GEOMAGNETIC AND MORPHOLOGICAL SIGNATURE OF SMALL CRATERIFORM STRUCTURES IN THE ALPINE FORELAND, SOUTHEAST GERMANY GP11A-1023

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Introduction

Lots of rimmed crateriform structures (Fig. 1) with diameters of the order of meters and ten meters in young fluvial and moraine sediments in Southeast Germany (Fig. 2, 4) have raised increased interest in the last decade although they have been known since longtime. An anthropogenic origin (for smelting or lime kiln purposes, as prospecting pits, bomb craters, etc.) can in most cases be excluded, and the ring walls are speaking against a formation as simple sink holes. A model of formation was introduced when a possible meteorite impact for the Altötting/Burghausen region (Fig. 2) was discussed [1, 2, 3]. It got clearer contours in the so-called Chiemgau meteorite impact event which is considered to have produced a large strewn field (Fig. 2) of various impact features [4].

Fig. 1. Typical rimmed crateriform structures with diameters between 6 m and 20 m.

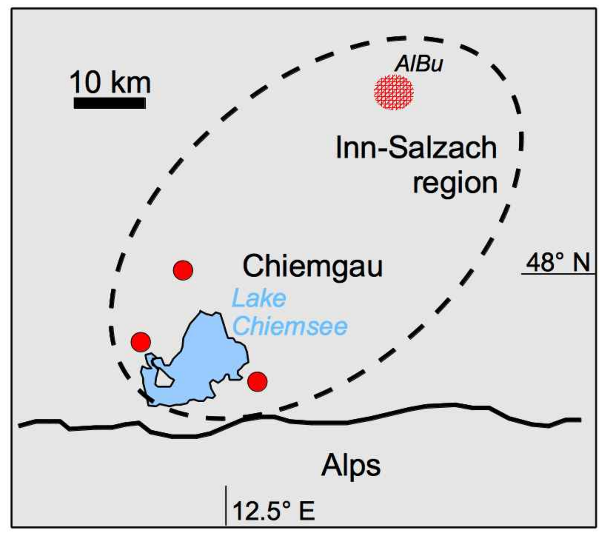

Fig. 2. Location map for the crateriform structures in the elliptically shaped Chiemgau strewn field. Al/Bu = Altötting-Burghausen region. Red circles: location details in Fig. 4.

Within the strewn field, roughly 80 craters have in detail been documented, but regularly new observations are added, and a total number of several hundred craters is conceivable.

In general, the relatively shallow craters show a characteristic profile which when appropriately scaled appear remarkably similar (Fig. 4).

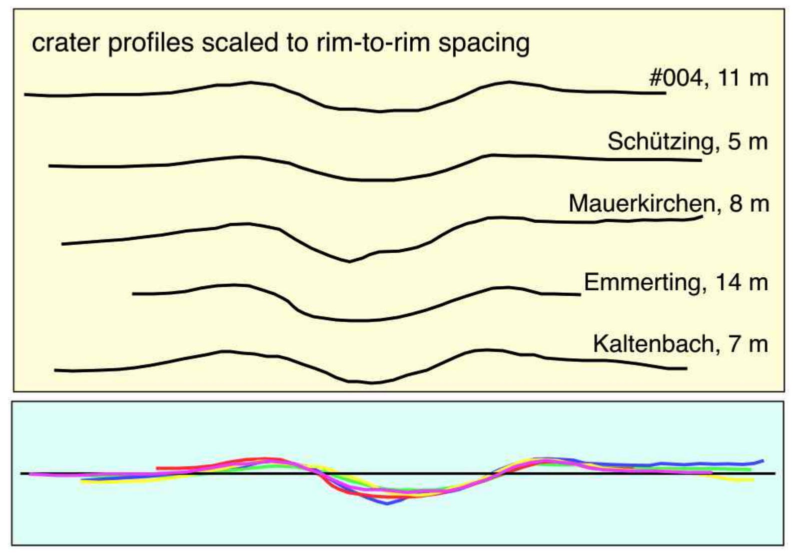

Fig. 3. Crater profiles (without exaggeration) for five structures scaled to rim-to-rim diameter. The profiles when piled up (lower) show remarkable similarity.

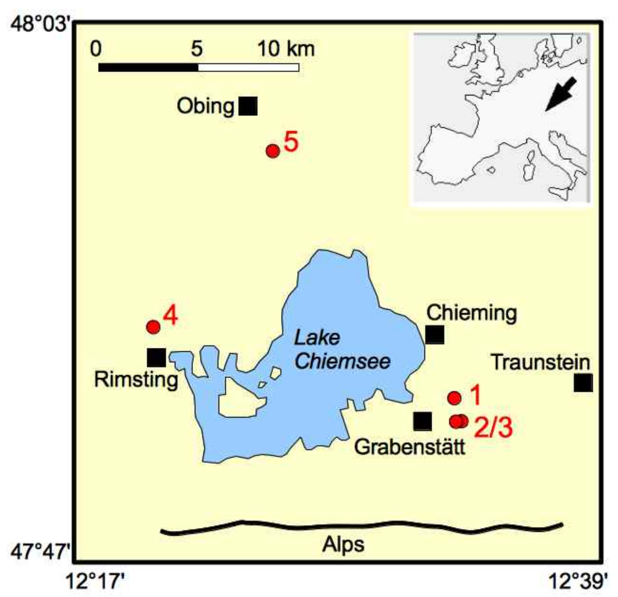

Fig. 4. Location map for the investigated sites around Lake Chiemsee.

Some earlier geomagnetic field and soil susceptibility measurements in the Altötting/Burghausen region [1, 3] found anomalies without, however, giving them further enhanced consideration. Here, we report on a new geomagnetic campaign exemplarily investigating a few of these craters in the environs of the towns of Grabenstätt, Rimsting and Obing (Fig. 4).

Geophysical measurements

The geomagnetic measurements comprised fluxgate gradiometer surveys and magnetic susceptibility measurements at the 1 Kaltenbach crater and the 2/3 Aschau craters near Grabenstätt, and at the Mauerkirchen crater near Rimsting (Fig. 4). For the Thalham location near Obing (5 in Fig. 4) where a dozen of small craters are concentrated over an area of a few hundred meters, preliminary continuous gradiometer measurements were performed on a single profile thereby crossing two of the smaller craters.

Rock samples digged from the craters supplied susceptibility and remnant magnetization data. Moreover, for comparison magnetic susceptibility measurements of cobbles from outside the crater locations were done. The field measurements used a Förster vertical field gradiometer probe and the ETsmart digital recording system. Susceptibility measurements were performed with the Magnetic Susceptibilty Meter SM 30 (ZH instruments).

Field data

Below, we show magnetic vertical gradient and soil susceptibility readings along diametral profiles across the Kaltenbach crater, the Mauerkirchen crater and one of the Aschau craters in each case together with the profile morphology. The gradiometer probe was conducted c. 30 cm above ground, and the susceptibility meter was placed right on the forest soil.

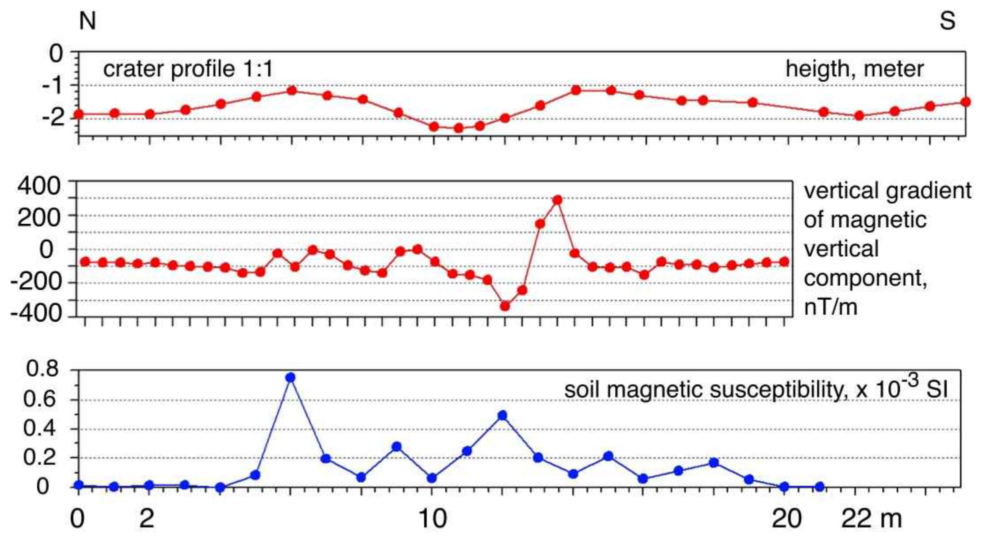

Fig. 5. The Kaltenbach crater and its morphological and magnetic signature.

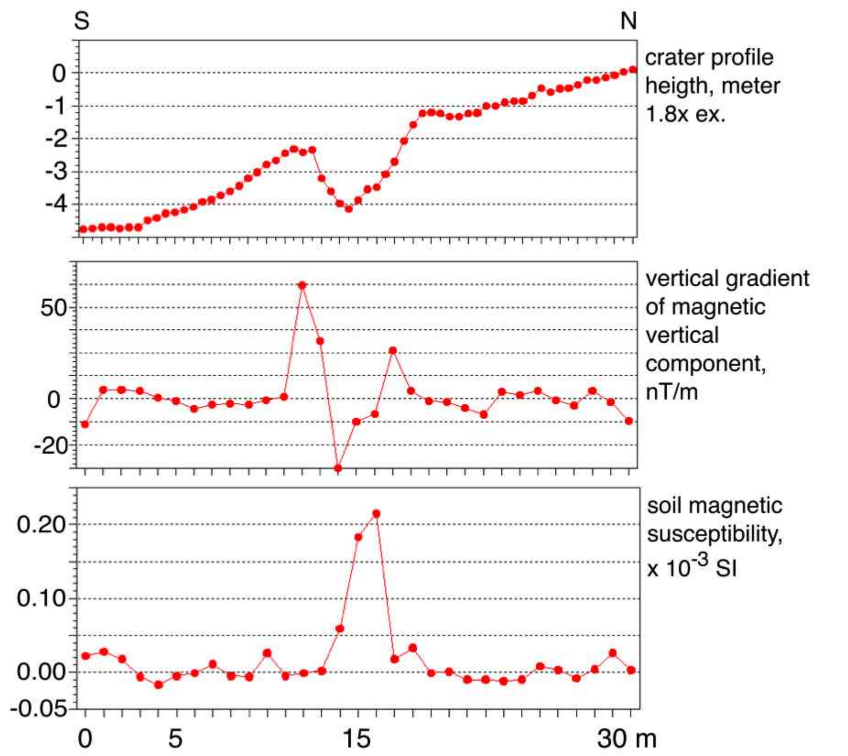

Fig. 6. The Mauerkirchen crater and its morphological and magnetic signature.

At the Kaltenbach crater (Fig. 5) magnetic anomalies are recorded for both the vertical gradient and the susceptibility covering the depression and most part of the rim wall. Maximum gradients, positive and negative, are as high as several hundred nT/m, and susceptibilities attain one to two orders of magnitude higher compared to outside the crater. At the Mauerkirchen crater (Fig. 6) the anomalies are concentrated more to the center of the structure, and the amplitudes of gradient and susceptibility are somewhat reduced however still considerable.

The Aschau crater (Fig. 7) is different. Apart from the normal magnetic "noise" and a single anomaly from an unknown object, no magnetic signature can be attributed to the crater area. The same holds true for the second Aschau crater some 50 m apart.

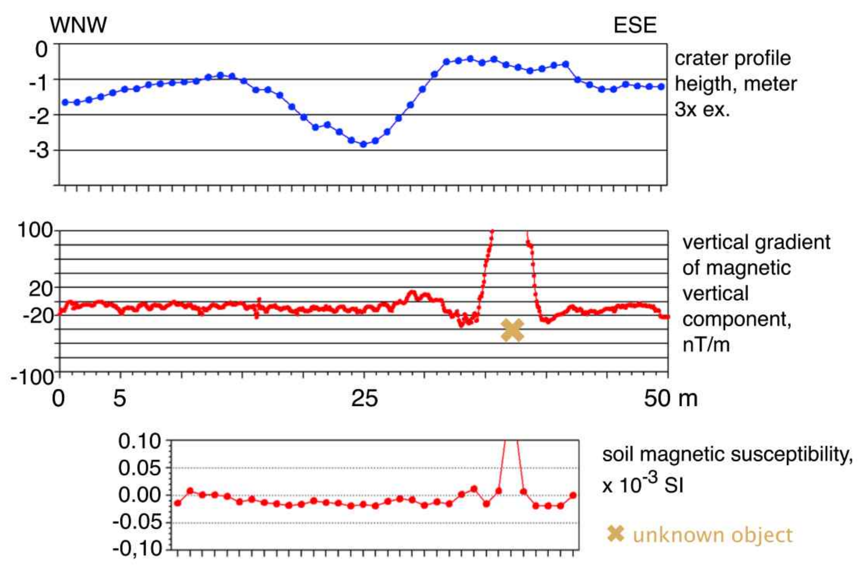

Fig. 7. One of the Aschau craters and its morphological and magnetic signature.

A peculiar situation is met with the concentration of craters at the Thalham location. Here, a profile of vertical gradient measurements revealed very strong anomalies up to several thousands of nT/m not only concentrated to craters that were crossed, but also to spots otherwise not especially noticeable in the forest (Fig. 8). No anthropogenic objects were found, but highly magnetized rocks could be sampled from the ground.

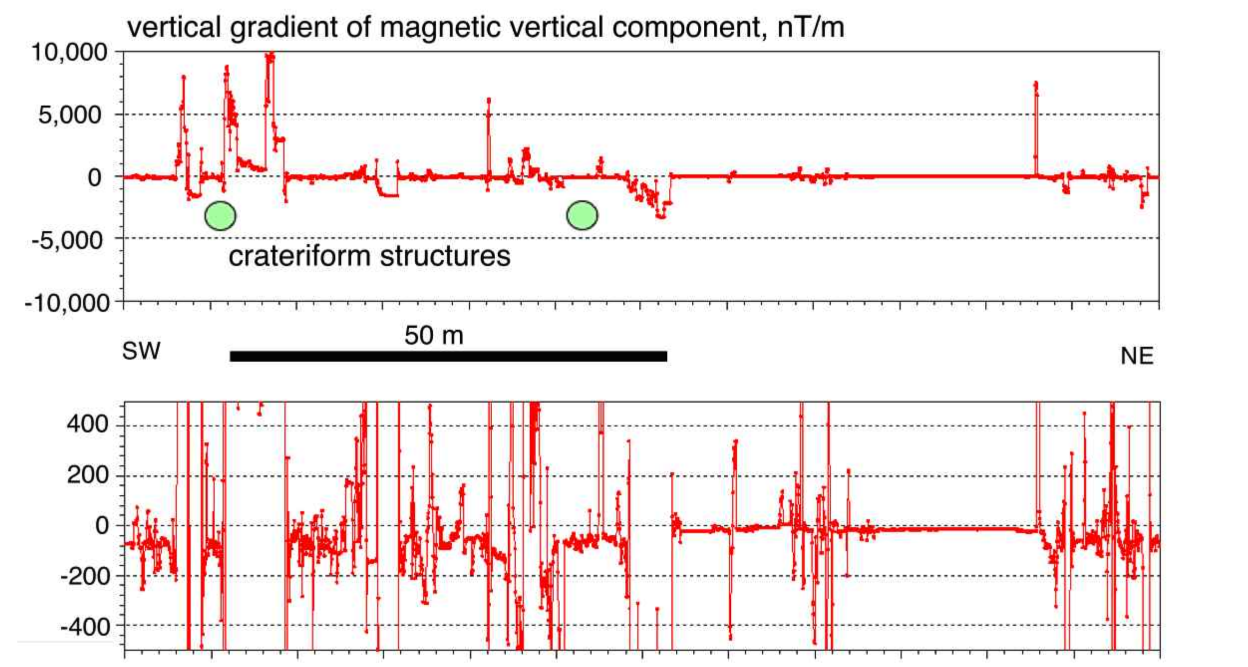

Fig. 8. Magnetic vertical gradient profile in the forest near Thalham where many crateriform structures are concentrated.

Excavation

Fig. 9. Fractured sandstone boulder with a greenish crust of glass. Kaltenbach crater.

We performed excavations in the "magnetic" Kaltenbach and Mauerkirchen craters revealing on the whole similar results. In the Kaltenbach crater a varied mixture of intact and, in part strongly, fractured sharp-edged cobbles and boulders in a sandy, silty and loamy matrix enriched in finely dispersed multi-colored rock fragments were encountered. Few tiny charcoal and sporadically tiny lumps of snow-white pasty carbonate matter were intermixed. In the center of the crater, cobbles and large boulders were excavated, as highlighting features giving evidence of very high temperatures in the form of intense melting and glass formation (Fig. 9).

In the "magnetic" Mauerkirchen crater, excavation in the center of the structure exhibited a profile as shown in Fig. 10. Compared with the Kaltenbach crater, heating of rocks appears to be reduced to spotted glass formation, although a quartzite cobble completely coated by a thin film of glass could be sampled. A small excavation in the ring wall revealed a roughly similar profile with fractured and corroded cobbles and evidence of heating. Below, at 60 cm depth, a small volume of pasty white carbonate matter, charcoal and slightly fired loam reminded of the occurence of similar material in the #004 crater in the Altötting/Burghausen area earlier described in connction with the postulated Chiemgau impact event [4; also see Discussion and conclusions]. From the Mauerkirchen crater it became evident that apart from strongly magnetized cobbles even most of the carbonate rocks show an enhanced magnetic signature (Fig. 11).

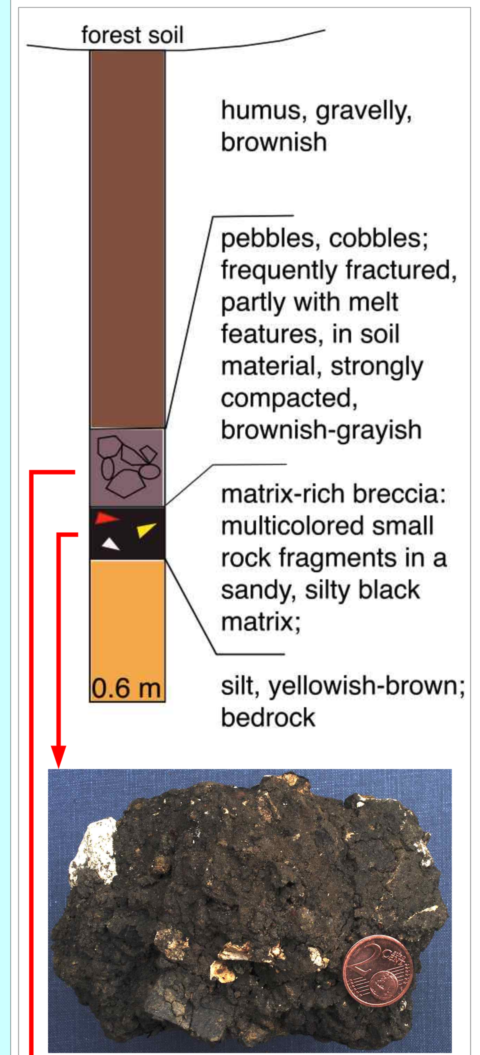

Fig. 10. From excavation in the center of the Mauerkirchen crater. Lower: A sample from the breccia horizon.

Fig. 11. Spectrum of cobbles from the Mauerkirchen crater arranged in increasing magnetization.

Rock-magnetic data

Preliminary rock magnetic data were obtained from simple measurements of whole cobbles. According to well-known practice the cobbles were considered a homogeneously magnetized sphere of equal volume and rotated in a definite distance below the magnetometer. From maximum and minimum magnetometer readings and the cobble volume induced and remnant magnetizations could be determined. In addition, the induced magnetization values were compared with those obtained from susceptibility measurements of the cobbles. Without going into detail, the measured data of cobbles of various lithologies (limestone, dolostone, sandstone, quartzite, gneiss, amphibolite) can be summerized as follows:

magnetic susceptibilities up to more than 6000 x 10^{-5} SI
maximum remnant magnetization of the order of 10 A/m
Koenigsberger ratio, remnant/induced magnetization up to 3.5

So far enigmatic are very high susceptibilities and remnant magnetizations of limestone clasts. While in general we measured susceptibilities of the order of 0.00005 x 10^{-5} SI and negligible remanence for carbonate clasts of the region, we obtained up to more than 1500 x 10^{-5} SI and remnant magnetizations of up to 2 A/m (Koeningsberger ratio up to 3) for limestone samples from the craters (e.g., Fig. 12).

Fig. 12. Strongly magnetized limestone boulder exposed in the Kaltenbach crater.

Discussion and conclusions

It appears that crater formation, crushed rocks and breccias, melt rocks and strong magnetic anomalies belong to the very same event. ❖ The excavations and also metal detector soundings revealed no human remains. Lacking charcoal (apart from spotty appearance), ash layers, slag and ore are basically speaking against glassworks, smelting or lime kiln. A very short heating process is indicated by the extremely thin coating of glass (Fig. 9) and by the absence of pervasively fired loam and burnt carbonate clasts. ❖ Hence, the craters have a natural origin, while an underground source can reasonably be excluded, and they were produced in a very short event. ❖ They probably formed by an explosion that because of the relatively flat depressions was released near or at the ground. ❖ The pressure of the explosion crushed the rocks, and the explosion heat produced the rock melt and the natural rock glass. ❖ The in part markedly enhanced susceptibility and strong remnant magnetization of rocks responsible for the measured magnetic anomalies is ascribed to the event. ❖ The enhanced susceptibility requires the formation of new magnetic phases. ❖ The natural remnant magnetization (NRM) may be considered a TRM (thermo-remnant magnetization), an IRM (iso-thermal remnant magnetization), a SRM (shock-remnant magnetization), or a superposition of various components. TRM could have been acquired upon cooling of the heated rocks. IRM is more difficult to understand, but it is known that strong explosions (chemical and nuclear) may produce various electromagnetic pulses [5, and references therein]. For now, IRM from such explosion effects must remain speculative. SRM is a well-known process [e.g., 6] and may have resulted from shock wave propagation induced by the postulated near-ground explosion. It must be left to assumptions whether thermal shock is able to produce or change NRM. ❖ The high susceptibilities and strong remnant magnetizations/high Koenigsberger ratios of carbonate rocks from the "magnetic" craters are so far enigmatic. The formation of new magnetic phases upon heating and following TRM upon cooling may in principle be understood but raises the question why the surfaces of the affected cobbles do not show evidence of any heating in the form of burnt lime. Rather a shock magnetization should be taken into consideration. ❖ All in all, detailed rock-magnetic studies are indispensable in order to understand the magnetization processes. ❖ The probable formation of the "magnetic" craters in a highly energetic explosion process is explained within the frame of the postulated so-called Chiemgau meteorite impact event. The craters as described here are no typical meteorite impact craters having originated from the impact of a projectile like, e.g., in the case of the 13 m-diameter Carancas, Peru, crater. Correspondingly, no meteoritic matter has been found in and around the structures. ❖ The "magnetic" craters around Lake Chiemsee show basic similarities to the #004 crater located in the northern part of the strewn field in the Altötting/Burghausen region (Fig. 2). The 11 m-diameter #004 crater has a strong magnetic signature [3], contains abundant melt rocks and fractured cobbles and boulders, and reveals shock effects (planar deformation features, PDFs, and diaplectic glass) [4]. A formation by a near-ground burst has also been suggested [4]. Hence, the peculiar #004 crater and the unsolved question of its formation has counterparts also in the most southerly part of the meteorite impact strewn field adding to the general peculiarities of this impact event. ❖ The magnetizing process was able to strongly magnetize also near-surface rocks without the formation of craters (Fig. 8). This may be explained by a meteoritic airburst without however giving insight into this process.

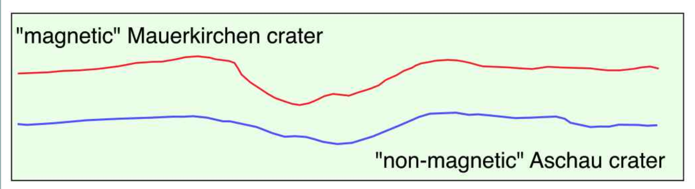

Fig. 13. Crater profiles (1:1) for a "magnetic" and a "non-magnetic" crater scaled to rim-to-rim diameters.

❖ Rimmed craters without magnetic signature appear to show a somewhat different morphology (Fig. 13). They have comparable preservation but are suggested to have another, endogenetic, origin possibly by soil liquefaction and sand explosion in the course of the same postulated impact event [7]. Possibly, the impact event produced two kinds of craters: craters "from above" with a geomagnetic signature and craters "from below" without such a signature. More evidence by investigating more structures is needed.

References

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