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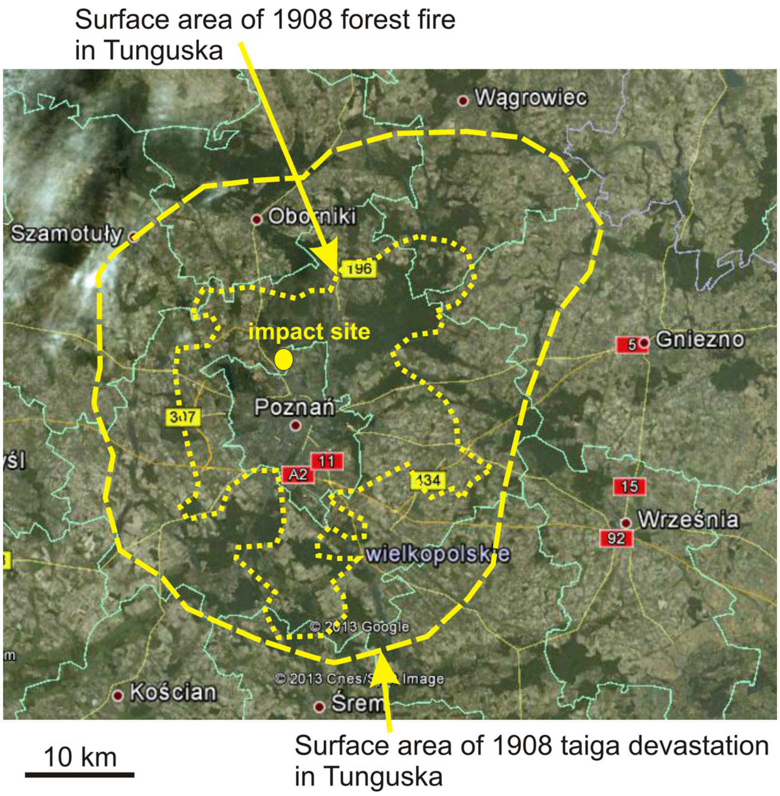

Field excursion guidebook

The Morasko Meteorite Reserve

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Field excursion to the "Morasko Meteorite" Reserve

Andrzej MUSZYŃSKI, Wojciech STANKOWSKI, Witold SZCZUCIŃSKI

Institute of Geology, Adam Mickiewicz University, ul. Maków Polnych 16, 60-606 Poznań, Poland;

1. Introduction

The largest iron meteorite shower in Central Europe have taken place nearby contemporary Morasko district of the city of Poznań, western Poland (Pilski, Walton 1999). The Morasko Meteorite has already a 100 years long history of investigations. The first findings date back to 1914, when four meteorite pieces were found by dr. Cobliner while digging of military trenches. The weights of these meteorites were 77.5 kg, 4.2 kg and two pieces of 3.5 kg each. Up to now, more than 1500 kg of extraterrestrial matter has been documented with particular pieces ranging in weight from a few grams to more than 260 kg. Particularly successful were surveys in 2006, when several large lumps of meteorite, including 164 kg heavy one, were found. So far, the largest meteorite was found in October 2012 (261.2 kg).

Another specific feature of the Morasko area are impact craters. The depressions up to 100 m in diameter located nearby the site of the first meteorite pieces findings were for the first time suggested to be the craters by Pokrzywnicki (1957). The presence of both, extraterrestrial metallic material and the morphological effects of its fall, make the Morasko to be one from less than 20 documented sites worldwide, where the remnants of the impacting body are found next to the craters.

During the field excursion, we will visit the site of the Morasko craters and discuss the problems of the meteorite fall onto the soft glacigenic sediments which have been raised in several publications (e.g., Hurinik 1976, Stankowski 2008, Muszyński et al. 2012). Also, interesting geomorphological aspects and a gerelationships of the deposits in which the craters were formed will be presented.

2. Geological setting, distribution and morphology of the Morasko craters; glacitectonics

Góra Moraska (Morasko hill) is built of deformed Neogene and Pleistocene deposits (the oldest > 0.5 Ma), and its palaeomorphological rise is older than the last glaciation (Stankowski 2001).

During the ice maximum extent of the last glaciation (Vistulian, ~20000 BP), shallow glacitectonic deformation took place and morphological features similar to present day features were formed. The degradation of permafrost in Moraska Góra and surroundings occurred between 14,000 and 10,000 yr BP. Evorsive depressions and kettle-holes, predominantly longitudinal and irregular in shape, started to fill with organic deposits before the Holocene (Tobolski 1976; Stankowski 2008). The age of the deepest organic infill in the thermocarst depressions is documented palynologically (Tobolski 1976) and by ^{14}C dating (Stankowski 2001).

In a small area NE of the Góra Moraska summit, several regular oval depressions are found, with circumferential ridges of different shape (Fig.1). The age of their organic infill is much younger than that in cryogenic ones from pre-Holocene times.

Fig. 1. Depression forms of evorsive and ice-melting origin (a) and meteorite craters (b) in the neighbourhood of Moraska Góra (after Stankowski 2001)

The Moraska Góra hill has a glacitectonic structure developed not only during the last glaciation. Complexity of the geologicical building was elaborated by Karczewski (1976) - see Fig. 2. Very characteristic is high position (up to 150 m a.s.l) of Neogene Poznań clay.

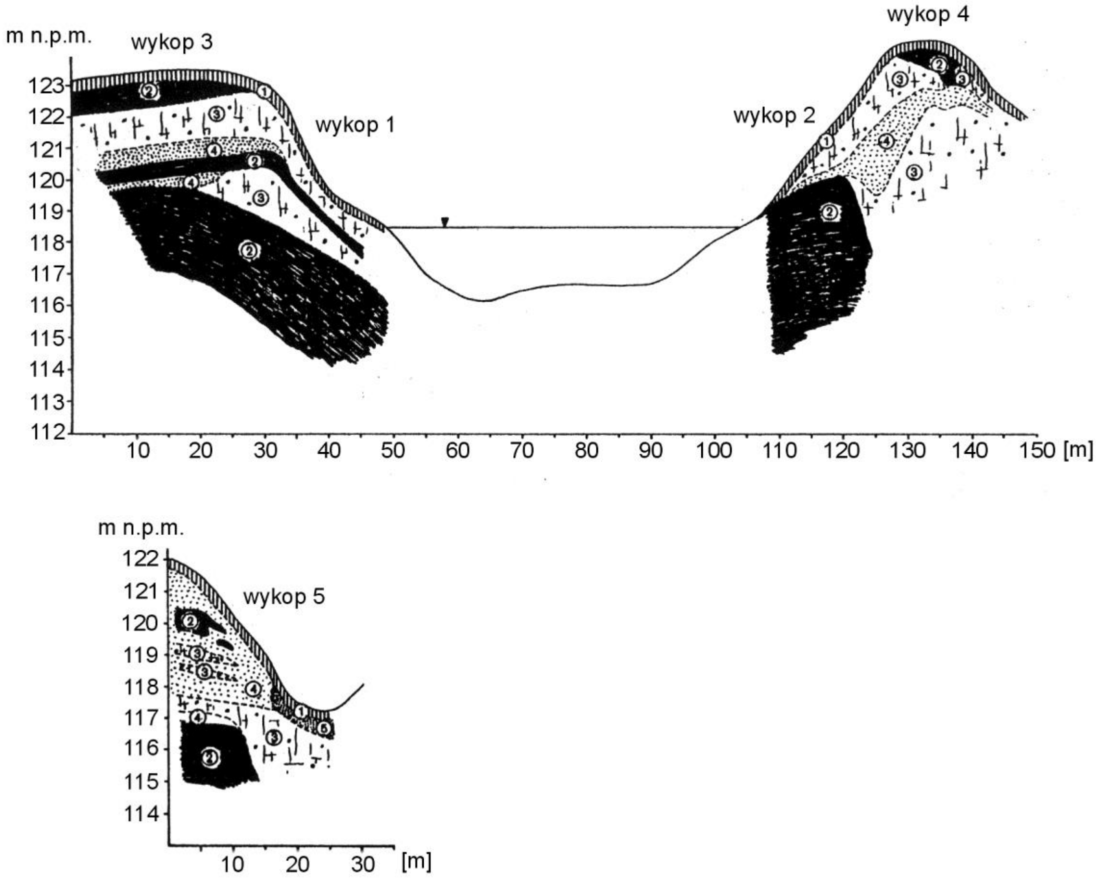

Fig. 2. Schematic cross-sections through depressions A (above) and F (below), (after Karczewski 1976). 1 – soil, 2 – Poznań variegated clay, 3 – sandy loam, 4 – clayey sand, 5 – organodetrital deposits

3. Timing of the meteorite fall

The age of the Morasko meteorite impact was assessed using several methods. They include methods based on thermoluminescence (TL), optically stimulated luminescence (OSL), radiocarbon dating (^{14}C), as well as pollen analyses.

As a result of the meteorite passage through the atmosphere, its surface is heated and partly melted and while reaching the ground often a thin crust layer of melt and sinter with some grains of impacted sediments is formed. These sediment grains are characterised by impact-zeroed luminescence, thus providing an excellent material for dating of the impact (Stankowski et al. in press). The TL datings of the Morasko meteorite sinter layer revealed ages from 4700 to 6100 years. The same method used for material obtained from the thin layer of melt gave ages of 4600 to 4900 years ago.

The insight into the age of the meteorite fall is provided not only from the surface crusts of the meteorites but also through analyses of the material from the bottom and slopes of the impact craters. The original sediments were of Neogene and Quaternary age (more than 10000 years old). The measurements of 101 samples using OSL dosimetric technique provided age range from about 350 000 to about 4000 years ago. Among the results 43% revealed age younger than 10000 years, with 13% indicating age of about 5000 years ago. It suggests that at least a portion of the analysed sediments were zeroed or partly zeroed during the impact (Stankowski, Bluszcz 2012). The results are an important argument in favour of impact origin of the Morasko craters.

According to palynological analyses by Tobolski (1976) the beginning of sedentation (filling with organic matter) in the craters have started not earlier than the middle of Atlantic period (Table 1). This results were conformed later by ^{14}C data (see Table 1). Based on all the available data the Morasko meteorite shower took place around 5000 years ago.

Years BP	Beginning of crater organic infilling				
	Palynological estimations (Tobolski 1976; Milecka, unpublished)	^{14}C datings (Gliwice and *Poznań* laboratories) Craters: A B C E			
0			260±80 690±95	640±90 690±150 990±160	610±75 650±110
1000					
2000			2690±170		
3000					3360±100
4000		*4465±35* *4495±35*	*4760±40*		
5000	5000-5500				
6000					
7000					
8000					
9000					
10000	Permafrost degradation not later than 10000 years BP (Kozarski 1963)				

^{14}C data for mineral/organic boundary in different boreholes, elaborated by Pazdur (Gliwice) and Goslar (Poznań; in italics).

Table 1. Morasko meteorite craters - radiometric data and palynological estimations (after Stankowski, Muszyński 2008).

4. Distribution of the meteorite finds

The great majority of finds of Morasko are confined to a relatively small area on the northern slope of a terminal moraine from the last glaciation. No find has been reported north of the moraine, except two doubtful irons which were reportedly found in the town of Oborniki, and lost before detailed examination could be made (Pokrzywnicki 1964). Most meteorite fragments were found at a depth of ~50-80 cm. However, the latest findings indicate that the meteorites can occur deeper than 160 cm (Pilski et al. 2012).

5. The Morasko strewn field

As accepted by many authors, the fall of the Morasko iron produced several craters, up to a few tens of meters across, in soft glacial sedimentary deposits (Pilski, Walton 1999). The relief of the fall site is typical of a glacitectonically deformed front moraine of the latest Vistulian stage (see details in Stankowski 2001, 2008). Stankowski(2008) summarized the current state of knowledge on the Morasko meteorite fall and gave an extended reference list.

The distribution of the Morasko iron finds is shown in Fig. 3a and 3b. The three iron falls, Morasko, Przełazy and Jankowo Dolne, broadly lie along a WSW-ENE line, with the largest Morasko fall situated approximately midway between Przełazy and Jankowo Dolne (Pilski et al. 2013). Meteorite Morasko is known as the largest iron-meteorite shower in Europe (Pilski, Walton 1999). Three well known iron meteorites (IAB-MG) from central-west Poland: Morasko, Seeläsgen (Przełazy) and Jankowo Dolne, belong to the Morasko iron meteorite shower. The size of the strewn field, including Seeläsgen and Jankowo Dolne, as well as hundreds of finds, suggest together that the shower originated from a large meteoroid.

The first interpretation of the Morasko strewn field came from Pokrzywnicki (1964), who first discovered that Morasko maybe an iron shower, and mapped Morasko finds. A next attempt to determine the Morasko strewn field was made by Pilski (2003,), who added to the localities published by Pokrzywnicki several localities of recent finds submitted by private meteorite hunters. All new finds were situated not far from the old ones known to Pokrzywnicki, mostly on the northern slope of a terminal moraine.

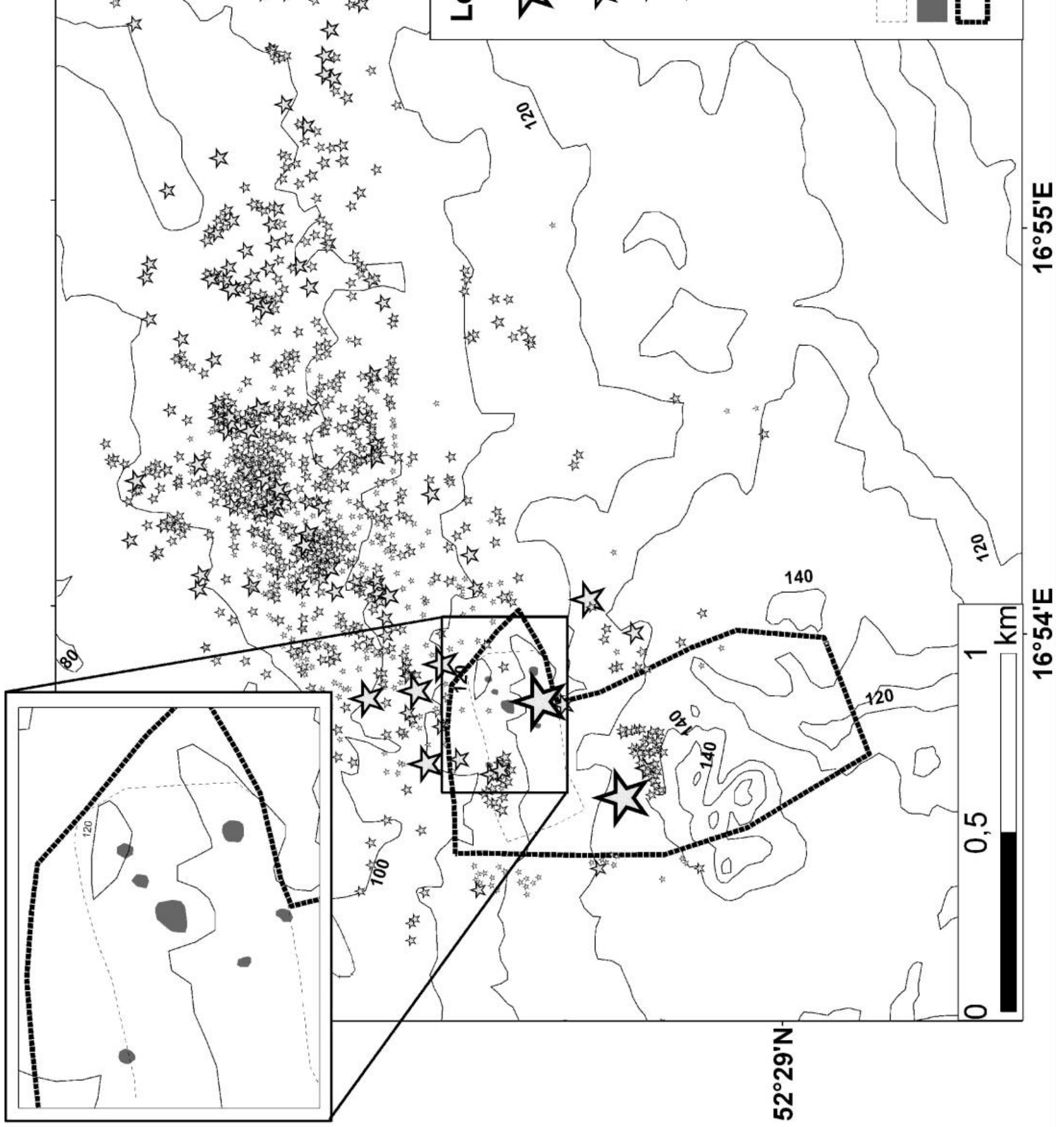

Fig. 3a. The Morasko iron: distribution of meteorite finds (after Pilski et al. 2013)

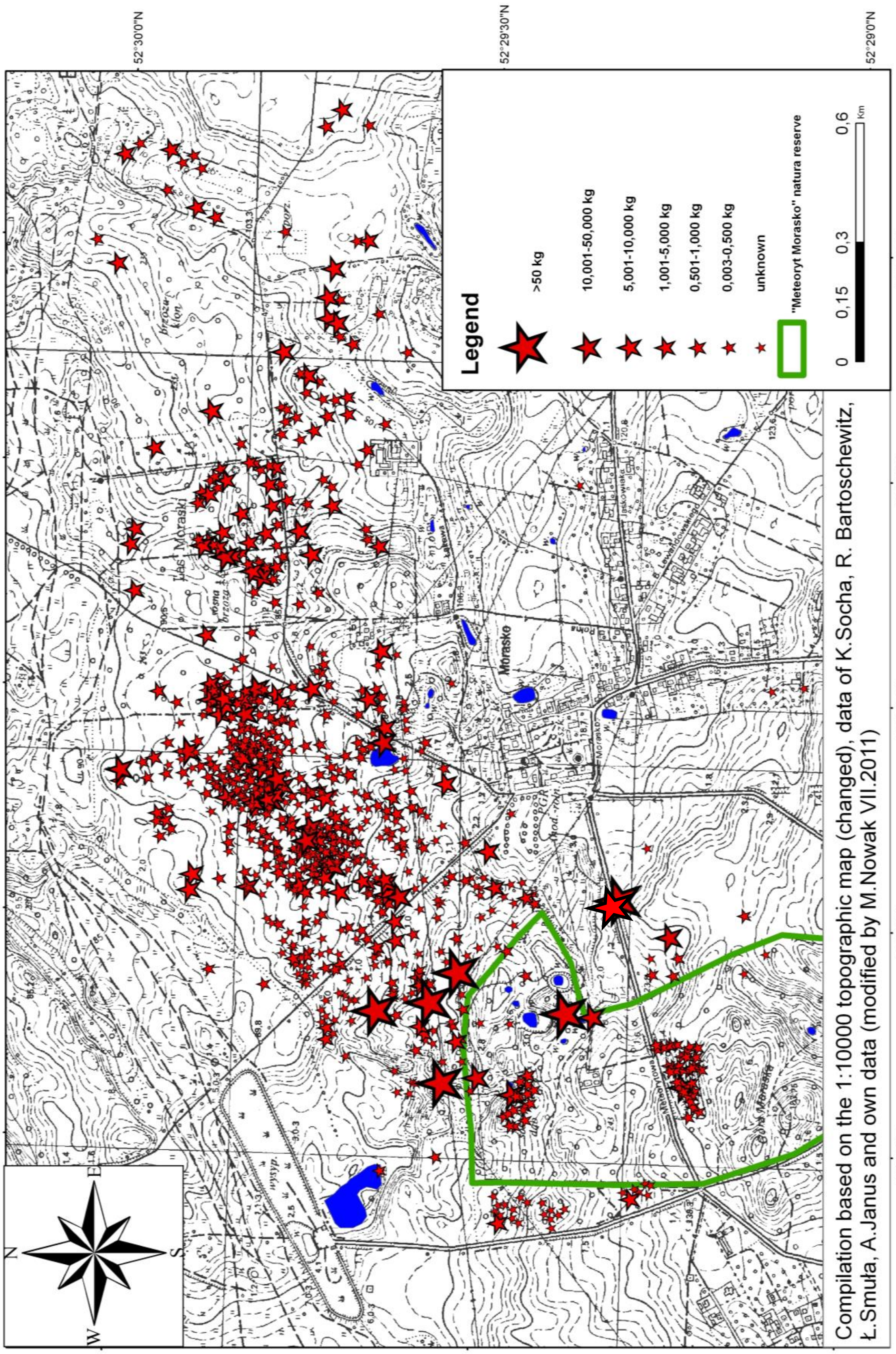

Fig. 3b. The Morasko iron: distribution of meteorite finds (after Pilski et al. 2013)

6. Petrography, mineralogy and chemistry of the meteorites

The meteorites have been studied by many authors (including a few MSc students), e.g. Pokrzywnicki (1964), Dominik (1976), Hurnik et al. (1976), Classen (1978), Czegka (1996), Pilski and Walton (1999), Stankowski (2001), Muszyński et al. (2001), Karwowski (2004, 2005), Karwowski and Muszyński (2006, 2007, 2008), Karwowski et al. (2009a, 2009b), Wojnarowska at al. (2008), Jastrzębska (2009), Pilski et al. (2012) (for more references see Dworzyńska, Muszyński, 2012).

The three iron falls display many similarities in petrography, mineralogy and chemical features. All three meteorites belong to the IAB–MG group. They are composed mainly of coarse-grained kamacite and taenite, with accessory cohenite and schreibersite. A distinct feature of all three irons is the presence of characteristic nodules, usually ca. 1-1.5cm in size, composed of graphite and troilite, with minor silicates, sulphides, oxides and phosphates.

The large size of the body would explain the observed small differences in Ir contents, similar to those reported from the Canyon Diablo iron. The similar chemical compositions of the irons studied, in particular the Ir contents, indicate that the meteoroid was rather homogeneous and no important fractional crystallization processes took place in it.

7. Micrometeorites and meteoritic dust in soil

Micrometeorites (0.1–15 mm in diameter) can be often found as magnetic particles in the soil of the Morasko reserve area. In the Morasko micrometeorites, the original minerals are iron and nickel alloys: kamacite, taenite and schreibersite. Goethite and lepidocrocite are the stable minerals of final weathering, whilst micrometeorites in the intermediate stage of weathering contain magnetite, maghemite and akaganeite (Karwowski, Gurdziel 2009). Chemical analysis of partly weathered micrometeorites showed that nickel was present in numerous analyzed grains (for more details see: Dworzyńska, Muszyński, 2012). The studied micrometeorites have the same mineralogical composition as the Morasko iron and originated from the common meteorite shower.

Micrometeorites and meteoritic dust have been proven at many localities within the Morasko strewn field (unpublished data). Marini et al. (2004) have shown that tiny fragments of meteorites can form at various stages of impact. They can form from metal-rich vapour, melt or due to disintegration of larger solid particles (Fig. 4).

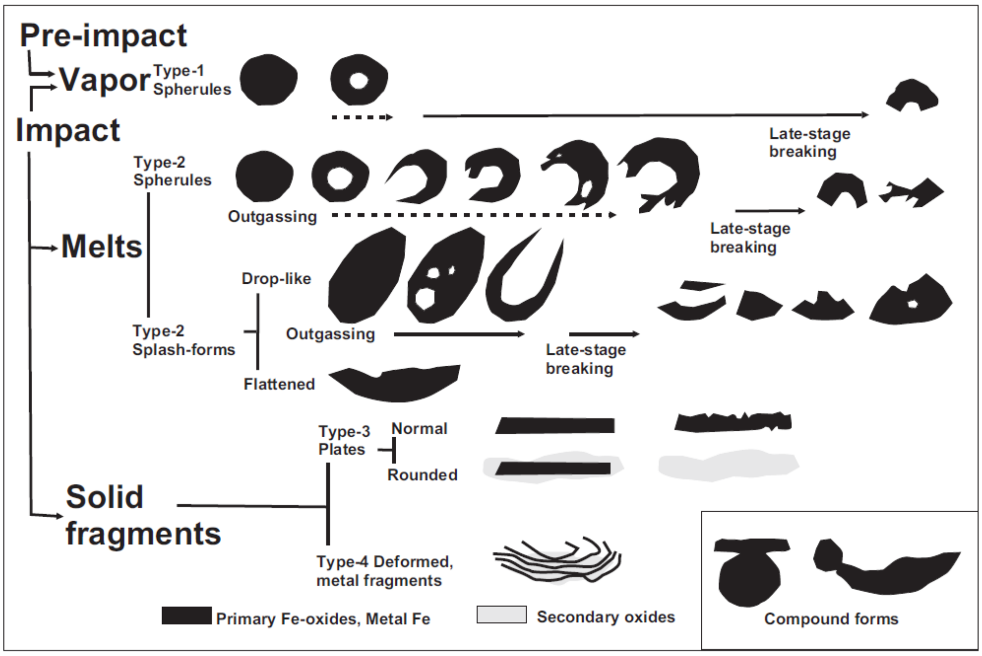

Fig. 4. Various genetic types of “magnetic fines” (after Marini et al. 2004)

8. Meteorite weathering

Iron meteorites show various degrees of weathering, depending on their location and local conditions (Fig. 5). In the case of the Morasko iron, weakly weathered fragments are found at shallow depth in loams, whereas those from sandy and clayey deposits at deeper levels are much more strongly altered. The weathering products include Ni-rich iron hydroxides, and chlorides, sulphates, phosphates and carbonates. Locally, microaggregates of a Ge-rich (up to 5at.%) metal phase are found within secondary hydroxides (Karwowski, Gurdziel 2009).

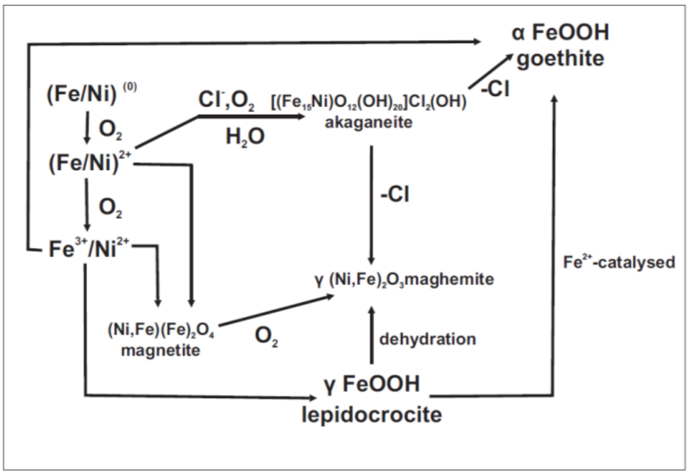

Fig. 5. Scheme of weathering of iron meteorites (after Golden et al. 1995)

9. Morasko iron shower model

Summarizing the available observations, we may conclude that the three iron meteorite falls, Morasko, Seeläsgen (Przełazy) and Jankowo Dolne, represent a single meteorite shower dated at ca 5000 Ma. They originated from a large and rather homogeneous meteoroid. A model showing the geological and environmental circumstances preceding the impact of the Morasko iron shower, after Stankowski (2001), is presented in Fig. 6.

10. Effects of meteorite impact in unconsolidated sediments - new research directions

So far, the studies in the region focused on the meteorites properties (Muszyński et al. 2012 and references therein) and whether the depressions found in the area are related to the impact event. As for a long time both glacigenic and impact origin of the craters has been considered (Stankowski 2008, and references therein). The aim of the recently undertaken new research project is to extend the previous investigations and to undertake field and laboratory investigations, as well as to perform numerical modeling to reconstruct and assess the physical and environmental consequences of the Morasko iron meteorite shower.

The extent of the effects of the impact (ejecta layer, wildfire etc.) is not known yet. To give an approximated range of the size of the likely affected area one may compare the extent of forest fire and taiga devastation in Tunguska 1908 (vide Veski et al. 2001) to illustrate the possible scale of meteorite impact event. On the cover of the guide book is a map illustrating its possible range. This area was also considered in the new project, which aims to address several issues:

- the precise age of the impact (dating of paleosoils and lake sediments nearby),

- assessment of the volume, dispersal pattern and properties of the sediments ejected from the craters (field mapping supported by numerical modeling)

- estimation of the direction of the meteorite impact and the amount of released energy (geological evidence, mineralogical impact features and the modeling)

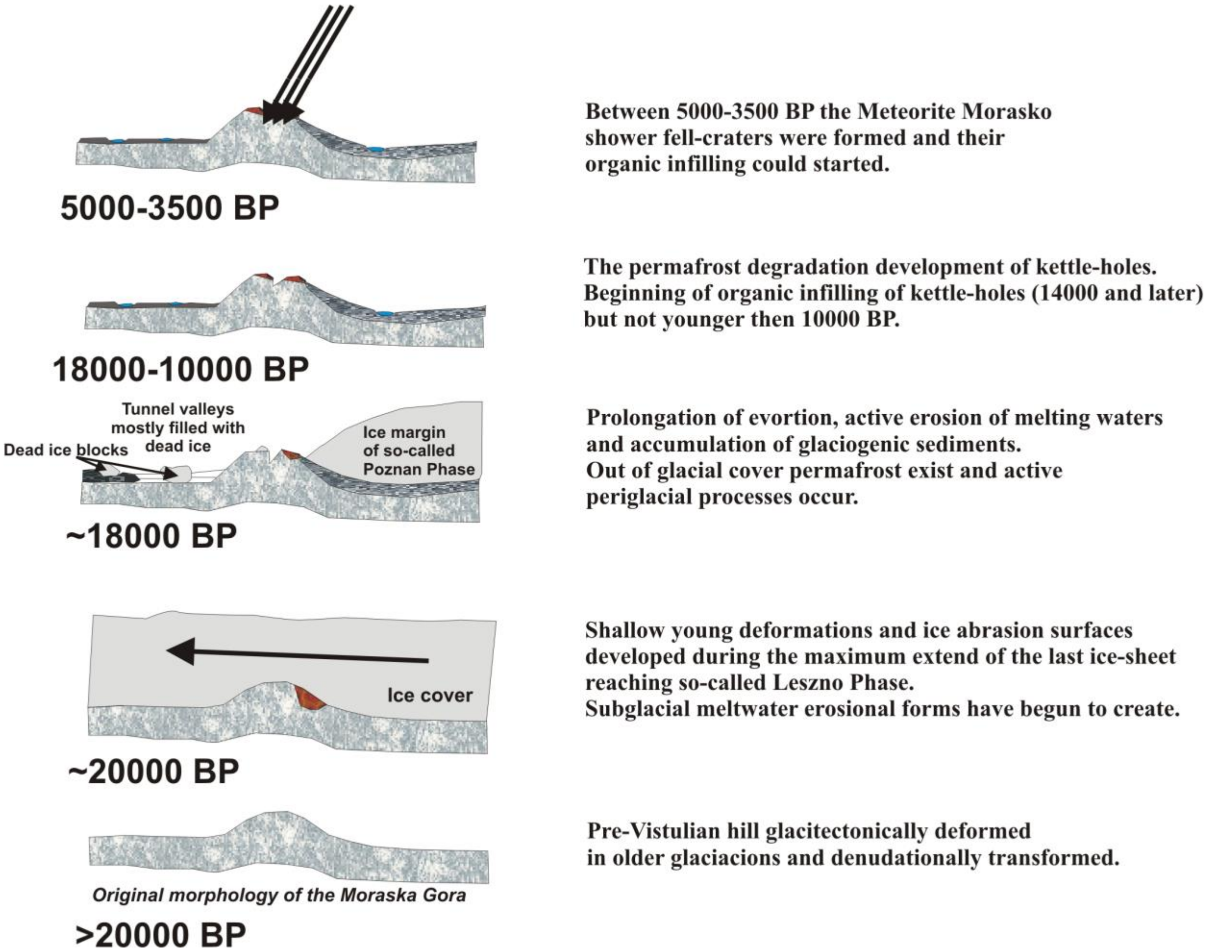

Fig. 6. Sketch showing the geological and environmental circumstances preceding the impact of the Morasko iron shower (after Stankowski 2001, modified)

- quantification of the pressure/ temperature conditions during the impact (mineralogical impact features and the modeling)

- identification of the sedimentological and geochemical signatures of the impact in distal region (>few hundred meters from the craters) in geological archives (lake, peat sediments)

- assessment of the environmental consequences due to an atmospheric blast wave, thermal radiation, ejecta and fallout (fires, changes in species composition, changes in surface waters hydrochemistry based on lake and peat sedimentary record)

- assessment of the duration and the sustainability of the effects of the impact on the environment

- assessment of potential consequences on local human settlements (correlation to existing archeological data)

- testing of various modeling approaches for impacts in unconsolidated sediments using the Morasko impact site as an unique real world example (benchmark)

- provide interdisciplinary and quantitative data on the impact effects of small / medium scale meteorite that may serve as a basis for the prediction of the consequences of similar future events.

The proposed project will involve a research collaboration between the Faculty of Geographical and Geological Sciences at Adam Mickiewicz University in Poznań and the impact research team and numerical modelling group from the Museum für Naturkunde, Leibniz Institute for Research on

Evolution and Biodiversity (Germany). To investigate the wide range of effects due to meteorite impact it is necessary to apply various approaches using different research methods: mineralogical, geochemical, sedimentological, geophysical, micropaleontological, as well as numerical modeling.

The project provides a unique opportunity to perform an interdisciplinary study on recent, well-preserved crater fields created by small/moderate size impact in unconsolidated sediments. The presence of several sedimentary archives (lakes, peat bogs) nearby opens an excellent possibility to reconstruct the magnitude, extent, duration, and sustainability of environmental effects. The relatively large data set on the topography, meteorite findings, local geology, ejecta layer distribution provides exceptional opportunities to test and improve existing numerical models, which on the other hand may significantly improve our understanding of the impact and provide feedback for field studies (e.g. expected from the model range of ejecta layer). The overall results may be of interest for natural disaster management, as they will provide estimates of the expected effects in case of a similar-sized future impact event. Moreover, Morasko - the region of the biggest known shower of iron meteorite in Central Europe, is very attractive topic for the public and the obtained results may be of wider interest and thus help in education on geo- and environmental sciences.

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