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The most distal moldavite findings from Lower Silesia, Poland

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Abstract: The present note reports new findings of moldavites from southwestern Poland. The material was found in the Nowa Wieś Kącka sandpit. To date, it represents the most distal locality where moldavites have been found. These moldavites, like other moldavites previously described from Lower Silesia, are recovered from fluvial sands and gravels of the Gozdnica Formation. Like other Polish moldavites, the moldavites in this study display high SiO_2 contents (~77 wt.%). Their dimensions range from 9 to 11 mm in maximum diameter. Their relatively large sizes suggest that the distribution of Polish tektites defines a sub-strewnfield larger than previously expected.

Key-words:

- tektite;
- moldavite;
- strewn field;
- redeposition;
- Miocene;
- Poland

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Résumé : ***Les découvertes les plus distales de moldavites en Basse-Silésie, Pologne.-*** De nouvelles découvertes de moldavites sont signalées dans le sud-ouest de la Pologne. Le matériel provient de la sablière de Nowa Wieś Kącka. À ce jour, ce site représente la localité la plus distale qui ait livré de la moldavite. Ces tectites, comme les autres moldavites répertoriées précédemment en Basse Silésie, ont toutes été extraites des dépôts de la Formation Gozdnica. À l'instar des autres tectites polonaises, le matériel étudié ici se caractérise par une haute teneur en SiO_2 (~77 % en masse). Les spécimens étudiés mesurent de 9 à 11 mm dans leur plus grande dimension. Leur taille relativement importane suggère que la répartition des tectites polonaises pourrait être bien plus large qu'il a été initialement envisagé.

Mots-clefs :

- tectite ;
- moldavite ;
- champ d'éjectas ;
- resédimentation ;
- Miocène ;
- Pologne

1. Introduction

The occurrence of tektites and microtektites/spherules in the geological record is one of the key features of meteorite impact. Remnants of extraterrestrial material or distal ejecta of Mesozoic and Paleozoic cosmic falls are quite rare and usually fade away by subsequent weathering and diagenesis (*e.g.*, CLAEYS and CASIER, 1994; KYTE, 1998; GLASS and SIMONSON, 2013; BRACHANIEC *et al.*, 2014a; SCHMITZ *et al.*, 2016; SZOPA *et al.*, 2017b). Nowadays, four main Cenozoic tektite strewn fields are recognized (KOEBERL, 2007): the North American, the Central European, the Australasian, and the Ivory Coast tektite strewn fields. Central European tektites, moldavites, originated from the Nördlinger Ries impact structure in southern Germany (*e.g.*, STÖFFLER *et al.*, 2002). The crater has been dated at 14.74 ± 0.20 Ma (BUCHNER *et al.*, 2013). The Ries crater was produced by the impact of an asteroid that was probably 1.5 km in diameter (STÖFFLER *et al.*, 2002). European tektites originated from the melting of the uppermost sedimentary target rocks that belong to the Upper Freshwater Molasse, which overlies the Swabian-Franconian Alb plateau (MEISEL *et al.*, 1997; TRNKA and HOUZAR, 2002; ŘANDA *et al.*, 2008; MAGNA *et al.*, 2011; ŽÁK *et al.*,

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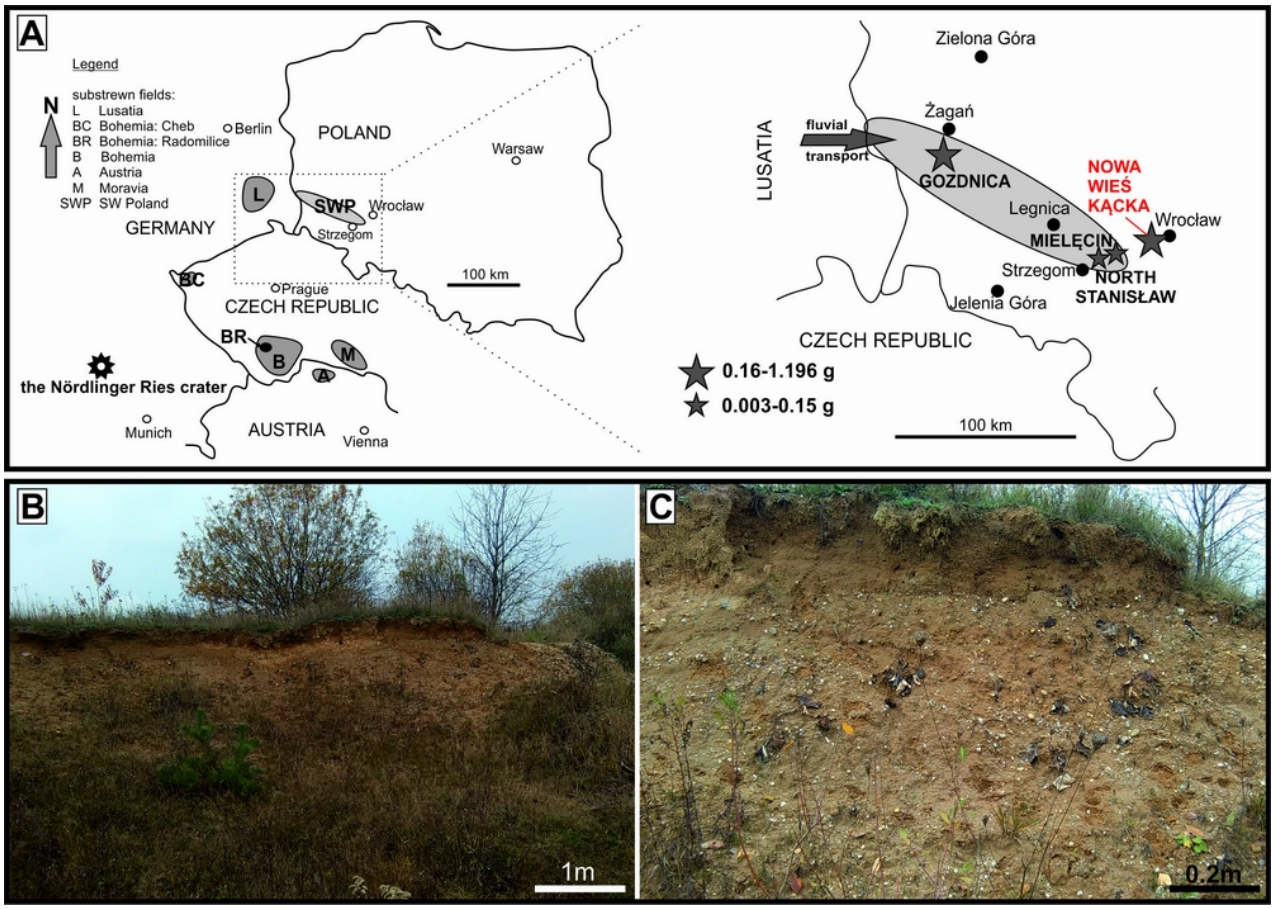

Figure 1: A. Schematic distribution map of moldavites with direction of fluvial redeposition of tektites from Lusatia to SW Poland. Size range of Polish moldavites (according to BRACHANIEC *et al.*, 2014b, 2015, 2016, and this study). **B.** and **C.** General view of the Gozdnica Formation in the western part of the Nowa Wieś Kącka sandpit.
Figure 1 : A. *Carte schématique de répartition de la moldavite avec direction de resédimentation fluviale des tectites depuis Lusatia jusqu'au nord-ouest de la Pologne. Distribution de la taille des moldavites polonaises (d'après* BRACHANIEC et al.*, 2014b, 2015, 2016, et la présente étude).* ***B.*** *et* ***C.*** *Vue générale de la Formation Gozdnica dans la partie occidentale de la sablière de Nowa Wieś Kącka.*

2012, 2016; SKÁLA *et al.*, 2016; RODOVSKÁ *et al.*, 2016). BRACHANIEC *et al.* (2014b, 2015, 2016) and SZOPA *et al.* (2017a) recently described moldavite finds in SW Poland. The present communication discusses the recently discovered Polish moldavites.

2. Locality and geological setting

New moldavite specimens were collected in the Nowa Wieś Kącka sandpit (51°01'37.5"N; 16° 43'14.0"E), near Wrocław, in SW Poland. This section is situated some 20 km north-east of the North Stanisław and Mielęcin pits (Fig. 1.A), where moldavites had previously been discovered (BRACHANIEC *et al.*, 2015). These tektites lie about 485 km from the Ries crater.

Miocene and Pleistocene sediments crop out in the Nowa Wieś Kącka sandpit. Miocene strata are represented by grey muds and clays of the Poznańska Formation, and fluvial dark yellow sands with gravels of the overlying Gozdnica Formation. Pleistocene sediments mainly consist of glacio-fluvial tills and silts (URBAŃSKI *et al.*, 2011). The sand pit is located ca. 500 m west of the village of Nowa Wieś Kącka. Field work was conducted in the west part of this pit where, according to URBAŃSKI *et al.* (2011), only Miocene deposits are exposed (Fig. 1.B-C). The thickness of these deposits can reach up to 3.5 m.

The Gozdnica Formation is dated at a Late Miocene age corresponding to the Pannonian (Tortonian) (STACHURSKA *et al.*, 1971; DYJOR *et al.*, 1992, 1998; SADOWSKA, 1992; PIWOCKI and ZIEMBIŃSKA-TWORZYDŁO, 1997; SZYNKIEWICZ, 2011). Gravel in these deposits is mostly composed of quartz, with grains between 0.5 and 5 cm in diameter. The sand is yellow to grey in colour. The Gozdnica Formation also contains grey clay lenses. According to STACHURSKA *et al.* (1971), coarse and poorly sorted sands with gravel embedded in fine-grained sand and sandy silt suggest that these deposits originated in meandering river systems, indicating relatively low-energy sedimentation.

3. Methodology

Electron microprobe analyses of main elements in thin slices of investigated moldavites were conducted in the Inter-Institutional Laboratory of Microanalyses of Minerals and Synthetic Substances, Warsaw, using a CAMECA SX-100 electron microprobe. The analytical conditions were: acceleration voltage 15 kV, beam current 20 nA, counting time 4s for peak and background, beam diameter 1 mm. Methodology was the same as used in BRACHANIEC *et al.* (2015).

The studied material is housed in the Museum of the Faculty of Earth Sciences, University of Silesia, Poland, under registration number WNOZ/Mt/91.

4. Results

During field work, two moldavite specimens were recovered from a new locality in the Nowa Wieś Kącka pit (Fig. 2), both from the Gozdnica Fm. deposits. Their individual weight is 0.44 g (sample NWK1) and 0.38 g (sample NWK2), respectively (Table 1). Both specimens display the characteristic bottle-green colour. In their structure many bubbles were noted. Electron microprobe analyses were also carried out. The investigated glassy material is characterized by similar SiO_2 concentrations (~77wt%) comparable to those of moldavites from other Polish sections but low concentrations compared to those from the Lusatia area (Table 2). Low total amounts of elements can be connected with high content of bubbles in glass structure.

5. Discussion

Moldavites have been usually found in the main part of the strewn field within a 200–450 km range from the Ries crater (*e.g.*, TRNKA and HOUZAR, 2002; STÖFFLER *et al.*, 2002). Polish moldavites occur in Upper Miocene fluvial sediments; such a mode of occurrence indicates that they were redeposited after fall. One possible source of Polish moldavites is in the upper part of the drainage basin of the Lusatian Neisse (SZOPA *et al.*, 2017a), where Middle and Late Miocene large rivers flowed (BADURA and PRZYBYLSKI, 2004). Additionally, the Sudete Mountain range limited the river-flow from the southern territory of the Czech Republic. According to BOUŠKA *et al.* (1968), LANGE (1995, 1996), TRNKA and HOUZAR (2002), and to BUCHNER and SCHMIEDER (2009), the brittle character of tektite glass is thought to drastically reduce the lifetime of fluvially transported glasses, and the distance of transport. Accordingly, BRACHANIEC *et al.* (2015, 2016) claimed that the largest Polish tektites (ranging from 0.15 to 1.196 g), found in the Gozdnica section near the German border, indicate rather short fluvial transport. Additionally, the small amount of gravel in deposits and paleoriver meanders of the Gozdnica Formation, along with some low-

Table 1. Mass and dimensions of moldavite specimens from the Nowa Wieś Kącka section.
Table 1. *Dimensions des spécimens de moldavite de la coupe de Nowa Wieś Kącka.*

Sample	Mass (g)	Dimensions – length/width (mm)
NWK1	0.44	11/9
NWK2	0.38	9/7

Table 2. Chemical composition (based on electron microprobe analysis) of Polish moldavites from all known localities; *data from BRACHANIEC *et al.* (2015), ** data from BRACHANIEC *et al.* (2016), *** this study, **** LANGE (1995).
Table 2. *Composition chimique (par microsonde) des moldavites polonaises de toutes les localités connues ; *données tirées de BRACHANIEC* et al. *(2015), ** données tirées de BRACHANIEC* et al. *(2016), ***présente étude,****LANGE (1995).*

Element (oxide wt%)	Location				
	Mielęcin pit*	North Stanisław pit*	East Gozdnica pit**	Nowa Wieś Kącka pit ***	Lusatia****
SiO_2	78.31	76.28	77.34	77.28	79.30
TiO_2	0.27	0.12	0.24	0.19	0.34
Al_2O_3	11.01	10.87	10.71	10.91	10.50
FeO_{total}	1.89	1.92	1.88	1.83	1.84
MnO	0.01	0.02	0.04	0.04	0.06
MgO	1.78	1.75	1.75	1.74	1.75
CaO	2.08	2.12	2.20	2.14	2.00
Na_2O	0.51	0.57	0.49	0.52	0.47
K_2O	3.58	3.21	3.36	3.33	3.46
P_2O_5	0.05	0.07	0.05	0.06	-
TOTAL	**99.49**	**96.93**	**98.06**	**98.04**	**99.72**

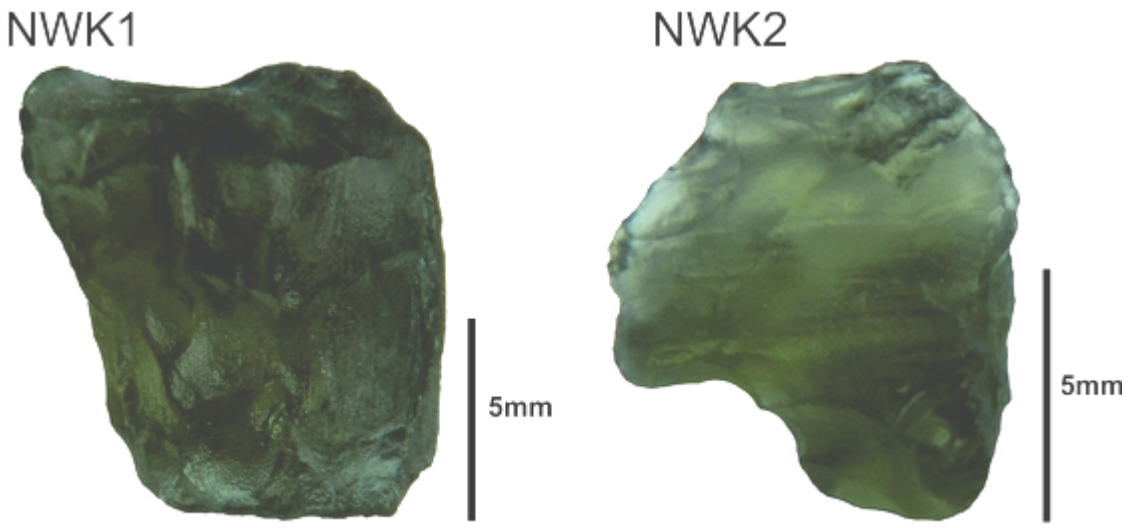

Figure 2: Polish moldavites from the Nowa Wieś Kącka sandpit.
Figure 2 :*Moldavites polonaises de la sablière de Nowa Wieś Kącka.*

energy deposition, seems to have favored well preserved tektites. Near Strzegom, the North Stanisław and Mielęcin pits hosted smaller (0.003–0.15 g) tektite fragments, indicating probably fragmentation during fluvial reworking (Brachaniec *et al.*, in prep). The original size of tektite was strongly reduced during erosion, transport and redeposition. In the Nowa Wieś Kącka section, the two tektites have sizes and sculpturing similar to those of the Gozdnica moldavite specimens. It indicates short fuvial reworking, because it is impossible to retain deep sculpture on tektite surfaces after long redeposition. The minute moldavite fragments from North Stanisław and Mielęcin suggest that these tektite specimens occur relatively close to the outer limit of tektite distribution, beyond which fluvially transported tektites would have been completely destroyed. However, tektites from Nowa Wieś Kącka were large enough to withstand further redeposition in the Miocene river flow. Such an hypothesis would explain both the size of tektites in Nowa Wieś Kącka, and the very small moldavite fragments in North Stanisław and Mielęcin sections. Also the hypothesis provided by Stöffler *et al.* (2002) about potential moldavites fall up to ~500 km from the Ries structure cannot be finally rejected. Nonetheless, validation of such a hypothesis requires further analytical field work and additional samples to be investigated for more robust statistical considerations.

6. Conclusion

The discovery of new moldavite specimens in the Nowa Wieś Kącka region constitutes the most distal tektite occurrence (~500 km radial distance from the center of the Ries crater) known so far in Central Europe. Relatively large tektite sizes, and the survival of the impact glass after long-distance fluvial transport, suggest additional moldavites are expected to be found farther eastwards. Further sampling and investigation of Middle Miocene sections in southwestern Poland are required to confirm this hypothesis.

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