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^{14}C and TL DATING AS A METHOD OF ESTABLISHING THE ORIGIN OF KETTLE-LIKE HOLLOWS

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Abstract: Small circular hollows are very common in the glacial topography of NW Poland. Among them there are also some of meteorite origin. An important example of impact craters exists in the Morasko Meteorite Natural Reserve. The ^{14}C and Luminescence datings are very helpful in establishing their origin. The last ice sheet retreat and permafrost degradation created kettle-like hollows around the Morasko Hill. Organic infilling started in them between 14,000 – 10,000 BP. The Morasko meteorite shower fell between 5000 – 3500 BP. The craters origins and young hollow bottom organic infillings then started.

On the Great Poland Lowland there are other potential areas with forms connected to meteorite falls, the such as Oborniki - Obrzycko area and probably in the so called KKR object fron the south-east part of Great Poland Lowland.

1. INTRODUCTION

Very similarly shaped hollows can be generated by: processes of dead ice block melting, evorsion (subglacial water erosion under hydrostatic pressure), degradation of pingos, karstification, impact of meteorite bodies arriving from outer space, as well as human activity.

Small symetrical, almost circular hollows are a fairly common element of glacial reliefs. They are very characteristic features in central and northern part of Poland, where the last glacial topography occured (**Fig. 1**). In the areas that were glacialy generated before the last glaciation, the kettle-like hollows are relatively rare (**Fig. 3**). In both cases most of them are of ice block melting and of evorsion or of periglacial processes in origin. It is also

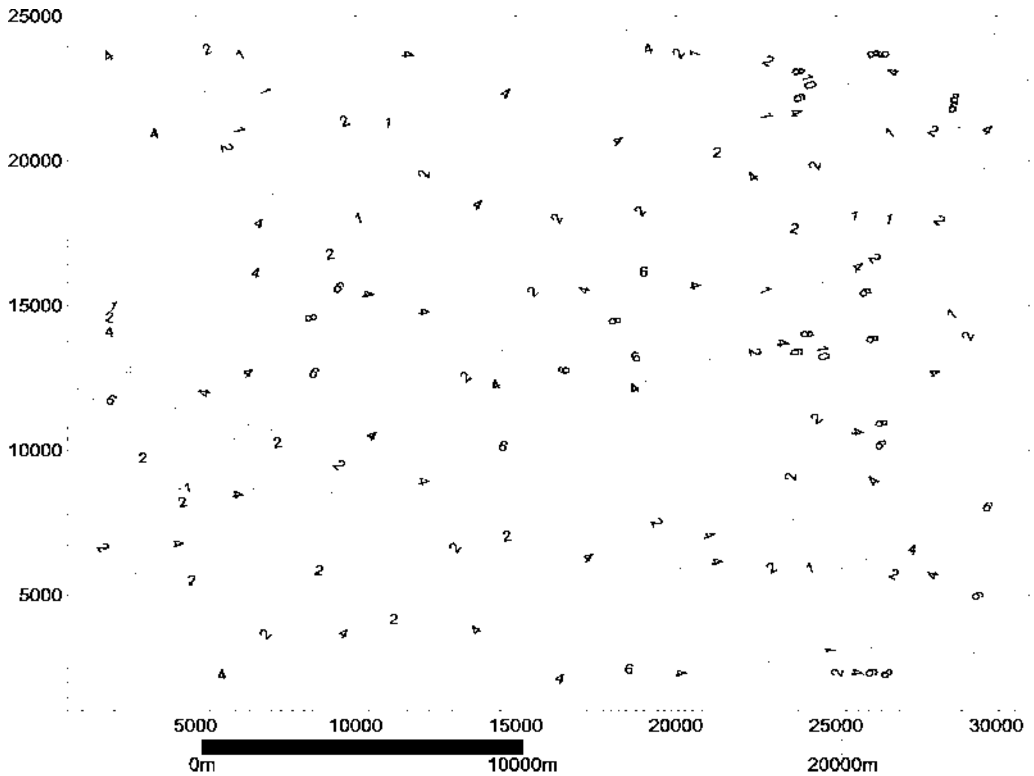

Fig. 1. *The density of small circular hollows in the area of the last glacial topography. (The existance of hollows in an area of 950 km^2 in 4 km^2 surface net)*

probable, that there exist kettle-like hollows that have beenproduced by human activity and by meteorite falls.

In order to prove the origin of the hollows it is necessary to study them by using various methods – geodetic; geological (lithology); mineralogical (establishing the mineral composition of the hollows bottom and their rims); by identifying meteoritic matter (meteorites, micrometeorites, tectites and spherulites, also slags similar to those found on sandy deserts – Wynn and Shoemaker, 1999) and structures developed due to pressure and temperature shock which are visible in mineral grains (mainly quartz), as well as the botanical and radiometric dating of sediments which fill the hollows. In the author's opinion, also TL signal cleaning beneath/around the hollows by impact influence, is likely to occur.

2. THE METEORITE MORASKO NATURAL RESERVE

Iron meteorites have been found on the Morasko Hill ("*Moraska Góra*"), north-east of the highest elevation in the Poznań region (156 m a.s.l.) and in the village of Morasko since 1914, when a lump of metal weighing 77.5 kg was found during military trench digging (Pokrzywnicki, 1955, 1964; Pilski and Walton, 1999). The lumps of the iron meteorites, various in size, were collected between 1919–1939, 1947–1960 and 1970 till the present day (more than 600 kg in total). The largest meteorite found up to now is somewhat above 80 kg. There are many papers to deal with the "Meteoryt Morasko Reserve" (Dominik, 1976; Hurnik, 1976; Hurnik *et al.,* 1976; Karczewski, 1976; Kuźmiński, 1976; Tobolski, 1976; Classen, 1978; Czegka, 1996 and recently Stankowski and Muszyński, 1999, 2000; Stankowski, 2001; Stankowski and Muszyński, in press).

In the 1970's, a debate on the origin of the Morasko kettle-like hollows was started. Two points of view were presented: a) by Hurnik *et al.* (1976) and Kuźmiński (1976) considered them as a result of the impact of the meteorites fall and b) by Karczewski (1976) interpreted them as the result of the melting of dead ice blocks.

The geological, geoelectrical and radiometric studies, combined with searching for meteorite bodies were performed in 1997–1999 (Stankowski and Muszyński, 1999 and in press). The new meteorite lumps: 7.5 kg, ~40 kg and ~80 kg in weight were found. Morasko appears to be a typical inclusion-rich coarse octahedrite which has many polimineral nodules, clasified in group IA-Og. The principal iron-nickel minerals are kamacite and taenite. Other subordinary minerals, include schreibersite, rhabdite, troilite, cohenite, graphite and sphalerite (Buchwald, 1975; Dominik , 1976). The mean nickel content of the Morasko meteorite is 6.8 %.

Based on the results of meteorite studies (cooling rate of 1.8 °C per million years, on the average content of germanium, 40 ppm, and on the established value of impact pressure, 130–750 kbar) as well as on the mineral composition and structure of the Morasko meteorite, Buchwald (1975) concluded that the kamacite locally underwent extensive change into a granular pattern, and the crystals of cohenite were markedly recrystallised. Such as pattern provides significant evidence that the Morasko meteorite belongs to the type which produces impact craters.

In loose and loosely coherent Quaternary and Tertiary deposits which make up the Morsako Hill, neither impact breccia nor high-pressure minerals or glass have been found. However the micro-meteorites protoliths of maghemite and goethite as well as shock-pressure structures in quartz grains were recorded there.

The geological and geoelectrical studies revealed the internal structure of the hills. They are made up of Quaternary tills, sand-and-gravel sediments, and fine-grained sediments of the late Miocene Poznań series, deformed by glacitectonic processes. The deformations happened before the last glacial advance (Baltic ice cover of the Vistulian glacial). The Morasko Hill, in terms of both the formation of its internal structure and the existence of the palaeomorphological rise, can be dated back to the Middle Polish Glacial (Saale). This author's interpretation agrees with Krygowski's concept (1960, 1961 and 1964) of old geological structures existing within a young glacial relief.

According to author, during the maximal extension of the last ice-sheet, the so-called Leszno Phase (about 20,000 years BP), only shallow young deformations, as well as ice abrasion surfaces developed. A subglacial meltwater erosional relief (evorsion one) began to form. The prolongation of evorsion, active erosion of melt waters and accumulation of glaciogenic sediments continued during the so-called Poznań Phase (between 18,000 to 17,000 years BP). Beyond glacial cover permafrost existed and active periglacial processes occured. Ice sheet recession and later permafrost degradation led to the formation of kettle-like holes, produced by the melting of dead ice blocks. The beginning of the organic infilling of the kettle holes started about 14,000 up to 10,000 BP (not later). At that time the main topographic feature of the Morasko Hill and its sourounding area was formed.

On the north-eastern slope of the Morasko Hill there are some kettle-like hollows that look very young and seem not to be connected with ice block melting processes, but have meteorite fall. The earlier palynological tests of the two profiles collected from the hollows indicated that the beginning of the organic accumulation occurred between 5500 and 5000 BP, in the middle stage of theAtlantic period (Tobolski, 1976).

The new borings performed by the author for establishing the properties of the sediments accumulated in the hollows and to date their bottom layers by means of the radiocarbon method (all data were supplied by the Department of Radioisotopes of the Silesian University of Technology in Gliwice).

The study of sediments filling the hollows suggests that they underwent marked paleoenvironmental changes. Conditions suitable for the development of organic sediments, including peat, are young and appeared in each hollow at a different time (**Table 1**).

There is one hollow still dry and not filled with organic matter. Particularly interesting is the profile from the (E) hollow, where organic substance were sampled from two levels, separated by a gravitationally accumulated mineral matter. The deeper organic layer is dated 3360 ±100 BP and it is the oldest of all the dates obtained. The second oldest date was that of the floor of organic sediments from the (B) hollow, amounting to 2690±170 BP. Both dates are considerably younger than the age of the floor of the organic sediments in the (A) hollow, which was established by palynological methods (Tobolski, 1976).

The shallower organic layer from the (E) hollow is dated at 610±75 BP The other three dates are below 1000 BP They belong to the same period as the shallower organic interbedding in the E hollow. Possibly it was not earlier than 700 BP that the organic matter began to accumulate in the investigated hollows in extensively large amounts.

The results of previous palynological tests (Tobolski, 1976) and radiocarbon dating presented in this study differ distinctly. Yet, they seem to disprove the idea that the hollows under disscussion were produced by ice melting. The accumulation of the organic matter did not start earlier than app. 5000 BP, this having been several thousand years later than the degradation of the permafrost in the area of Great the Poland Lowland, which occurred more than app. 10,000 BP (Kozarski, 1963).

It is possible to state that between 5000–3500 BP the Morasko meteoriteshower fell and the meteorite craters were formed. This event seems to be comparable ti the age of the Kaali craters (Raukas *et al*., 1995).

	MORASKO					OBRZYCKO			CZAPLINIEC
Hollows	A	B	C	D	E	2	5	6	
[BP]									
0		#	#		#				
		#							
					#				
									#
5000	X						#		
	X						#		
									#
									#
						#			
10,000									
							#		

Fig. 2. *The comparison of dating of the bottom organic sediments infilling the hollows of the Morasko craters and depressions from the area of Obrzycko as well, as the Czapliniec tunnel valley. (Detailed data of Morasko organic matter see Table 1).*

3. NEW AREAS ON THE GREAT POLAND LOWLAND OF POSSIBLE METEORITE FALL

Before World War II iron meteorites were found in the area of Oborniki. This is why we expect meteorite craters in this area.

Small depresions (from several meters up to 90 m in diameter), very regular in shape, were found near Obrzycko (about 12 km east of Oborniki Wlkp. and 30 km to the north-west of Morasko). There are 4 hollows situated close to each other on a small area and a few being located separately. In 1999 geological studies of these hollows were started. The dating of of their organic infilling were taken into account. Unfortunately the first obtained ^{14}C dates of the bottom organic layers for the three hollows gave an age older than 6000 BP, up to 11,500 BP (**Fig. 2**). Therefore the hollows are of a dead-ice melting origin. The studies are not yet finished and we will investigate other hollows from Obrzycko and as well as the Oborniki area.

The interim postulate of the meteoritic origin of the hollows is now being verified through studies of the relief in the area situated south of the last glacial maximum. There are many (hundreds) of small hollows, on the morain plateau thatoriginated during the Middle Polish Glaciation. The number of hollows per 1 km^2 in one particular area is twice as large as the young glacial refief (**Fig. 3**, compare to **Fig. 1**). This area is actually called the KKR object, because it is not certain that any of the hollows are really of meteoritic origin. In this particular area the question is, are all these hollows only melting, evorsion, pingos degradation origin, or arethey artifically made ? We can not exclude their meteorite origin either.

The new project, for meteoritic hollows looking in both of the mentioned areas was started in the spring of 2001. The investigations to fix one's attention on the age determination of the infilling organic matter, temperature and pressure shock structures in quartz grains. On the moraine plateau built with Quaternary till and Tertiary Poznań clay series it is not expected to find the impact brecia. Otherwise the cleaning of the TL signals in the bottom of the hollows, on the circumferential ridges and in the narrow area around them can be an equivalent of these typical impactite effects. The TL data should be much younger than in the rocks that built the morenic plateau.

Beside the standard radiometric methods of ^{14}C, which could show the age of hollow organic infilling, the TL method seems to be very promising in establishing the meteoritic hollows origin.

Table 1. *The ^{14}C age of bottom organic sediments from Morasko craters.*

Crater B		**Crater C**		**Crater E**	
Lab. No.	Age [BP]	Lab. No.	Age [BP]	Lab. No.	Age [BP]
Gd-10895	260±80 690±95	Gd-10900 Gd-13028	640±90 690±150 990±160	Gd-10898	610±75 690±110
Gd-14030	2690±170			Gd-10894	3360±100

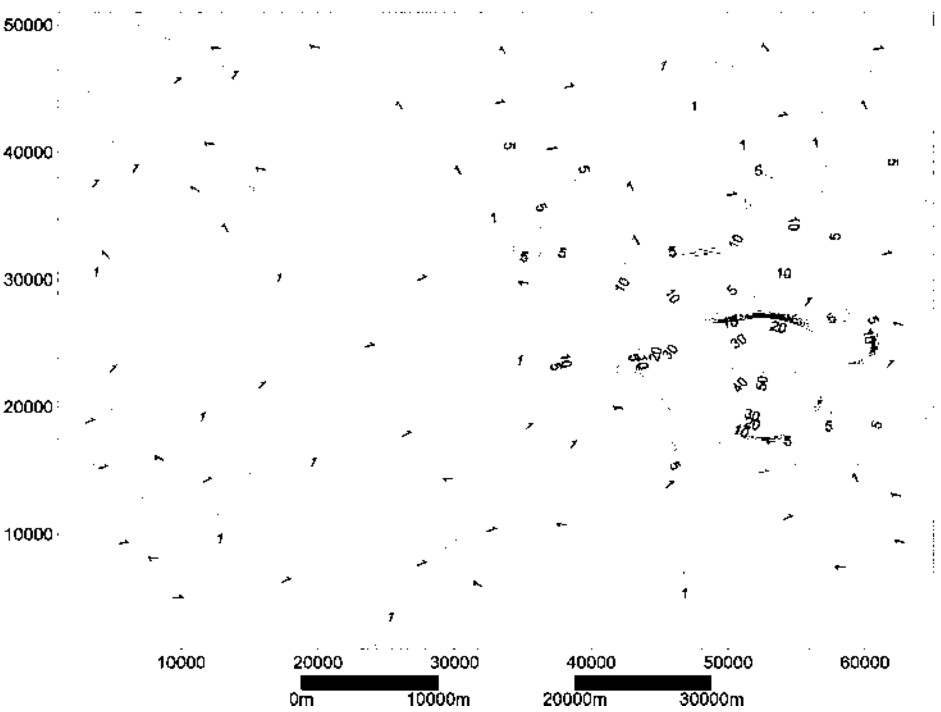

Fig. 3. The density of small circular hollows in the area out of the last glacial maximum extent – left side of the average density, right side of the particular area called KKR object. (The existance of hollows in an area of 3,800 km² in 4 km² surfaces net).

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