THE MELILITE NEPHELINITE DIATREMES OF THE SWABIAN ALB/GERMANY AND THE FORMATION OF AUTOLITHS

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The melilite nephelinite diatremes of the Swabian Alb, well-known since Cloos's careful analysis (1941), have frequently been compared with kimberlite diatremes and vice versa. Recent studies allow a new interpretation in respect to the cause of their formation and a phreatomagmatic origin is suggested. Consequently the formation of autoliths, typically developed in the Swabian diatremes, is dicussed from this point of view.

The 350 diatreme structures of the Swabian Alb formed in Upper Miocene time soon after the sea had covered the southern half of the Swabian Alb and deposited the Upper Marine Molasse. Retreat of the sea was followed by the deposition of the Upper Freshwater Molasse during which most of the diatremes were emplaced immediately north a few also south of the previous coastline. Strong uplift and erosion affected the Swabian Alb only in Pliocene/Pleistocene time and, therefore, the landsurface of the diatreme area was near the sea-level.

The diatremes as such extend downwards for about 1.5 km to the boundary between the basement and its sedimentary cover. The latter consists of Permian clastic rocks including coarse grained conglomerates and rather undeformed Triassic and Jurassic clastic and carbonate rocks. The well-jointed Upper Jurassic limestones display karst phenomena initiated at least in Eocene time.

Judging from the internal structure and fresh-water lake deposits in the upper parts of the larger diatremes the diatremes must have ended at the original surface in maars which were cut into the Upper Jurassic limestones. Evidence of subsidence of the floors of the fresh-water lakes as for instance slump structures and large blocks of Upper Jurassic limestone embedded in the lake deposits points to accumulation of groundwater within these maars immediately after the diatremes stopped erupting. The slightly younger Ries and Steinheim meteorite impact craters east of the diatremes also show evidence of deep fresh-water lakes.

In all probability these data suggest the existance of copious amounts of groundwater and a rather free groundwater table within the sedimentary cover of the basement near the original landsurface during the time of diatreme emplacement. It seems for the respective magma to have been rather inevitable to contact groundwater during its rise through the sedimentary cover of the dense basement and consequently to get involved in phreatomagmatic eruption processes. Internal structures of the diatremes are very similar in a number of aspects to those from other diatremes for which a phreatomagmatic origin has already been suggested (Lorenz 1973, 1974).

Within some 20 diatremes melilite nephelinite magma was able to rise at the end of the eruptive activity towards high levels, in a few cases up to levels of only several tens of meters below the original surface or possibly even less. As the original land surface has been lowered by erosion no original surface deposits of the diatremes are preserved and,therefore, it cannot be judged if the magma of the respective intrusive rocks had actually reached the surface and formed cinder cones and lava flows. The high level intrusive rocks, however, are not highly vesicular at their chilled margins which points out that the previously dissolved gasphase had neither very much nor very rapidly exsolved at the time of intrusion. It may not have been very high amounts of gas dissolved in the magma at all.

The juvenile fraction of the pyroclastic rocks of the Swabian diatremes occurs mostly as spherical ash grains or lapilli, i.e. autoliths. Larger juvenile particles are mostly angular. Typically both the small and large juvenile particles contain hardly any vesicles despite the fact that they represent chilled magma droplets. The core of the spherical autoliths consists either of a phenocryst or of a xenolith derived from the Mesozoic sediments. As formation of the spherical particles points to spraying of a liquid into a free space and action of surface tension formation of these autoliths must have taken place within the diatremes themselves, i.e. above their respective feeder dikes.

Up to now autoliths have been assumed to be the result of rapid fragmentation of the magma owing to explosive exsolution of the contained very large amounts of gases. On the other hand a number of features point to rapid chilling of the pyroclastic rocks as well which is widely accepted. This poses the question of how rapid exsolution of the gasphase, consequent disintegration of the magma into droplets, and rapid chilling can take place near-simultaneously without the particles showing any evidence of such an exsolution of the gasphase. At the surface such a process leads to formation of cinders or pumice with the vesicles largely preserved owing to chilling by air. As the Swabian diatremes are suggested to have been of phreatomagmatic origin, the autoliths representing the major part of the juvenile fraction of these diatremes should be of phreatomagmatic origin as well. Most phreatomagmatic eruptions, however, give rise to production of angular fragments their vesicle content indicating the state of vesiculation at the time of magma/water contact. The vesicle content may thus vary between nearly nil and values found in pumice depending on the depth at which the contact takes place. In diatremes of appreciable depth, e.g. the Saar-Nahe diatremes/SW Germany the vesicle content and size is in fact small and negligible. Judging from the literature autoliths are only found in diatremes from $SiO2$ undersaturated basic to ultrabasic magmas. This suggests influence of the chemistry and thus of the viscosity and surface tension on their formation. Experiments on water vapour explosions owing to metallic liquids getting into contact with water show that production of droplets can take place when the liquid metal is sprayed into an open space as a result of the explosion (Fröhlich pers. communication 1977). It is therefore suggested that the autoliths of the Swabian diatremes formed when the respective magma, the most SiO_2 undersaturated of central Europe (35% SiO_2), contacted copious amounts of groundwater available in the sedimentary cover of the basement. During the consequent water vapour explosions the magma disintegrated into fragments which were sprayed into the space surrounding the explosion foci. The surface tension of the liquid enabled formation of droplets even around xenoliths derived from the wall-rocks. The cool temperatures of the water vapour and the remaining water caused rapid chilling and thus preservation of the autoliths in their original shape. The assumption of water vapour explosions as a result of magma/water contact would explain the lack of vesicles in the juvenile fraction of the pyroclastic rocks as at the depth of contact the juvenile gasphase need not have exsolved yet to any great extent.

At some cinder cones in the West Eifel/Germany it can be shown that external water intermittantly got into contact with the rising magma. This caused phreatomagmatic eruptions and typical phreatomagmatic eruptionproducts including cauliflower bombs and autoliths.

References:

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