FORMATION OF MAAR-DIATREME VOLCANOES AND ITS RELEVANCE TO KIMBERLITE DIATREMES.

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The author's studies of numerous diatremes, maars, and tuff-rings in Europe (Germany, France, Scotland, Iceland) and USA suggest a specific process in their formation.

Magma rises along a fissure and, at a certain depth below the surface, contacts water that pours into the fissure from either aquifers or from the surface - sea-water, lake-water, river or stream water.

At the interface the magma is chilled; it solidifies into glass and consequently disintegrates into discrete, angular, solid fragments of ash or lapilli size. The water is heated at the base of the water column until it boils and finally flashes into steam giving rise to a phreatomagmatic eruption. During refill of the system with water pressure within the fissure is considerably lower than the lithostatic pressure in the surrounding country-rocks. As a consequence spalling leads to enlargement of the fissure into an eruption channel and introduction of wall-rock material into the eruptive system. This cyclic, geysir-like activity gives rise to bedded air-fall and base surge deposits at the surface characterized by wet and partly muddy deposits and consisting of a mixture of wall-rock and juvenile material.

Above a critical diameter of the enlarged eruption channel instability of the walls leads to formation of a ring-fault which may be considerably larger in diameter than the eruption channel and reach several 100 to 1.5 km. Along the ring-fault the enclosed wall-rocks and overlying subaerially deposited, bedded pyroclastic debris subside and form a saucer-shaped structure at depth. This process results in a large crater at the surface with a diameter at its rim 1.5 to 2.5 times the diameter of the ring-fault at near-surface level.

At a relatively shallow level of contact between magma and water spalling of country-rocks into the fissure is of minor importance. Consequently the ring-fault will be smaller in diameter and the resulting pyroclastic debris relatively poor in wall-rock material. At the surface a tuff-ring forms, the crater floor of which is elevated compared with the regional surface.

At a relatively deep level of magma/water contact spalling is of major importance. A much greater amount of wall-rock material is thus incorporated into the system and ejected during eruptions. Subsidence along the ring-fault therefore leads to a maar crater the floor of which is cut into the regional surface.

Prolonged activity results in continuing subsidence. In addition the faulted and fractured subsided rocks get intruded by pyroclastic debris which in part may replace the subsided rocks.

Owing to subsidence and pyroclastic intrusion as well as shifting of the eruption channel the saucer-shaped subsidence structure is finally destroyed and the whole content inside the ring-fault circulates. An eruption channel with upward movements during eruptions is surrounded by a marginal zone characterized by slow downward movement.

Once the ring-fault has formed very little additional country-rock material is introduced into the system. During eruptions a certain percentage of country-rock and juvenile material is ejected and lost to the surrounding area. Simultaneously, however, juvenile material is introduced from the fissure into the diatreme. With time this leads to a decrease of country-rock debris in the ejecta as well as in the debris inside the diatreme. Prolonged activity in the case of a deep magma/water contact will therefore give rise to a transformation of a maar into a tuff-ring.

At the end of eruption subsidence owing to compaction of the whole diatreme content takes place in addition to slumping and erosion of the rim deposits. Thus redeposited tuffs and other sediments (lake sediments) even subside along the ring-fault as e.g. at the maar at Senèze, France, and at some diatremes in Scotland and Arizona. If the water supply is cut off prior to the end of magma supply magma may intrude the diatreme and even extrude.

Kimberlite diatremes display various features that seem to be consistent with the above model:

At depth they extend into fissures along which hot magmatic kimberlite rose. The diatreme contents, however, indicate emplacement by a cool gas phase, which may have been, at least in part, derived from ground or surface water. An appreciable amount of water in the respective eruption clouds seems to be indicated by large accretionary lapilli occuring in the Murfreesburo kimberlite diatreme, Arkansas (MOORE & PECK 1962). Adiabatic expansion of the juvenile gas phase has been assumed responsible for the cool emplacement of the pyroclastic debris (DAWSON 1971). This ignores the presence of the hot juvenile particles. Their heat capacity takes part in controlling the temperature and expansion of the gas phase. It would be large enough to heat copious amounts of ground or surface water. If juvenile gas was responsible for the eruptions many highly vesicular lapilli should exist especially if they were colled rapidly by the gases.

If the gases would be of juvenile origin it is also not clear why kimberlite dykes and sills which contained similar amounts of gas were emplaced at even shallower depth than the diatreme roots (DAWSON & HAWTHORNE 1970) without showing any evidence of disruption of the magma into pyroclastic debris. Phreatomagmatic formation of the diatremes would solve this apparent problem.

Fluidization has been advocated for explaining the large subsided 'floating reefs' and concentrations of xenoliths of specific horizons within certain areas (DAWSON 1971). Both features, however, could be interpreted as remnants of nearly completely destroyed subsidence structures. Vertical striations on diatreme walls and zoning of diatreme contents indicate en masse subsidence of a marginal zone whereas the inner zone represents an eruption channel. Such channeling also contradicts formation of the whole body of large diatremes by fluidization. Once a small channel has been formed only reaction of the wall-rocks - initially by spalling and later also by formation of a ring-fault - seems to provide the space for the later large kimberlite diatreme body.

The kimberlite diatremes in Montana clearly are saucer-shaped subsidence structures that extend into dykes at depth and are surrounded by ring-faults (HEARN 1968).

References:

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