Juvenile fragment studies on lapilli tuffs of the Messel maar-diatreme-volcano, Germany: implications for rockmagnetic properties

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Introduction

The fossil-bearing *Messel Pit* (UNESCO World Heritage Site), 25 km south of Frankfurt (Germany), lies on the Upper Rhine Graben shoulder (Fig. 1) and has a maar-diatreme-structure beneath its surface (Fig. 2a). In addition to lacustrine sediments (0-200 m), the research drilling 2001 discovered volcaniclastic units of lapilli tuffs (240-373 m) and the diatreme breccia (373-433 m). The volcanic material shows a distinct downhole magnetic anomaly pattern (Fig. 2). Thereby, juvenile fragments attach great importance to the magnetic signature.

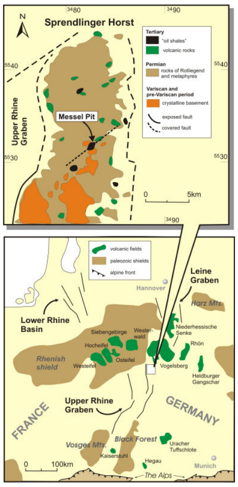


Fig. 1 Messel Pit genesis is associated to Tertiary (Quaternary) intraplate volcanism in Germany

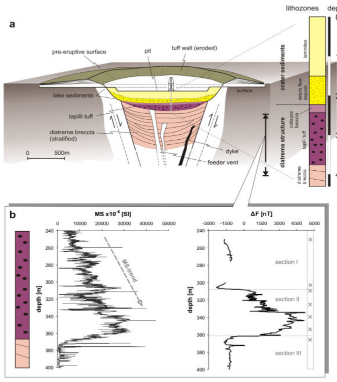


Fig. 2 a) Sketch of the *Messel* maar-diatreme-structure and the drilled lithozones. **b)** Downhole magnetic measurements performed during the drilling project 2001. Magnetic field anomalies are most pronounced to the lower half of the lapilli tuffs

Rockmagnetic properties

Throughout the lapilli tuffs, fine-grained Fe-oxides bound to the juvenile fragments are main carrier of ferrimagnetic properties. They have near magnetite composition (Fig 3) and are disseminated in a juvenile, glassy matrix (Fig. 4). Rock magnetic experiments (Nitzsche et al., *in press*) on the lapilli tuffs clarified the origin of the magnetic anomalies and approved emplacement temperatures >300 °C (section II) and <300 °C (section I) (Fig. 5, 6).

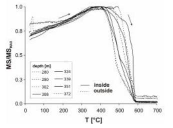


Fig. 3 Ferrites of the lapilli tuffs are dominated by a near magnetite composition (Tc: 500-580 °C).

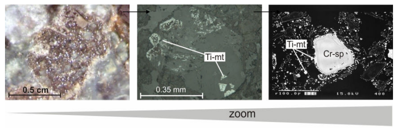


Fig. 4 Fe-oxides are bound to the juvenile fragments and frequently show skeleton-like structures around Cr-spinels.

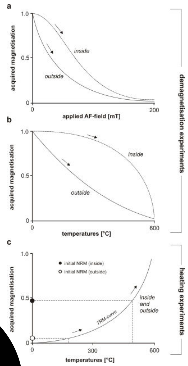


Fig. 5 a) Alternating field (AF) and **b)** thermal demagnetisation experiments show differences in magnetic stability behaviour for the lapilli tuffs deposited inside and outside (section I and II) the anomalies. **c)** Thermal heating experiments approve the differently availed temperatures of the material.

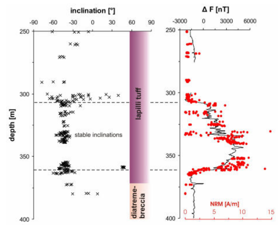
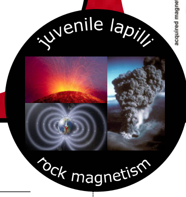


Fig. 6 The most pronounced temperature effect is given by high magnetic field and NRM (natural remanent magnetisation) intensities as well as stable magnetic inclinations.

TEMPERATURE



Juvenile fragments

Due to very difficult petrographical differentiation of the lapilli tuffs on a macro/microscopic scale (Fig. 7), the volcaniclastic particles have been studied with image analytical methods in more detail. The accidental clasts do not show a dependency on magnetic susceptibility (Fig. 8) and NRM intensities, but juvenile fragments do (Fig. 9). The latter explain the origin of heat source by their amount, size and grade of plastic deformation.

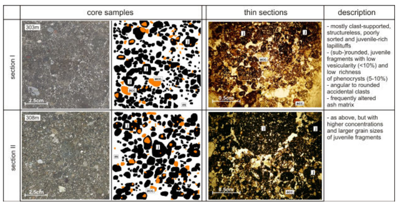


Fig. 7 Core and thin section photographs of samples from section I and II, reflecting the onset of the downhole magnetic field anomalies.

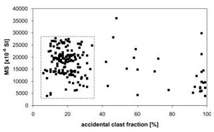


Fig. 8 Accidental clast fraction mainly ranges between 5-35 % and do not show a dependency on the magnetic susceptibilities, i.e no negative correlation due to "MS dilution"!.

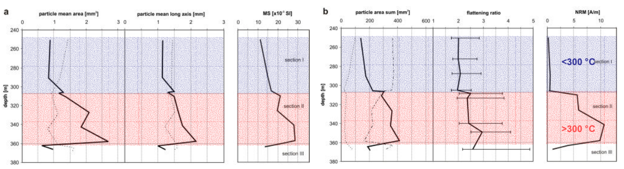


Figure 9 a) Image analytical data shows that the juvenile particle sizes correlate with the susceptibility log with an increasing trend from relatively low to high values. **b)** The juvenile proportion (area sums) and the juvenile flattening ratios are most pronounced in section II (red), where high NRM intensities are due to high depositional temperatures. Low values of image analytical data represents the low depositional temperatures.

image analysis

HEAT SOURCE

Averaged major element values of microprobe analysis scans (Fig. 10) separate the juvenile fraction into two groups (Fig 11, 12). REE elements show a typical trend of volcanic suits of potassic continental rift zone magmatism (Fig. 13a). The intra-plate basalts derive from enriched mantle source (Fig. 13b)

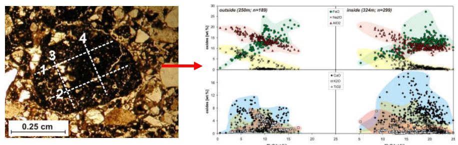


Fig. 10 Microprobe analysis scans reflect different MgO variation diagrams of juvenile lapilli deposited inside (section II) and outside (section I) the magnetic anomalies.

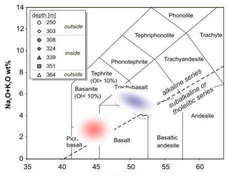


Fig. 11 Total alkalis (Na2O+K2O wt.%) versus silica diagram with groupings of the juvenile material from inside (section II) and outside (section I) the ΔF-anomalies.

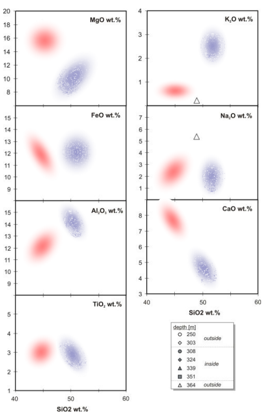


Fig. 12 Harker variation diagrams of SiO2 versus oxides of Mg, Fe, Al, Ti, K, Na and Ca showing groupings of the juvenile material deposited inside (section II) and outside (section I) the ΔF-anomalies.

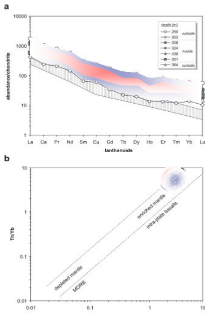


Fig. 13 a) REE-diagramm of the juvenile material and the schematised pattern of the leucitic composition field of volcanic rocks of the western branch of the East African Rift (EAR). **b)** Th/Yb versus Ta/Yb plot showing the magmatic mantle source character of the juvenile lapilli.

geochemistry

MAGMA SOURCE

Conclusions

➢ Rock magnetic and juvenile fragment data suggest a clear subdivision of the lapilli tuffs into a two-condition eruption phase at the end of volcanic activity.

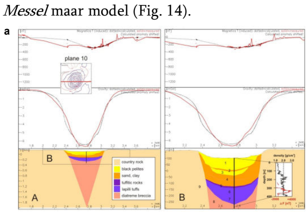
➢ The volcaniclastic material is separated into a relatively hot, geochemically undifferentiated and cold, differentiated phase.

➢ The juvenile fragments are mainly identified as primary, despite complex sedimentation processes (post/syn-eruptive re-sedimentation, subsidence etc.) occurring in intra-crater settings.

➢The interdisciplinary analytical studies may explain possible criteria of diatreme facies and contribute to the understanding of magnetic field anomalies in volcaniclastic settings.

Perspectives

The combination of gravity and magnetic data allows the reconstruction of a 3D *Messel* maar model (Fig. 14).



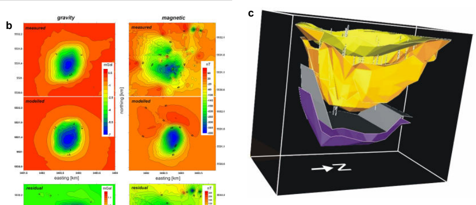


Fig. 14 a) Vertical cross section of the Messel maar model based on gravity and magnetisation data, **b)** results of the measured and modelled potential field anomalies and **c)** 3D illustration of the Messel subsurface.

Reference: Nitzsche, T., Rolf, C. and De Wall, H., *in press.* Origin of magnetic anomalies in volcaniclastic units of the Messel maar-diatreme (Germany). Zeitschrift der Deutschen Geowissenschaftlichen Gesellschaft 157, xx-xx.

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