2005). Due to explosive events on the ground, mineral substance, transformed by the pressure and temperature, is ejected into the air and, combined with vestiges of extraterrestrial matter, may fall either in the actual impact area or in a wide stretch of land around it (Raukas and Laigna 2005).

In the magnetic grains from the Przełazy peat, both fractions interpreted as extraterrestrial and anthropogenic objects have been identified. The extraterrestrial category may, in turn, be divided into two varieties: (A), in which iron compounds predominate (c. 74 to nearly 100% Fe_2O_3) and there is a relatively low silicon compounds content, and (B) (only one such object has been identified), in which the iron compounds content is significant, albeit much lower (nearly 50% Fe_2O_3), and there is a much higher silicon compounds content (c 34% SiO_2) (cf. Table 3).

The sizes of the spherules of the first variety (A) are in the range of 50 µm. They are dark coloured and their surfaces are shiny with a metallic sheen. The texture of the surface varies from a dendritic pattern to a smooth texture with small pores resembling an orange rind.

The spherules of the second variety (B) are larger, with sizes in the range of 200 µm, and have a characteristic brown color. Their surfaces are matt, with a texture varying from smooth and almost homogeneous to a surface covered with numerous pores or a pattern of tiny cracks. It may be assumed that these objects appeared after the impact, when the high temperature and pressure enhanced the mixing of the chemical elements making up the meteorite and the rock of the subsoil.

As already mentioned, in the Przełazy sections there were also objects whose chemical composition differed from that described above. They have a distinctive regular spherical shape and a smooth surface texture with small, relatively sporadic orifices. The sizes of these spherules are in the range of 300 µm. Since they are encountered in the section only at depths of 0–20 cm, they were obviously not capable of a deeper penetration, a fact which must be considered a reliable indication of their industrial origin.

DISCUSSION AND CONCLUSIONS

The authors believe that the variable frequency of the fine-grained magnetic fraction in the profiles studied is related to the rate of sedentation. There is no evidence of any particular secondary processes, e.g. a gravitational transfer of magnetic material or its concentration in zones at certain depths. The same is true of the soil profiles of the clastic sediments in the moraine plateau where, however, the possible intermittent peaks in the arrival of new material always occurred in the same locations.

The increasing frequency of metallic material from one layer to another and the above-mentioned differences in the composition of the spherules warrant the following conclusions:

(a) It is only in the surface layers of peat in the Przełazy I and II sections, as well as in the mineral soil profiles, that anthropogenic spherules may appear, along with natural material. The peat in the Przełazy III, III' and IIIa sections contain only natural magnetic objects.

(b) In the peat and gyttja layers in the studied sections the natural magnetic matter occurs only rarely. The identified laminar enrichment with this fraction may not be of volcanic origin. The most recent well-documented volcanic event of Laaher (see Bogaard and Schminck 1985) took place during the Ållerød Interstadial, and the range of the dispersion of volcanic dust was practically out of the Przełazy area.

(c) The magnetic fraction identified in the profiles studied may be of biogenic and/or extraterrestrial origin; the well-developed spherules must be classified as extraterrestrial.

(d) The marked increase in the concentration of spherules in the bottom parts of the Przełazy II, III, III' and IIIa sections is of a synsedentational nature. This provides evidence of a heightened fall of extraterrestrial matter at the end of the Late Glacial and the beginning of the Holocene. A second, less probable possibility of a fall of extraterrestrial material can be connected with a relatively young event, about 3000–2000 years BP.

(e) The Przełazy meteorite, excavated from a depth of c. 4 m, apparently fell at the beginning of the period of organic sedentation in the study area. The enrichment in spherules of a layer of peat whose approximate age is slightly more than 2000 years BP (the estimated age of the layer of peat enriched in spherules in the Przełazy II section) may be correlated with the age of the basal part of the organic matter in the Las profiles. At the time of the impact in Przełazy (2000-3000 years ago), the meteorite should sank in the peat and arrived at its clastic substrate.

(f) The fall of the Przełazy meteorite is inferred to have taken place, based on the evidence of the noticeable concentration of fine-grained magnetic matter in organic sediments, in one of two possible periods. The first, less likely date, is less than 3000 years ago, although it nevertheless coincides with the time of the assumed second fall of magnetic matter in Morasko (Stankowski 2008). No increased spherule content has been discovered in the highly compressed peat under a layer of sand-and-gravel sediments (cf. Przełazy sections III and IIIa) at a level corresponding to that date. The more likely date of the fall of the Przełazy meteorite is in the Late Glacial and Holocene, or in the early Holocene (11000–9000 years BP). A credible site of the fall and the excavation of the meteorite is a peat-bog directly south-west of the village of Przełazy.

(g) The above inferred date of the fall of the Przełazy meteorite (11000–9000 years BP) differs from the time of the principal impact in Morasko (c. 5000 years BP). This clearly disproves the hypothesis that the meteorites of Tabarz, Przełazy and Morasko had a common trajectory. The Przełazy and Morasko meteorites fell at different times, albeit their chemical compositions are similar.

Acknowledgements

This work was made possible by the funding of research by Adam Mickiewicz University. We express our gratitude to the MSc students A. Filipek and T. Jopek for their cooperation in the fieldwork and laboratory studies.

REFERENCES

Bartoschewitz, R. 2001. Tabarz-A Fragment of the Morasko Strewn Field? *Meteoritics and Planetary Science*, **36**, A15–A16.

Bogaard, P. van den and Schmincke, H.U. 1985. Laaher See tephra – a widespread isochronous Late Quaternary tephra layer in Central and Northern Europe. *Geological Society American Bulletin*, **96**, 12

Filipek A. 2008. Is the magnetic matter enlarged in the Przełazy neighbourhood strata. Unpublished MSc thesis. Institute of Geology, Adam Mickiewicz University UAM. [In Polish]

Firestone, R.B., West, A., Kennet, J.P., Becker, L., Bunch, T.E., Revay, Z.S., Schultz, P.H., Belgya, T., Kennett, D.J., Erlanson, J.M., Dickenson, O.J., Goodyear, A.C., Harris, R.S., Howard, G.A., Kloosterman, J.B., Lechler, P., Mayewski, P.A., Montgomery, J., Poreda, R., Darrah, T., Que Hee, S.S., Smith, A.R., Stich, A., Topping, W., Wittke, J.H. and Wolbach, W.S. 2007. Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas Cooling. PNAS, October 9, 2007, 104 (41), 16016–16021.

Hurnik, H. 1976. In: Hurnik, H. (Ed.), Meteorite Morasko and region of its fall. Adam Mickiewicz University Press, Seria Astronomia 2, Poznań, pp. 3–6. [In Polish]

Hurnik, B. and Hurnik, H. 1997. The problems of meteoritic dust at Morasko. Proceedings of Meteoritic Conference in Olsztyn, June 1977, pp 4–5. [In Polish]

Hurnik, B. and Hurnik, H. 2005. Cosmic matter on the Earth, its sources and evolution, 282 pp. Adam Mickiewicz University Press; Poznań. [In Polish]

Jopek, T. 2006. The magnetic matter in the selected organic sections from the Przełazy neighbourhood. Unpublished M.Sc. thesis; Institute of Geology, Adam Mickiewicz University. [In Polish]

Karwowski, L. 2004. Jankowo Dolne – the new Polish iron meteorite. Third Meteoritic Conference, Poznań, September 25–26. Institute of Geology Adam Mickiewicz University, Polish Meteoritic Society. Abstracts of papers, pp. 23–29. [In Polish]

Liiva, A., Kessel, H. and Aaloe, A. 1979. The age of Ilumetsa Craters. *Estonian Nature*, **12**, 762–764.

Magiera, T. 2004. Use of magnetometry in assessment of soil and lake sediments pollution. Instytut Podstaw Inżynierii Środowiska PAN, Prace i Studia, 59, 130.

Pokrzywniki, J. 1964. I. Meteorites of Poland, II. Catalogue of Meteorites in Polish Collections. *Studia Geologica Polonica*, **15**, 176 pp.

Raukas A. 2004. Distribution and composition of extraterrestrial spherules in the Kaali area (Island of Saaremaa, Estonia). *Geochemical Journal*, **38**, 101–106.

Raukas, A. and Laigna, K-O. 2005. Height of the turbulent gas flow and transport distance of glassy spherules on the example of the Kaali impact, Estonia. *Proceedings of Estonian Academy of Sciences, Geology*, **54** (3), 145–152.

Raukas, A., Tiirmaa, R., Kaup, E. and Kimme, K. 2001. The age of the Ilumetsa meteorite craters in South-East Estonia. *Meteoritices and Planetary Science*, **36**, 1507–1514.

Stankowski, W. 2006. Od sferulek po glob ziemski. Uniwersytet im. A. Mickiewicza, Instytut Geologii; Polish Geological Society, Oddział w Poznaniu, Referaty XV (J. Skoczylas, Ed.), pp. 155–169.

Stankowski, W. 2008. Morasko Meteorite. A curiosity of the Poznań region. 91 pp. Adam Mickiewicz University Press; Poznań.

Tobolski, K. 2005. The basics of biogenic accumulation. In: Miot-Szpigniewicz, G., Tobolski, K. and. Zachiewicz, J. (Eds), Deposits of the biogenic accumulation reservoirs. Polish Geological Institute, Centre of Excellence. Research on Abiotic Environment REA, pp. 7–16. Gdańsk.

Uścinowicz, G. 2008. Cosmic spherules in the land and sea sediments – can we use them in stratigraphy. *Baltica*, **21** (1-2), 95–97.

Manuscript submitted: 01st September 2009
Revised version accepted: 15th December 2010