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Origin of maar volcanoes: external water, internal volatiles, or both?

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The origin of maar volcanoes has been interpreted as due to explosive magma-water interaction for more than 40 years (Fisher and Waters 1970; Lorenz 1973 and Fisher and Schmincke 1984). Earlier suspicions that CO_2-degassing plays a role in maar formation (Schmincke 1977) are now followed up by re-examining maar deposits of four different compositions in the maar-type locality (Eifel, Germany). These four compositions comprise: (1) melilite-nephelinites (West Eifel), (2) leucitites/nephelinites (West Eifel), (3) Na-rich basanites (West Eifel), and (4) K-rich basanites (East Eifel). At present, we focus on high-resolution stratigraphy, sedimentology, grain-size distribution, component analysis (accidental vs. juvenile clasts), and morphological and textural particle studies, accompanied by standard glass and bulk chemical and mineralogical analyses. Interestingly, maar deposits of highly silica-undersaturated and - by inference - CO_2-rich composition (melilite-nephelinites and leucitites/nephelinites) show features contrasting with the classical catalogue of criteria for hydroclastic fragmentation (Fisher and Schmincke 1984). Their deposits are medium- to coarse-grained (MdØ mainly: 2 – 8 mm), mostly moderate- to well-sorted (σØ mainly: 1 – 2.5) and in some cases juvenile-rich (up to 50-70 wt. %). Transport and depositional mechanisms comprise a mixture of surge and fallout differing from the general assumption that maar deposits are dominated by surges. Additionally, features of juvenile clasts of highly silica-undersaturated composition largely differ from the features of “classic” hydroclastic particles (e.g.: dense, blocky, glassy shards). Juvenile clasts of highly silica-undersaturated composition show: (a) round- to semiround morphologies, (b) slight- to moderate vesicularities, (c) near absence of glassy material, (d) abundance of deep-seated xenoliths (mantle and lower crust), (e) agglutinated lava rinds enveloping the mantle- and crust-xenoliths, and (f) carbonate fragments, most probably of magmatic origin, within the groundmass. In contrast, basanitic maar deposits - by inference with low CO_2 concentrations - and particularly their juvenile clasts show more conventional features of hydroclastic fragmentation processes. They are finer-grained, moderate- to poorly-sorted, extremely lithoclast-rich, and the juvenile clasts are generally angular, slightly- to non-vesicular and glassy. Moreover, deep-seated xenoliths and carbonate fragments are lacking. At this stage in our study we postulate that the high CO_2 concentrations of highly silica-undersaturated maar volcanoes in the West Eifel could have played a significant role in maar-forming processes. These magmas may have undergone magmatic fragmentation due to rapid CO_2-exsolution prior to shallow magma-water interaction resulting in explosive eruptions governed by both, magmatic and phreatomagmatic fragmentation and eruptive processes.