Geomunoreum Lava Tube System, Jeju Island

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Abstract

The lava tubes associated with the Geomun volcano on Jeju Island (Korea) are amongst the longest and most spectacular on the island. The tubes were formed some 200 000 to 300 000 years ago and today are, arguably, the most significant element of the volcanic province World Heritage site on Jeju, which also includes the Hallasan Nature Reserve (encompassing the highest peak in Korea) and Seongsan Ichulbong, an eroded tuff cone on the eastern coast of Jeju.

The lava tube system, comprising at least eight separate caves separated by infilled lavas and breakdown, trends for some 15km in a north-northeasterly direction from the crater to near the northern coast of Jeju.

During field trips for the 13th International Symposium on Vulcanospeleology in 2008, participants visited three caves in the system (Manjanggul, Gimnyeongul and Yongcheongul) and this paper focuses on some of the features observed on those field trips.

Introduction

In 2008, the 13th International Symposium on Vulcanospeleology was held on Jeju Island, located off the southern coast of the Korean Peninsula.

During Symposium field trips, a considerable amount of time was devoted to studying some of the lava tubes in the Geomunoreum system (*oreum* is the Korean word for volcanic cone).

Jeju is approximately 70km long and 30km wide and is composed almost entirely of lavas and volcanic ash. There are more than 300 volcanic cones scattered across the island and many of them are visible from the largest cone, Hallasan, located near the centre of the island (Fig. 1). At 1950m, Hallasan (Mt Halla) dominates the island and is Korea's highest mountain.

There are many spectacular and unusual volcanic features on the island, including numerous lava tubes.

Fig. 1. Many volcanic cones can be seen from the upper slopes of Hallasan, Korea's highest mountain.

Such is the importance of this volcanic province that parts of the island were designated as a UNESCO World Heritage site in 2007, the first natural World Heritage site designated in Korea.

The Jeju Island Volcanic Province World Heritage Area covers an area of approximately 1885 hectares and comprises the (1) Hallasan Nature Reserve, (2) Seongsan Ichulbong (an eroded tuff cone) and (3) the Geomunoreum Lava Tube System (see Fig. 2).

finally, Woljeongnamjimidonggul near the down-flow end. This latter tube is of note as it was detected by remote sensing methods and subsequently penetrated by drilling in June 2009 (Park, 2009). It apparently has considerable secondary calcite speleothem development.

This paper will now look at three of the caves (Manjanggul, Gimnyeongul and Yongcheongul) in more detail.

Fig. 2. Map of Jeju Island showing the location of the three components of the Jeju Island Volcanic Province World Heritage Area.

Arguably, the Geomunoreum complex is the most important part of the World Heritage area.

The Geomunoreum was active 100,000-300,000 years ago and resulted in the formation of some of the most spectacular and famous lava tube systems on Jeju. The lava flow in which the caves formed trends in a north-northeasterly direction for about 15km from the crater to the northern coast of Jeju (see Fig. 3).

The tubes include Manjanggul, Gimnyeongul, and Yongcheongul tubes, visited on the Symposium field trips. Other tubes in the system include Bengdwigul, an extraordinarily complex tube system with more than 4.4km of passage; an unnamed short vertical lava tube near the crater; Bugoreumdonggul, a small lava tube; Dangcheomuldonggul, a simple tube just 110m long, but packed with secondary calcite decoration; and

Manjanggul

Manjanggul is longest and most spacious tube in the Geomunoreum system. It has 3 entrances, two main passages levels and a total of about 7.4km of passage (Fig. 4). Passages range in size up to 23m wide and 30m high and contain a wide and spectacular range of lava features.

Symposium delegates visited Manjanggul (gul = cave) (Fig. 5) on three separate occasions over the course of the symposium and had opportunities to inspect most of the system.

A section of Manjanggul, approximately 1km long and up-flow from the middle entrance has been developed as a self-guiding show cave. Entry is via a large flight of stone steps (Fig. 6).

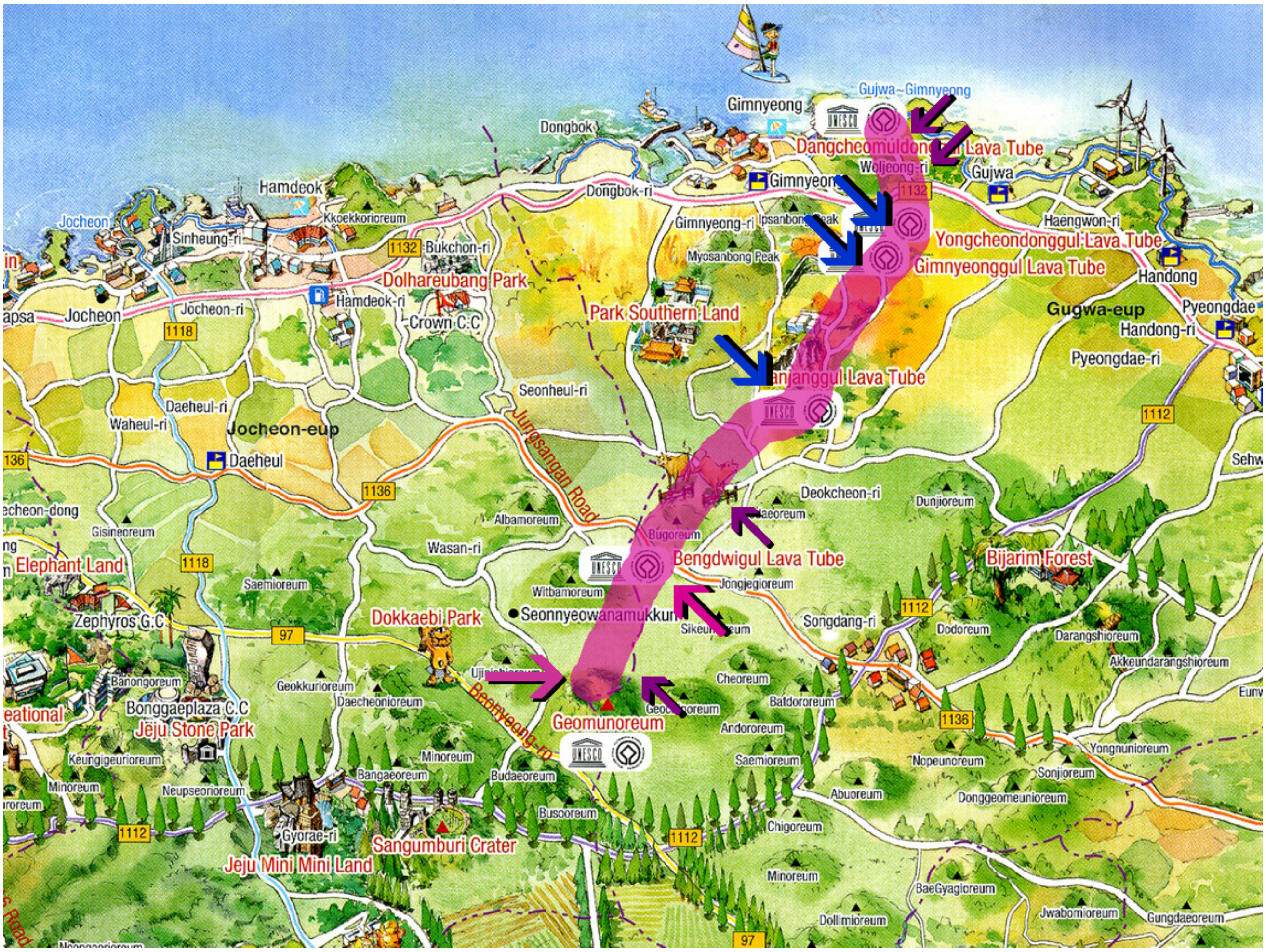

Figure 3. The Geomun area showing approximate locations of the crater (large horizontal pink arrow), the 3 lava tubes covered by this paper: Manjanggul, Gimnyeongul and Yongcheongul (blue arrows). Other tubes in the system include Bengdwigul (large pink arrow) and several smaller tubes (smaller purple arrows).

Fig. 4. Schematic diagram of Manjanggul, modified to show the approximate extent of the upper level section.

After the long flight of steps into the cave, it is an easy walk on an almost-level smooth lava floor.

The show cave section is electrically lit, with many of the lights camouflaged by fibreglass structures textured to look like piles of rock (Fig. 7). The light housings are arranged so that the lights face into the cave. This gives visitors a better view on the way in, but makes it harder to see on the way out.

In places grey coloured shotcrete has been sprayed onto the cave walls and ceiling, presumably to bind the surface and reduce the risk of minor rock fall. With subdued lighting in the cave, the shotcrete is not very obvious, but it does stand out in photographs, unfortunately (Fig. 7).

The main hazards along the show cave route are drips and resulting puddles of water. The drip problem can be overcome by wearing a rain jacket or carrying an umbrella and cave management has addressed the

Fig. 5. Symposium delegates approaching the Manjanggul visitor centre.

Fig. 6. Stephan Kempe, Kyung Sik Woo and Gunnhildur Stefansdottir entering the show cave section of Manjanggul.

puddle problem by strategically placing loose concrete stepping stones along the wettest sections of passage (Fig. 8).

The show cave section ends at an impressive lava column, more than 7m tall, where lava flowing along an upper level passage (no longer accessible) has dribbled down to the main level and more or less frozen in situ (Fig. 9).

Towards the end of the Symposium, the field trip program was amended so that participants could return to Manjang to visit the long up-flow section beyond the end of the tourist trail. The goal was to see the full 3km of passage beyond the lava column (Fig. 10). To see it all was an 8km round trip from the tourist entrance; a full day trip.

The up-flow passages are generally quite spacious but there are some lower sections (Figs 11-13). There are also extensive areas of breakdown, where the roof lining has collapsed, which at one point provides access to an upper level section. The upper level is an important roost site for a population of long-Winged bats (*Miniopterus schreibersii fulginosus*). This colony, with an estimated popul-ation of 30,000 bats, is the largest known bat colony in Korea. Manjang is also an important site for invertebrates and more than 38 species have been identified.

The cave ends at a large collapse entrance. This up-flow entrance was used at one time as an access point to the cave, but the only evidence for this now is a large block of concrete that apparently marked the mid point of a flight of stairs (Fig. 14).

On the second visit to Manjanggul, delegates made their way to the bottom of the show cave steps and turned left into the lower (main) level of the down-flow section. It is a relatively short section (less than 1km long) with easy walking on a flat lava floor (Fig. 15). For most of its length down-flow from the show cave entrance, Manjanggul has two levels. Access to the upper level is gained by walking halfway down the stone access steps from the show cave entrance (Fig. 16) and pushing through a narrow gap between the steps and the passage wall.

Fig. 7. Marjorie Coggan in the show cave section of Manjanggul.

Fig. 8. Manjanggul show cave section, note the flat lava floor, concrete 'stepping stones' and fibreglass light housings.

Fig. 9. A 7m tall lava column marks the end of the show cave section.

Fig. 10. Symposium delegates heading beyond the show cave section (and lava column) to explore the up-flow sections of passage.

Fig. 11. A lava toe and minor breakdown in Manjanggul.

Fig. 12. Low section of passage with lateral flow lines.

Fig. 13. A section of passage with lava benches, flow lines and a small amount of breakdown.

Fig. 14. Vertical entrance at the up-flow end on Manjanggul. A good spot for a lunch break

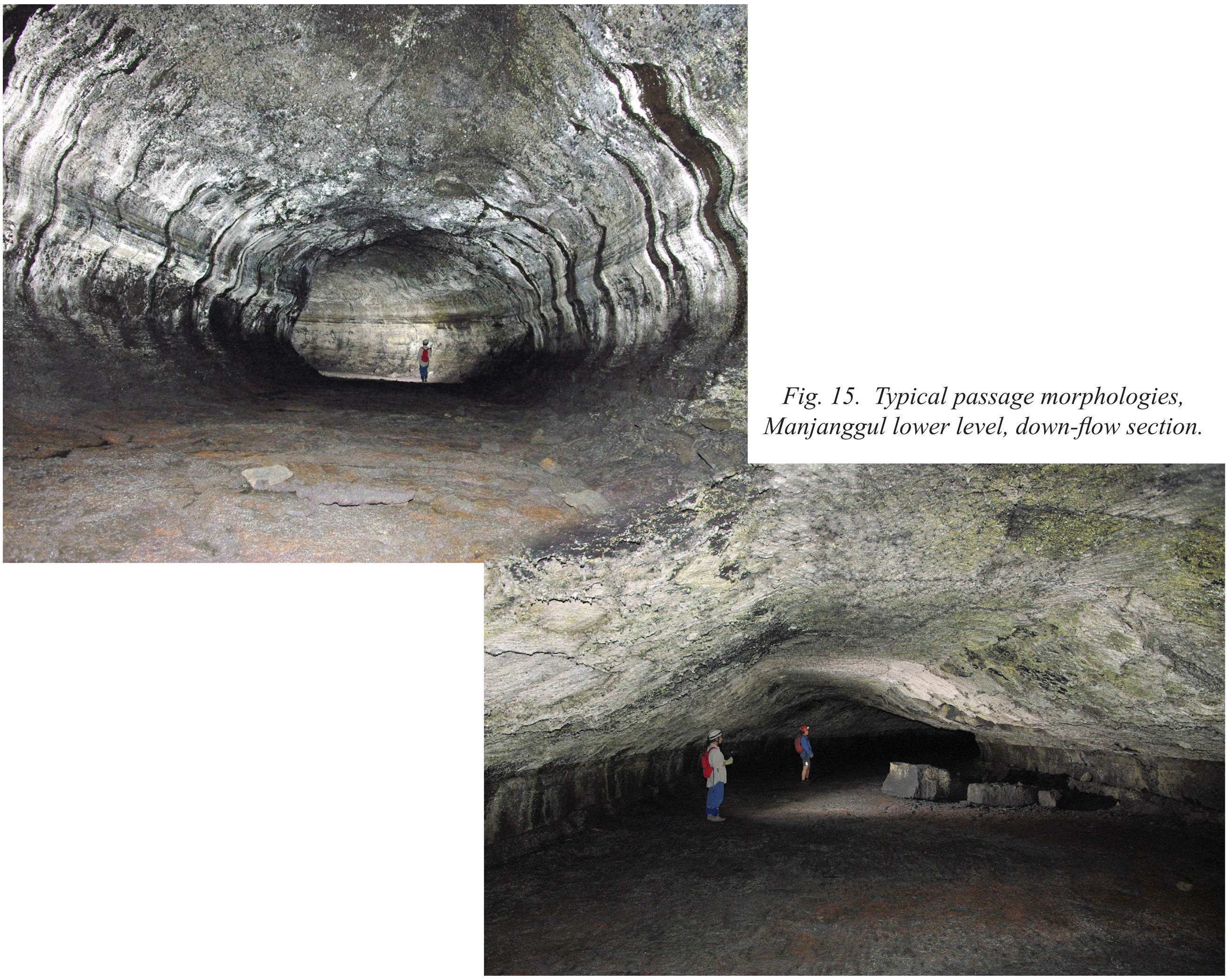

Fig. 15. Typical passage morphologies, Manjanggul lower level, down-flow section.

The upper, or balcony, level has quite a different character to the lower level passage referred to above. It has large areas of collapsed lava floors (Fig. 17) and lava bridges (Fig. 18) where sections of floor have partly collapsed (tube in tube structures).

Fig. 16. Manjanggul main entrance viewed from the upper (or balcony) level of the down-flow section of cave.

The balcony level of Manjanggul also has large areas of pahoehoe (ropey) lava (Figs 19 & 20) and, towards the lower end, areas of bright red lava (Fig. 21) where the iron content has oxidised to ferric iron.

Fig. 17. Marjorie Coggan and Claude Mouret on an extensive section of collapsed lava floor in the upper level section of Manjanggul (down-flow end).

Gimnyeongul

The next cave down-flow from Manjang is Gimnyeon. It is a mostly spacious cave about 700m long. Passage dimensions range up to 12m high and 5m wide.

The passage goes in two directions from the large collapse entrance. The short down-flow section of passage is a fauna reserve and was not entered on the symposium field trip.

The main up-flow section of passage is accessed via a flight of stone steps, now vegetation covered, (Fig. 22) that apparently date from its time as a show cave. The cave was open from 1962 to 1991 and plans are afoot to reopen in 2012.

The first 100-150m of up-flow passage has a floor of white calcitic sand (Figure 23). The sand has blown in from nearby coastal areas and is apparently responsible for choking off the short down-flow section. The sand is also the source of calcite for secondary speleothem growth in several of the Geomunoreum lava tubes. More about that below.

Towards the up-flow end, there is a 2m high lava fall (Figure 24) and above that, passage dimensions are quite small (Figure 25). The passage soon pinches out and at that point, it is just 90m to Manjanggul. However, as both passages end in solid lava, and there is an area of collapse in between, it seems unlikely that an underground connection will ever be made.

Yongcheongul

Yongcheongul is just a short distance down-flow from Gimnyeongul.

The cave was accidentally discovered in 2005 when excavations for a new power pole broke through into the tube. Somewhat

Fig. 18. Lava bridge/ collapsed floor in the upper level of Manjanggul.

Fig. 19. Horst-Volkel Henschel on Pahoehoe (ropey) lava floor, Manjanggul balcony level. The green netting in the background is a simple rock fall monitoring system.

Fig. 20. Amos Frumkin and Marjorie Coggan inspecting a pahoehoe (ropey) lava floor.

Fig. 21. Red lava floor towards the down-flow end of the balcony level in Manjanggul.

Fig. 22. *Symposium delegates pushing through thick vegetation towards the Gimnyeongul entrance.*

Fig. 23. White calcite sand floor in the outer section of passage in Gimnyeongul.

Fig. 24. Small lava falls near the up-flow end of Gimnyeongul.

Fig. 25. Marjorie Coggan, Stein-Eric Lauritzen and Birgit Stav above the Gimnyeon lava falls.

disconcertingly, entry to the cave is now down beside the offending cement power pole, around and under the bottom of it and then down a wobbly 10m aluminium extension ladder.

The cave has impressive lava features, extensive calcite speleothem development and contains important archaeological artefacts. In view of its values, it was designated as a National Monument in 2006, just months after its discovery and it now forms a key part of the Jeju Volcanic Province World Heritage Area. The entrance is right beside a major road and is protected by an alarm system, a padlocked stainless steel plate (Fig. 26) and under this, a securely locked gate.

Fig. 27. Cathy Plowman, David Butler and Kyung-Sik Woo in the up-flow section of Yongcheon.

The cave has about 2.5 km of passage, is generally 7-15 m wide and 1.5-20 m high. Most of the passage (approx 75%

Fig. 26. Lifting the lid on Yongcheongul. The well-protected entrance is right beside a major road.

is down-flow from the entrance. The shorter up-flow section has more modest passage dimensions but has more calcite speleothem development (Figs 27-34).

Calcite speleothems in Yongcheon result from solution of surficial deposits of sand that have blown in from the nearby coastal areas.

There are several lava falls in the cave (Fig. 43), including one that has a thin coating of calcite (Fig. 29), and one that has an elevation change of 10m in two stages.

In the more delicate up-flow section, a trail has been delineated with large reflective markers (Figs 28-30). In places the markers are several metres apart, leaving the precise route open to interpretation. Happily, visitor numbers are very low as access is very tightly controlled. In addition to the permanent (but unfixed) reflective markers, several other protective measures were implemented specially for the visit by symposium delegates. These included several lengths of temporary plastic sheeting (see Fig. 29) and the use of protective overshoes (Figs 31-33) in particularly sensitive areas.

Fig. 28. Calcite straws are in abundance and the longest are an estimated 5 m long.

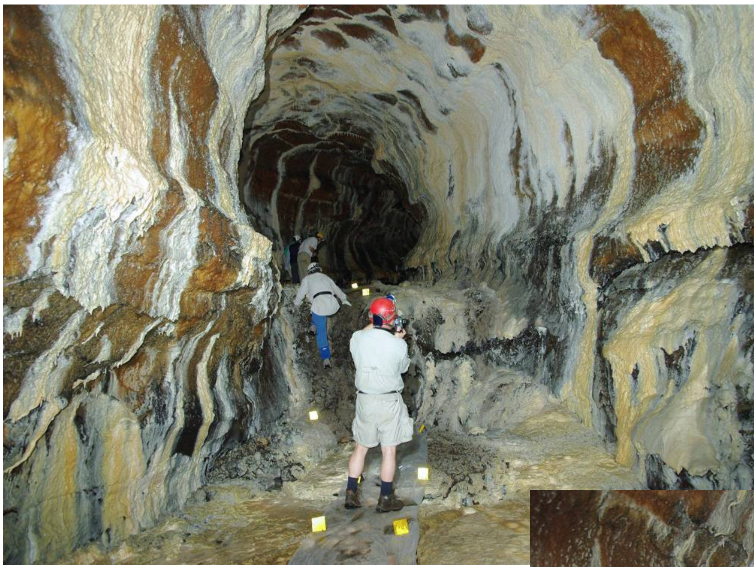

Fig. 29. David Wools-Cobb, Marjorie Coggan, Greg Middleton and Julia James near calcite coated lava falls. The temporary plastic matting was specially laid for symposium delegates.

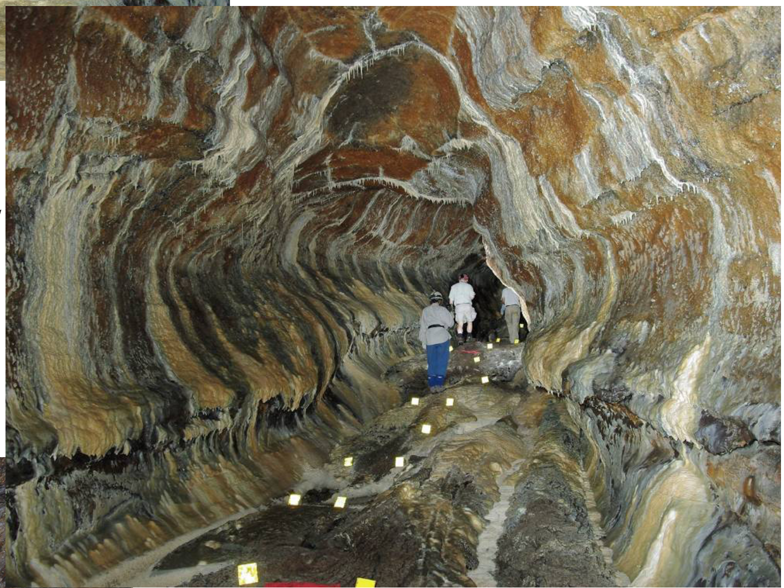

Fig. 30. Passage above the calcite-covered lava falls.

Fig. 31. The wide range of calcite speleothems in Yongcheon Cave includes flowstones, stalagmites, straws, cave corals, oolites and microgours.

The party was also split into several small groups, each with a local leader.

Many artefacts such as iron tools, pottery fragments, large animal bones, abalone shells and the remains of wooden torches have been found throughout the cave. Radio-carbon studies suggest the artefacts date from 500-600AD and this is apparently consistent with the pottery styles found in the cave. Some artefacts apparently been removed for protection or for research purposes, but many can still be seen in the cave (Fig. 35).

The artefacts point to an earlier period of human access through an entrance that is assumed to be now sand/soil covered.

Down-flow from the entrance pitch, there is less calcite speleothem development, but there are some impressive lava features including flow lines (Figs 36 and 37), lava falls up to 10 m tall, tube in tube structures (Fig. 38) and lava stalactites.

Fig. 32. Marjorie Coggan standing beside a nice lava roll; forest of straws above.

Fig. 33. A small lava bridge marked the end of our upstream investigations. The passage continues for a short distance, but is constricted and does not have a marked trail.

Fig. 34. Marjorie Coggan heading back towards the entrance.

Calcite speleothems are more common towards the lower end of the down-flow section of the cave. Thin calcite layers on walls, straws and small stalagmites are common (Figs 39 and 40). In some parts of the cave, the floor calcite is redissolving (Fig. 41), suggesting more acidic percolation waters in areas where the overlying calcite-rich sands are depleted.

Fig. 35. Artefacts in the cave include pottery dating from 5-600AD.

Fig. 36. Impressive flow lines down-flow from the entrance.

Fig. 37. Lava features predominate in much of the down-flow section. The white 'straws' are tree roots.

Fig. 38. A collapsed lava crust, or tube-in-tube structure.

Fig. 39. Typical calcite decoration in the down-flow section of Yongcheon Cave.

Fig. 40. Calcite and lava speleothems near the terminal lake.

Near the lower end of the cave, a lava fall drops 5m into the terminal lake. The first pool of the lake is only a few metres across and has been bridged with an aluminium ladder (Fig. 42). From a vantage point near the end of the horizontal ladder, the main section lake disappears from view around a bend, but is apparently some 200m long and up to 15m deep.

Conclusions

The range of features observed in the Geomunoreum lava tubes, and the Yongcheon tube in particular, is truly remarkable. As such, the tubes form a fitting and prominent part of the Jeju Island Volcanic Province World Heritage Area. Apart from the show cave section of Manjang, there are strict access controls on all caves in the Geomun system and entry to Yongcheon Cave is very tightly controlled. Symposium delegates were privileged to be granted access and the organisers of the Symposium (and various Korean officials) deserve special thanks for making it all possible.

Fig. 41. Floor calcite is redissolving in parts of the downflow section.

Fig. 42. Crossing a horizontal ladder over a pit (a lava fall) that drops to the terminal lake.

Fig. 43. Marjorie Coggan and Greg Middleton climbing a small lava fall on their return journey to the entrance.

Fig. 45. Passage near the entry ladder, which is vaguely visible through the build up of condensation

Fig. 46. Jan-Paul van de Pas and party (David Butler, Marjorie Coggan, David Wools-Cobb and Jean-Pierre Bartholeyns) returned safely to the surface, thanks to the Dolharubung (Grandfather figure) warding off evil spirits.

Acknowledgements

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Footnote: This paper was presented as a slide show at the 14th International Symposium on Vulcanospeleology at Undara in August 2008 and has been reformatted for the Symposium Proceedings. Apologies if the great pics don't look as good as they do in the ppt version – Ed.