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AN UNUSUAL LAVA CAVE FROM OL DOINYO LENGAI, TANZANIA

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A new type of lava cave is described from the summit crater of Ol Doinyo Lengai, a unique active carbonatite volcano in Tanzania. This and other similar caves on Ol Doinyo Lengai are formed by thermal erosion and aqueous dissolution of otherwise solid spatter cones. Meteoritic water and endogenous condensates act to form speleothems of complex mineralogy up to 3 m in length. We propose the new classification of "polygenetic spatter cone cave".

Ol Doinyo Lengai (or Oldo Inyo Lengai), Tanzania (2.751°S, 35.902°E), the Masai "Mountain of God", is a unique, 2890 m, active stratovolcano in the East African Rift Valley. Current eruptive activity in the summit's north crater produces a natrocarbonatite lava at relatively low temperature (540 to 593° C; Pinkerton *et al.* 1995), and low viscosity (flows of 1-5 m/s have been observed; BGVN 13:06, 1988). The primary constituents of the natrocarbonatite are nyerereite ($Na_2Ca[CO_3]_2$) and gregoryite ($\{Na,K,Ca\}_2CO_3$) (Mitchell 2000), anhydrous carbonates of high solubility.

The geomorphology of the crater interior is dominated by a field of sub-cones (Figs. 1 and 2) ranging from a meter or two to more than 10 m in height. Extensive flows of carbonatite lava cover the crater floor, and exhibit small scale features typically associated with basaltic pahoehoe flows, including lava tubes of ~0.5 m diameter. Carbonatite lava is frequently ejected from the summit vents of the cones, or occasionally released in larger flows resulting from structural collapse of the cones.

THE CAVE AND ITS DECORATIONS

In June 2003, the cone designated T45 (Figs. 1 & 2), which probably formed in 1997, (BGVN 23:09, 1998) was observed to be breached near its northwestern base by a hole approximately 1 m square. Although a cave could be seen, at that time active de-gassing through the cone precluded entry; by early August 2003 a marked increase of de-gassing made it difficult to see into the cave at all; however, entry and examination was possible in July of 2004. The cone was revealed to be thin-walled (<0.75 m in places) and hollow. The resultant cave had a very simple circular plan and dome-shaped cross-section with relatively flat floors and rather delicate walls (Fig. 3).

The cave is fragile and dynamic. The breached base of T45 is the first sign of the inevitable structural failure of the cone's flank as the cave grows. This is evident in another example: in July 1998, a 3 m² section of the flank of cone number T40 (BGVN 27:10) collapsed into its interior cave (BGVN 23:09, 1998). The T45 cave, by 1 July 2004, had been partially filled by lava flows originating from T56B and possibly other sources. The floor of the cave was about one meter below the crater floor. The cave contained stalactites up to 3 m long. The summit vent of T45 formed a skylight into the cave. The cave's floor, composed of recent pahoehoe lava, was littered with small blocks that had fallen from the ceiling. On the afternoon of 15 July 2004 the cave's entrance was obliterated by a large lava flow from a newly formed vent, T58C. In view of the thin walls and low structural integrity of weathered natrocarbonatite, it should be noted that these caves present some danger to people climbing on the cones.

The cave was well ornamented with stalactites and columns up to 3 m. in length (Fig. 4). These are not the endogenetic lava stalactites that are common to volcanic caves and indeed occur in other parts of Ol Doinyo Lengai. For example, in July 2000 'lavatites' were seen around the inner rim of the active vent in cone T51 (BGVN 25:12, Fig 68). They were rapidly formed by the dripping of liquid lava ejected onto the cone's rim from a lava pond within the cone. Their formation process is identical to that seen in lavatites and lava drip pendants in typical basaltic lava tubes (Wood 1976; Hill & Forti 1997). The stalactites and columns of T45 cave are instead crystalline deposits from dripping water, composed of hydrated sodium carbonate (trona; $Na_3(CO_3)(HCO_3)2H_2O$) with smaller quantities of sodium and potassium sulfates, chlorides and fluorides; specifically, bands of aphthitalite $(K,Na)_3Na(SO_4)_2$ and kogarkoite $Na_3(SO_4)F$ with traces of sylvite (KCl) and halite (NaCl) (Mitchell, R., pers comm; determined by xray diffraction). Stalactites near the cave's entrance were observed to be dripping every 2-4 seconds. They form in the manner of most meteoric water stalactites, by deposition of a rim of crystals around a drip to form the initial straw stalactite that may later become thickened into more substantial stalactites and columns.

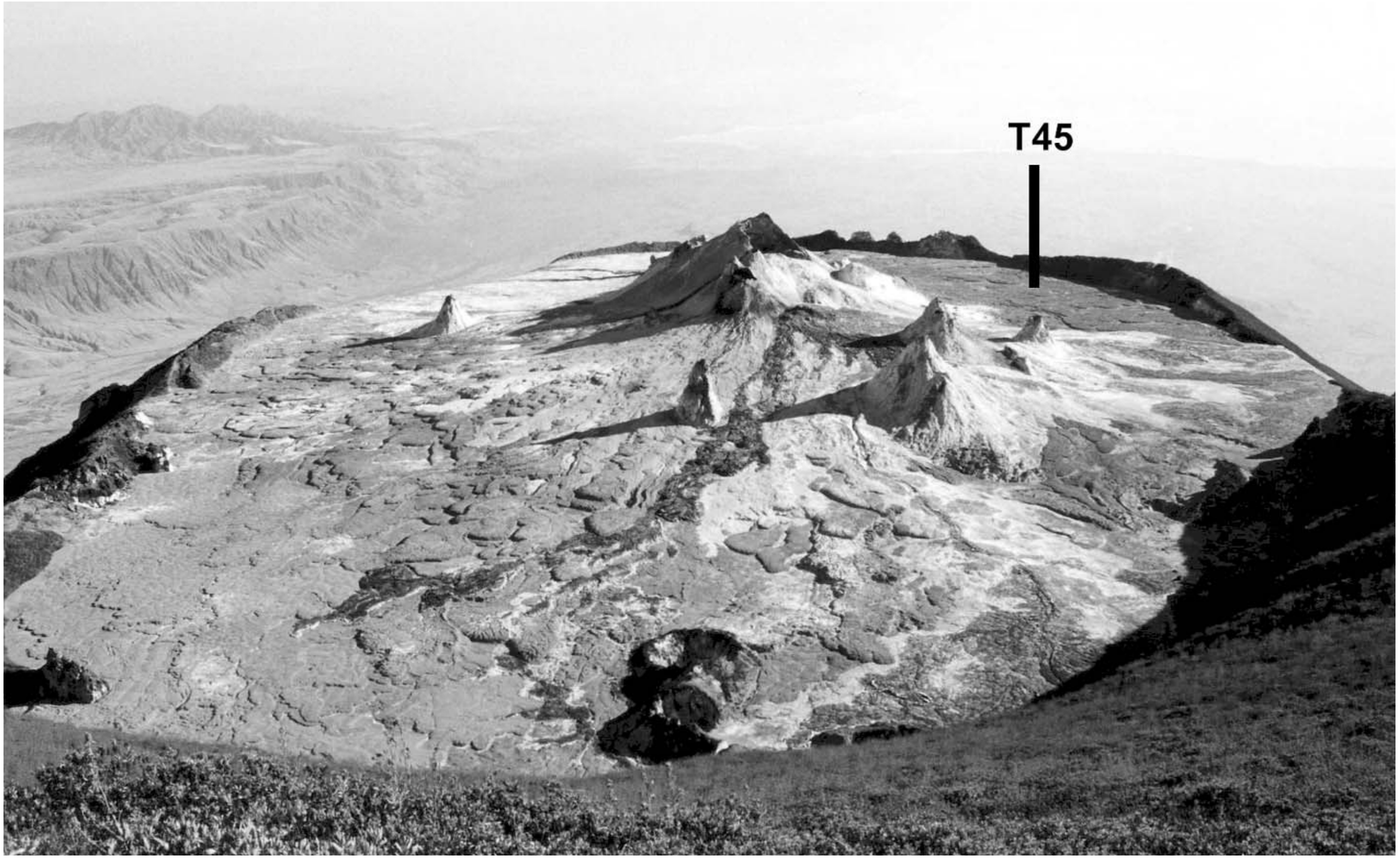

Figure 1. Interior of the active crater on Oldo Inyo Lengai, August 2004.

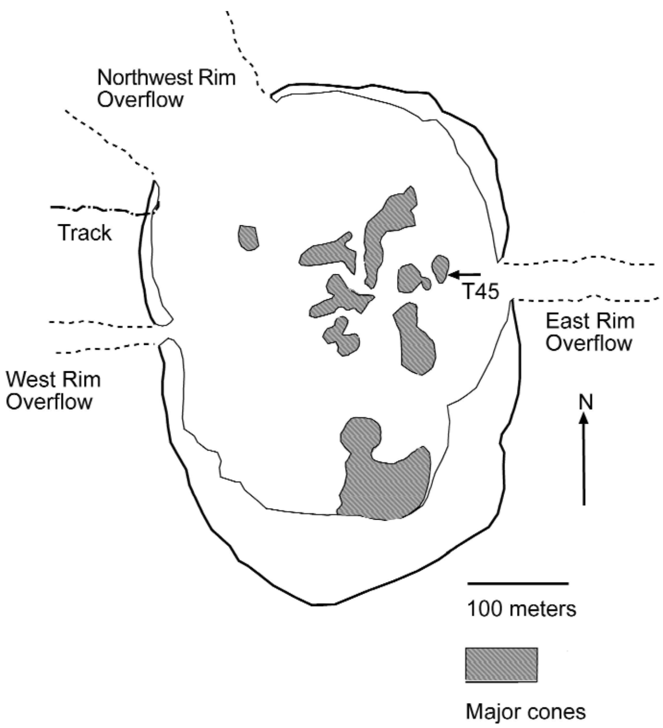

Figure 2. Plan of the summit crater, Oldoinyo lengai, showing T45. Adapted from a 2002 plan by F. Belton.

Speleogenesis

The dome-like cave described here differs from the variety of other lava caves previously reported (see classification in Wood, 1976). The crater of Ol Doinyo Lengai does have some narrow conduits associated with paths of lava flows that are clearly small lava 'tubes', but this cave does not fit that category. It also does not fit the category of lava 'blister' because it did not form from the surface cooling and solidification of a lava bubble. It seems to fit into the category of 'spatter cone' cave, yet it has a more complex morphology and speleogenesis. A simple spatter cone cave was described by Ollier (1967) from Mt. Eccles, Australia, that consisted of only an endogenetic evacuated vertical conduit. Most of Ol Doinyo Lengai's sub-cones form as spatter cones and are presumably solid with a central hollow conduit during growth (Fig. 5, 1-2). Some remnant vertical conduits from spatter cones are quite narrow, but it has been observed that wider conduits, such as this one, also form. These appear to be formed as the result of spatter from de-gassing of an interior lava lake rather than an isolated pipe of lava (Fig. 5, 3). If the lava lake level drops, a wide conduit or basin, large enough to be called a cave, remains inside the cone and may extend a number of meters into the crater floor beneath the cone, with one or more horizontal passages branching off to the sides (BGVN 23:09, 1998).

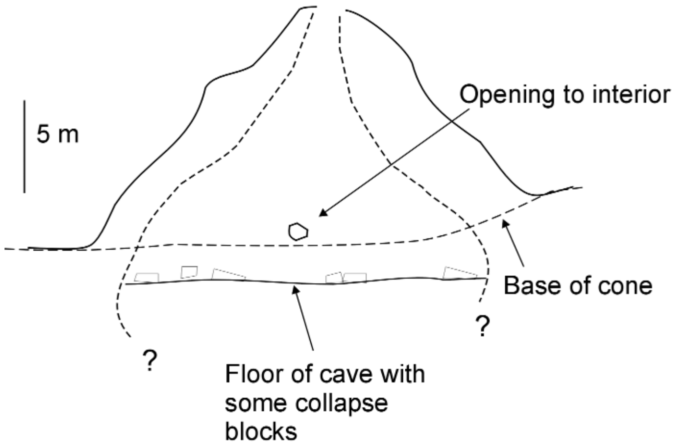

Figure 3. Profile of T45; interior profile is estimated.

This process is only the initial step in the speleogenesis. We hypothesize that renewed activity of a lava lake within a cone can further expand the hollow interior through the process of thermal erosion (Fig. 5, 4). Such erosion may progress rapidly and has been observed in carbonatite lava channels on Ol Doinyo Lengai progressing at rates of 2 mm/min (Dawson *et al.* 1990; Pinkerton *et al*. 1990; BGVN 27:10, 2002). Hollow cones have been observed to rapidly refill with fluid natrocarbonatite lava, and rates of degassing are highly variable.

A third speleogenetic process then takes over: it appears that senescence also contributes to the growth of the hollow interiors. We hypothesize that rainfall and frequent heavy dews penetrate the outer surface of the cone, increasing the size of the hollow interior by carbonate dissolution (Fig. 5,5). The Ol Doinyo Lengai caves can thus be considered to be significantly exogenetic features. Drip water entering the cavity may precipitate out sodium carbonate as speleothems (Fig. 5, 6), according to the interior microclimate of the cave, which fluctuates rapidly. Steam from within the cone may also contribute to the amount of water available for the process. Although the thermal diffusivity of natrocarbonatite is low (Pinkerton *et al.* 1995), the thin walls of the subcones and the low ambient air temperatures (~ 5° C at night) are likely to generate a significant temperature differential between the interior wall and the cave atmosphere, resulting in substantial condensation corrosion.

The continued growth of a cave within a cone will eventually result in structural failure of the cone's flank. The precise reason for a specific collapse event is often impossible to determine, but changes in eruptive activity have been observed to cause structural failure of cones. For example, in Aug 2003 the hollow cone T58B (BGVN 27:10) collapsed after a period of intense steam emission from a vertical crack in its flank. Clearly the event was caused by unsustainable gas pressure within the cone. The collapse was followed after a few seconds by strong strombolian activity which eventually rebuilt the cone.

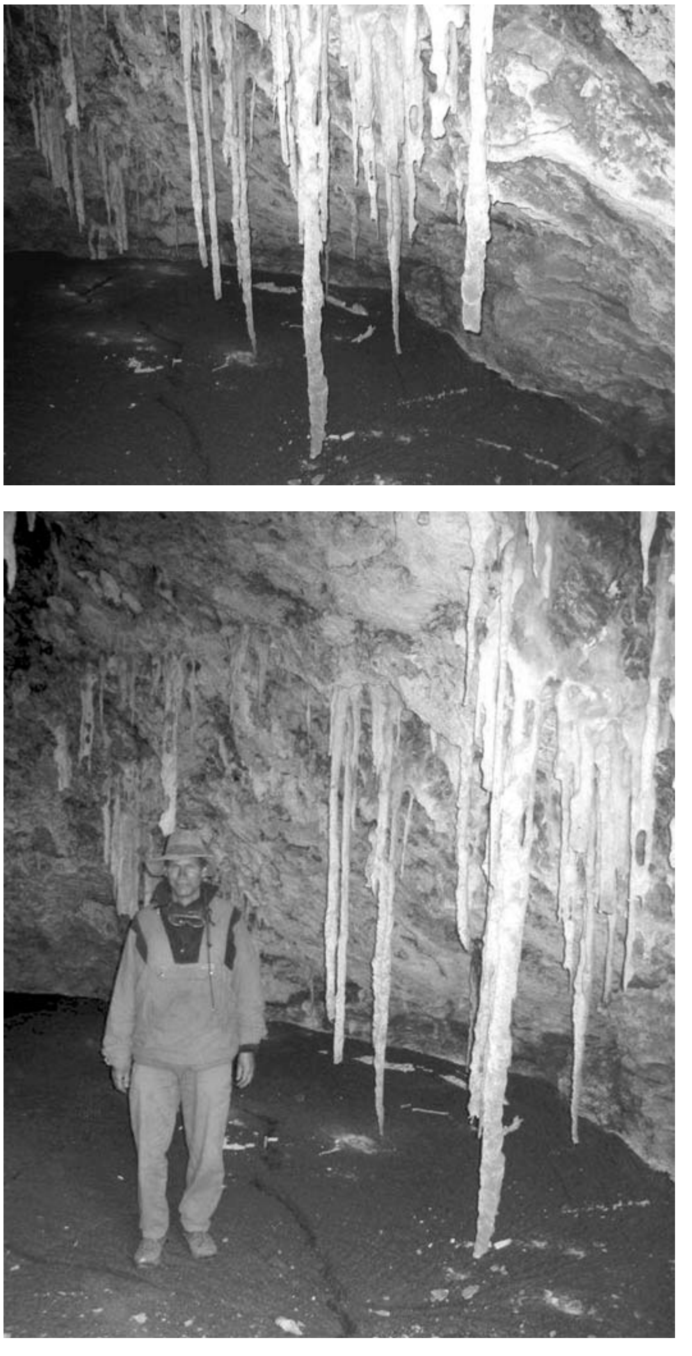

Figure 4. Sodium carbonate speleothems, T45 Cave, Ol Doinyo Lengai.

CLASSIFICATION

Since the processes of formation of these caves are more complex than other lava caves described in the literature, we propose to designate them polygenetic spatter cone caves, essentially a sub-type within the category of spatter cone caves. It is likely that this model of speleogenesis is rare because the circumstances, a combination of active eruption and thermal erosion of a highly soluble, very low viscosity lava, are presently only found on Ol Doinyo Lengai.

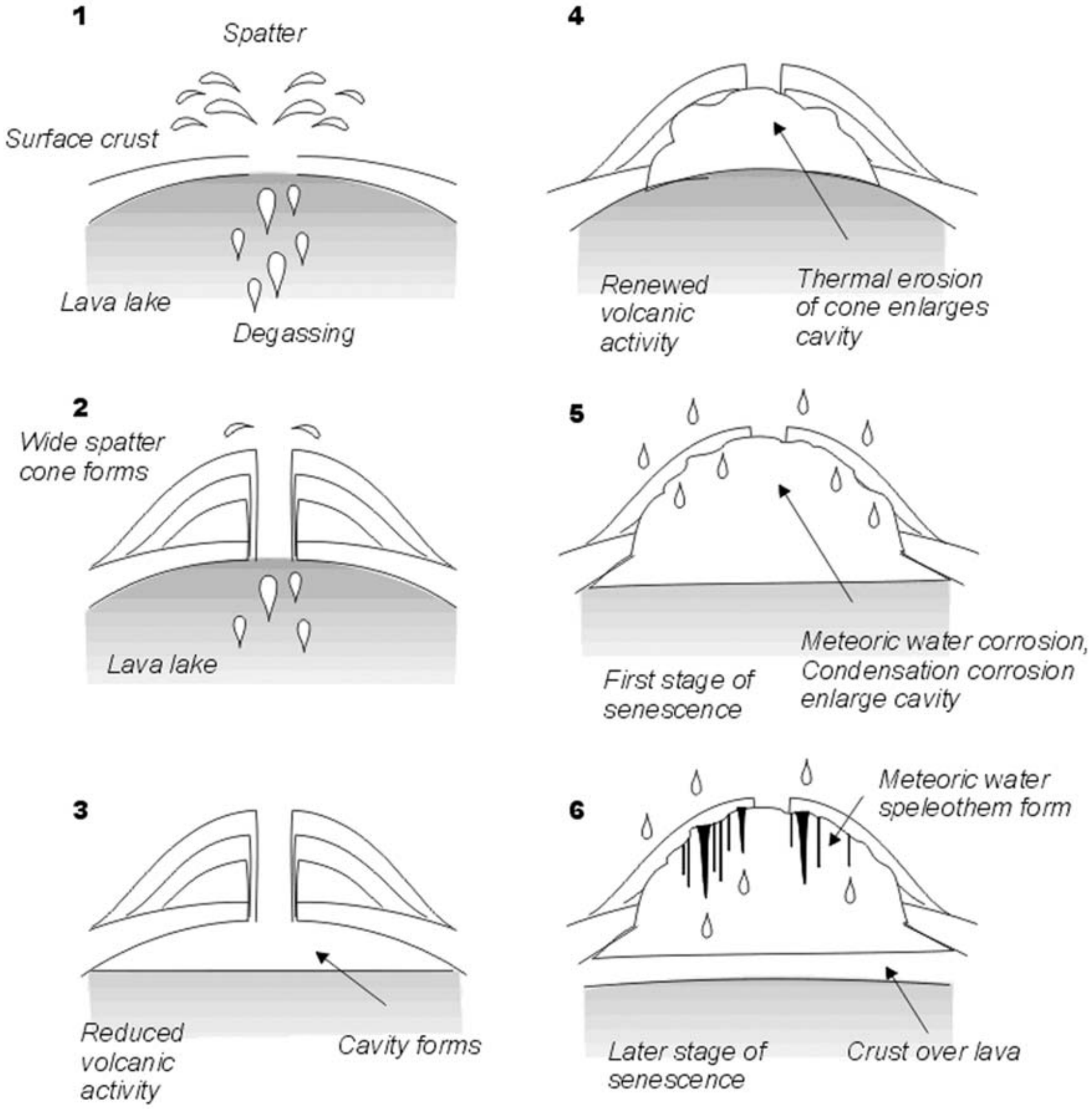

Figure 5. Speleogenetic sequence: 1. degassing of lava lake breaks through surface crust; 2. wide spatter cone forms; 3. reduced volcanic activity creates cavity under cone; 4. renewed volcanic activity causes thermal erosion of cavity walls; 5. reduced volcanic activity combined with meteoric water corrosion and condensation corrosion of cavity walls; 6. deposition of meteoric water stalactites.

Acknowledgements

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