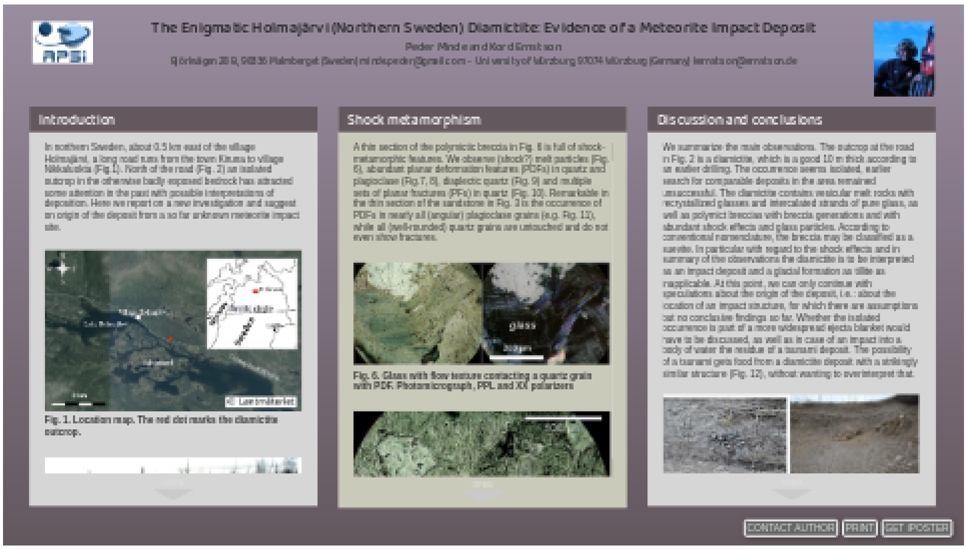
The Enigmatic Holmajärvi (Northern Sweden) Diamictite: Evidence of a Meteorite Impact Deposit



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INTRODUCTION

In northern Sweden, about 0.5 km east of the village Holmajärvi, a long road runs from the town Kiruna to village Nikkaluokta (Fig.1). North of the road (Fig. 2) an isolated outcrop in the otherwise badly exposed bedrock has attracted some attention in the past with possible interpretations of deposition. Here we report on a new investigation and suggest on origin of the deposit from a so far unknown meteorite impact site.

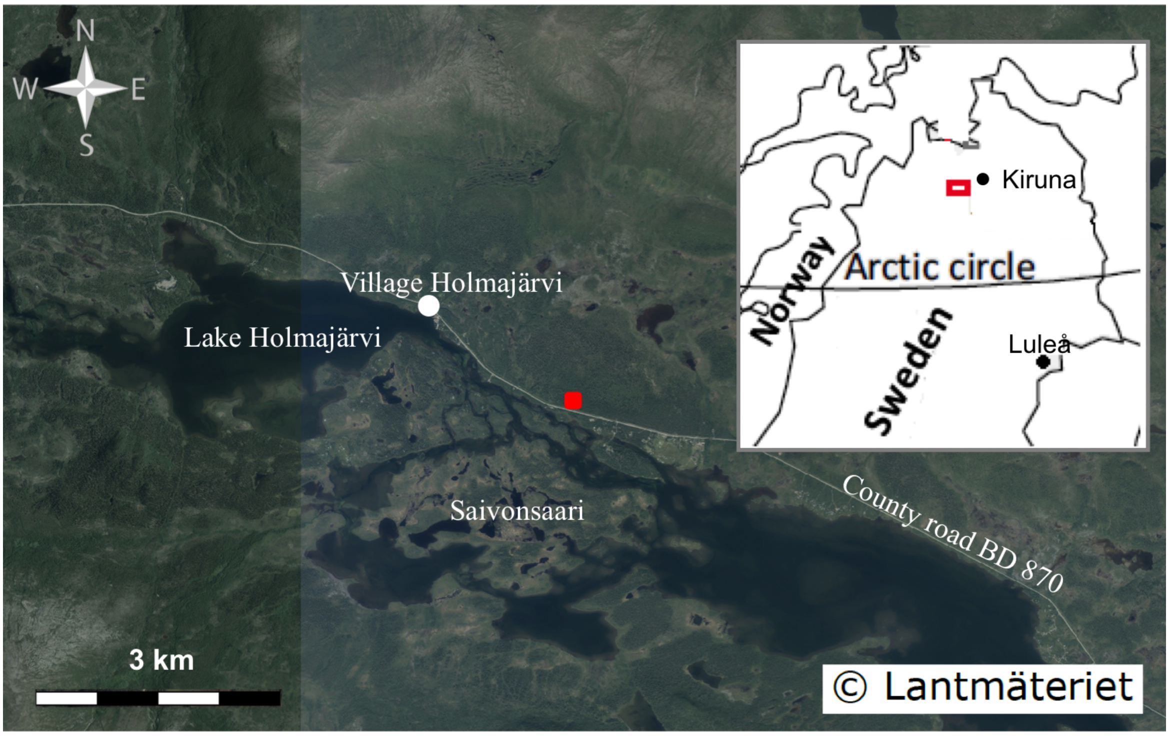

Fig. 1. Location map. The red dot marks the diamictite outcrop.

Fig. 2. The diamictite outcrop.

Earlier studies

In 1951 state geologists described the rock in the outcrop as a "conglomerate" reminding of the tillites reported from the Scandinavian Caledonides [1]. The rock was cored with a vertical drillhole, which at 13.7 m depth reached a basement of quartz-syenite [2]. A search for further outcrops in the 1950s was unsuccessful despite a thorough search [2]. In a more recent paper the rocks where re-classified as a diamictite [3].

The Material

The sampled rocks (from P.M) show a wide lithological variety from sedimentary to ultrabasic rocks and, significant for the present study, melt rocks and polymictic breccias.

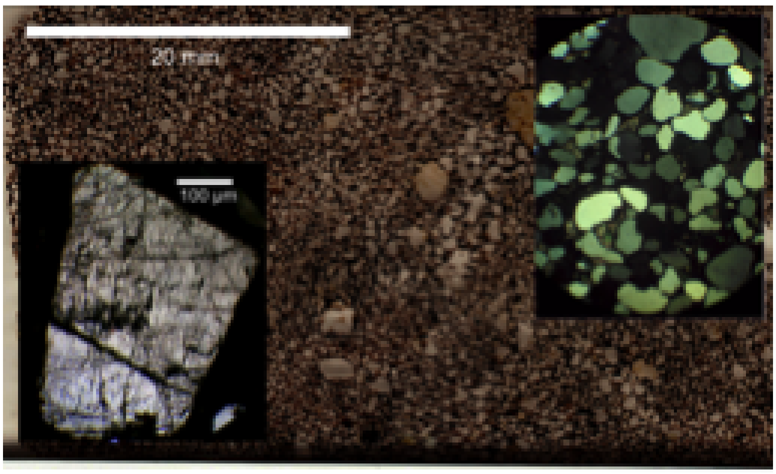

Fig. 3. A sandstone from the diamictic outcrop composed of mainly quartz pebbles and few feldspar and calcite in iron cement. Thin section photomicrograph, crossed polarizers, upper right; a feldspar grain (lower left) with planar deformation features (PDF), see later.

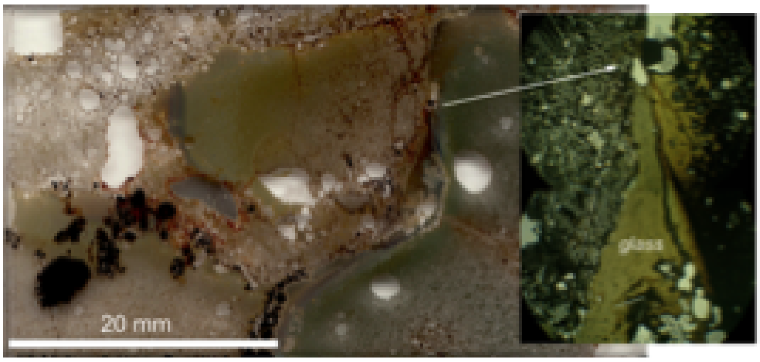

Fig. 4. Thin section scanner image of a polymictic melt rock from the diamictite composed mainly of recrystallized glass and inclusions of pure glass (photomicrograph to the right, PPL).

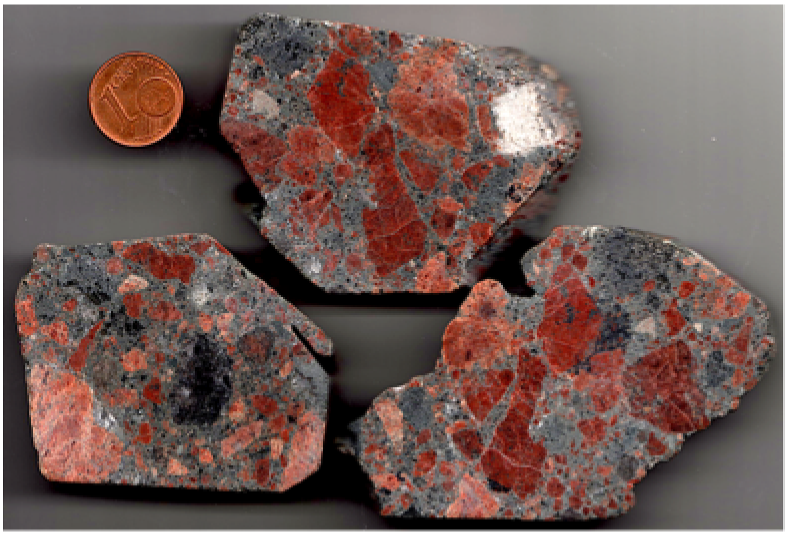

Fig. 5. The so far most analyzed polymictic breccia from the outcrop. Breccias-within-breccia are common, and few three-generation breccias (breccia-within-breccia-within-breccia) are also observed.

SHOCK METAMORPHISM

A thin section of the polymictic breccia in Fig. 6 is full of shock-metamorphic features. We observe (shock?) melt particles (Fig. 6), abundant planar deformation features (PDFs) in quartz and plagioclase (Fig.7, 8), diaplectic quartz (Fig. 9) and multiple sets of planar fractures (PFs) in quartz (Fig. 10). Remarkable in the thin section of the sandstone in Fig. 3 is the occurrence of PDFs in nearly all (angular) plagioclase grains (e.g. Fig. 11), while all (well-rounded) quartz grains are untouched and do not even show fractures.

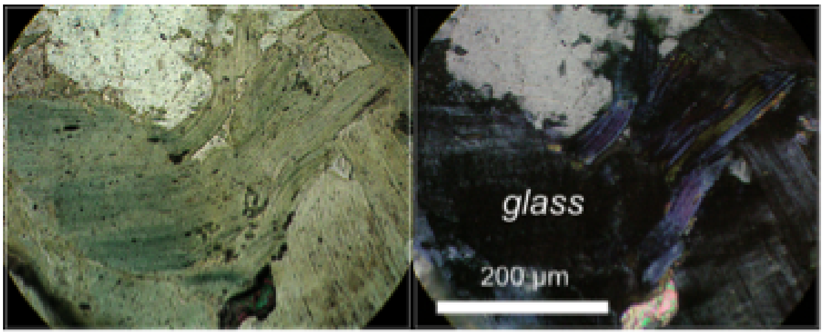

Fig. 6. Glass with flow texture contacting a quartz grain with PDF. Photomicrograph, PPL and XX polarizers

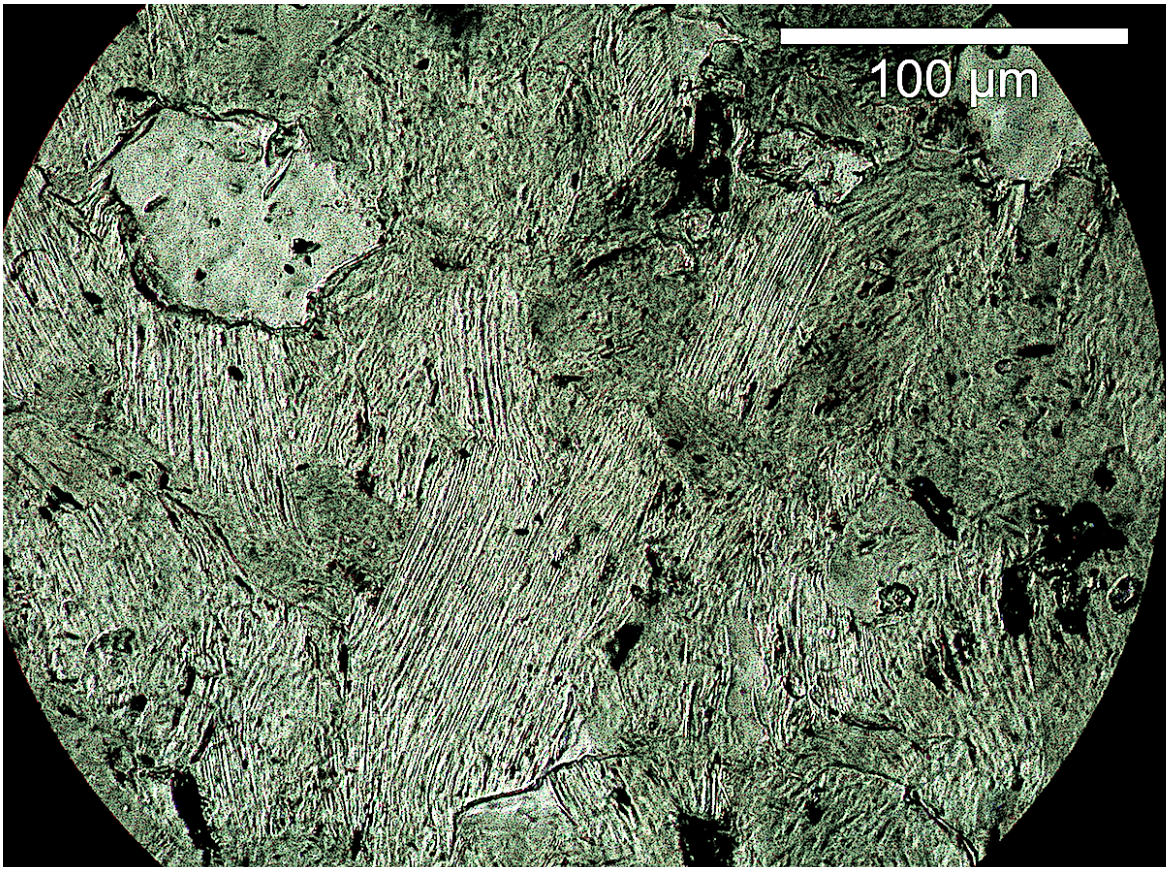

Fig. 7. Densely formed PDF in quartz. Photomicro-graph, PPL.

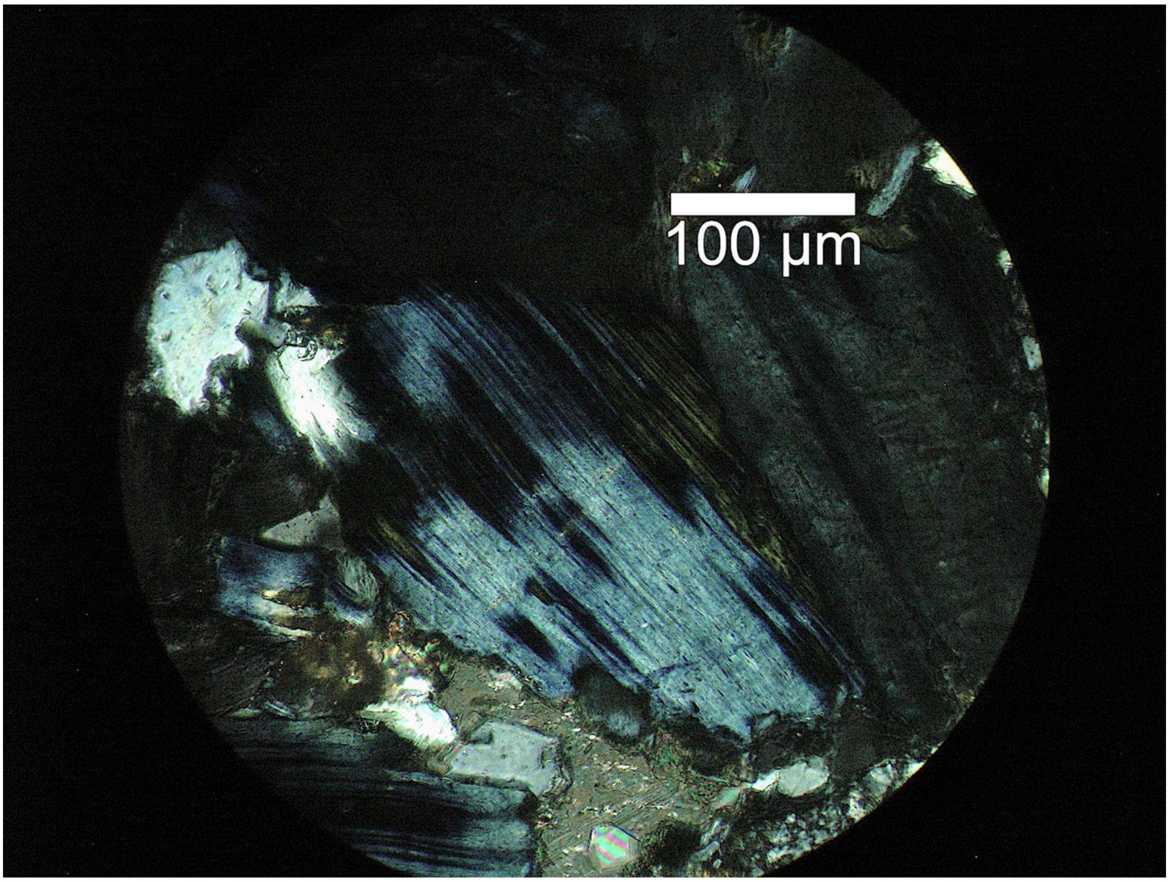

Fig. 8. PDF merging into diaplectic glass in quartz.

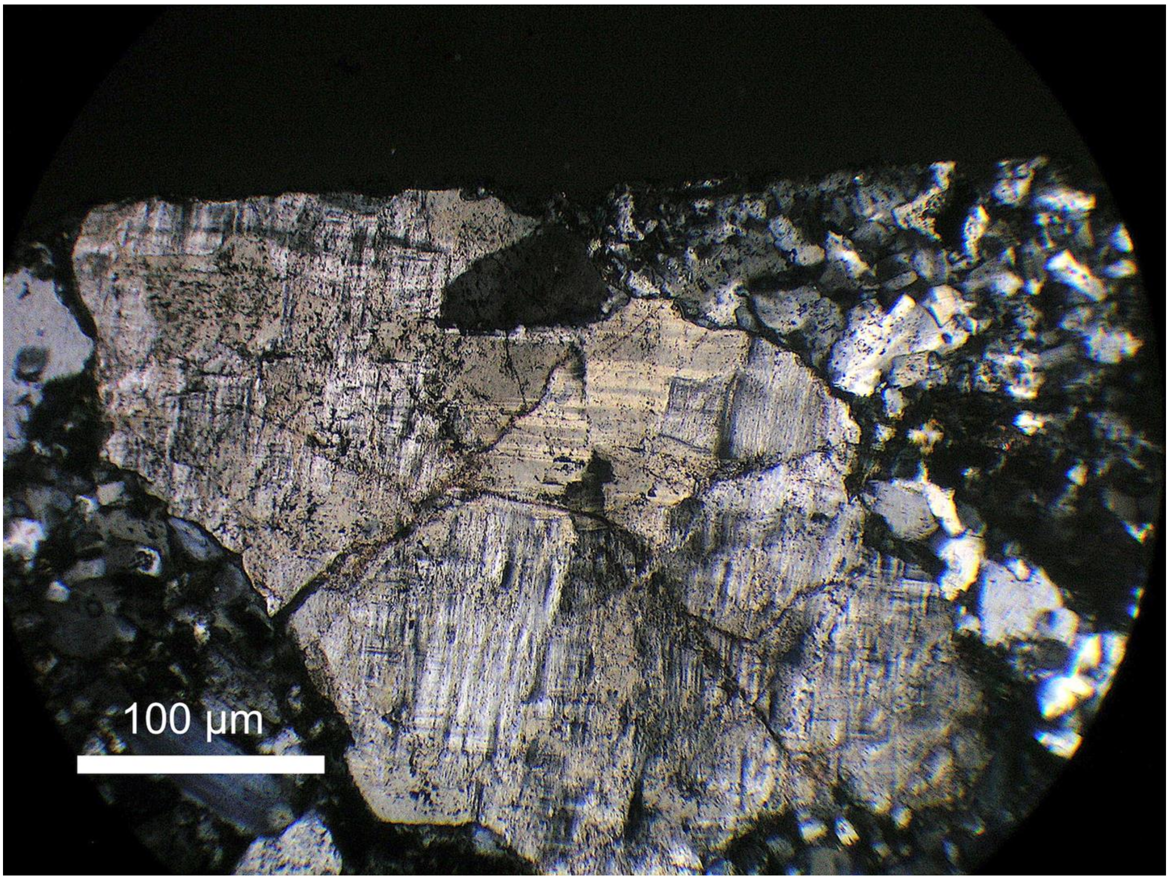

Fig. 9. PDF in plagioclase. Photomicrographs, XX polarizers.

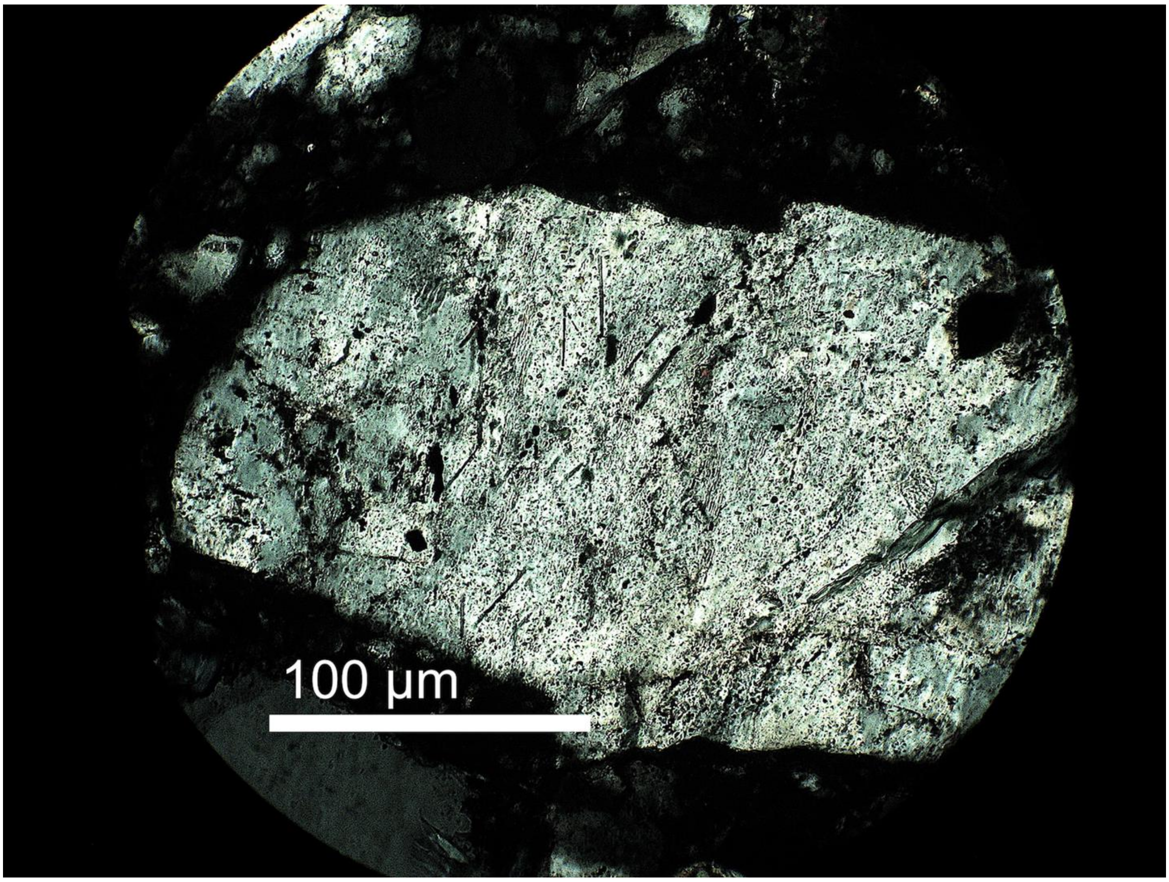

Fig. 10. Multiple sets of planar fractures (PF) in quartz.

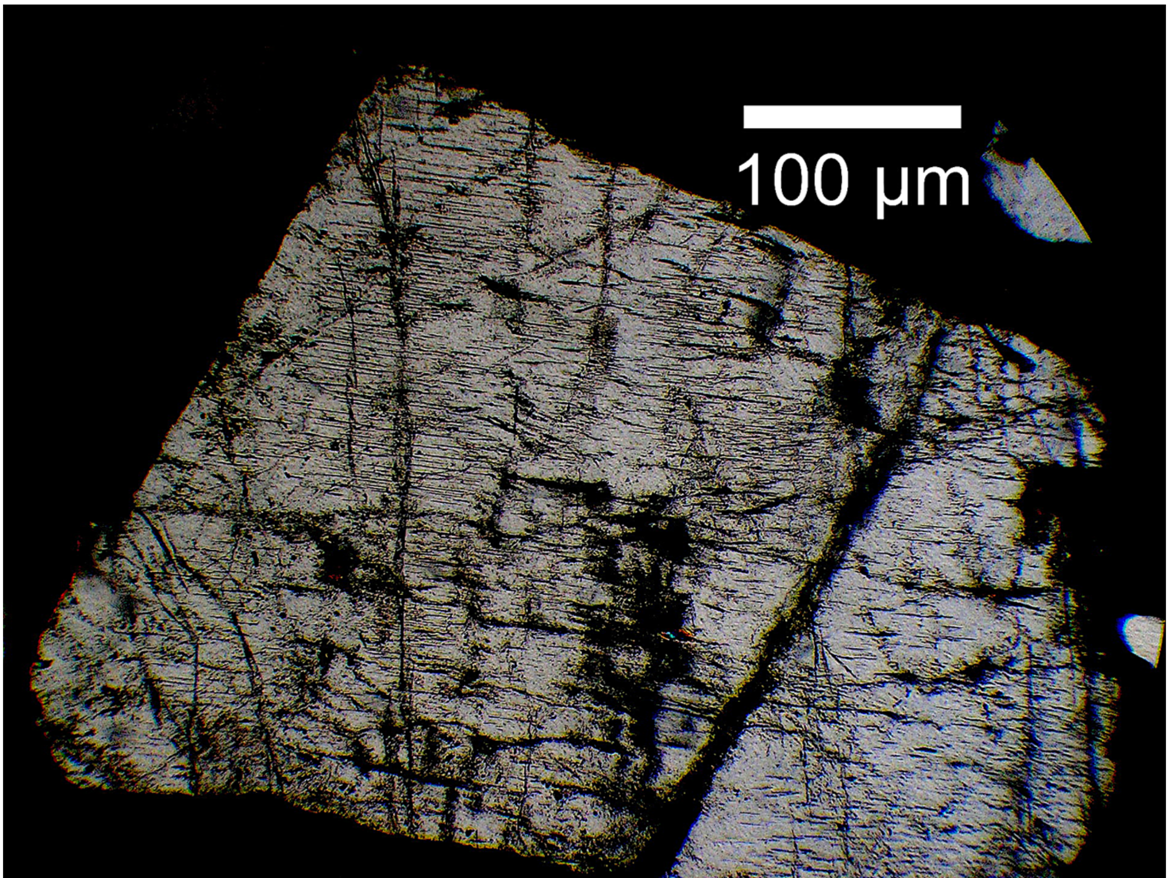

Fig. 11. The feldspar grain from Fig. 3 in higher magnification shows a pronounced set of PDF. A few more sets of different orientation are only faintly developed.

DISCUSSION AND CONCLUSIONS

We summarize the main observations. The outcrop at the road in Fig. 2 is a diamictite, which is a good 10 m thick according to an earlier drilling. The occurrence seems isolated, earlier search for comparable deposits in the area remained unsuccessful. The diamictite contains vesicular melt rocks with recrystallized glasses and intercalated strands of pure glass, as well as polymict breccias with breccia generations and with abundant shock effects and glass particles. According to conventional nomenclature, the breccia may be classified as a suevite. In particular with regard to the shock effects and in summary of the observations the diamictite is to be interpreted as an impact deposit and a glacial formation as tillite as inapplicable. At this point, we can only continue with speculations about the origin of the deposit, i.e.: about the location of an impact structure, for which there are assumptions but no conclusive findings so far. Whether the isolated occurrence is part of a more widespread ejecta blanket would have to be discussed, as well as in case of an impact into a body of water the residue of a tsunami deposit. The possibility of a tsunami gets food from a diamictite deposit with a strikingly similar structure (Fig. 12), without wanting to overinterpret that.

Fig. 12. Similar agglomerations of boulders in the Holmajärvi diamictite and the Eglsee diamictite, which is interpreted as a cross-bedded tsunami deposit during the Chiemgau impact event ([4];see text).

The new finding on the enigmatic diamictite deposit goes well with the common observation that diamictites can form during very different geologic processes, with the similarity in the megascopic texture of glacial tillites and ejecta of impact structures often emphasized. The report on a recently discovered outcrop in a gravel pit about 2.5 km off the shore of Lake Chiemsee in Bavaria (Germany) and on compelling geologic evidence of a giant tsunami starting from the doublet meteorite impact into that lake during the Chiemgau multiple impact event [4] highlights this discussion, and interestingly enough very similar depositional features can be observed in both exposures (Fig. 12).

This reminds of the so-called ice age paradox [5]. The diamictic character of many impact ejecta has established the hypothesis that glacigene tillite deposits may in fact have originated from large impacts (the ice age paradox). This hypothesis has not yet been supported by compelling evidence, which is easily explained by the fact that glacial-geologic processes and ice age terrain features are part of the "normal" geologic inventory, but impact and impact ejecta tend not to be. The many Scandinavian tillites [e.g., 6] offer the opportunity to trace the ice age paradox.

References

[1] Eriksson, T. (1951) Day diary-1, in Swedish, (SGU archive). [2] Ödman, O.H. (1957) SGU Avhandlingar och uppsatser 4:o Nr41 (p. 151). [3] Romer, R. L. & Bax, G. (1992) Geol. Rundschau, 81(2), 391- 401. [4] Ernstson, K. (2016) 47th Lunar and Planetary Science Conference, Abstract #1263. [5] Rampino, M.R. (1994) J. Geology, 120, 439-456. [6] Kautsky, G. (1949) GFF, 71:4, 595-603, DOI: 10.1080/11035894909453288