New Zealand lava caves worth preserving for their geologic and geomorphic features(MEMORIAL VOLUME TO THE LATE PROFESSOR TERUHIKO SAMESHIMA)

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Abstract Auckland is the only district in New Zealand that is known to have lava tube caves. Many small cavities and short tube segments have been found within lava flows from several of the small, late Pleistocene-Holocene, basalt-basanite volcanoes of Auckland Volcanic Field. Excavations for construction sites within the city have uncovered, and destroyed, many small cavernous features. No large or long lava caves have been discovered. Wiri Lava Cave, imminently threatened by quarrying activities, is rated of international significance, and fourteen other lava caves are considered to be of national importance for scientific, or educational reasons.

Key words : volcanospeleology, conservation, lava tube, lava cave, New Zealand

INTRODUCTION

The New Zealand Geopreservation Inventory, organised jointly by the earth sciences societies (Weaver & Hayward 1983), has identified and listed many geological and geomorphological features in New Zealand of scientific or educational value that are worthy of protection. Lava caves have been tentatively assessed for their international, national, or regional significance (Kermode *et al.* 1992).

In 1988, Prof. T. Sameshima encouraged the author to prepare a paper, on "the distribution and characteristics of New Zealand volcanic caves" that was presented at the Izu-Nagaoka meeting of the 5th International Symposium on Volcanospeleology (proceedings not yet published). The field trips in Japan and Korea associated with that symposium provided an opportunity for discussion of New Zealand lava caves in a contemporary, international context.

The preparation of the text for a new geological map of Auckland urban area (Kermode 1992) revealed generalisations that indicated further detailed research was essential. The possibility of a correlation between petrological and petrochemical variations and the spatial distribution and temporal sequences of the lavas of Auckland Volcanic Field was clearly a topic to be researched. Similar research was current in Japan (Umino *et al.* 1991). A further possibility was that a long lava tube system, which had experienced several discrete flows, could include an accessible juxtaposition of compositional variables.

Several associated lines of research were commenced. Prof. T. Sameshima provided a broad petrological classification for the whole volcanic field (Sameshima 1990ms), and compiled a list of volcano ages including some new results from Japan (Sameshima 1990). A student, T. Sano (Shizuoka), examined the petrology of two Auckland lava flow systems in detail (Sano *et al.* 1990; Sano 1991ms). Dr. H. Shibuya (Osaka) recorded a geomagnetic excursion in the Brunhes epoch (Shibuya *et al.* 1992).

Dr. I.E.M. Smith (Auckland) continues research on detailed petrochemical signatures, and Dr. T. Itaya (Okayama) continues the geochronology of Quaternary volcanics project.

Over several decades speleologists have explored the Auckland lava caves, and produced simple outline plans (Crossley 1988), but few scientific or educational reports with photographs have been published. Visits to lava caves in Japan, Korea, Australia, and United States have allowed some tentative international comparisons to be made. Elsewhere in New Zealand there are a few erosional or collapse caves in other volcanic rocks (Fig. 1).

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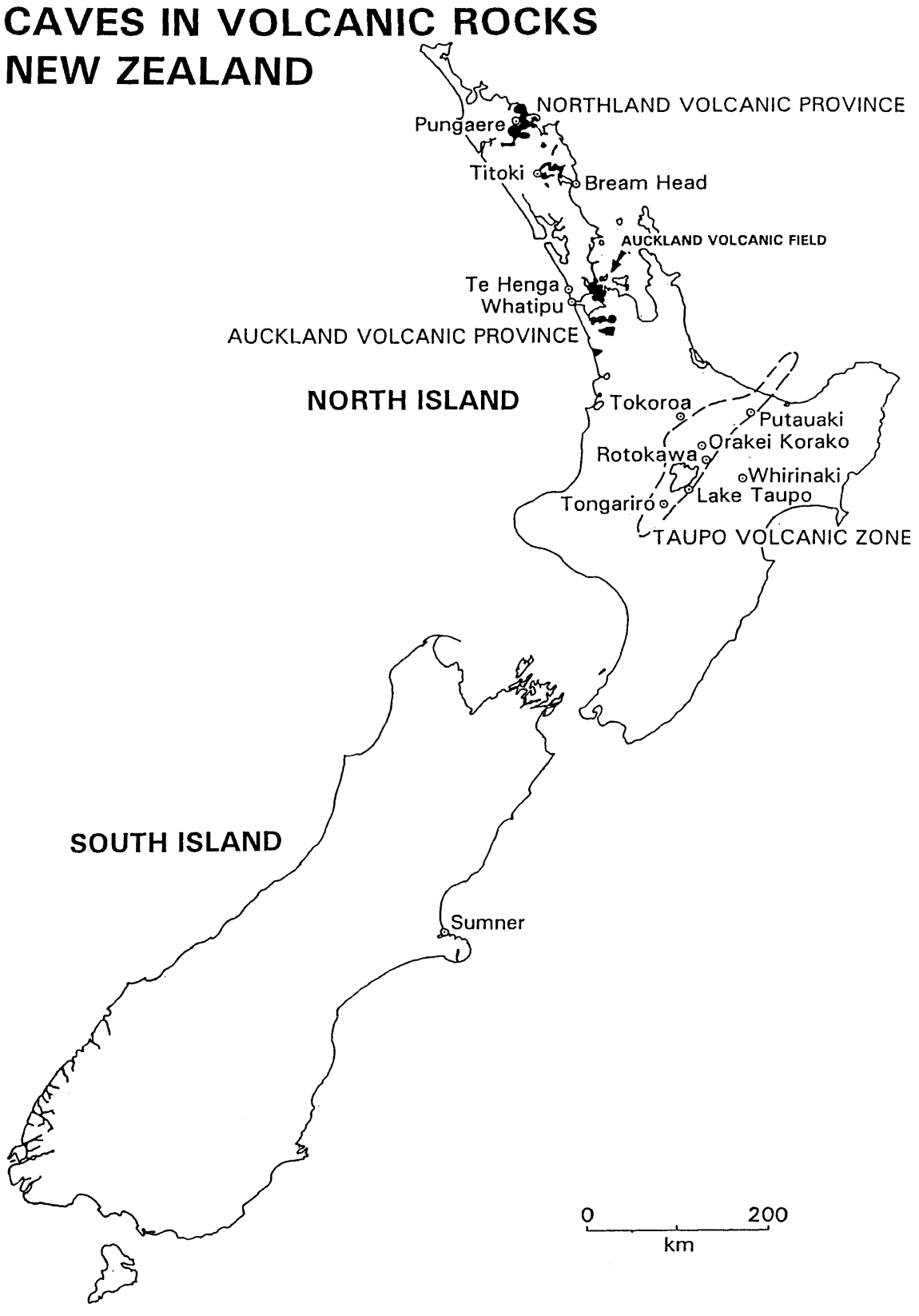


Fig. 1 Locations of all the known caves in volcanic rocks in New Zealand. Only Auckland Volcanic Field contains lava tube caves. The other caves were formed by erosion, or collapse.

OBSERVATIONS

There are 48 monogenetic, Pleistocene-Holocene, basalt-basanite volcanoes in the Auckland Volcanic Field, and 32 of them extruded lava (Kermode 1986). The following 14 volcanoes produced lava flows in which there are tubes or caves (described and numbered from the north). Of more than 100 cavities that have been investigated, about 40 are greater than 20 m in total length, and all the lava tubes are within 8 m of the ground surface (Fig. 2).

RANGITOTO volcano is about 600 years old and produced a lava cone capped by a scoria cone 260 m above sea level. This circular island with an area of about 23 km^2, consists mainly of rubbly, aa flows (Searle 1964) comprising subalkalic olivine basalt (Sameshima 1990ms) or olivine tholeiite of surprisingly consistent petrochemistry (Sano *et al.* 1990; Sano 1991ms). Pahoehoe lava has been encountered at depth, and near the lava crater rim. Rangitoto contains about 50% of the total volume of volcanic products erupted by Auckland Volcanic Field.

Southern (unnamed) lava cave (1), the southernmost of the main group, is near the rim of the lava crater at grid reference R11/768885, about 150 m above sea level and within Hauraki Gulf Maritime Park. This straight downslope segment of a closed lava trench is about 60 m long. The upper and lower entrances are natural roof collapses, and the third central entrance is a natural skylight surrounded by a raised spatter rim. A cave plan has been published (Crossley 1970). Small mineral encrustations from within the cave have been identified as gypsum, opaline silica, and plagioclase feldspars (Cody 1980).

Wallaby Cave (2), the westernmost of the main group, is also near the rim of the lava crater at grid reference R11/767885, about 140 m above sea level, and also within the Maritime Park. This is a two-level system containing several branches with a total length of 112 m. All the interior surfaces are very spinose. The cave was probably formed by the draining of overlapping pahoehoe lobes. A cave plan has been published (Crossley 1972a).

Five other lava tube segments were investigated (Crossley 1970, 1972a, 1988).

PUPUKE volcano has a large crater (1700 m in diameter) containing a lake (1.04 km^2) surrounded by a basaltic tuff ring overlying numerous thin, very vesicular pahoehoe lava flows of subalkalic olivine basalt (Sameshima 1990ms; Sano 1991ms) or transitional basalt (Allen & Smith 1991). Pupuke was one of the earlier eruptions in Auckland Volcanic Field (Wood 1991ms). Lava covers an area of about 2.8 km^2, but about 90% of it lies beneath thick basaltic tephra.

No caves have been found, but lava tube structures and tree moulds (Kermode 1992) are exposed along the sea coast walkway (Crossley 1988, Allen & Smith 1991).

MT EDEN volcano is a scoria cone, 196 m above sea level, with an encircling lava field that has an area of about 5.6 km^2 bounded on most sides by a high, steep front of lava (Hochstetter 1864). This thick, viscous, pahoehoe lava comprises alkalic olivine basalt (Sameshima 1990ms; Sano 1991ms).

Mortimer Pass lava cave (3), is near the steep periphery of the lava pedestal at grid reference R11/686796, about 37 m above sea level, and is 35 m long. The cave, easily accessed from a public street, is a pull-apart or rift structure, of S cross-section, transverse to the flow direction. It is beneath a private residential area. A cave plan with cross-sections has been published (Crossley 1972a). Small mineral encrustations from within the cave have been identified as opal and calcite (Cody 1980).

No lava tube caves were found in the Mt Eden lava field.

MT ALBERT volcano produced a scoria cone on a prevolcanic ridge, and from the vent, pahoehoe lava flowed into the valleys on both sides. This nepheline basanite lava (Sameshima 1990ms) covers an area of about 4.0 km^2. Four small lava tube segments (proximal and medial) were examined. Cave plans have been published (Crossley 1970, 1972a, 1973a).

MT WELLINGTON volcano produced a scoria cone about 9200 years ago (Kermode 1992) and spread small, pahoehoe lava flows in every direction, but the major effusion of several thick flows filled an adjacent valley and advanced about 6 km to Manukau Harbour (Kermode & Searle 1967). The nepheline basanite lava (Sameshima 1990ms; Sano 1991ms) covers an area of about 6.8 km^2. Ruapotaka lava shaft (4), is within a public park near the western foot of the scoria cone, at grid reference R11/747773, about 64 m above sea level. It is a 16 m deep, bell-shaped chamber (Crossley 1976a). Near floor level this shaft has some striations and ledges left by the surging, solidifying lava. Some small (dm) burst blisters of thin (mm), smooth, very dark lava are still extant. Some photographs have been published (Crossley 1976a), but no plan or cross-section.

Motor Holdings lava cave (5) is beneath an industrial area at the eastern foot of the scoria cone at grid reference R11/752770, about 30 m above sea level. It is an almost straight downslope lava tube 114 m in length. A cave plan has been published (Crossley 1988).

Most of the other 11 known lava cavities (Crossley 1970, 1972a) are in the hummocky area about 3 km southwest of the vent.

THREE KINGS volcano is a large tuff ring (about 1200 m diameter), which encircled several

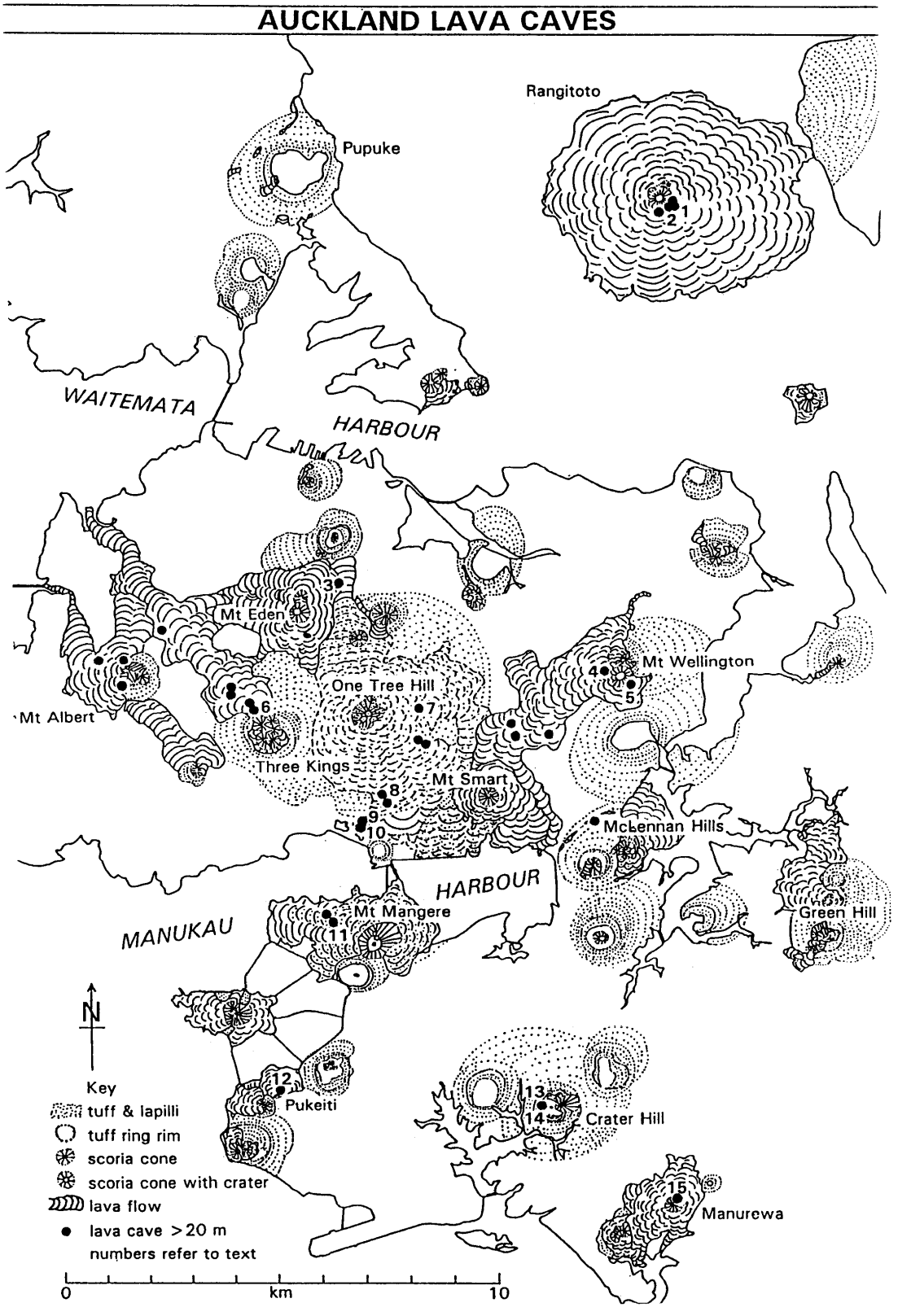


Fig. 2 Auckland Volcanic Field showing the locations (numbered) of the lava caves discussed, their associated lava fields, and naming their source volcanoes. Other lava tube caves with lengths greater than 20 m are also shown.

scoria cones. Lava was initially confined within the tuff crater, but later overtopped the rim, filled an adjacent valley, and advanced about 10 km from the source vent into Waitemata Harbour (Kermode 1975). The pahoehoe lava is nepheline basanite (Sameshima 1990ms; Sano 1991ms) and covers an area of about 6.4 km².

Stewarts Cave (6) is close to the point where lava flowed out over the tuff ring rim at grid reference R11/666765, about 70 m above sea level and beneath a private residential area. This lava tube system is 180 m long and comprises a converging two-level part connected with a third tube. It contains lava flow features, lava surge level marks, kerbs, a short cave-in-cave, and a large terminal lobe. The floor is mainly aa surface, or fallen blocks. A detailed cave plan and longitudinal sections have been published (Stewart 1869). Small mineral encrustations from within the cave have been identified as opal and calcite (T. Sameshima, personal communication).

There are sixteen other lava tube segments within 700 m of Stewarts Cave. Some cave plans have been published (Crossley 1970, 1975a).

ONE TREE HILL volcano is a scoria cone surrounded by extensive lava flows that probably cover more than 22 km² (Kermode 1989), and contain about 8% of the total volume of volcanic products of Auckland Volcanic Field. The pahoehoe lava is subalkaline olivine basalt (Sameshima 1990ms), and the One Tree Hill lava field is about 75% mantled with tephra mainly from the younger, neighbouring Three Kings volcano.

Cave of the Thousand Press-ups (7) is in the middle of the lava field at grid reference R11/703765, approximately 60 m above sea level. This lava cave, mainly beneath a public street, is a network of diverging and interconnecting tubes, which total about 270 m in length, although it is less than 70 m in greatest extent. A cave plan has been published (Crossley 1979). The cave is used for the disposal of stormwater from the street. Small mineral encrustations from within the cave have been identified as opal (Cody 1980).

Scotlands lava cave (8), is mainly beneath a commercial area, at grid reference R11/695744, about 40 m above sea level, and 2 km from the source vent. It is an almost straight, 160 m long lava tube. A cave plan has been published (Crossley 1970). The cave is used for the disposal of stormwater from a street.

Ratcliffe lava cave (9) is beneath an industrial area at grid reference R11/690738. It is adjacent to, but not connected with Helena Rubinstein Lava Cave, about 10 m above sea level. There are about 130 m of mainly lobe passages. A cave plan has been published (Crossley 1972a; Martin 1988). Helena Rubinstein Lava Cave (10) is at the end of a major lava flow, about 2.5 km from its source vent, at grid reference R11/698737, at 10 m above sea level, and beneath a commercial area. It comprises a diverging pattern of terminal, pahoehoe lobes totalling about 320 m in length, but only 40 m in maximum extent. A cave plan with cross-sections has been published (Kermode 1970). Some photographs have also been published (Kermode 1970).

Twenty-two other lava tube segments were examined. Some cave plans have been published (Crossley 1972a, 1972b, 1973b; Martin 1988).

MT SMART volcano was a scoria cone (now removed) encircled by its lava field of about 2.8 km². The pahoehoe lava is nepheline basanite (Sameshima 1990ms). A few crater vents and tubes, exposed during the construction of the sports stadium, were explored (Crossley 1976b), but are now removed or buried. A few distal blisters were broken into during railway construction. Some cave plans and photographs have been published (Crossley 1972a, 1975b).

MCLENNAN HILLS volcano produced a complex scoria cone surmounting a lava field that probably covered about 2.6 km², but almost 50% was mantled with lithic tuff from the contiguous and contemporaneous Mt Richmond volcano. The lava is undifferentiated basalt. Two gas vents in the scoria cone (Lambert 1957) and a distal tube 63 m long (D. Dunn, personal communication) were examined. No cave plans, cross-sections, or photographs have been published.

GREEN HILL volcano produced a scoria cone (now removed) and a hummocky, pahoehoe lava field of nepheline basanite (Sameshima 1990ms; Sano 1991ms) which covered an area of about 2.2 km².

One crateral and four small proximal lava caves have all now been destroyed by quarrying operations. Some cave plans have been published (Crossley 1972a, 1988).

MT MANGERE volcano produced a scoria cone almost surrounded by lava fields that comprise many thin, very vesicular, pahoehoe flows of nepheline basanite (Sameshima 1990ms), and cover about 6.4 km². It is the only scoria cone crater with a lava plug (tholoid) exposed in the vent (Searle 1959).

Ambury Road lava cave (11), is beneath a private residential area in the middle of the lava field at grid reference R11/682714, about 20 m above sea level. The cave has two branch tubes totalling about 140 m in length. A cave plan has been published (Crossley 1970).

A further 32 small cavities were examined beneath the farmland of Ambury Regional Park (Crossley 1988; Auckland Regional Parks unpublished manuscript).

PUKEITI volcano produced a very small scoria cone and a pahoehoe lava field of undifferentiated basalt that covers about 0.4 km².

Lino lava cave (12), beneath privately owned

farmland, and close to the scoria cone is at grid reference R11/668673, about 20 m above sea level. The length of passages totals about 90 m. It is probably a gas conduit between pahoehoe lobe cavities rather than an empty, fluid-lava tube. A cave plan has been published (Crossley 1970).

One other adjacent lava blister was examined, and a cave plan has been published (Crossley 1970).

CRATER HILL volcano produced a tuff ring (about 900 m diameter) and small scoria cone (now removed). Although there is no external lava field, there is a lava terrace about 0.2 km^2 in area within the tuff ring crater (Hochstetter 1864; Firth 1930). The pahoehoe lava is basanite and alkali basalt (Houghton *et al.* 1986).

Selfs lava cave (13) is beneath privately owned farmland near the edge of the stranded lava terrace within the tuff ring crater, at grid reference R11/728667, about 10 m above sea level. It is a straight chamber 48 m long, 8 m wide, and 2.5 m high. The cave orientation is circumferential behind the solidified distal front of the withdrawn lava flow. A sketch plan of the cave has been published (Crossley 1988).

Underground Press lava cave (14) is also beneath privately owned farmland near the edge of the stranded lava terrace within the tuff ring crater, at grid reference R11/728666, about 10 m above sea level. The central chamber has four branch lobes totalling about 40 m. A sketch plan of the cave has been published (Crossley 1988).

MANUREWA volcano produced a scoria cone (now removed) and a pahoehoe lava field (extensively quarried) with an area of about 2.5km^2, comprising alkalic olivine basalt (Sameshima 1990ms).

Wiri Lava Cave (15) is within an operating quarry at the northern foot of the now demolished scoria cone, at grid reference R11/758645. The main (upper) entrance is 38 m above sea level. The cave is an unbranched lava tube 290 m long, with a variety of passage shapes and flow features (Fig. 3a). Small mineral encrustations from within the cave have been identified as calcite (Cody 1980). A cave plan and cross-sections has been published (Kermode 1970).

One other lava blister in the middle of the lava field was examined. A cave plan has been published (Crossley 1988).

DISCUSSION

The known lava caves of Auckland Volcanic Field were assessed for their scientific and educational significance, and for their vulnerability to human activities (Kermode *et al.* 1992). Field discussions with foreign volcanospeleologists brought some objectivity into the assessments. This research project revealed no spectacular lava caves of world record status. There are lava caves in Japan, Korea, Kenya, Australia, Canarias, Hawaii, Washington, California, Idaho, etc. that rank more highly for length, diameter, or uniqueness of flow features.

The feasibility of correlating the development of lava tubes with petrological characteristics of the basalt has not been demonstrated. Although two major compositional variations (which cannot be derived from each other) were found in the long Three Kings lava flow (Sano *et al.* 1990), the cave-in-cave feature of Stewarts Cave was not sampled (Sano 1991ms). Further detailed fieldwork is necessary.

CONCLUSIONS

A list of fifteen lava caves of educational or scientific significance (Table 1) has been assessed in three categories.

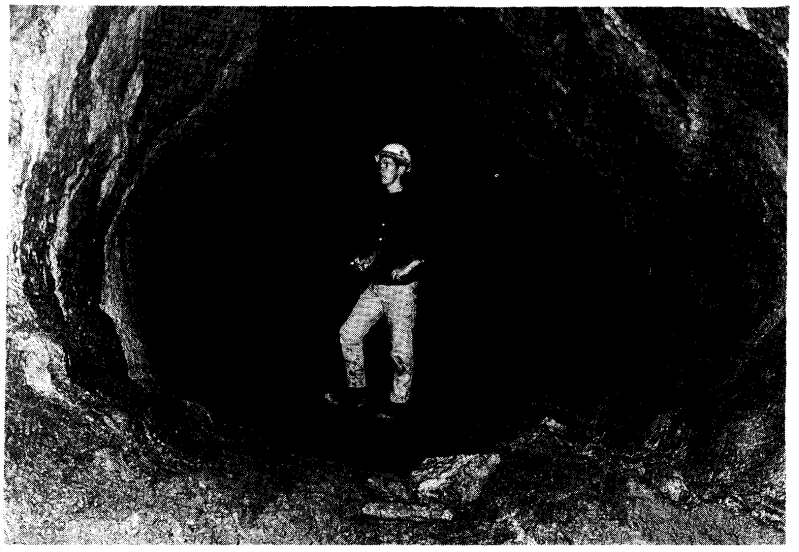
1. Caves that are internationally significant, and highly vulnerable to complete destruction or major modification by humans.

Wiri Lava Cave (15) has a variety of cross-sectional shapes, and many diverse flow features on the walls, floor, and ceiling (Kermode 1970, 1987, 1988; Searle 1964). The main gas-vent entrance, to this lava tube is within a quarry, but it has been sealed, and a second permanent, artificial entrance from a public street is also sealed. The cave is extremely difficult to negotiate from the second entrance. However, this well-documented cave is easily negotiated from the main entrance, and is still in a good state of preservation (Fig. 3a) It was last inspected in 1992. Destruction of this cave by quarrying is a constant threat. Protection by legislation has been sought for more than 20 years. However, local, regional, and central governments have been reluctant to accept responsibility for the cave's protection (Hughes 1990). This is New Zealand's longest and most important educational lava cave, and therefore, is of international significance.

2. Caves that are nationally significant, and moderately vulnerable to modification by humans (listed alphabetically).

Ambury Road lava cave (11), contains the best examples of small (cm) lava bubble stalagmites found to date. It is easy to enter through a natural roof collapse, and has been modified in places by humans. Ancient burials have been removed, and there is much refuse in the collapse pit entrance. The future existence of this cave could be threatened by residential development.

Cave of the Thousands Press-ups (7) is a complex network of lava tube crawlways. Entry, by way of a drainage inspection hatchway, is difficult and restricted. The future existence of this cave is threatened by the heavy traffic using the roadway



a

b

c

Fig. 3 Features of Auckland lava tube caves.

a. Typical cross-section of Wiri Lava Cave, which is considered to be the lava tube cave with the greatest scientific and educational significance in New Zealand. (Photo: L. Kermode)

b. An excellent example of a lava wall roll (lava peel) in Helena Rubinstein Lava Cave. A surge of hot, fluid lava rose high on the wall of the existing tube or lobe, then as the lava level subsided the lining of slightly cooler, plastic lava that remained adhering to the wall was unsupported and peeled off like poorly-hung wallpaper. (Photo: L. Dunn)

c. A lateral view of a small, mud-mantled lava roll in Helena Rubinstein Lava Cave. (Photo: L. Kermode)

Table 1 Lava caves assessed for their educational or scientific significance.

Name	type	latitude south	longitude east	map ref R11	elev m	length m	source volcano
1 Southern	trench	36°47′26"	174°51′46"	768885	150	<60	Rangitoto
2 Wallaby	lobe	36°47′27"	174°51′43"	767885	140	112	Rangitoto
3 Mortimer Pass	rift	36°52′23"	174°46′31"	686796	37	35	Mt Eden
4 Ruapotaka	shaft	36°53′35"	174°50′38"	747773	64	16(deep)	Mt Wellington
5 Motor Holdings	tube	36°53′43"	174°51′00"	752770	30	114	Mt Wellington
6 Stewarts	tube	36°54′02"	174°45′12"	666765	70	180	Three Kings
7 1000 Press-ups	net	36°54′01"	174°47′42"	703765	60	270	One Tree Hill
8 Scotlands	tube	36°54′11"	174°47′07"	695744	40	160	One Tree Hill
9 Ratcliffe	lobe	36°55′29"	174°46′48"	690738	10	130	One Tree Hill
10 Helena Rubinstein	lobe	36°55′31"	174°46′47"	698737	10	320	One Tree Hill
11 Ambury Rd	tube	36°56′48"	174°46′18"	682714	20	140	Mt Mangere
12 Lino	lobe	36°59′10"	174°45′26"	668673	20	90	Pukeiti
13 Selfs	front	36°59′07"	174°49′29"	728667	10	48	Crater Hill
14 Underground Press	lobe	36°59′09"	174°49′28"	728666	10	40	Crater Hill
15 Wiri	tube	37°00′26"	174°51′31"	758645	38	290	Manurewa

on a few metres above it. The cave is visited occasionally.

Helena Rubinstein Lava Cave (10) consists of several lava lobes, and contains many excellent lava wall rolls (lava peels) which are probably of international significance (Fig. 3b, c). There are innumerable small (cm) lava stalactites on the ceiling, and the floor of pahoehoe lava slabs is covered with sticky mud. Both artificial entrances have been blocked since the last inspection in 1966. The future existence of this cave could be threatened by building construction.

Lino lava cave (12) contains many small (cm) lava stalactites and lava stalagmites. It is extremely difficult to negotiate beyond the natural collapse entrance-chamber. This lava lobe cave is not immediately threatened, but future urban development could destroy it.

Mortimer Pass lava cave (3) is an excellent example of a pull-apart rift cave parallel to the distal front of a lava flow. It is easily accessible, but difficult to negotiate. Landscaping of the public street could lead to the future blocking of the artificial cave entrance.

Motor Holdings lava cave (5) contains some incipient lava wall rolls (Crossley 1988), and unusual broken slabs of flow crust jammed against the ceiling or welded into the floor (D. Dunn, personal communication). The artificial entrance was found in 1975, but immediately buried and lost during site development. No photographs have been published. The future existence of this lava tube cave is threatened by proposed highway construction.

Ratcliffe lava cave (9) contains some well-developed lava wall rolls. It is easily entered by way of a permanent, artificial entrance. The future existence of this cave could be threatened by building construction.

Ruapotaka lava shaft (4) has unusual features, structure, and origin. It is difficult and hazardous to enter. The shaft was last inspected in 1988, and the vertical entrance has been sealed for safety reasons.

Scotlands lava cave (8) is a representative example of an almost straight midflow lava tube. It now has only one permanent, artificial entrance from a public street. The future existence of this cave is also threatened by building construction, and by the accumulation of silt washed from the street through stormwater drains. This cave is visited occasionally.

Selfs lava cave (13) is unusual in its position within a tuff crater, and also its orientation, which is circumferential to the distal lava front. It is easy to enter by way of a natural roof collapse, and contains some lava wall rolls (lava peels). This cave is not immediately threatened, but future urban development could destroy it.

Stewarts Cave (6) has a variety of lava cave

features, and is easy to enter and mostly easy to negotiate. The natural roof collapse entrance has been modified slightly. The future existence of this lava tube cave could be threatened by residential development. It is often visited by educational groups.

Underground Press lava cave (14) contains small (cm) lava stalactites and lava stalagmites. It is easily entered by way of a natural roof collapse. This lava lobe cave is not immediately threatened, but future urban development could destroy it.

3. Caves that are nationally significant, and unlikely to be damaged by humans (listed alphabetically).

Southern (unnamed) lava cave (1) is a good example of a trench cave near to the vent. It is accessible and is easily entered by way of natural roof collapses, and easy to negotiate. This cave is frequently visited.

Wallaby Cave (2) has an interesting layout and a very spinose interior typical of a drained pahoehoe lobe. It is accessible, but difficult to enter through a natural roof collapse. The cave is rarely visited.

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