Volcanic Centres and Lava Caves in China

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Abstract

There are many active volcanic centres in China that occur in contrasting geotectonic zones and some of these are known to possess basaltic lava flows and lava tube caves. The volcanoes in the east of the country, which are products of the collision of the Indian and Eurasian tectonic plates, are little explored, and it is regarded that their magma chemistry may not be suitable for the formation of cavernous lavas. In contrast the volcanic centres in the northeast and south of China have erupted large volumes of basalts in which lava caves are known to occur. Nevertheless, accessible information on these cave areas is limited and so this paper makes a first attempt to record the presence of lava caves in three locations: the volcanic fields of Wudalianchi and Jingpo Hu in Heilongjiang province, northeast China, and the Leiqiong volcanic field in Guangdong and Hainan provinces, south China. The caves presently known to occur in these volcanic fields have not been mapped and are relatively short (up to 500m), nor have these lava fields been systematically explored for caves. Adding interest is speculation that a long lava tube cave may exist at Jingpo Hu, while the Leiqiong field may eventually reveal substantial cave networks. Beyond these three sites, there are other basaltic volcanic fields that in the future may reveal significant cave finds.

Introduction

Few people are aware that there are volcanoes in China, while in fact there are many, located across this vast country in contrasting geotectonic environments. Furthermore, it is known that in a number of these areas basaltic volcanism has emplaced extensive lava flow fields, some of which contain evidence of lava caves. This paper briefly locates China's principal volcanic centres and describes three areas which are known to contain lava caves. The paper is not definitive because the volcanic geomorphology of many of the Chinese volcanic centres has not been described, and if it has, publication has been in the Chinese language and in relatively inaccessible local publications. In addition, while there has been extensive exploration by Chinese and international speleologists of caves in China's outstanding karstic terrains, virtually no exploration of potentially cavernous lavas has taken place. There is therefore a good potential for prospecting for lava caves and their subsequent mapping will aid a better understanding the emplacement history of these lava fields.

China's volcanoes

Figure 1 shows the distribution of the fifteen volcanic centres in China that have been active in the Holocene (i.e., the last 10,000 years), based on evidence from the Smithsonian Institution's Global Volcanism Programme (http://www.volcano.si.edu) and papers by Liu (1999) and Liu (2000), These volcanic centres occur in contrasting tectonic environments and therefore display a wide variety of magma chemistry, not always effusing lavas capable of tube-fed flow. Practically all of the centres possess multiple historic eruptive vents, many numbering tens of vents, with associated lava flows.

Complex ocean/ocean - ocean/continental plate subduction: The only active subduction zone in China is at Taiwan. Eight Holocene volcanoes have been recorded here, to the north, west (Penglu Islands) and south. The volcanoes consist mainly of andesitic submarine and terrestrial stratovolcanoes and domes. While there are some basaltic lava flows, the writers are not aware of any caves being reported (although there will be many sea caves).

Continent-continent plate collision: Collision between the Indian and Eurasian continental plates caused deep subduction of the Indian plate beneath the Tibetan plateau, producing extensive volcano clusters in the Xinjiang (Tianshan and Turfan volcano groups), Tibet (Kunlun volcano group) and Yunnan (Tenchong volcano group) provinces. These volcanic areas are extensive and usually have erupted a mixture of basalts, andesites and trachy-andesites, not generally known for producing caves.

Back-arc volcanisms (i.e., volcanism occurring behind plate subduction zones, on the Eurasian

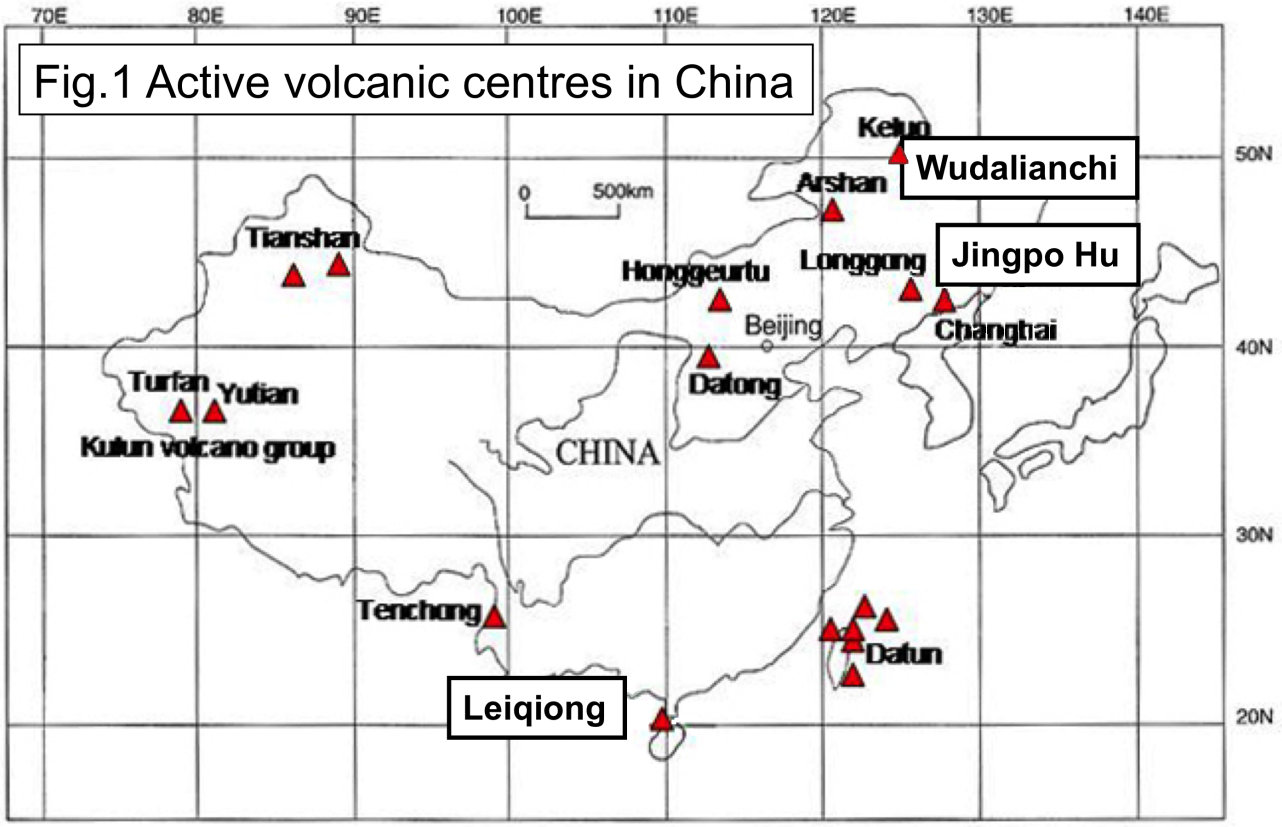

Fig. 1. Distribution of the fifteen volcanic centres in China that have been active in the Holocene. Lava caves are known to exist in the Wudalianchi and Jingpo Hu volcanic fields in northern China's Heilongjiang province, and in the Leiqiong volcanic field in Guangdong and Hainan provinces.

tectonic plate): back-arc volcanism in China occurs in the near back-arc (back-arc basin) and far back-arc (intra-continental) environments.

Near back-arc or back-arc basin: one of China's largest volcano clusters, known as the Leiqiong volcanic field, occurs on the Leizhou peninsula, Guangdong province, and Hainan Island, in the South China Sea. Over 100 vents have erupted copious amounts of potentially cave-forming basalt in the Pleistocene and Holocene.

Far back-arc or intra-continental: volcano groups in central and northern China all lie a considerable distance (1000-2000 km) behind the Pacific plate/ Eurasian plate subduction zone. With the exception of Changbai, which is a large Holocene stratovolcano, all of these sites are monogenetic volcanic fields that erupted large amounts of K-rich basalt. Lava tube caves have been found in some of these fields and they all hold the potential for new cave finds.

To date, and to the knowledge of the present authors, lava caves are known to exist in the Wudalianchi and Jingpo Hu volcanic fields in northern China's Heilongjiang province, and in the Leiqiong volcanic field in Guangdong and Hainan provinces. There may be reference to other volcanic cave sites in the popular literature, but because of language translation problems, the diversity of locations, and immense scale of the task, a full literature search has not been undertaken, and so this paper will describe the three sites of which the authors have some personal knowledge.

Caves at Wudalianchi National Park and Global Geopark

Wudalianchi (literally 'five connected lakes' - Figure 2) is a monogenetic volcanic field located in northern Heilongjiang Province, 251 km south of Heihe City and the China/Russia border marked by the Heilong or Amur River. It consists of 25 volcanic vents, all being small lava shields, with 14 surmounted by pyroclastic cones. It is believed the volcanic field formed in seven phases in the last 2.1 million years, the last eruptions being of the volcanoes Loaheishan and Huoshoashan in 1720-21, although there was a small additional eruption of Laoheishan in 1776. The Wudalianchi activity has consistently erupted K-rich basaltic magma (a variety of phonolite) which because of its unusual chemical properties has been given the local name Shilongite. This eruption effused large amounts of lava, building an extensive plateau (known locally as the Shilongite plateau) of about 60 km² in extent, and blocking the N-S flowing Shilong River in four places to form the string of five lakes.

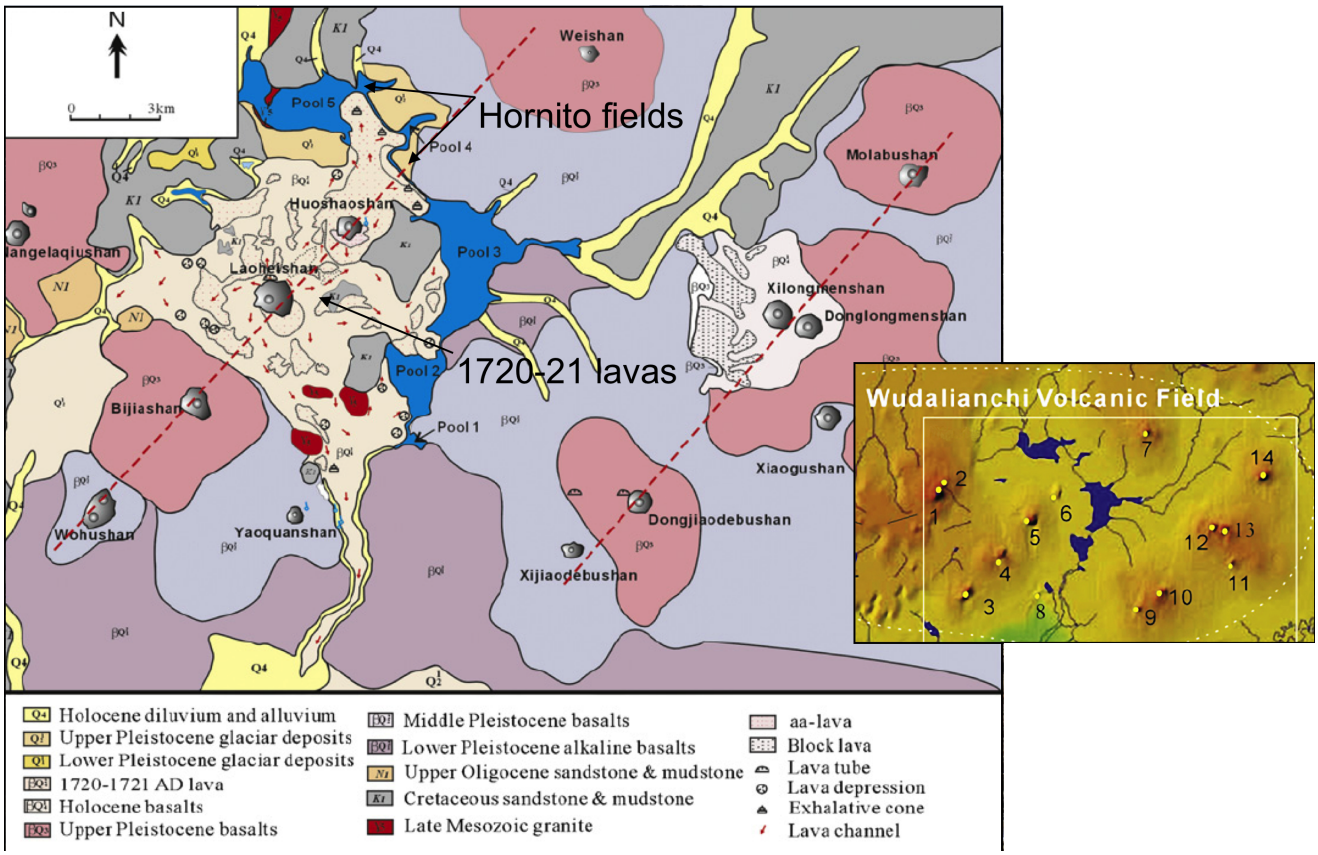

Fig. 2. Geological map of the Wudalianchi volcanic field (after Xiao & Wang 2008)

There are four lava caves so far known at Wudalianchi, all being lava tube caves. Fairy Palace Cave and Waterfall Palace Cave are both found in the new (1720-21) lavas close to the base of the Laoheishan crater, while Ice Cave and Underground Ice River Cave are located in the much older lava (dated about 0.70-0.88 Ma) erupted from the East Jiaodebushan volcano.

Laoheishan volcano

Fairy Maidan Palace Cave: This cave is approx. 225.5 m in length and is located on the lava plateau about 1000 m north of the Loaheishan cone. It was formed in the lava fan that had developed at the north-west outflow from the crater and its entrance is at the end of a boardwalk trail from the visitor car park at the base of the cone wall. The entrance occurs in a collapse pit. Inside, just beyond the entrance, the cave branches into two sub-parallel passages, lying 15-30 m apart, with the east branch being about 5 m lower than the more easterly one. A connecting passage with sub-branches occurs between a point 93.5 m down the west branch and 69 m down the east branch.

The western branch is about 103.5 m long, trends generally 330°N, and has a slope of 2-5°. This branch is 3-6 m wide, rising to a maximum width of 7.8 m, and 1.5-4 m high, rising to a maximum of 6 m. About 36 m in from the entrance there is a small hole in the roof, allowing daylight into the cave. The east passage is about 106 m long, and initially has a width of 3-4 m, and a height of 1 -12 m, although about 32 m in the width changes to 5 m and height 3-5 m. This passage divides with one branch connecting to the west passage and the other to the surface through a small portal. The sub-branch connecting to the east passage makes the connection via a circular pit, about 3.5 m deep, represented by a hole in the roof of the western branch, The cave has minimal breakdown and a clinkery floor, in winter covered by sheet ice. Lava sags and drapes and conical stalactites decorate the roof and walls.

Waterfall Palace Cave: This is a short cave with a steep gradient (28°) located at the base of the NW slope of Loaheishan cone. Its length is 26 m and the passage is 3.8-4.5 m wide, and 1.5-2.5 m high.

East Jiaodebushan volcano

Underground Ice Cave: This cave has a total length of 515 m, and may be the longest lava cave so far known in China (accurate mapping of caves at Jingpo Hu or Hainan Island may prove that some may be longer). The lava is dated as 0.512 Ma. The entrance of the cave is 1.4-1.8 m wide and 6-7 m high, although the ceiling becomes higher inside the cave. There is a hall 206 m beyond the entrance with a width of 26.8 m, broken by two rock pillars, each c.3.2 m high and a diameter of 4.5 m. In the main part of the cave sheet ice about a metre thick covers the floor, which has a

general gradient of 2-5 degrees. There are stalactites on the roof and small amounts of breakdown. This is a very cold cave with a temperature between 0-5°C.

Ice Cave: This cave is more than 150 m long and has a vertical range of 23 m. The entrance is 0.6 m in height and 1 m wide. An initial steep slope becomes one of about 12 degrees inside the cave. 25 m from the entrance is a hall 8 m high and 12.4 m wide. The walls are covered by ice crystals, and decorated with lava drapes and stalactites.

Driblet cones

One of the very special features of the newer lavas at Wudalianchi is the large number of driblet cones and driblet dishes (also known as hornitos). In total there are 1537 of these features, all well-formed and quite large, and together they form an outstanding example of volcanic geomorphology. The site is comparable with the hornito fields of Jorullo Volcano, Mexico (Siebe *et al.* 2009) or those of the Aðaldalshraun, NE Iceland (note the paper by Gadanyi 2008), presented at the 13th International Symposium on Vulcanospeleology). Some hornitos have hollow centres and can be descended for several metres to a basal chamber. It is considered the hornitos formed where the mobile lava flow advanced across wet ground during the period when the lava-dammed lakes were being created.

Caves at Jingpo Hu National Park and Global Geopark

The Jingpo Hu (Jingpo Lake) protected area (Figure 3) is located in the upper-middle reaches of the Mudanjiang River, in southeast Heilongjiang Province. It is 110 kilometres south from Mudanjiang City. The park covers an area of 1400 km². The first author was drawn to investigate this area because Chinese geologists and some tourist websites had stated that there was a long lava tube cave that was over 35 km in length. It now seems to be unlikely that a single cave of this length exists, although there is at least one long lava flow in the area that has a string of cave segments down its length and the original feeder lava tube from which these caves formed may well have had a length in excess of 50 km.

The Jingpo Hu volcanic field is Pliocene-Holocene in age and the scenic Jingpo Hu ("Mirror Lake"), which is a major tourist attraction, was formed when lava flows blocked the Mudan River (Mudanjiang). The location of many volcanic vents was influenced by the important NE-striking Dunhua-Mishan fault. A large number of volcanoes and basaltic lava flows are distributed in and around the lake, while many Holocene trachybasaltic or basanitic cones and lava flows lie atop plateaus along the Mudan River. In total the lavas cover an area of approximately 500 km². The youngest cluster of vents comprises of 13 impressive craters, located in remote mountains, at about 800-1000 m above sea level, in the north-west corner of the park. Lava flows that effused from the youngest craters travelled in a south-easterly direction down a tributary valley of the Mudanjiang, the lava eventually blocking the Mudanjiang where it entered the main valley, about 60 km from the vent. This event created the beautiful Jingpo Hu lake and a most impressive waterfall, known as Diaosuilou. The most recent lavas from the craters have been dated by radiocarbon method and given ages of 3430-3490 BP and 2470 BP.

Four of the recent volcanic vents possess large and impressive craters, accessible to the general public. They lie in an area known as the Crater National Forest Park, which is also known as the "Underground Forest" because of the lush primeval forest that flourishes in the craters. The largest crater lies at an elevation of 1070 m and is nearly 500 m in diameter and 132 m deep. Two of the craters are connected by a short cave through which it is possible to walk from the interior of one crater to another.

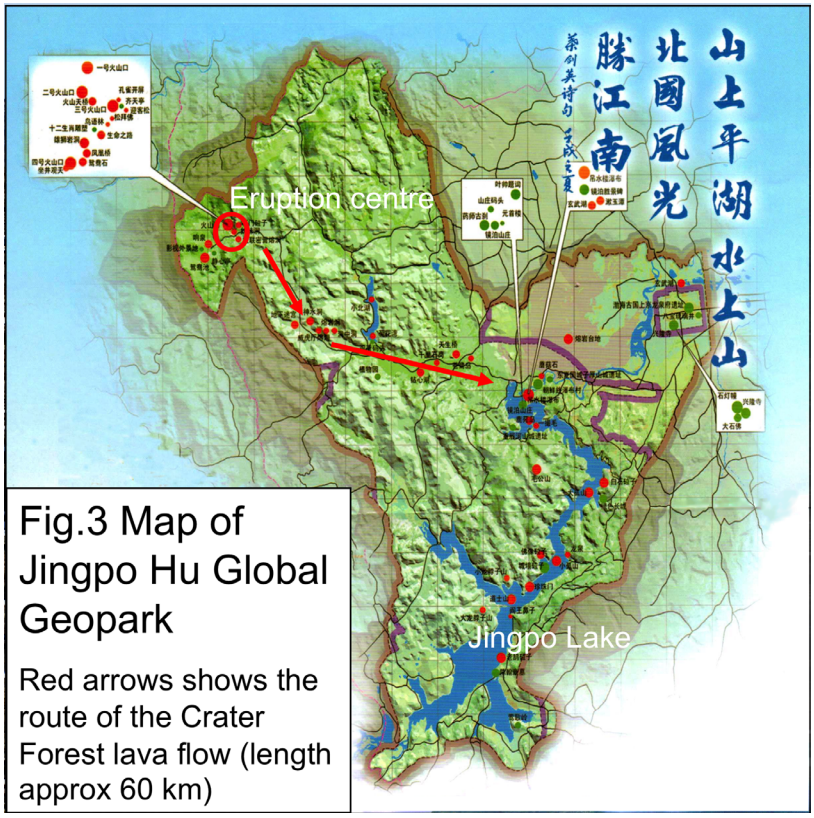

Fig.3 Map of Jingpo Hu Global Geopark

Red arrows shows the route of the Crater Forest lava flow (length approx 60 km)

Fig. 3. Map of Jingpo Hu Global Geopark

The important lava caves lie as a series, aligned down the narrow, valley-confined lava flow that extends from the craters to the lake. These caves are mostly accessible from the forest park highway, which is the route used by the buses taking tourists to the craters. The caves are presumably segments of an axial lava tube system that probably formed along the whole length of the narrow lava flow, but while some caves have been explored and mapped, the complete series of caves and the spatial relationships between them are not known. Several of the caves have been developed to receive tourists.

The caves currently recorded in the crater forest lava field are described below. These descriptions are shortened versions of ones that appear in a web publication by the park authority (http://www.jingpohu.com.cn/dizhi/Eshow.asp?id=117), and while cave lengths are not given, one cave (Longyandongtian) of at least 500 m in length has been briefly investigated by the authors.

Weihuting Cave: This cave can be found 100 m north of the 5.2 km point from the entrance gate to the crater forest park highway. The cave entrance is 7 m wide and 1.7 m high, although the passage height increases to 2.0 m farther into the cave. The ceiling is densely packed with conical lava stalactites. The wall surface is smooth and there are layers of protruding glaze. The floor is patterned pahoehoe. There are also floor driblets of different sizes. It is a spacious cavern, like a large hall.

Longyandongtian Cave (Dragon Rock Cave): Access to this cave lies about 9.2 km up-flow from the entrance gate to the crater forest park highway. There are 10 collapse entrances in this area, the largest and best-formed providing access to the most complete lava cave segment. Progress along the passage is easy, past colourful walls and beneath a ceiling of stalactites, with lateral benches and as many as three shelves protruding from either wall. The floor is pahoehoe, with impressive floor patterns.

Shenshui Cave (Driven Water Cave): The entrance to this cave lies 200 m southeast of Longyandongtian and it divides the cave into two parts. The northern passage is 1.8 m wide, 1.7 m high and more than 50 m long. The southern one is 2.0 m wide, 1.8 m high. The two passages have the same structure and character, with an arched form. The surface of the walls and ceiling is a grey purple-sorrel glaze, with densely distributed small conical lava stalactites (1 to 2 cm). The surface of the wall is smooth and the lava has sagged and dripped forming layers of protruding glaze. In the northern cavern, clean and drinkable water collects all year round and is the reason the local people have called it Shenshui Cavern.

Gubingdong Cave (Ancient Ice Cave): Access to this cave lies about 15 km up-flow from the entrance gate of the crater forest park highway. There are 3 collapse pits overlying a cave that branches in two, the northern branch being known as Gubingdong. This cave has a passage diameter of about 8 m. In summer surface water seeps into the cave through ceiling cracks and runs to the low-lying places in the cave, where it freezes in winter. The ice remains frozen through the summer.

Jiemei Cave (Sisters Cave): Access to this cave lies 13.3 km from the gate of the crater forest park highway. This is two lava caves, separated by a small collapse pit. The northern cave is 3 m wide and 2 m high and the southern one is 7 m wide and 4 m high. They have the same structure and character. Each has an arched ceiling and the surface of the walls is a smooth glaze. The ceiling displays abundant short conical lava stalactites, the largest being about 4 cm long.

Kanlianmiying Cave (Anti-J Allied Army Secret Camp): The entrance to this cave lies 19 km up the crater forest park highway. During the anti-Japanese period, anti-J soldiers were positioned here, and remains of their encampment are still present in the cave. The cave therefore has great historical significance.

There remains great potential for further discovery, exploration and mapping of lava tube caves at Jingpo Hu, particularly in the long crater forest park lava flow. While the flow is covered with dense mixed broadleaved and conifer forest, aerial or satellite photography of the flow taken in winter when the leaves have dropped from the trees may reveal many more collapse entrances and their relationships one to another along the length of the flow. The rumoured 30+ km lava tube cave still remains to be found.

Caves at Leiqiong Global Geopark

The Leiqiong volcanic area is a 7300 km² basalt-basanite plateau (Fig. 4), which extends across the Leizhou Peninsula, Guangzhou Province, and the northern part of Hainan Island, either side of the Qiongzhou Strait, in south-east China. The whole area was designated a volcanic Global Geopark in 2006. The area belongs to the so-called Leiqiong Rift Volcanic Belt, and is the largest area of exposed basalt in southern China. Volcanic activity may have commenced in the Oligocene, but was most extensive during the Pleistocene, declining in the Holocene. Early volcanism produced flood type fissure eruptions of quartz tholeiites and olivine tholeiites, while later phases were dominated by central type eruptions of alkaline olivine basalts and olivine tholeiites.

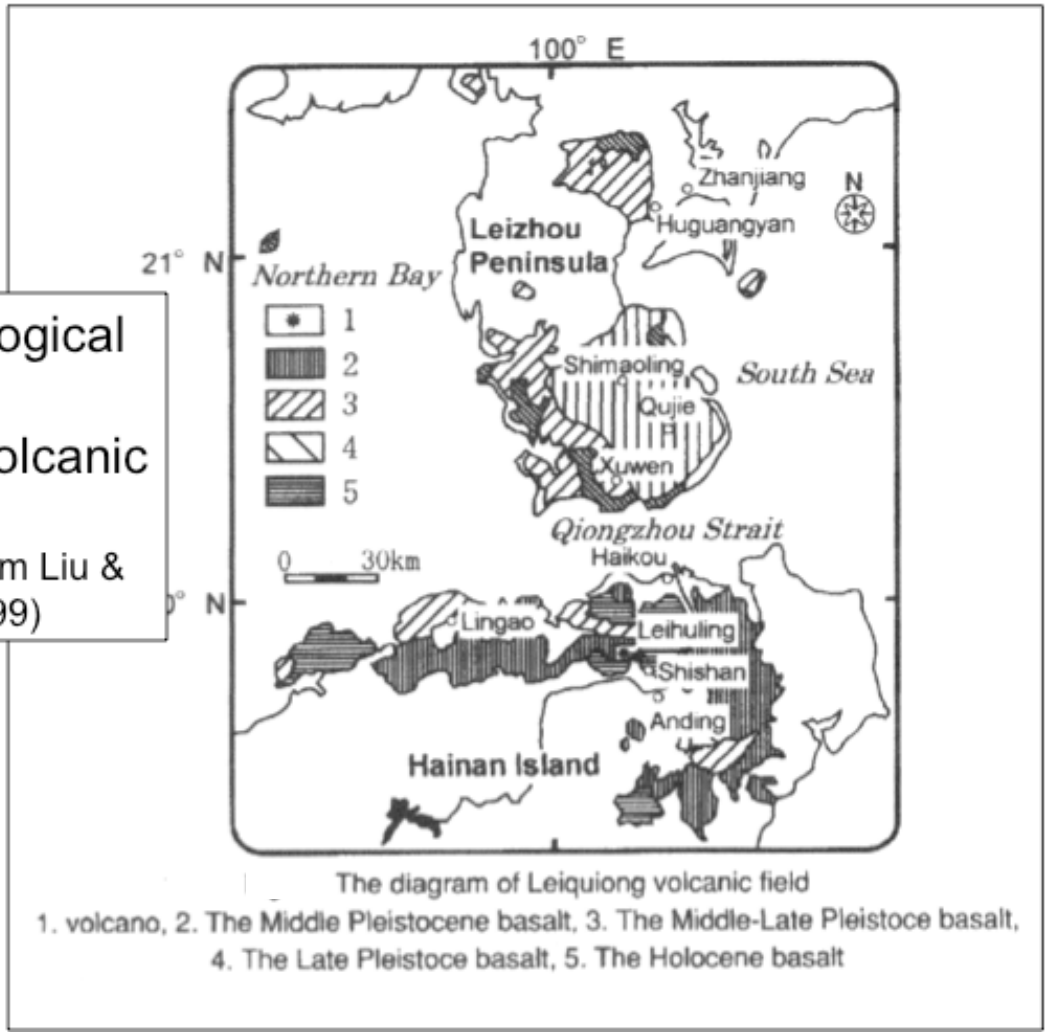

Fig.4 Geological map of the Leiqiong volcanic field
Abstracted from Liu & Taniguchi (1999)

The diagram of Leiquiong volcanic field
1. volcano, 2. The Middle Pleistocene basalt, 3. The Middle-Late Pleistoce basalt, 4. The Late Pleistoce basalt, 5. The Holocene basalt

The volcanism was influenced by N-S crustal extension related to the opening of the South China Sea Basin, and the area is considered to be a back-arc basin. Much of the volcanism consists of Pleistocene-Holocene volcanic cones, forming an extensive monogenetic volcanic field with an estimated 177 small volcanoes, although Yingfengling and Tianyang are two Pleistocene stratovolcanoes. The youngest cones are Ma'anshan and Leihuling, and members of 30 or more cones in the Shishan and Yongxing regions of Hainan. The latest eruptions occurred in northern Hainan in 1883 and 1933.

There are abundant basaltic lava flows, but the literature makes no reference to caves, except those that have been opened for tourists in the Hainan or Qiongbei Volcano Geopark (that part of the Leiqiong geopark lying in the northern part of Hainan Island - confusingly this area of Hainan has also been called Haikou Crater Cluster Geopark and Haikou-Shishan Volcanic Group Geopark). The Haikou-Shishan district is said by tourist literature to have "more than 40 volcanic cones and 30 volcanic caves." Some of the caves can be explored by tourists in Shishan Park. The Lonely Planet Guide notes that here "the Seventy Two Cave Lava Tunnel ... is said to be hundreds of meters long, 20 m wide and 15 m high."

The Leiqiong volcanic field, both on the Leizhou Peninsula and northern Hainan Island, is undoubtedly a place that will reveal many more lava caves in the future, both through a careful search of local knowledge and more scientifically-based physical exploration.

Prospects for the future

China's volcanoes hold great promise of some major lava cave discoveries in the future. Apart from Wudalianchi, whose lava fields are quite well investigated, many of the other volcanic fields hold the possibilities of new cave discoveries. Lava flows at Jingpo Hu and in the Leiqiong volcanic fields must be a priority for investigation. At Jingpo Hu a thorough scientific investigation of the 60 km long crater forest lava flow may reveal more and possibly longer caves and if these are systematically mapped and plotted on a map of the flow field, they may reveal a substantial amount about the form of the original master feeder tube system. A necessary start to look for caves on the Leizhou Peninsula and the northern part of Hainan Island will be to record all known cave locations from literature sources and local knowledge, which can then be followed-up by physical exploration.

There are other volcanic fields in China that may hold the promise of lava caves. High on the list must be Long'gang in Jilin Province, NE China, which has 160 volcanic cones scattered over 2000 km², with extensive alkali basalt lava flows. Other possibilities are the recently discovered Arshan volcanic field in Inner Mongolia, which contains 40 volcanic cones, with long Holocene lava flows that blocked the Halahale River, and the Honggeertu volcanic field, which contains 12 cones and lava flows of Holocene age. Little is known about the volcanic fields of Tibet and Xinjiang, but a cavernous lava found here might well hold one of the highest lava caves in the world.

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