EMPLACEMENT AND TUBE DEVELOPMENT IN LONG TUBE-FED LAVAS IN N QUEENSLAND. AUSTRALIA

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Abstract

Long tube-fed lavas that erupted in north Queensland flowed for distances of up to 160 km. They are basalts and erupted at temperatures around 1150° C, with normal basalt viscosity. There is no evidence of significant cooling down the flows, nor of much progressive crystallisation. Emplacement is held to have involved melt transportation in lava tubes, and some flows display extensive tube systems with lava caves. In some of the flows, the tubes appear to have remained filled. Most tubes appear to have been generated as subcrustal preferred pathways. Accessibility hinders fuller tube mapping, but geophysical methods hold great promise, including gravity and magnetic measurements. Seismic and ground-penetrating radar may also prove effective methods. Aeromagnetic surveys may provide new information about filled tubes in old lavas. Recently raised problems regarding flood basalt emplacement (such as for the Columbia River basalts) may also apply to the north Queensland long flows.

Introduction

A 4000 km-long belt of Cainozoic volcanic activity extends the full length of Eastern Australia (Figure 1). It is known as the Eastern Australian Volcanic Zone (EAVZ) and is reviewed by JOHNSON (1989). The EAVZ ranges in age from 70 Ma (late Cretaceous) to 4.3 ka (Holocene). In different parts of the EAVZ, especially in areas of young volcanism, lava caves are preserved. The nature and distribution of a number of the caves were described by WEBB et al. (1982).

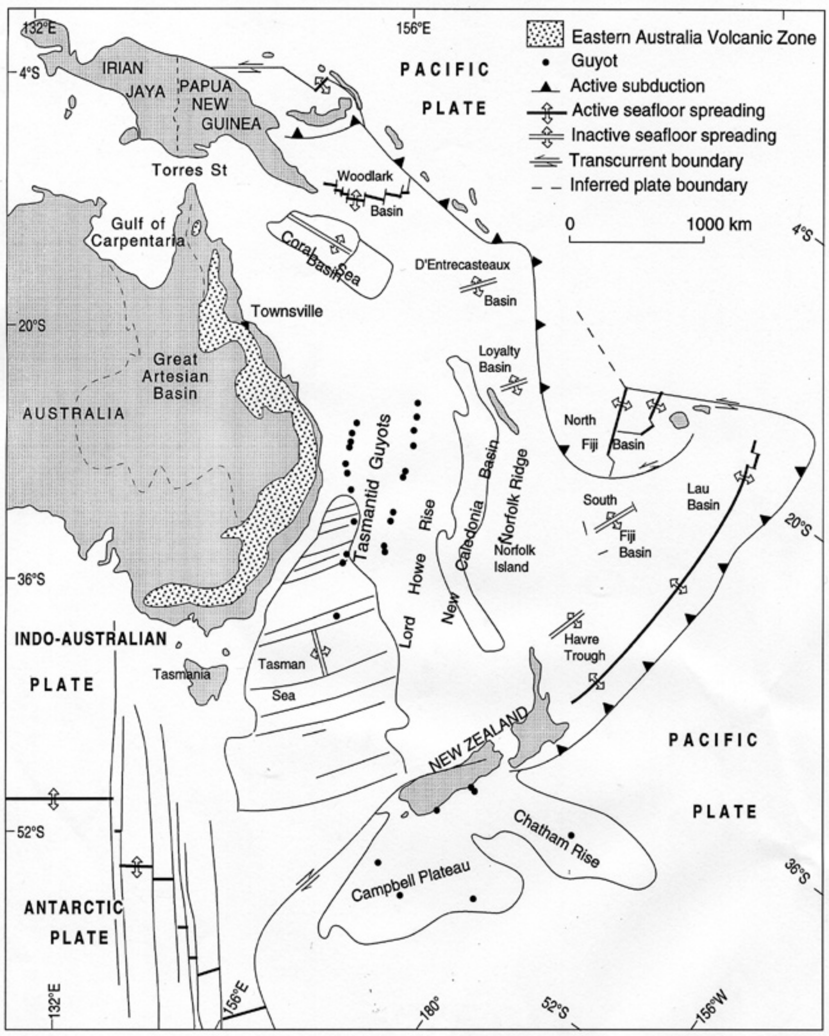

Fig. 1 - Cainozoic volcanic areas in Eastern Australia. The Eastern Australian Volcanic Zone (EAVZ) is dotted and extends for 4000 km. It is distant from plate boundaries (from STEPHENSON ET AL., 1998)

Most of the Cainozoic volcanic areas in north Queensland (Figure 2) range in age from 8 Ma to Holocene, but there was some earlier Cainozoic volcanic activity (from 44 Ma). Some of the younger lava fields contain extensive lava caves and it is likely lava tubes were very important in the emplacement of all the more extensive lava flows. Some tubes partially drained to form caves, but others which were more extensive remained filled.

This paper describes the style of basaltic activity in the north Queensland region, documents the occurrences of known lava caves and discusses the importance of lava tubes in lava flow emplacement.

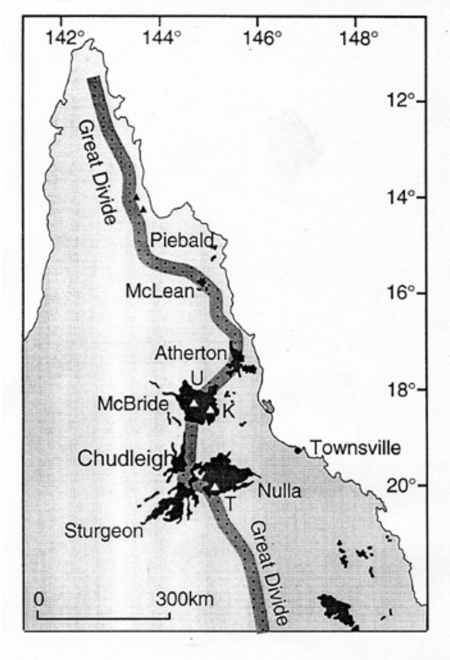

Fig. 2 - Cainozoic volcanic areas in north Queensland. The discrete areas are recognised as provinces and are all basaltic.

North Queensland Cainozoic Volcanism

The region contains a number of geographic areas containing Cainozoic volcanic rocks, referred to as volcanic provinces. Altogether 11 provinces occur north and inland from Townsville (Figure 2) and are all basaltic. Cainozoic volcanism in the region was reviewed by STEPHENSON et al. (1980) and STEPHENSON (1989). There are numerous volcanic centres in each province and age determinations indicate that sporadic activity has occurred, over periods of up to 5 million years. There have been no historic eruptions, but several provinces (Figure 2: Atherton, McBride, Chudleigh, Sturgeon and Nulla) are unlikely to be extinct. They show intermittent activity up until less than a million years ago. Age determinations indicate that although there have been concentrated periods of activity, the eruption centres were individual monogenetic volcanoes of relatively short eruption. There were long dormant periods (up to half a million years, or longer), before a new volcano erupted in the same province.

The volcanic regions have mild topography. Some provinces have radial drainage patterns and relationships suggest that very broad uplifts occurred shortly before the volcanism commenced. These uplifts are around 100 km across and rising up to 600 m. The central regions contain the volcanic centres, within oval-shaped areas 60 to 80 km long and 35 to 45 km across. The volcanic provinces do not appear to have been focused by exposed structural boundaries and they are not evidently controlled by bedrock geology. It is conjectured that lower crust or upper mantle structures determined their location, perhaps above small "plumes" in the mantle (STEPHENSON, 1989).

This paper will discuss those provinces which have known lava tubes (from the evidence of caves or of surface depressions interpreted to have been collapses). The essential characteristics of these provinces, (McBride, Chudleigh and Nulla) are summarised in Table 1. Lava caves may well come to be discovered in some of the other provinces of similar age. It is suggested that many lava fields in north Queensland are likely to contain numerous lava tubes which did not drain to form caves. Confirmation of these

Table 1. Summary details of three basaltic provinces in north Queensland which contain long lava flows and lava tubes.

	Area. km^2	Volume* km^3	Centres	Ages
McBride	5500	137	165	3 Ma-20 ka
Chudleigh	2000	50	46	8-0.2 Ma
Nulla	7500	187	46	5.2 Ma-13 ka

* Average thickness of 25 m assumed

filled tubes and further details of the recognised drained tubes will require indirect geophysical techniques for discovery.

Three volcanic provinces (McBride. Chudleigh. Nulla: Figure 2) These areas contain predominantly alkaline basalts. Most are hawaiites with less abundant alkali basalts and basanites, minor olivine tholeiites and rare mafic phonolite (as defined on the basis of their chemical compositions, using normative parameters; Johnson, 1989). A number of workers (eg. in JOHNSON, 1989; O'REILLY and ZHANG, 1995; and ZHANG et al., 1996) discussed the geochemistry and likely origin of the melts.

The provinces are broad constructional plateaus containing relatively thin lavas, usually from 5 to 30 m thick which flowed down low gradients in the landscape, commonly less than 2°. The lavas were typically captured by the natural drainage, flowing down depressions to reach and follow the drainage lines of dry stream courses and in some cases, sandy river beds. The evidence available suggests most were erupted during the long dry season. Water-interaction structures such as pillow lavas or hyaloclastites are generally absent.

The common volcanoes are broad lava shields with general similarity to Icelandic volcanoes. Some shields have summit craters. In a few instances, there is evidence of local fissure effusion. Some of the other volcanoes have steeper cones of pyroclastic or composite materials.

The surface structures of the lava flows has been examined to determine their pahoehoe or aa nature. This is difficult for older lava fields because weathering and erosion has lowered their surfaces and completely removed the original flow details. In some places, the nature of the lava can be seen where cave collapses permit examination of earlier flow units, as in the Undara lava flow (McBride Province). In the case of young lavas (such as Kinrara, McBride Province; and Toomba, Nulla Province), the original surfaces are very well preserved. Kinrara lavas are mainly pahoehoe, but extensive aa fields occur, especially near the volcano. Toomba lavas are almost entirely pahoehoe, with local aa areas and some more extensive aa fields near the volcano. Evidence in other lava fields in North Queensland indicates that pahoehoe was the dominant lava type.

Most of the lava fields have structures and morphology formed by inflation (melt injection beneath surface crust; WALKER 1991; HON et al, 1994). These structures include tumuli, broader lava rises, and lava rise ridges. Some of the lava rise ridges are up to 40 km long, 20 m high and 500 m wide, and are interpreted to have formed above river and stream channels (WHITEHEAD and STEPHENSON, 1998; STEPHENSON et al., 1998) Younger flows have crevasse-like clefts, some over 8 m deep. Although older lava fields have been affected by weathering and erosion, such that their surfaces have been lowered by more than a metre, lava rise topography formed by inflation can still be recognised in many cases. Many of the lava forms can be termed pahoehoe sheet flows and hummocky pahoehoe (compare HON et al., 1994).

The lengths of many of the lava flows are noteworthy, taking account of their estimated volumes and the very gentle topographic gradients down which they flowed. A "long" flow is nominally regarded here as more than 50 km and some examples are illustrated in Figure 3. Twenty long flows are known in the McBride, Chudleigh, Sturgeon and Nulla provinces. Three of these long flows were described by STEPHENSON et al. (1998), especially in relation to their likely emplacement. This study concluded the lavas had normal viscosity (12-105 Pas), erupted at typical basaltic temperatures (around 1150°C) and do not show evidence of unusually high eruption rates. Lava channels occur in only a few of the volcanoes, like Kinrara. The lava outpourings must have been continuous to sustain the progressive advance of the flows. It was probably important that there were no impediments to flow advance through the open savannah vegetation, that eruption was in the dry season and that there were natural pathways for the lavas down gentle drainage lines. The importance of lava tubes in the emplacement of extensive lava fields has been emphasised by many researchers, being seen as necessary to insulate the flows. The recent paper (STEPHENSON et al., 1998) referred to the modelling of temperatures of lava flowing in lava tubes by KESZTHELYI (1995) and by SAKIMOTO and ZUBER (1998) which concluded that very long lava flows can be produced with effusion rates of the order of 20-100 m^3 s^{-1}. These models can account for the very small differences in apparent lava temperatures which have been measured in specimens from near the flow source down the very long Gingko basalt flow in the Columbia River Basalt Province (USA), using geothermometry (HO and CASHMAN, 1997). A noteworthy feature of the long flows in north Queensland is that the basalt textures show little change from near the volcano to the flow terminus. Glass compositions have been analysed from the Toomba flow to estimate flow temperatures from various places from the volcano to near the flow terminus, and the results ranged from 1130° to 1155° and their scatter does not appear to confirm higher temperatures closer to the volcano (STEPHENSON et al., 1998).

Evidence for the presence of Lava tubes

A number of lava cave localities are known in north Queensland and are referred to below. Four of these were referred to by WEBB et al (1982) and it is to be expected that further caves will be discovered in other volcanoes in north Queensland.:

McBride Province

Undara (Figure 3 a) has been most thoroughly investigated. Its age has been measured by K-Ar as close to 189 ka (GRIFFIN and MCDOUGALL, 1975). There are three extensive lava tube systems: north, north west and west. Aspects of the caves were described by ATKINSON et al.(1975) and are very well illustrated by ATKINSON AND ATKINSON (1995). They were further discussed by STEPHENSON et al. (1998).

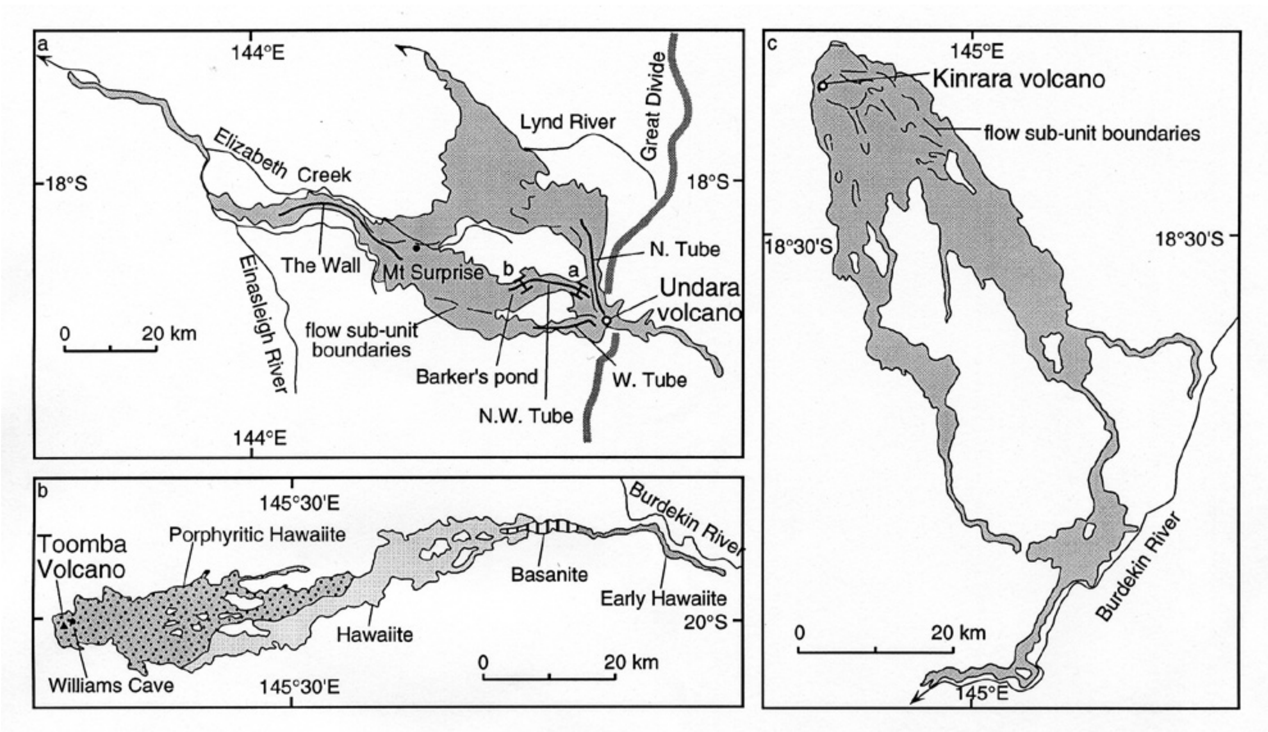

Fig. 3 - Maps showing the outlines of three long flow lava fields in the McBride Province. (From STEPHENSON ET AL., 1998).

a. Map showing the outline of the Undara lava field. Three lava tube lines are shown (N. Tube, N.W. Tube and W.Tube). The 40 km-long Wall is marked, west of Mt. Surprise. Some possible lava field boundaries are marked.

b. Map showing the Toomba lava field. This flow is composite, and four successive units are shown which can be distinguished on the basis of their phenocryst associations and chemical composition The distal part of the flow reached the ancestral Burdekin River and flowed down it.

c. Kinrara volcano and its lava field. The flows reached and flowed down the Burdekin River. Lava tubes occur south east of the volcano, within 6 km. Some likely lava field boundaries are indicated.

In 1988 Operation Raleigh, a young exploration group from the United Kingdom continued earlier exploration in the Undara lava field discovering a number of new caves, and a total of more than 60 are now known. The majority occur along the 30 km-long north west lava tube, and include the longest known caves, Bayliss (1.3 km) and Barkers (800 m).
The north lava tube appears to have formed after the north west tube. For much of their length the presence of the lava tubes is indicated by oval shaped depressions which have been referred to as "ponds', by analogy with lava ponds which occur on some of the Kilauea flows on Hawaii. These 'ponds' are conspicuous on aerial photographs, usually supporting dark vine scrub. The way in which these features were formed is uncertain - whether lava ponds (ATKINSON et al., 1975); lava-rise pits (WALKER, 1991; STEPHENSON, 1996); or generated in some other way (such as the rock rings described by KAUAHIKAUA et al, 1998). Their occurrence at Undara is along the lava tube lines, but they are found beyond the last known caves, suggesting undrained tube continuations. The relationship of some of the 'ponds' to the lava caves suggests they acted as a constraint to the later activity of the tubes which formed caves, which branch around or bypass the 'ponds'. The ponds themselves do not give access to caves. Cave entrances are usually found at the ends of narrower depressions which are probably cave collapses.
The Undara caves are usually of generous size, typical dimensions being 20m across and up to 16 m high. Most of the caves have a semi-circular roman - arch profile, with a lava-filled floor, but many are covered with later sediment which has caused the termination of some caves. Barkers Cave has profiles near its entrance which have elegant 'gothic-arch' shape, which may have been influenced in some way by the locally steeper gradient of up to 7°.
The caves carry typical ornaments, with well-formed linings concealing the near-horizontal layered lava behind. Level lines are common, from near the roof of many caves to the floor level, and seem likely to confirm progressive downward lava erosion (KAUAHIKAUA et al., 1998; GREELEY et al., 1998; STEPHENSON et al., 1998) rather than fluctuating levels in a lava stream. The thickness of cave roofs vary and in Barkers Cave it increases from 3 m near the entrance to 30 m, and the cave gets progressively deeper down its known 800 m, flooded by mud sediment at its apparent terminus (STEPHENSON AND WHITEHEAD, 1996).
The Undara lava field continues to the north and much further west, well beyond the last known caves. There are ridges interpreted as lava rise ridges formed by inflation above stream channels followed by the lava flows (STEPHENSON et al., 1998). The most impressive is "the Wall" which extends for 40 km and is 20 m high and up to 500 m wide.
Racecourse Mountain is 10 km west of Undara. It has a broad shield which contains several small caves and the larger Trimble Cave. Silent Hill. 13 km north west of Undara, has one inconspicuous vertical shaft and is a multiple-level cave system. Both these volcanoes are older than Undara.
Kinrara (Figure 3 c) is a volcano 30 km south east of Undara. It is a much younger volcano (~20 ka) and has well-preserved lava fields with pahoehoe and aa surfaces. It contains several tube systems south east of the volcano and a number of its caves were discovered and investigated by STANTON (1993). Brief descriptions are given in STEPHENSON et al. (1998), as a complex system of drained tubes up to 6 km from the volcano. These caves have a height of 8 m and have very well preserved flow features.
Mt. Joy and Murronga are volcanoes 8 and 13 km south of Undara. They are younger than Undara but over 100 ka. They are known to contain cave systems.

Chudleigh Province

Barkers Crater has a 5 known lava caves, with a total length of 250 m and a maximum height of 10 m and width of 15 m (SHANNON, 1974). There is also an impressive lava rise pit north west of the volcano's crater, with no tube caves leading from it.
Black Braes is 25 km to the west, where there are two craters. The western crater has 7 caves near it (GRIMES, 1978) ranging in size from a large cave 300 m long, 20 m wide and 7 m high. Grimes

described a number of shallow, irregular depressions which he suggested may represent lava ponds.

Nulla Province

Toomba (Figure 3b) is a well-preserved young volcano (13 ka) with lava fields extending 120 km to the east in a relatively narrow flow field. There are numerous small caves on the slopes of the volcano. Williams Cave is situated 4 km north east of the volcano. It is not much more than 100 m long but is interesting in having developed 3 levels. A new cave, Kelly Cave, has been recently discovered 15 km east of the volcano from a helicopter but awaits full exploration and mapping.
HATHEWAY AND HERRING (1970) suggested that a flow gradient of 0.5° is required for lava tubes to drain and form caves. This limit seems to account reasonably well for the occurrence of lava tube caves down the tube lines at Undara (STEPHENSON et al. 1998) and also at Toomba, where no caves have been found in the main part of the flow (gradients 0.4° decreasing to 0.1°).
Although no lava tube caves have been confirmed in the main parts of the Toomba flow, evidence indicates that subcrustal conduits must have been active. Inflationary lava rises over much of the flow suggest this (STEPHENSON et al., 1998 Figure 6), as do numerous pits, some over 60 m across and close to 20 m deep (STEPHENSON AND WHITEHEAD, 1996). Long, very wide lava rise ridges were formed in the last 15 km of the flow, where it reached and flowed down the Burdekin River (WHITEHEAD AND STEPHENSON, 1998).

Formation of Lava Tubes

The different ways in which lava tubes form have been well documented in active lava flows in Hawaii by different workers (referenced by KAUAHIKAUA et al., 1998). Many of the earlier observations on Mauna Ulu tubes were made near the vents on a moderately sloping surface and confirmed details of roofing-over of lava channels by crust growth, levee accretion and crustal raft aggregation.
OLLIER AND BROWN (1965) postulated that some lava tubes developed as subcrustal features within layered lava (multiple flow units) with diameters many time greater than the thickness of the layers. OLLIER (1988) quoted the following statement from Hatheway and Herring (1970): The lava tubes .. appear to have been formed by the development of mobile cylinders of lava in a cooler, more viscous host rock. These cylinders transported fluid lavas, to the toe of the flow as long as the source provided a continuous supply. When this ceased, the tube probably drained rapidly.' A similar subcrustal formation was deduced for some of the active tubes in Hawaiian pahoehoe sheet flows (HON et al, 1994) and detailed by KAUAHIKAUA et al. (1998).
CALVARI and PINKERTON (1998) confirmed that lava tubes on Mount Etna play a more important role in the formation of extensive aa flow fields than had been previously recognized. These tubes, which have been further described by CALVARI (1999), formed initially on distal parts of arterial flows where they encountered a reduced ground slope. Some tubes developed Systems more than 7 km long.
It is difficult to interpret how the tube systems originated at Undara from their final configurations which developed under progressive change. Cave details are certainly dominated by late-stage lava accretion, after an active history involving downward erosion (GREELEY et al. 1998; KAUAHIKAUA, 1998; STEPHENSON et al., 1998). Originally, the details in lava cave entrances at Undara were studied and interpreted (in Atkinson et al. 1975) as evidence for roofing of lava stream channels but re-evaluation confirms this evidence is uncertain. Cave entrance details could equally be seen to show that the tubes began as subcrustal, 'mobile zones' which appear to have increased in diameter and eroded across the 'layered lava' host basalts seen beyond the cave lava linings. On balance, this is the tube formation preferred for Undara. All the evidence suggests the Undara lava tubes developed in pahoehoe lavas, and this was also the case at Toomba.

The relationships of the tube lines at Undara suggest that they may have been active in the last stages of flow activity. They occur in proximity to the highest central line of the lava fields, and they appear to have been active later than the lava processes originating the "ponds" (STEPHENSON et al., 1998). There are some shorter lava tubes (evidenced by caves) near the southern edge of the Undara lava field. These tubes would appear to have been active much earlier than the main lava tubes. It is possible that older tube systems exist in all the lava fields, buried by the latest lavas.
Evidence was given from studies of the three long flow examples (Undara, Toomba, Kinrara; STEPHENSON et al. 1998) that each of their lava fields is composite. This is most easily seen in Toomba, where at least 4 lava units are apparent from differences in the sizes, abundance and association of different phenocrysts. The later Toomba lavas completely bury earlier ones, but did not flow as far as them, so that some units have only been recognised in their distal regions. Flow emplacement may well have involved successive tube systems which are concealed beneath the later units.

Detection of Lava Tubes

Lava tubes were first recognised on Hawaii through the occurrence of skylights above lava caves containing running lava. The existence of lava caves confirms the presence and course of drained lava tubes. At places like Undara the accessible lava caves confirm the dimensions of the active tubes, but raise numerous unanswered questions. Why do some relatively large caves attenuate or terminate unexpectedly? In particular, did known accessible caves really connect as parts of the same tube system? The recurrence of large caves down the northwest tube line at Undara strongly suggests this, but there are many sections several km long between some caves, in which no accessible caves have been discovered.
How can the presence of inaccessible caves be confirmed? Several methods may be applicable in detecting large cavities beneath the surface, apart from drilling, such as the following surface geophysical methods: seismic; magnetic; conductivity; gravity; and ground-penetrating radar.
Magnetic investigations have been made across several known Undara caves. Some of the results hold promise, but measurements indicated considerable fluctuation in measured intensities (Figure 4). It has not been fully confirmed why some segments have smooth variation, interrupted by more variable intervals, some of which may be associated with lava tubes. Some lava caves have a lava lining (tens of cm thick, and in places much thicker) and in places these basalts contain strongly oxidised olivines (eg. ATKINSON et al., 1975). Perhaps subcrustal parts of the flow contain other varied magnetic zones (such as vesicular crusts), as well as larger cavities.

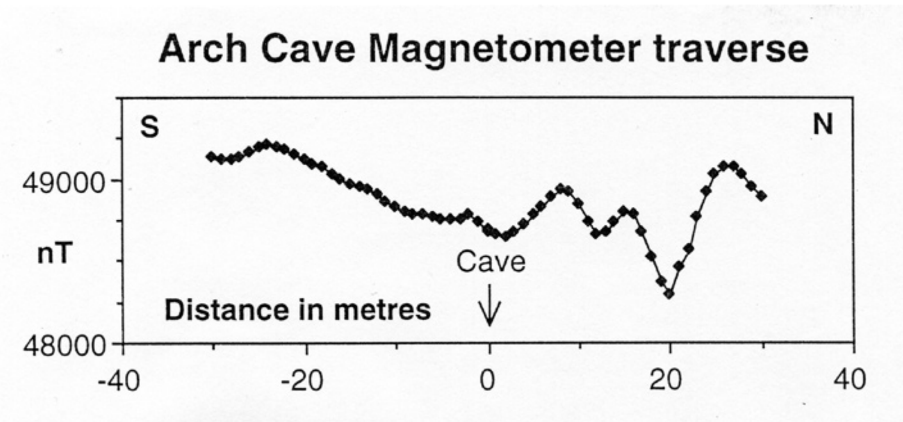

Fig. 4 - A magnetic profile across Arch Cave, Undara lava field. The known position of the 30 m-wide cave under the surface is shown.

Conductivity measurements were undertaken at Undara by SAM et al. (1996), using electromagnetic induction (EMI) technology. A transect over Road Cave showed a significant reduction in conductivity over the cave. Transects over Barkers Cave, which is smaller in diameter showed inconsistent, anomalous readings, but the general ground conductivity was very low around this cave in 1996 which was a very dry year. Although the EMI method was apparently able to detect some tubes, other surface targets also gave low apparent conductivity readings. These targets were presumably unweathered bedrock which often has very low conductivity. The lack of conductivity contrast between the cave and the surrounding rock thus places a major limitation on the use of the EMI technology. When ground conditions are wetter the situation would be improved. Further, water and moist sediment-filled caves would represent a very high conductivity target and may be easier to detect. The EMI instrument was also used to measure the thickness of high conductivity moist sediment inside Road Cave. The sediment thickness varied between 3 and 4 m in the first 50 m from the entrance and increased to 8 m at the rear approximately 90 m from the entrance. The conductivity of the top layer increased from 40 mS/m to 50 mS/m in the first 50 m and then decreased to about 30 mS/m at the rear. The bottom layer, presumably basalt, had a conductivity of less than 2 mS/m.
Gravity measurements were carried out at Undara in August 1999. The researchers (M.A. Sexton and R.G Hill, personal communication) used a gravimeter with a sensitivity of 0.02 mGal at stations 10 metre apart along three linear traverses. Elevations were accurately measured with an EDM theodolite. Corrections were made for time and altitude to obtain residual Bouguer anomaly profiles. Two of these were made above known caves:
Arch Cave, and Road Cave 90 m from its entrance (where the conductivity studies referred to earlier indicated thick cave sediments). Each profile was measured 150 m each way from a point near the cave axis. The results (eg., Figure 5) clearly indicated the presence of the caves, with local Bouguer anomalies of 0.6 and 0.25 mGal respectively. A third traverse was made across ground 100 m further up the flow from the collapse depression at Road Cave, suspected to conceal an inaccessible continuation of the cave.

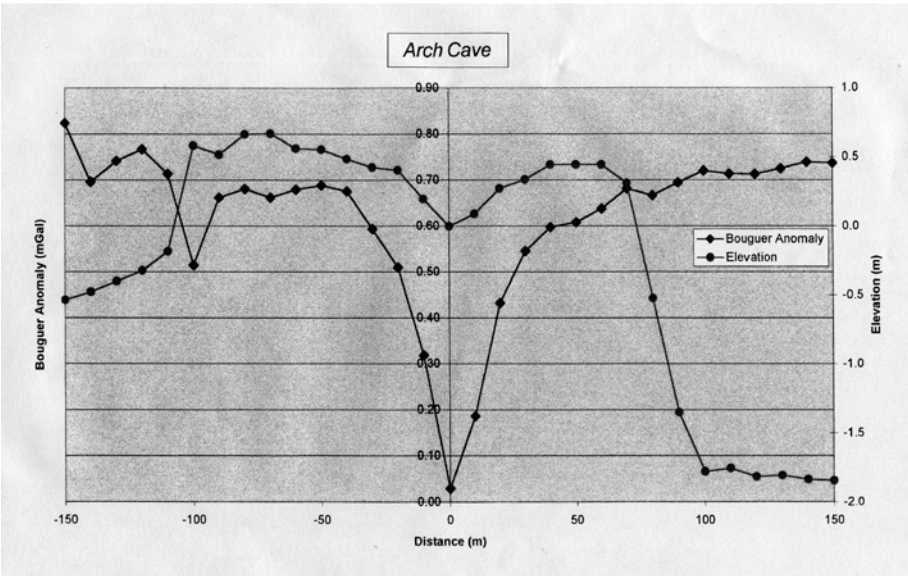

Fig. 5 - A gravity profile measured across Arch Cave, Undara lava field.
The minimum accurately indicates the cave position.

The measurements along a 250 m traverse also clearly demonstrated the presence of a cave, with a 0.17 mGal anomaly. Thus gravity measurements hold strong promise for revealing a variety of hidden details of lava tube cave systems.

The other surface methods suggested, seismic and ground-penetrating radar, have not yet been undertaken at Undara. Similar geophysical experiments could be undertaken at Toomba, but over somewhat rougher, more thickly-vegetated country with more remote lava caves.
Certain airborne geophysical methods may be capable of detecting lava tubes, drained and undrained. Thermal techniques are well established for tracing active lava tubes. Airborne magnetometer methods may be capable of delineating ancient tube systems. No results are known over lava caves, but several districts including Undara and Toomba have produced magnetic anomaly patterns over lava fields believed to contain undrained tubes. An example (provided by Normandy Exploration, Townsville) is shown in Figure 6, showing part of the Toomba lava field 20 km from the volcano where there are no known caves and the generally low lava gradient (0.3) may not have resulted in drained tubes. The anomaly patterns shows several narrow tube-like ribbons up to 15 km long which have configurations resembling lava tubes, though the anomalies are wider (100 to 300 m). Less distinct anomalies can been recognised in aeromagnetic surveys of some areas of Undara basalt, in the Mt. Garling survey (Normandy Exploration, Townsville).

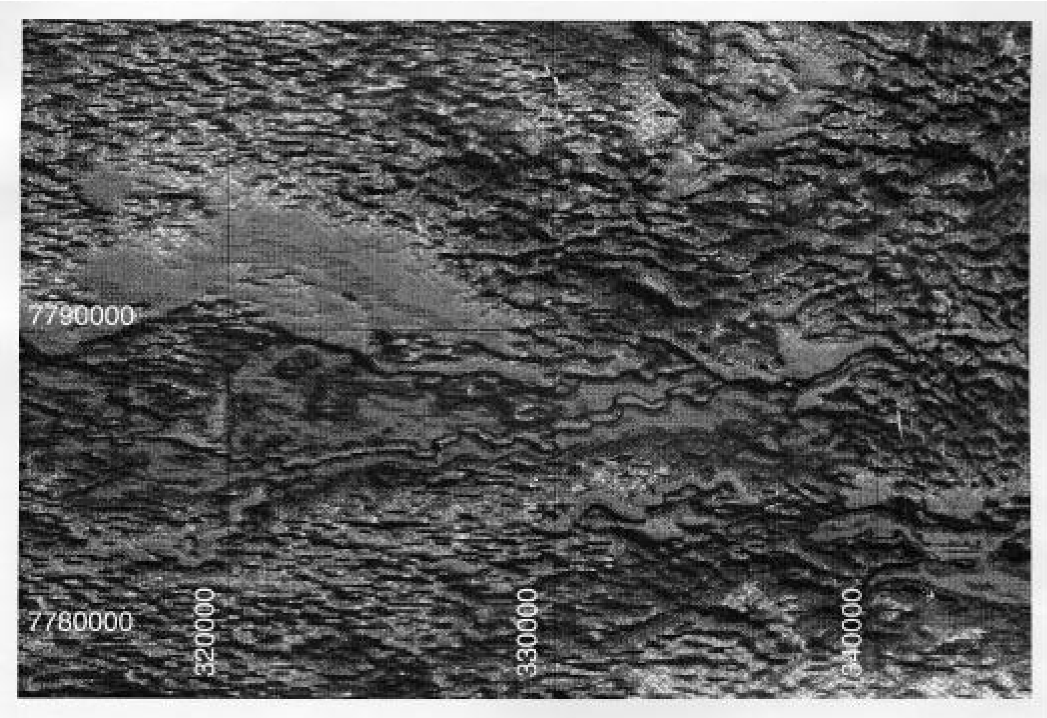

Fig. 6 - Airborne magnetic map of part of the Toomba lava field, 20 km east of the volcano. The high magnetic anomalies have geometries suggesting lava tubes. Lava caves are known closer to the volcano. The grid shown has a spacing of 10 km (Australian Map Grid).

Conclusions

Long lava flows extend for distances over 50 km and up to 160 km in north Queensland and some are known to contain lava tube systems. Individual tubes can be traced for up to 30 km from caves. They are believed to extend much further beyond the last known caves as undrained tubes. It is suggested that lava tubes provided the essential mechanism for transporting the lava in flow emplacement. Lava crust inflation was developed in most parts of the lava fields, forming an array of tumuli, lava rises and lava rise ridges, fed by a complex tube system.
To confirm the existence of such a complex of tubes, more information is needed to delineate systems in better detail than from known, accessible caves. Surface and airborne geophysical methods may prove successful in this exploration.

For longer flows, if tubes really do provide the essential lava transportation, a fuller knowledge of complete tube systems may help address some major questions. For example, how is a major, artery-like tube network sustained during the progressive emplacement of a long lava flow? This seems paradoxical, when only relatively short, disconnected cave sections are now accessible in extinct flows like Undara or Toomba. Likewise, the actual temperatures of the north Queensland long lava flows call for more careful study, especially in relation to the apparently slow cooling and minor crystal growth which seems to have occurred down the flows. Such details are closely relevant to the major problems raised by ANDERSON et al. (1999) about models for the emplacement of major lava floods like Columbia River Basalts on Hawaiian-style inflated flow mechanisms. The north Queensland flows are closely similar to those in Hawaii, and the severe difficulties raised by ANDERSON et al. (1999) for CRBs may also be seen to apply to them.

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