tional authorizations and assistance on Lanzarote were kindly provided by D. Jose Ramirez Cerda and D. Antonio Alvarez Rodriguez, president and vice-president of the Cabildo Insular, and by D. Serafin Martin Rodriguez of Arrecife and D. Aquilino Rodriguez of Haria.

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ORIGINAL CONTRIBUTIONS TO VULCANO-SPELEOLOGY FROM ICELAND

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The study of Icelandic lava caves by members of the Shepton Mallet Caving Club began in 1969 in preparation for the club's 21st anniversary expedition to Raufarhólshellir, the famous lava tube cave in the south-west of the island. As a result of the preparatory bibliographic work and the experience gained in the field during the 1970 project, research has continued in the compilation of a comprehensive bibliography of Icelandic lava caves, in the improvement of the accuracy of cave surveying in basalt terrains, and in the improvement of geological field techniques. This paper traces the lines of research which this group has followed in the study of Icelandic lava caves, and discusses future plans of research which are based tentatively upon a new model of lava tube evolution.

ICELANDIC CAVES AND CAVE EXPLORATION

In order that considerations might be given to the area in which the group would cave in the summer of 1970, a bibliography was compiled by one of us (M.T.M) and this now much expanded has allowed a map to be compiled of the location of cave sites in Iceland. It must be remembered that the cave sites mentioned here are those recorded in the literature and as such do not represent a complete picture. The majority lie in post-glacial basaltic lava flows and it is in some of these enormous expanses of unexplored lava that future discoveries would seem inevit able.

Examination of the literature of known caves provides an interesting study concerning their age and the history of cave exploration. Some references to Icelandic caves may be traced to the saga period of the twelfth to the fourteenth centuries. The sagas are also of great importance to the vulcanospeleologist in that they contain records of volcanic eruptions which help to date lava flows. The Völuspá, a Sibylline poem descriptive of Scandinavian mythology, and the Daemi-

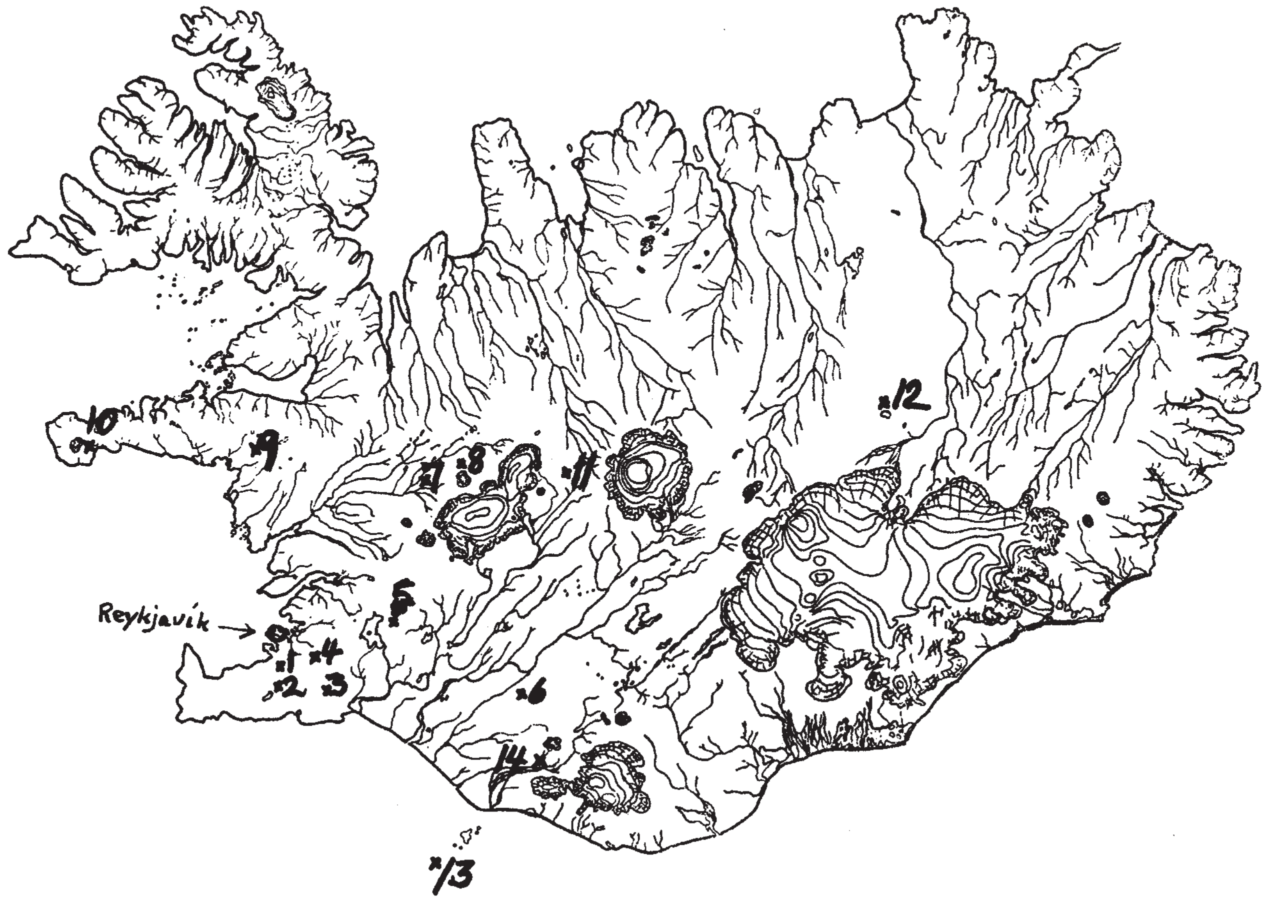

Figure 12-1: Location of well known lava tube caves of Iceland, courtesy Dr. Gudmundur Kjartansson.
1. Several small caverns south of Hafnarfjordur.
2. Daudalier, a group of closely spaced small caverns.
3. Raufarholshellir.
4. Narrow tube under the main road.
5. Gjabakkahellir.
6. Karelshellir, a 133-meter tube in a lava flow formed by the Hekja eruption of 1947-'48.
7. Group of three large lava tubes, Surtshellir, Stefanshellir and Vidgelmir, and some smaller ones.
8. Halmundarhellir.
9. Several tubes found in 1957 in the lava flow Gullborgar hraum.
10. Vegamannahellir, found in 1963.
11. Grettishellir.
12. Small tubes in the Askja lava, formed 1961.
13. Several tubes in the new lava of Surtsey.
14. Mogugilshellir, not a real lava tube, formed in an intrusive vein.

saga mention Ragnaröckr in Snorro's Edda in connection with Surtur, the black prince of fire after whom Surtshellir was named, and the Sturlunga Saga recalls the bandits of Surtshellir. Surtur and Surtshellir are also recorded in the Holmverja and Landnama sagas. The underground dwellings of Surtur was part only of the cave of the Fire Giant, which was said to stretch across the whole of Iceland. An outlaw is thought to have found his way into the cave and to have walked through it for a long time in pitch darkness, and when he came out at the other end his shoes were full of gold with which he purchased his freedom. Such enchanting stories are associated with more than one Icelandic lava cave.

In more recent times the caves were most written about following visits by European Victorian explorers and travellers. Hooker's records, for example, are typical: 'Journal of a tour in Iceland in the summer of 1809'. Some were women who crossed hundreds of miles of Icelandic country on horseback, and one can almost imagine their determination to visit those wonderfully inaccessible places of the Icelandic interior: 'Journey to Iceland: and travels in Sweden and Norway' by Ida Pfeiffer was written in 1852. 'Iceland: Its scenes and sagas' was written by Sabine Baring-Gould in 1863. Although many of these works are beautifully written and produced, they

Figure 12-2: 1860 representation of the entrance of Surtshellir, from Forbes' Iceland: Its Volcanoes, Geysers and Glaciers.

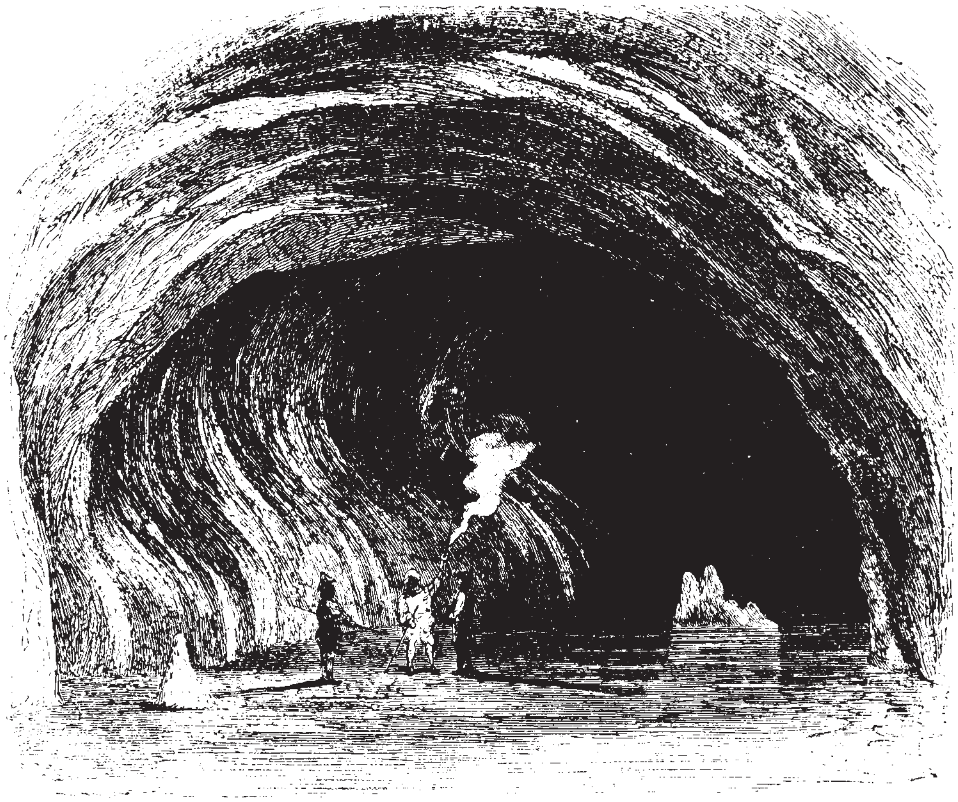

Figure 12-3: Sketch of main passage of Surtshellir from Forbes' Iceland, Its Volcanoes, Geysers and Glaciers.

Figure 12-4: Cross-section of wall of lava tube ("The Church") at Myratn, north Iceland; a postcard view from the Halliday collection.

generally lack details of the location of speleological features mentioned in the text. Exploration of the lava caves was usually by candle light and Icelandic guide, the women in skirts, and it is difficult to envisage how such beautiful and accurate engravings of the caves could have been produced under these conditions, particularly as many Icelandic caves are covered with ice and snow.

Generally, the maps of the Geodetic Institute of Copenhagen have been found most useful in locating cave sites, though many await confirmation and detailed description. Most recently there are a few caves which have been described by modern Icelandic vulcanologists such as Einarsson and Thorarinsson. One lava tube cave was actually observed forming during the eruption of Hekla in 1948.

To describe the caves as lava caves is a generalization and several different forms may be readily identified. The famous fissure Grjotagjá, for example, is noted for its 260m of cave passage, much of which holds water at a temperature of 105.5°C, and provides a swimming place for visitors to the Lake Myvatn area. Caving under such conditions has been found to be extremely strenuous and dangerous. Sea caves in columnar basalt are mentioned in the literature at Stappen and Cape Dyrholar, while a variety of smaller cavitites associated with pahoehoe lava flows have been described from numerous localities. In many caves evidence has been found that suggests that they were used for human habitation.

The large and more important lava tube caves are numerous and it would not be unreasonable to say that most Icelandic pahoehoe lava flows possess larger or smaller spelean features. It would be tedious to record the geographical distribution of these features here. Suffice it to say that one of us (M.T.M.) has found references to locations of over 30 lava tube caves, none of which have been explored in any great detail. As one would expect, many of these features are located in the more densely peopled regions such as the Snaefells peninsula, mid-west Iceland, south-west Iceland and the Reykjanes peninsula. There are, however, vast areas of basalt in Iceland which are completely unexplored by the speleologist, such as the enormous expanse of the Odádahraun and the region around Lake Myvatn in the north-east of the country.

THE GROWTH OF SCIENTIFIC THOUGHT ON THE EVOLUTION OF LAVA CAVES

It is interesting to trace historically from the references the lines along which scientific thought developed on the origin of Icelandic lava caves. The earliest reference so far traced with any suggestion of a possible mechanism to explain the origin of lava caves is that provided by Kant who, in his 'Physische Geographie' of 1803 recorded of Surtshellir that 'one can almost not quite believe it, that this cave is made from a river of molten lava, which has built a way through the mountain'. The inference that the molten lava had melted its way through the hillside was greatly expanded by Olafsen & Povelsen who visited Iceland in 1755 and 1801. In their discussion concerning the origin of Surtshellir, they have much to say of lava stalactites and the glaze lining the cave, and they held these as 'certain proof of subterranean fires, and that the lava, in a state of fusion, has passed like a rivulet through this channel, while it began to cool on the sides and the top of the cavern'. They noted additional proof that 'the whole of these caves had formed by the melting or dissolution of stones', but that constrictions in the cave passage were the result of more resistant rock.

In 1810 Mackenzie's visit to Iceland resulted in his 'Travels in the Island of Iceland', in which he introduced the term 'cavernous lava'. He had noticed during his travels through south-west Iceland that there were two distinct formations of lava. One of these gave the appearance of not having flowed, it having been heaved up into large bubbles or blisters, round to oval in shape, and from a few meters to 10 or 15 meters in diameter. He termed this lava 'cavernous' due to the fact that a great many of the bubbles had burst to reveal caves of considerable depth. Mackenzie concluded that this lava may have been formed by heat at depth melting the rocks in situ, or that the lava had been erupted beneath water, causing it to blister. He noted that near Mt. Hekla the lava was covered by sand and gravel, affording evidence of the sea having once been upon it, though today such deposits may be regarded as pyroclastic and glacial. Indeed, Mackenzie's descriptions of seas of lava which consisted of waves and domes is a description of a typical pahoehoe surface, many of the waves being pressure ridges and many of the domes being tumuli.

Extension of the blister hypothesis persisted in the literature even until 1902. Both Bisiker and Baring-Gould postulated the origin of Surtshellir as a chain of gas bubbles. Bisiker suggested that such a formation was helped partly 'by a crust of lava being forced upward in the form of an arch by pressure acting from the sides '. Furthermore, he was certain that the cavern had been deepened and enlarged by the eroding action of flowing water, for along the sides of the caves were found numerous water-worn lines, indicating different levels of the old river.

Henderson was one of the first to suggest in 1818 that lava cave formation was the result of the conge lation of a crust upon the lava flow: 'the sides of the cave, run into vitrified horizontal stripes, that appear to have been formed by the flowing of the stream of melted stones, while its exterior parts have been cooled by their exposure to the atmosphere'. Dufferin in 1857, Burton in 1875 and Chapman as late as 1930, suggested that this mechanism of cavern formation, followed by roof collapse, resulting in the formation of the huge tectonic rifts which disect Iceland, such as the Almannagjá at Thíngvellir. Paijkull in 1868 noted that the large dimensions and complex forms of lava caves could not be explained by blistering of the flow, and if this had been the case the roof of the cave would have been arched above the surface of the flow. Instead, he favoured the congelation of the surface and the draining of the underlying mass of fluid lava. With the exception of Lloyd Morgan all other references to lava cave evolution followed this traditional concept.

Lloyd Morgan proposed in 1919 an hypothesis which involved the entrapment of snow in a ravine, which subsequently became buried by lava, as an explanation of lava cave evolution. The ice and snow was not melted, but during the following warmer climate (i.e. post-glacial) the loss of the snow and ice from the ravine left a cave beneath the lava. That the cave had been cut by a stream was indicated by 'all the familiar evidence of water action on the sides', and it is clear that Lloyd Morgan* was mistaking lava flow features for water worn features. The probable reason for the ice remaining beneath the hot lava, he suggested, was that a layer of volcanic dust, whose ulterstices were filled with steam, was formed on the upper surface of the ice.

Corbel modified the traditional hypothesis of lava cave evolution after visits to Icelandic lava caves in 1955. He was the first to attempt to account for tributary passages: 'The flow of the lava cooled more rapidly on the surface, solidifying higher up while those parts below remained fluid and continued to flow. The lava which is fluid, being no longer fed from upstream continues to flow under the solid crust of the surface, thus producing a void. This is the origin of the central tunnel. The void is in turn a point of discharge for pockets of lava which are still fluid on the sides. These flow into the tunnel. The emptied pockets are the origin of side galleries'. Apart from several cave studies by Icelandic geologists, which are in the process of being translated, and apart from the work of a Spanish team which reputedly examined thirteen Icelandic lava caves in 1968, but whose report is still awaited, no other modern work had been completed in Iceland prior to the Raufarhólshellir study of 1970.

TECHNIQUES USED IN THE MEASUREMENT OF ICELANDIC LAVA TUBE CAVES

It is astonishing that geological thought on the evolution of lava tube caves has advanced very little since 1818, not only in Iceland, but through-out the world. The traditional model has been modified somewhat to include the formation of small tubes in pahoehoe toes, and an internal feeding system in pahoehoe flows is envisaged by Hawaiian geologists to consist of a complex of minor distributary tubes which branch from one or more larger feeder tubes. Yet, although this seems to be a sound hypothesis, based upon observations on the surface and at the advancing front of active pahoehoe flows, and observations of cross-sectional structures of ancient flows, workers have found difficulty in reconciling the model with forms of lava tube caves they have met with in the field. Halliday has pointed out in 'Caves of Washington', for example, that 'As a group, these tubes do not seem entirely in accord with the traditional concept of these caves as simple lava conduits with distal ramifications'. In a similar fashion Ollier & Brown in their survey of the lava caves of Victoria, Australia, have noted that the traditional model of lava tube evolution 'does not account for all the observed shapes and structural features encountered in lava tubes'. They proposed a more elaborate explanation of laminar flow, which was based upon recognizable structures within the flow and the caves. Although a stimulating hypothesis, however, there are several difficulties with the concept of laminar flow and layered lava as a prerequisite to lava tube cave evolution: a) it has been argued elsewhere that the detailed description of layered lava given by Ollier & Brown would also well describe the structure of a flow composed of superimposed flow units which were observed at an exposure which was longitudinal to the direction of flow (i.e. , not cross-section); b) it has also been argued that the liquid lava which is confined between laminae must have lost much of its original heat and therefore its capacity to erode solid lava; c) it is difficult to envisage a horizontal arrangement of laminae and shear planes in a lava flow, rather than a concentric arrangement of these features. Poli, in his description of the lava caves of Mt. Etna, Sicily, envisaged a lava flow to constitute many successively enclosed cylinders of lava whose viscosity increased outward, thus retaining a central liquid core.

It is our contention here that it has been difficult to reconcile the traditional model with the wide diversity of lava tube cave morphologies met in the field, because inadequate care has been taken in establishing the flow structure, the cave morphology, and the topographical environs in which cave formation is induced. Ollier & Brown have pointed the way to more detailed examination of lava tube caves, and the study can be recommended for its detail in scientific method. It was primarily due to the fact that no model could satifactorily explain the evolution of complex lava caves, that a determined effort was made in the study of Raufarhólshellir to establish a

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* and E.-A. Martel (W.R.H.).

standard in methodology upon which other such studies by us could be based, in the hope that a new model would be constructed. Of greatest interest was the upgrading of cave surveying in basalt terrains. The surveying programme is regarded by us as the most important single contribution to cave research, for it is not only essential to establish the form of the cave which is undergoing study, but also to understand the morphology of the flow surface so that some relationship between the two may be ascertained. The survey of lava tube caves can therefore be divided into two units--surface surveying and cave surveying, the two being linked at primary survey points at collapse holes.

Study of geological literature prior to our visit to Iceland suggested a strong possibility of there being magnetic anomalies in areas of basaltic lava, but in all previous accounts of surveying lava caves this had been ignored, and corresponce with persons from the U.S.A. and Spain who had carried out such surveys produced the information that, although this interference was appreciated, it had not been investigated, and magnetic surveys had been used because of time considerations.

A preliminary closed traverse was therefore made from the entrance of Raufarhólshellir, along the first 100m of cave passage, out through the last collapse hole and back over the surface to the entrance. Both magnetic and theodolite bearings were taken, and on calculating the results it was found that the theodolite traverse had a 0.84% misclosure, and the magnetic traverse failed to close by 6.24% (as compared with less than 0.5% which would have been expected in a limestone cave). Forward and backward compass bearings had been taken along each survey leg and were found to differ by up to 16.5' (as compared with less than 2' which would have been expected in a limestone cave). Three subsequent magnetic and theodolite closed traverses confirmed that the above results were typical, and provided data for further research. In view of our findings it was decided that the survey of Raufarhólshellir would have to be based upon a theodolite traverse to obtain maximum accuracy.

The survey comprised a simple (i.e., not polygon) traverse made with a tripod mounted simple cave theodolite, comprising an abney level read to the nearest 0.5' and a 15cm diameter horizontal circle that was graduated to 0.5', but read to the nearest 0.25' by estimation. The distances were measured with a 30m 'Fibron' tape to the nearest 1.5cm, and never did the distance between stations exceed the length of the tape. At every survey station distances left and right to the passage walls, to the instrument and roof heights, and where possible the height of the highest point of the original tube glazing, were also recorded. Sufficient measurements were taken to enable representative cross-sections to be drawn of the cave passage; the location of approximately half of these were chosen to illustrate geomorphological features which were measured in much greater detail.

The survey was plotted roughly in the field and a copy of this plot was taken into the cave to check for gross errors and the plotting of passage detail between stations. The measurement of the height of tunnel glazing meant that'an estimated line of the original tube roof' could be plotted on the extended section of the cave. This gave a good indication of the amount of breakdown that had occurred in the cave. From the survey measurements, the rectangular co-ordinates of each survey station was calculated and the survey plotted from these. No closed traverses were surveyed entirely within the cave and estimations of the accuracy of the resultant survey are based on the results of the four experimental closed traverses, but it was expected that the error in the position of any point in the cave as shown on the survey would be less than 2% horizontally, and 0.2% vertically, of the traverse distance from the cave entrance to that point.

The bearings between survey stations and the horizontal equivalent of the slope distance between each were repeated using the cave theodolite on the surface of the lava flow, commencing from the same cave survey station at the entrance. Thus the line of the cave below ground was traced upon the surface, and with a theodolite and staff the relative levels of the cave survey station positions on the surface were found, from which, by plotting these on the extended section, the position of the cave in relation to the flow surface could be ascertained, and also the thickness of the roof. This was the principal project of the surface surveying programme, but the measurement of a profile down the lava flow for 3km from the cave, and also the determination of the magnetic declination at the cave entrance, were also carried out.

It was found by us that the position the lava tube cave occupied within the flow, and relative to the vent, was of great significance. The cave was found to be situated 10km below the fissure from which the flow was extruded, in a part of the flow which was constricted in a narrow valley, and was located immediately above a part of the flow which had a rapidly steepening gradient.

TOWARDS A NEW MODEL OF LAVA TUBE EVOLUTION

As we have noted above, any model of lava tube evolution must be based soundly upon the relationship of the cave morphology and the structure of the lava flow. It was found at Raufarhólshellir, that there was a direct relationship between the confluent form of the cave and the flow unit structure of the parent flow, for the smallest tributary tubes were discovered to be the drained cores of single flow units. Working then upon the basis that each flow unit represented a potential small lava tube, evidence was found to suggest that the larger tube forms had originated by the coalescence of the drainage channels of adjacent and superimposed units. The consequent elimination of the crusts of the flow units was thought to be the result of erosion and remelting by the lava stream, which at that time was still in direct contact with the vent. Although the origin of the main tube was not as fully established as that of the tributary tubes due to the considerable amount of breakdown, it was believed that this too had a similar mode of formation, and loop tubes were flow unit meanders which had been truncated by the lava stream of the main tube.

Although only a single, isolated study which needs confirmation, this model of the origin of Raufarhólshellir can be reconciled with the traditional concept of lava tube evolution. Let us speculate with the information that is available.

Lava tube caves may be sub-divided on the basis of morphology into simple and complex varieties. The simple or 'unitary' form, as Dr. Halliday has termed it, is unbranching, sinuous, elongated and generally uni-level in character. It is frequently of considerable length. Some may extend for over 10km. The Cueva de los Verdes, for example, is considered by Bravo to be 10.8km long if its collapsed portions are also considered, while a greatly collapsed cave of unitary form stretches through the length of the youngest lava flow of the Saddle Butte area, Oregon, and has been noted by Ciesiel and Wagner to be 13km in length. Furthermore, it is a general characteristic that caves of unitary form are more likely to have a source actually at the vent than caves of more complex morphology. The lava tube caves of more complex form range from confluent to anastomosing varieties, and some are particularly noted for their multi-level developments. The majority of these caves have a source which is situated a considerable distance from the vent. Our studies at Raufarhólshellir have shown that the cave is located 10km below the fissure from which the lava was extruded, and at Surtshellir/Stephanshellir, one large lava cave system of complex anastomosing form, a similar situation was found by us, with the cave located 26km below the vent.

Lava tube caves of unitary form are explained by the traditional hypothesis and appear to be the product of single unit flow. Nichols has suggested that flows emplaced as single units are the product of fluid lava, a steep gradient and rapid outpouring of magma from the vent. These factors inhibit the formation of flow units, and a high fluidity in particular will account for the extreme lengths of some unitary lava tube caves. Viscous lava, a flatter gradient and slower outwelling of lava from its source, Nichols suggested, gives a low velocity and favours the development of flow units and, if we tentatively accept the model of Raufarhólshellir, more complex lava tube caves.

It is apparent that the greater the distance the lava has travelled from the vent, the greater will become its viscosity, due to cooling and loss of volatiles. Thus it may be that single unit flow is characteristic of the initial emplacement of the lava, while multiple flow is more common in the distal regions of the flow. The most common form of lava tube cave to be developed under such conditions would therefore be similar to that envisaged by workers in Hawaii. Indeed, one collapsed lava tube cave near Butte Crater, Idaho, which is over 5km in length, does show a unitary form with distal anastomoses. These complete forms may be rare in the field, and difficulty may have been experience in reconciling diverse tube forms to the traditional concept, due to the fact that only parts of tube may have emptied of liquid lava. The study of Raufarhólshellir has shown that the cave emptied of liquid lava due to a rapid steepening of the gradient immediately downslope of the cave. Similar evidence may be found at Surtshellir/Stephanshellir, which also formed in a flow of multiple structure. In both cases lava tube development must obviously have occurred through the whole length of the parent flow, but subsequent draining of the tube was localized, occurring some 10km and 26km respectively from the vent. If drainage of these tubes had occurred in the higher parts of the flow, there would have been a greater likelihood, perhaps, of finding a cave of unitary form.

CONCLUSION

These conjectures are important because they illustrate the need for detailed examination of individual lava tube caves or individual lava flows. In general, one must conclude that research by speleologists on the evolution of lava tube caves has only just begun, and there is little evidence as yet with which to assess the importance of the models mentioned here. It must be emphasised that it is only on the basis of a large number of studies of diverse features that firm conclusions can be made. The study of each individual cave in our opinion must take place under the points outlined below:

1. It is imperative that an accurate survey of the cave by non-magnetic means must be executed, so that the true form of the cave in plan, long profile and cross-section, may be established, and the relationship of the various cave segments ascertained.
2. Details of the flow surface maut be plotted and must include measurements of the thickness of the cave roof so that the long profile may be competed, the plotting of the plan on the surface so that its position and location may be noted, the levelling of the surface of the

flow both above and below the cave entrance so that gradients may be noted.
3. The age, composition and, in particular, the structure of the flow must be determined.
4. Details of flow features must be noted so that the form of the cave, the age of various segments, and the history of the draining of the tube may be discovered.
5. The extent to which the morphology of the cave is related to the flow structure is of the utmost importance.

For our part, during our stay in Iceland this summer, we intend to make a detailed study of the lava tube caves of the Gullborganhraun and Snaefells peninsula, and to journey into the uninhabited interior of the island in order to examine and draw up a preliminary report on the vast Odadahraun flow of north-central Iceland.

LAVA CHANNELS AND ASSOCIATED CAVES IN VICTORIA, AUSTRALIA

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INTRODUCTION

Basaltic volcanoes of late Pliocene and Quaternary age are found over an extensive area of southeastern Australia (Fig. 13-1 , 13-2) as well as in several areas in the northeastern state of Queensland. Caves (Fig. 13-3) have been described from each area (Matthews, 1968). The caves of Victoria were described by Ollier and Brown in 1964. Until recently only minor new caves have been found (see Ollier and Joyce, 1968), but in the last few years caves have been found at Warrion Hill volcano (pers. comm., J. Taylor) and at Mt. Napier (pers. comm. L.K. Elmore), and further caves have been found at Mt. Eccles. The caves at Mt. Napier and Mt. Eccles are associated with the only lava channels known in Victoria. This paper discusses the channels and associated caves at Mt. Napier and Mt. Eccles, and describes their relationships. The features at Mt. Napier were discovered by Elmore and will be described elsewhere by him. Details of the lava channels and the newly-discovered caves at Mt. Eccles are given here for the first time.

THE MT. NAPIER AREA

The main area of lava flows around Mt. Napier (Fig. s 13-4 , 13-5) is about six miles across. An associated radiocarbon date suggests an early Holocene eruption. A lava channel and associated caves are found about 1 1/2 mile west of Mt. Napier, among the irregular flow ridges and depressions of the type known locally as "stony rises". A channel 2 to 3 m deep and 6 to 8 m wide leaves a lava depression at the foot of a small scoria cone with a crater, and runs for about 1/4 mile. Two caves open into the channel and a natural bridge across the channel is the remnant of a formerly more extensive cave. A number of other small cones and ridges are found up to two miles or more from the main volcano. Such a distribution is not known from any other local volcano. One spatter ridge contains a small cave about three or four meters long on its flank, possibly due to sagging.

The Byaduk Caves are about four miles southwest of the main volcano, where the lava began to flow down the Harman Valley for a further ten miles or more. Collapses in the flow surface (Fig. 13-7) give access to a number of caves here (Ollier and Brown, 1964). Mt. Napier itself (Fig. 13-4) is a multiple scoria and spatter cone which rests on a broad lava shield built up by the flows. On its northern flank are two small, irregular caves which were probably formed by later erosion beneath a small flow. On the western flank two small lava caves are associated with indistinct lava channels which lead out into the surrounding "stony rises". One cave here is in line with a channel which runs down the flank below a low point in the crater wall. It is within a small dome of lava built up of many thin layers (Fig. 13-9). Its cross-section has the form of a pointed arch, suggesting distortion of the upper walls and roof (Fig. 13-10). The floor and roof are parallel, and slope steeply down the flank of the volcano. Lava stalactites are inclined down-flow. Near the upper entrance the cave's lining has fallen away to expose thin layers of lava which make up the upper part of the cave wall. In the other cave nearby, are found groups of needle-like stalactites with individual diameters of 1 m or less. Some bunched and helictitic forms are present (Fig. 13-11).

THE MT. ECCLES AREA

Mt. Eccles volcano lies about 14 miles southwest of Mt. Napier and is probably about the same age. It is surrounded by an area of "stony rises" about six miles wide. Thence a valley flow ran west and south 19 miles to the coast, with a further nine miles now submerged. The main volcano