騰 龍 洞

TENG LONG DONG

THE LONGEST CAVE OF CHINA

REPORT ON THE FIRST BELGIAN-CHINESE SPELEOLOGICAL EXPEDITION IN 1988

PUBLISHED BY BELGIAN-CHINESE KARST AND CAVES ASSOCIATION
EDITED BY JAN MASSCHELEIN AND ZHANG SHOUYUE

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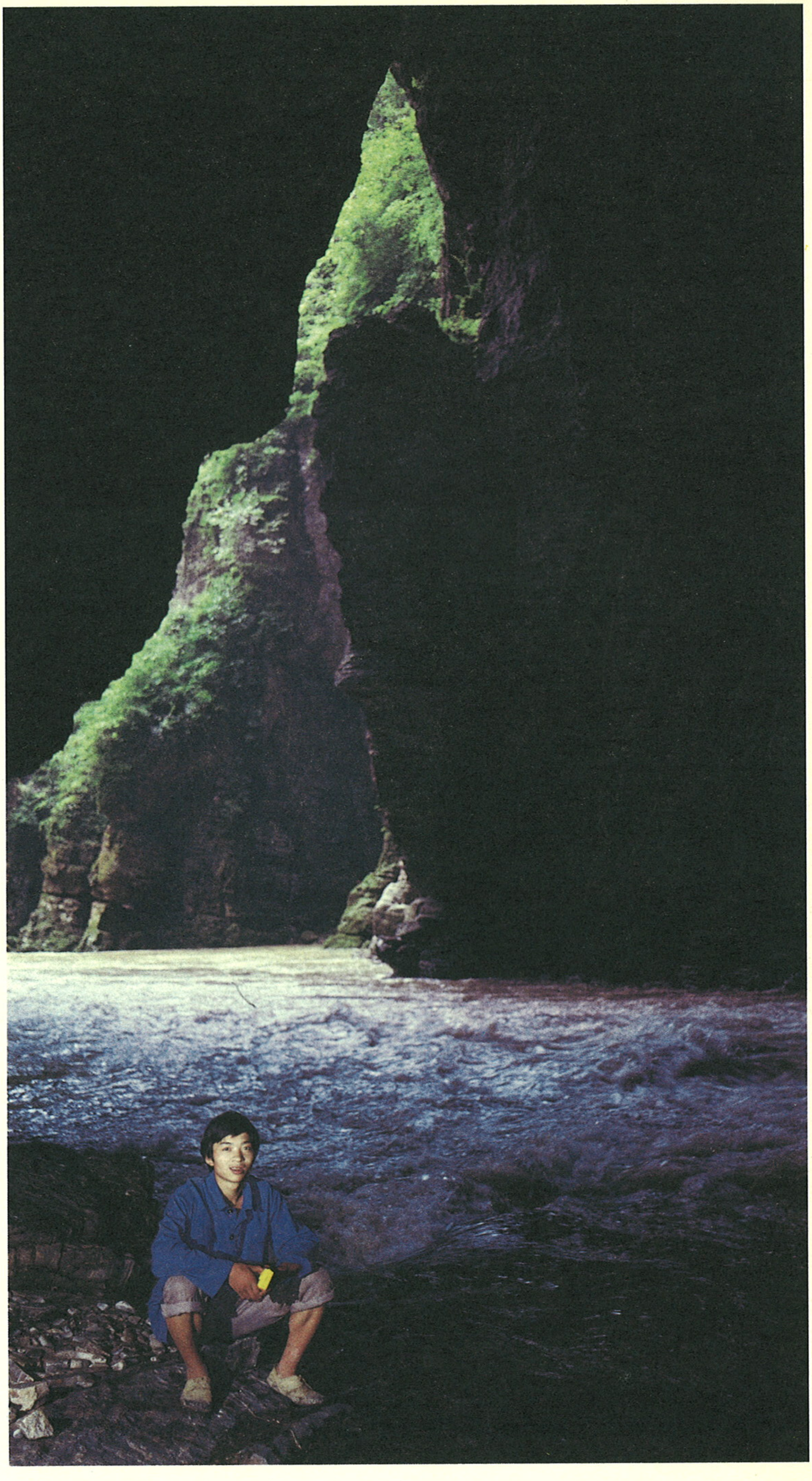
Tenglong Dong Resurgence.




Song descending Xiang Shui Dong.

INTRODUCTION

In 1984 the first plans were made to set up a belgian expedition to explore the unknown undergroundworld of China. It was known for many years that China was to become a cavers paradise, since the limestone that covers a great part of the country contains a fantastic potential for cave development. The greatest part of these caves are unexplored, never visited by man.

At the end of 1986, at the invitation of Prof. Zhang Shouyue from the Karst and Groundwater Research Group of the Institute of Geology in Beijing, a two man reconnaisance was made to Lichuan county (Hubei), (an area closed until 1989). Near Lichuan the Qingjiang river has made its way underground over a distance of 10 km trough an enormous cave: TENGLONG DONG or cave of the Flying Dragon.

In 1988 a 15 men belgian team, joint by a ten man chinese team, and assisted by the local authorities of the West Hubei Autonomous Region and Lichuan District, explored the greatest part of this underground river as well as a lot of fossil galleries in the surrounding area. Tenglong Dong became the longest cave in China (more than 40 km). This publication presents the results of the '88-expedition, supported by different Belgian governmental institutions, private companies and the National Geographic Society.

PART ONE

THE LICHUAN AREA

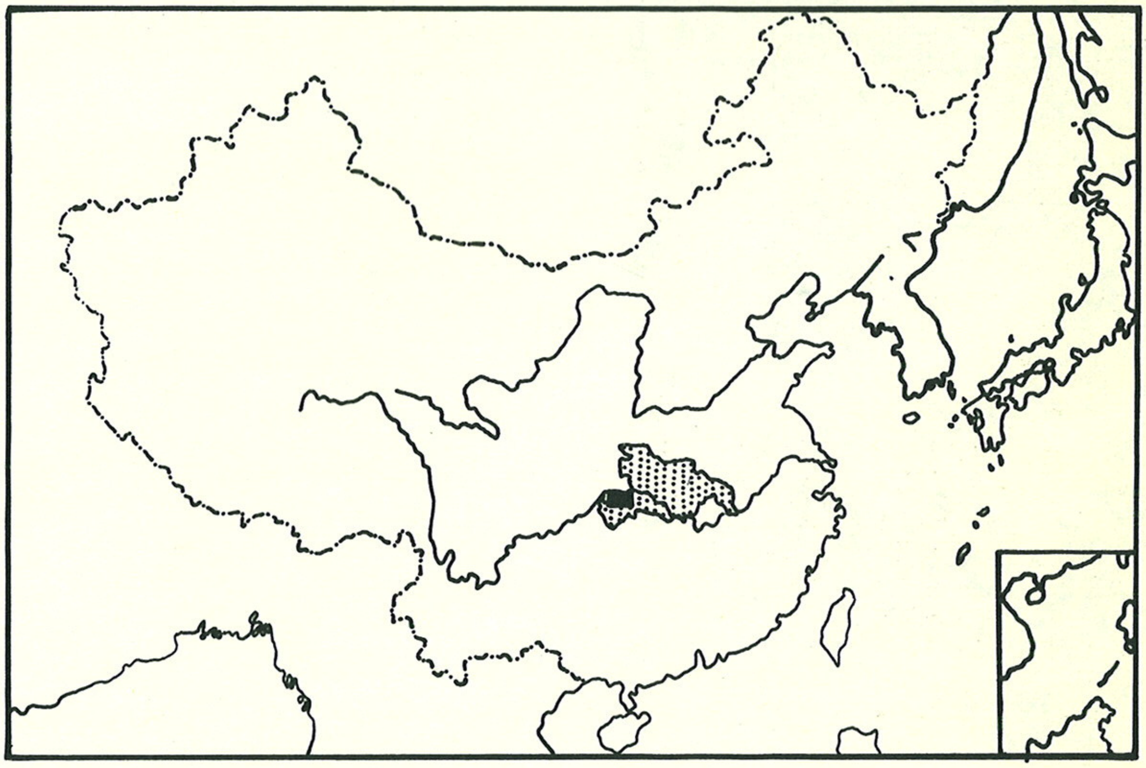
PRELIMINARIES

The main objective of our expedition was to explore the big cavesystem which was supposed to exist near the town called Lichuan, in the Hubei province, right in the centre of China. (Fig.1). Lichuan is situated at 30° N and 109° E. It belongs to the Enshi Tujia and Miao Autonomous Prefecture. The county extends over an area of more than 4600 sq.km where more than 700.000 people live, 45% of them belonging to the Tujia and Miao national minorities, live, the others being mainly Han. It is a mountainous area. Some summits exceed 2.000 above sea level, but most of them are between 1.100 and 1.500 m, the lowest point of the county being only 300 m a.s.l. Most of the rocks are carbonates: limestone and dolomites. At the northern limit of a large carbonate basin the huge depression where Lichuan is situated extends. This depression 25 km long and 30 km wide, extending SW-NE, is a true polje, a karstic depression with a relatively flat bottom and sharp breaks of slope at the base of bordering hills, mostly very steep.

The county of Lichuan abounds in natural resources: the first one, water, particularly in karst areas, representing a potential of over one hundred thousand kW. The explored coal resources reach sixty million tons and the undergroundtreasures of the county also include five billion cubic meters of natural gas. One should of course add on the surface: the farm lands, the forested mountainland and the grassfields. Ricecultivation abounds, but the main economic crops are raw lacquer, tea and tobacco. And let us remember, as a curiosity, the relicttree from Mesozoic Metasequoia glyptostroboïdes, of which an exemple is to be seen in the village of Mondao.

In 1987 the total value of the industrial and agricultural output was estimated to be about 340 million RMB Yuan*. Industry (mainly tobacco) makes up 53 % of this figure and agriculture 47 %. According to

Fig.1. Location-map of the studied area.



unpublished governmentstatistics, the total income of the county is 225 million RMB Yuan, whereas the annual income per farmer averages less than 200 RMB Yuan only.

Near the city of Lichuan streams the Qingjiang (Clear River). It is one of the most important tributaries of the Changjiang (Big River: the true name of the Yangtze). Downstream of the city, the Qingjiang disappears in order to become an undergroundstream for a distance of some 10 km as the crow flies. This big undergroundstream caused the development of an enormous cavesystem, Tenglong Dong. We were requested to explore this cavesystem.

One of the main objectives of our expedition was actually to try to follow the underground river from entrance to resurgence, realizing a world record in the same time: the longest undergroundtraverse of a river of that importance.

CLIMATE AND GEOMORPHOLOGY

Due to its geographical position - at the same latitude as Northern Africa - and its altitude - well above 1000 m - Lichuan generally possesses a mild and agreeable climate. The seasons are well marked, provoked by the monsoonregime which is influencing all China: cold dry northerly winds in winter give way to warm and humid southerly winds in summer and maximumrainfall.

By its position above the Three Gorges, Lichuan is protected from the oppressive heat, afflicting the Lower Yangtze plain; it rather leans to the unique and reliable regime of the Red Basin of Sichuan province, shielded by high mountainranges all around: there are no great temperatureextremes, and year round rainfall with few torrential rains. (Fig.2) The winters are damp and misty with occasional heavy snowfall. The remarkable decrease in rainfall during August was also observed during our expedition. It has a strong effect on the discharge of the Qingjiang river at Tenglong Dong. Soilerosion is very limited in Lichuan: green is the dominant colour on the hillslopes, testifying of good farmingpractices by the local inhabitants. Widespread use of coal- burning stoves (coal produced in local mines) has halted deforestation.

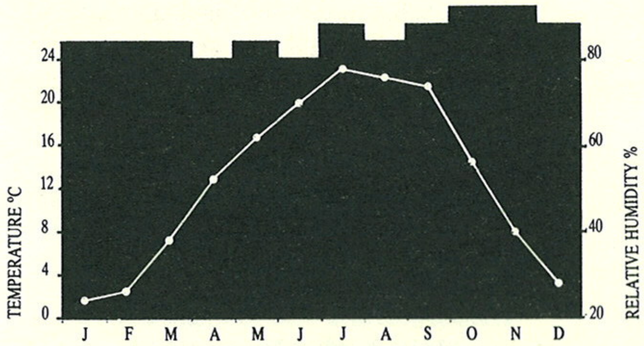
Lichuan possesses a very attractive countryside and an impressive scenic beauty. Human activities weld harmoniously with the variable landscapes. These evolved during millions of years as an interaction between climate and rock, ever rejuvenated by vertical movements of the earth's surfaces.

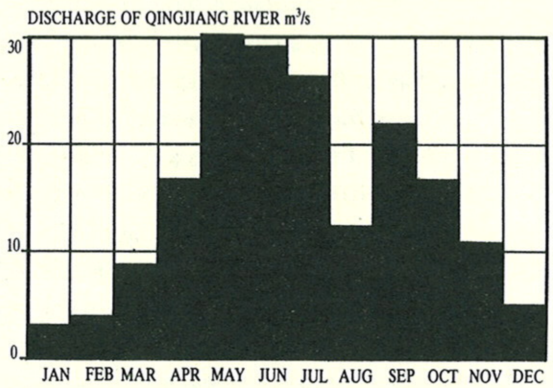
Since limestone is most abundant in western Hubei, an extensive karst has been developed. The karstlandscape is typical for south- central China and according to Zhang Shou Yue it is classified as a "qiufung-uvala" mountain landkarst. Qiufung is the indication for conekarst with gently sloping hills. A Landsat satellite photograph is available for the Lichuan area which allows the recognition of several major morphological units. (Fig.3)

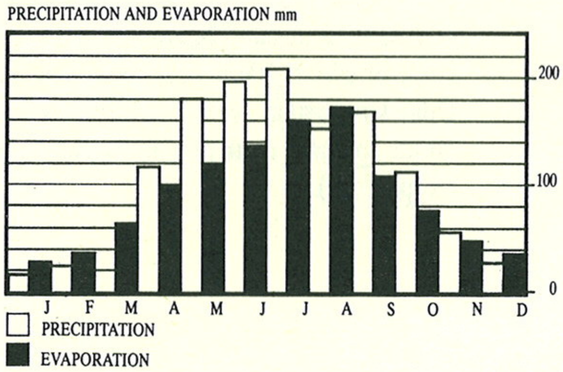
Except in the piemont plateau, surface drainage of karstic landscapes is restricted to some deep valleys. The T1d-T1j formation limit forms an important geomorphological limit around the Lichuan anticlinorium. The NW flank of this anticlinorium is marked by a range of uvalas, 100 m deep. The Tenglong Dong karstsystem developed near this limit on the southern flank (a plateau-canyon type morphology).

* 1$ = about 4 RMB Yuan

Fig.2 Precipitation (in bars) and temperature (curve) measured by Lichuan county weather station (Hubei province branch of state weather bureau), period 1959-1986.







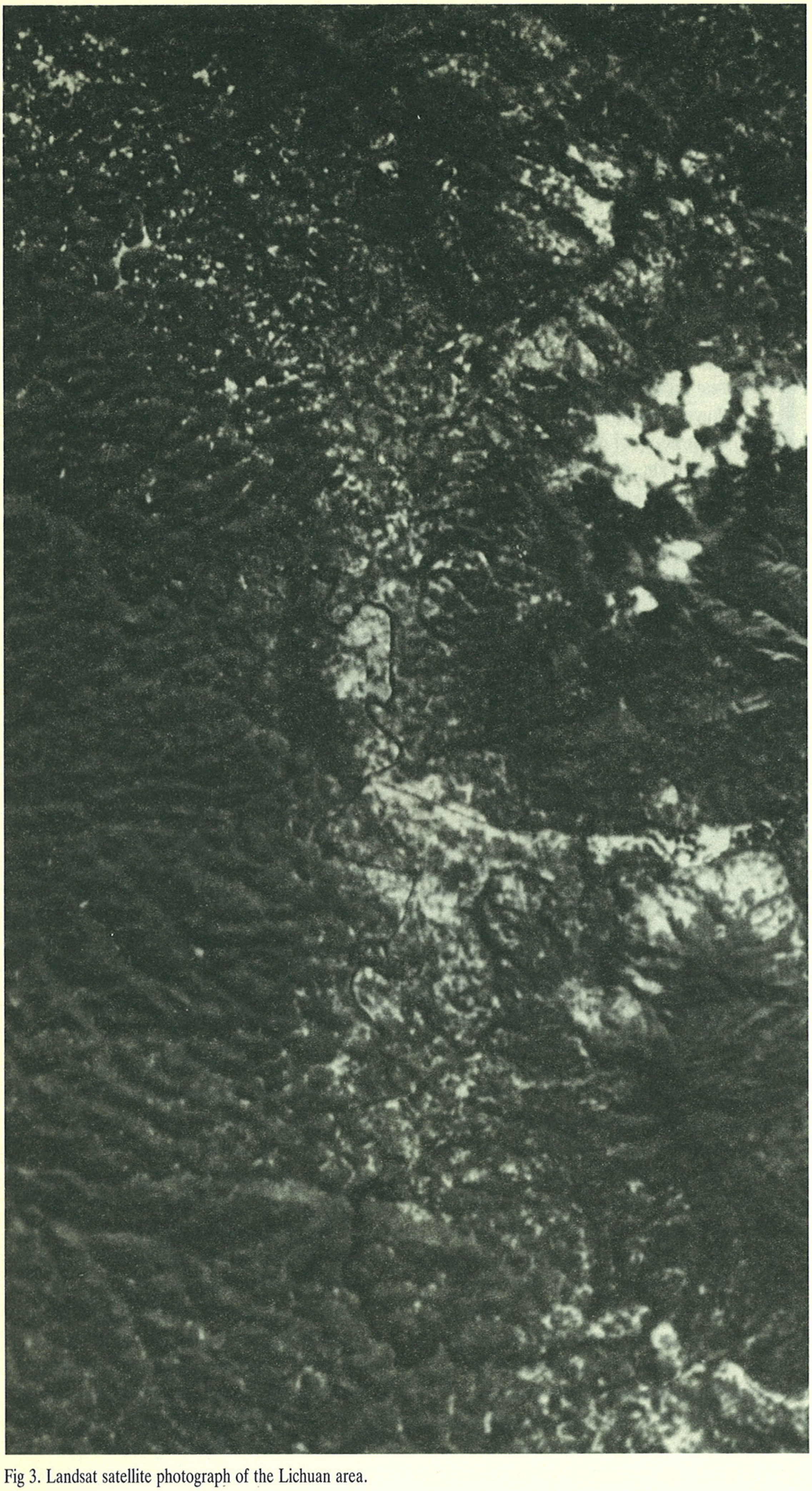


Fig 3. Landsat satellite photograph of the Lichuan area.

TENGLONG DONG: THE EXPLORATION

GENERAL DESCRIPTION

From Lichuan, the Qingjiang river flows northeastwards between the steep slopes of wooded hills over some 6 km, and disappears in a huge tunnel after a spectacular waterfall of more than 10 m. There is the lower entrance of the Dragons lair. This natural tunnel opens in a big limestonewall. In the same cliff there is also an upper entrance to the monster's palace. This ancient entrance is still huger than the lower one and reaches a width of 50 m and a height of some 70 m. These two entrances present the upstream access to the cave: the present-day ponor and the ancient one. (photograph) In the same area however, one can find three other caveentrances. Fish Cave (Nianyu Dong) which is in fact a window on the main river. And Oxnose Cave (Niubizi Dong) and Cold Wind cave (Liangfen Dong), which are also supposed to connect to the main river, although we could not actually connect them.

The main upperentrance of the cave gives access to the upper level. It is the most developed, as well in length as in volume. It includes several km of galleries, frequently exceeding 50 m in height and 40 m in width. At several places, the conjunction of the beams of our lamps wasn't enough to distinguish the roof. (To study this roof we sometimes used the 12 kg cinema spot lamp.)

The floor is generally sandy or silty in the uppergallery; in some places however, fallen blocks, sometimes gigantic, cover the soil. One of these breakdowns has a minimun height of 120 m and, above this so called "Fog Mountain" (Yaowushan), one cannot distinguish the roof, which is very probably more than 50 m above the top of the eboulis.

Some parts of the upperpassages display beautiful speleothems, covering the walls (curtains, various vertical flowstones..) or the floor (horizontal flowstones and mainly rimstones ..) but also important stalagmites, as in "Buddha's Hall" (Qianfoyan), sometimes 5 m high. In some places rivulets are also flowing at this level. But of course it is the lower cavelevel which was actually the real waterkingdom.

The Qingjiang rushes in the cave with a velocity and a power preventing any attempt of navigation. At the other end of the cave, at the resurgence called Black Cave, the situation was absolutely similar, at least during our stay. However, people told us that a row-boat could sometimes enter this resurgence for some distance during the dry season. The flowrate of the Qingjiang is quite impressive: at the hydrological station of Lichuan, 6 km upstream of the cave, the average discharge of the river is 15.5 m3. (But the discharge passed well over 50 m3 during the floods at the end of the monsoon, in the beginning of September 1988). This, together with the 140 m difference in height between the entrance and the resurgence, meant we could be expecting a very spectacular and tumultuous undergroundrivercourse. And indeed, we were not disappointed. One must imagine a big river with a strong current and an important fall, streaming through often very spacious galleries (up to 40m wide and - estimated - 60 m high), but sometimes narrow and low. This river made a tremendous noise and occupied the whole bottom of the gallery most of the time and unfortunately sometimes even disappeared into a sump.

The upper and lower levels of the cavesystem are connected by several inclined passages, but in some places, the lower level can also be reached by pitches opening in the dry valley. In fact, we used these often very beautiful pitches, like Xiangshui Dong and Longu Dong, to explore the underground river from different places at the same time, also hoping to eventually shunt the sumps we met almost immediately in the entrance, in Fish Cave and Oxnose Cave.

The dry valley, lying above the cave between the entrance of the water and the resurgence, is very uneven and varied. Sometimes wide, more often narrow and gorge-shaped, it displays a broken ground profile with dolines and lakes. The bottom is generally cultivated, in spite of its irregularities, but the flanks are generally far too steep - often almost vertical - and remain densely wooded. It is not surprising that in such a relief tunnel-caves are used as passageways between the different sections of the valley.

Tenglong Dong, present day ponor.

EXPLORATION-HISTORY

The major objective of our expedition was to explore the unknown underground course of the Qingjiang river and the enormous system which was supposed to exist there. At the same time, we were the first foreign visitors in this "closed" area, unaccesible for any visitors. Our objectives were realized, although within certain limits: Tenglong Dong has already some exploration history and Lichuan briefly welcomed some foreign guests, more precisely belgian missionaries fleeing from the eastern lowlands during the japanese invasion in the thirties!

The original name of Tenglong Dong was very prozaic: Dong Po (Shui Dong) or water hole. The name Tenglong Dong or cave of the Flying Dragon was derived from a chinese evergreen, the well known song about a flying dragon. This name is also in line with chinese folklore regarding the caves as the dragon's den during winter.

The many cavities of the Tenglong cavesystem, especially in the dry valley, certainly witnessed intensive utilisation by the local inhabitants for passage, shelter for man and his animals and as a source of water, buildingmaterials and nitrate (originated as bat dung).

During the japanese invasion, the Hubei provincial government was temporarily moved to Lichuan, well protected from the invaders by the surrounding mountains. Several caves around Lichuan became the seat of different administrationdepartments and the army as a protevtion against airraids. The bank cave (we were unfortunately too late to find any leftovers) close to the town is best known. The first written document concerning Tenglong Dong dates from the reign of the emperor Kangxi (1662-1722) of the Qing dynasty. The Lord of Lichuan, named Cheng Shikai, reported to the emperor about his homeland (preserved in the Lichuan county archives). He described the river disappearing in the cave as in "the gaping mouth of a sleeping dragon". During the reign of the emperor Qian Long (1736-1745), son of Kangxi, a poem about the same was written by Zhang Chushuang and reproduced in the country annals. At the beginning of the 19th Century, a small temple was constructed near the entrance.

The existence of nitrates in the fossil gallery is mentioned for the first time in the same country annals. At the end of the 19th Century, nitratemining for use in explosives (and not as fertilizer) was in full swing, occupying up to 100 people. This activity gradually came to an end around 1950. Remnants of burningpits can still be found in the dry gallery up to Fog Mountain at 2,2 km from the entrance and along other cave entrances as well. Unfortunately miningactivity has disturbed the sediments and destroyed the traces of older occupations. In 1884, a party of 10 miners, equiped with torches, traversed the caves for many kilometers and returned rather frightened as rumours go. However,local people ever continued to venture into the caves.

The first technical report about the fossil gallery was written in 1938, during the japanese occupation, by a chinese governmental team, Li and Xiao. They provided details on the geographical position, the surrounding scenery and the presence of vast chambers and galleries, and recommended its use as a military base. They were also the first to suggest touristical exploitation. A new era started in April 1985 with the first decision to start a touristical exploitation. Tourism emerged as a new economic activity in China, as a result of increasing affluence and a liberal economic policy. In June 1985, Yin Liangyin organized an expedition of 30 persons exploring 4 km, while Zhang Guofang and Yi Shaoyu organized an expedition of 42 persons surveying during one week, with military equipment. This team drew a map about the cavesystem, mentioning the known and the supposed parts of the system (remarkably this very large map was first drawn on two white sheets!).

In September 1985, the local authorithies created a touristical developmentagency recruiting a team of guides who, with the occasional assistance of the villagers, started to construct the paved touristpaths in the fossil gallery. This was described in the "Tourist Magazine", 1985-4, which declared that the cave would become worldfamous! In March 1986, an engineering geologist, named Dang Renshan, accompanied by 2 guides, made the first geological observations. In October 1986 occured the first exploration of the underground river by Zhang Guofang and Liu Zhishang, accompanied by 4 guides. They explored the area of the resurgence.

At the invitation of Zhang Shou Yue and the local authorities, a belgian pre-expedition made a first reconnaissance of the cave in November 1986. In January 1987, a tourist office was opened at Lichuan and Tenglong opened for tourists. In its first year 30.000 visitors made their way to Tenglong. In December 1987, the Academia Sinicagroup, led by Zhang Shou Yue surveyed part of the fossil gallery and collected rock and speleothem samples to be studied at their laboratory in Beijing.

The joint Belgian-Chinese speleological expedition was organised in august-october 1988. In March 1989, 5 months after our main expedition, Tenglong Dong was protected and declared a scenic spot by order of the provincial government of Hubei. Lichuan was opened for foreign visitors.

SOME HIGHLIGHTS OF THE EXPEDITON

July 1984: "Dear Mr. Zhang Shouyue, we would like to introduce ourselves,...". First letter, first step on our way to China. August-September 1986: Visit of Prof. Zhang to Belgium, first discussions about the possibilities of an expedition to Tenglong Dong. November 1986: reconnaissance. May-June 1988: three chinese scientists visit different research institutes in Belgium.

Monday, August 15th at 4.50 p.m. we leave Brussels Airport in a polish plane, direction Beijing. Tuesday, 3 p.m. local time: Beijing Airport. Prof. Zhang is waiting for us and accompanies us through the customs. Wednesday 17th our travel permits are arranged and after a visit to the forbidden city, near Tienanmen Square, we leave Beijing by train. The station is tremendous: thousands of people sitting, staying, laying down, running, sleeping in- and outside the station. Tropical heat, but a kind atmosphere. We have a two daystrip before us through a flat country: maize-, rice- and potatoefields under a covered sky. It rains but it remains hot. Our thoughts are already in Tenglong Dong.

Besides the route we took, there were three other possible ways to reach Lichuan. From Wuhan, capital of the Hubei province, one can reach Enshi by air and from there by bus Lichuan, the distance Enshi-Lichuan being only 97 km (which however means more than half a day bus). This is the fastest way. From Chongqing (Sichuan province), which can be reached by air from Beijing, one can travel downstream to Wanxian and then to Lichuan. And yet another possibility is to reach Dayang (Hunan province), which is famous for its pseudokarst landscape of the Zhangjiangjie National Park, by air or by train. From there, one reaches Lichuan by a busride of about 300 km (at least one long day of travel).

On the 19th at 6.00 a.m. we arrive in Yichang, a big city on the Yangtze river and one of the last places in the world where sturgeon is to be found. There is also the enormous Gezhouba-dam. In the evening, we take the riverboat for a trip lasting two nights and one day to Wanxian, about 340 km upstream. We pass one of the seven worldmiracles: the three gorges: Xiling, Wu and Qutang. The majestic river, the marvellous landscape and the misty weather, together with the typical karstfeatures and the snorring of the engines makes this journey unreally beautiful. From Wanxian, we have another 7 hourstrip to Lichuan, 126 km further in an area which has been closed to foreigners for almost 50 years.

In the evening of Sunday 21st we arrive as planned in Lichuan, although our equipment didn't. It had left Beijing the same day as we, but separately. Now the truck seemed to be blocked, while several parts of the road disappeared, due to the heavy rains. Until Monday 29th, we'll have to manage with almost no equipment. Nevertheless this time is spent on very useful recognitions of the main entrance and resurgence of Tenglong Dong, as well as other entrances in the dry valley, which in fact does follow more or less the traject of the undergroundriver.

The first view of the entrance of Tenglong Dong is fantastic. On the right side the enormous porch of the fossil gallery (70 m high and 50 m wide). On the left side, there is the entrance of the wet gallery, which leaves us speechless for a few moments, where the river (15 m3 at least) disappears in a boiling waterfall. We shall not be disappointed: some good, wet and hard caving is to be expected. On the other hand, it immediately becomes clear that maybe it will not be as easy as we thought it would be, to explore this river and make the traverse.

Anyway, we started to explore the dry gallery and the dry valley. Usually 4 or 5 teams, scientists and cavers, both Belgian and

Chinese, were working at different locations. When finally the long expected truck arrived we already had a good impression of Tenglong's general structure and immediately started exploring the undergroundriver, using the different entrances: Fish-cave, Xiangshui Dong and Milk Way.

The exploration of the underground Tenglong river is one of the most fascinating, captivating and exciting experiences. But unfortunately it is not possible to get experienced to this kind of riverexploration in Europe, as there are no undergroundrivers of this size. We were inspired by the french and british expeditions to Papoua New Guinea as for the explorationtechniques. But though it contained many useful tips, we also had to invent the right techniques and select the right equipment, adapted to the specific situations. Indeed, very big care must be taken as for the problems of lifelining (to be sure to save one's life rather then drawning him) and equipment (use of lifejackets, fins, whistle, boats, ..). Unfortunately some things can only be learned by actually doing them, so....

All days are more or less equal. Every morning, at 6.00 am, we are woken by loud music from the speakers in the streets of Lichuan. Even the early hour doesn't keep the people of this town to start their ever busy day. Breakfast at 7.30 and then to the caves by bus or Beijingjeep. It is often necessary to walk for 1 or 2 hours over very tiny paths between the cornfields befor getting to the entrances. Every inch of useful soil is cultivated.

Every evening, after a hard day of underground-work, a splendid meal is served at the hotel. Afterwards, we have to prepare the equipment for the next day and make some topographynotes. We report the new discoveries and discuss the objectives for the next day. At 11.00 p.m. we try to get some sleep. Even during the socalled recreationtime we still work: we learn our chinese guests about the single ropetechniques.

Monday 5th September: another access to the river is explored: Longu Dong. A beautiful 50 m shaft right above a big lake leads to another part of the river traject. Here also, we need lots of time and hard work for only a short distance. But it is unbelievably beautiful. In the meantime another team explores a sidepassage of the fossil gallery. To their surprise, they make the connection with ... Longu Dong. They arrive at the opposite side of the river at about 10m above the waterlevel. There is no way to reach each other and the heavy noise of the river makes it impossible to exchange messages. In the evening, when the two teams make a topography, the importance of the discovery becomes clear.

On the 7th, the teams working in Oxnose cave and Longu Dong report masses of water coming in from the sealing. Indeed, it has been rainy and cloudy for some days now. In the night of 7 to 8 september it starts raining heavily and continuously until the next evening. The river floods with a spectacular result: the water level raises 8 to 9 meters within a couple of hours. The next morning the decision falls: 'no team will work on the river for a few days: forbidden'. Everyone hopes that the equipment already in the cave, will resist the enormous turbulent forces of the water.

Forced by the weatherconditions, we start exploring the fossil gallery and the dry valley as good as possible. Even the photo- and filmteam gets more manpower to do its job. Two teams take the opportunity to make a two days underground camp in the fossil gallery, avoiding the long approaches. In some cases we already have to walk over 7 kilometers in the cave before reaching 'new ground'.

Sunday, September 11th. A first attempt is made to gain the river again. But the Longu team reports that the water level remains 3 meters too high. They can't reach the equipment, left in place. Another few days are spent waiting, exploring the dry passages. We now have the opportunity to meet the few farmers and their families living in the dry valley. We appreciate their fabulous hospitality, the only problem is the language.

Sunday, September 19th. We notice the damage to the equipment, caused by the waterforces. The waterlevel, back to normal, gives us the opportunity to see the broken ropes, the bended carabiners and bolts. Much work has to be done over again. But we are in a fantastic condition and already acquainted with the particularities of the riverexploration. On top of this, the weather is excellent and at last we get the chance of working overnight. So in the last days of the expedition we manage to explore many new kilometers.

Thursday, September 22nd. The last day in Tenglong Dong. Frank, back in shape, recovered from an urgent operation in Lichuan four weeks ago, receives the honour to accompany Rik who wants to measure from the main entrance to Fish cave (Nian Jiu). They discover a swollen pig, a discovery almost causing the death of Rik, since he became scared to ... death. Anyway, they finished the topography. In the evening, another marvellous banquet, endless 'kampeis'. The next day, a last goodbye to our local chinese friends, and then part of the group goes to Sangzhi, the others to Wufeng.

Wednesday, September 28th. The whole pack meets again in Sangzhi. We reach Changsha via Dayong, where we catch the train for Beijing. After the last visits to the remnants of the chinese emperors in and around Beijing, we get off to Brussels, back home.

THE '88 EXPLORATIONS

In a certain sense, the objective of the '88expedition to Tenglong was simple: make the connection between the entrance of the cave and the resurgence, both at the level of the active river and the fossil level. It turned out to be less simple than we thought. In fact, though the general structure of the development of the Tenglong is apparently straightforward, it soon became clear that the system was complex and that it wouldn't be easy to make the so wanted traverse. We attacked different spots simultaneously, trying to work as much as possible on the exploration of the river. This was very difficult, because of the immensity of the cave, the technical difficulties and dangers of the exploration of such a river, the unexpected amount of sumps, the long distances to cover every day before actually being able to make any progress, and - at least during a part of our stay - because of the high waterlevels. In the following pages one can find an account of some of our explorations in different areas of the system. In order to have a better impression of these explorations, especially how we managed to put some pieces of the immense puzzle together, one can use the overallmap of the cave and the map with the different entrances.

XIANGSHUI DONG

One of the most beautiful and spectacular sites to be explored is Xiangshui Dong, one of the pitches (in the dry valley) which give access to the river. Xiangshui Dong, a hole in the roof of the wet gallery, opens its mouth 28 m above an enormous turbulent waterfall. Jos had already done a good job here. He equiped the pitch at the only place where it was possible without too many bolts. One had to descend almost to the water level from an overhanging tree. Hanging there just above the middle of the enormous waterfall, one had to make a swing, trying to get on to a small platform on the right bank of the river. In fact, one could only make this pendulum starting right on top of the pitch and continuing descending into the void. Very spectacular and very beautiful.

Starting from the platform, Jos and Rik explored the most evident way, i.e. upstream. However, about 300 m upstream they were stopped by a sump. Today, Wim, André, Song and I would like to have a look downstream. Our first attempts failed. There is no possible way to get downstream starting from the platform. The very loose overhanging rocks prevent any possible traverse. We try a small sidegallery, which is probably used by the river in flood conditions, just to arrive at the foot of the waterfall, but unfortunately on the wrong side, namely behind the impervious watercurtain which is now in front of us.

Meanwhile we had been doing some thinking about the possibilities offered by the other river bank. But how to get there? Impossible to swing, so we decide to go upstream to look for a place where we could risk a crossing of the river. The water is a bit calmer about 200 m upstream. Here the river is about 25 m wide. We try it here. Wim gets ready. He leaves his boots and all the unnecessary equipment behind. Dré will keep the lifeline. The first attempt however, is a failure. Wim is almost immediately smashed against the wall downstream. For the second attempt he starts with a swim upstream and near the wall, then tries to use the waterforce to get to the middle of the stream and finally tries to cross. This sorts of exercises are not without real danger. Not only there are the rapids and the waterfall, being very near, but also the lifelining is delicate. Dré must hand free enough rope so that Wim is not blocked, but on the other hand he cannot give too much as it would become very difficult to hold Wim in case he would be carried away by the force of the river. And even if Dré should have to take in the rope to get Wim back to the riverbank, he should be very careful not to drawn Wim. Anyway, the second attempt is succesful, although it is a near thing. Once crossed, Wim attaches the rope and we install a 'tyrolienne' so that we can also cross. And we are very lucky indeed: after 50 m of traverse downstream on the other side we find a gallery that cuts off the meander of the river where the waterfall is. So this time, after descending a little pitch (4 m), we arrive at the base of the waterfall, but now on the correct side. It is only now that we see that the waterfall comes down in a passage that becomes immediately a very big chamber where the river, here over 40 m wide is searching its way through enormous blocks.

At the end of this chamber there is a big lake (50 x 40 m). Unfortunately we don't find any way on, just a sump at the far side. Even a difficult climb of about 20 m doesn't lead anywhere. Nevertheless, we were very pleased to have seen and explored this part, it was one of the most beautiful and spectacular places of the entire system.

A JUNCTION BETWEEN THE FOSSIL GALLERY AND THE UNDERGROUND RIVER.

The exploration of the undergroundriver is often hindered or even halted by dangerous rapids in canyon-style passages or by siphons. On the other hand the fossil gallery is collecting quite a lot of percolating water and draining it somehow to the undergroundriver. Thus small sidestreams can be formed. We chose to follow the most important one, disappearing in a sidegallery directed towards the undergroundriver, just in front of 'Fog Mountain'.

This stream quickly disappeared in a siphon but our chinese companion, a Tenglong guide, already discovered a dry overhead passage, bringing us to the other side of the siphon. Our stream developed into a real undergroundriverbed of quite variable form and dimensions, complete with sideloops and abandoned passages. Especially in muddy passages and sidestreams the Tenglong 'Fish' abound, curiously enough resembling overgrown tadpoles.

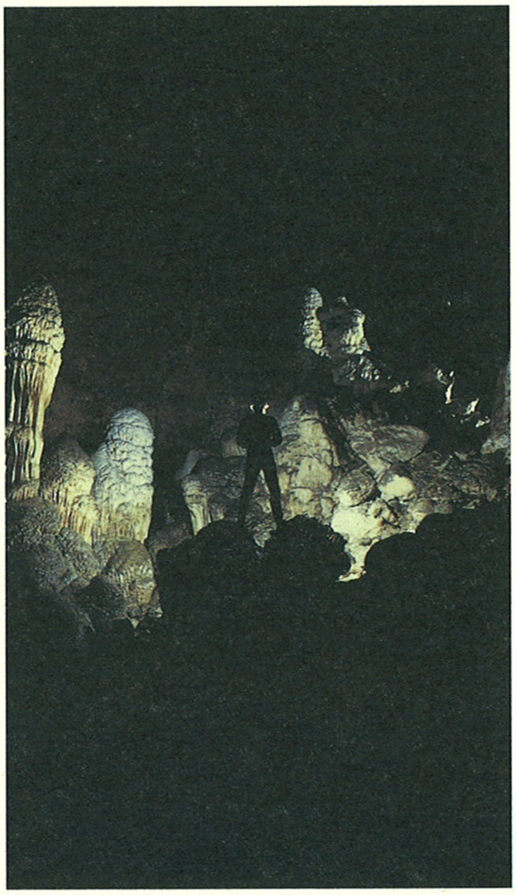
During three days we descended the stream along muddy banks, over rimstonebarriers and cascades, and through deep lakes forming the major obstacles as they could be crossed only by swimming (adopted only one day since we became too cold and numb for any serious work) and by boat. No further technical outfit was needed for this exploration, with exception of some safetylines. Nevertheless, it was a long and exhausting trip, because of the many passages we had to climb or to crawl, and more particularly because of the unavoidable baths, necessary for an adequate topography. After about two kilometers we felt the approach of the target: the air got warmer and moist; a multitude of flies danced in the wind. Soon we heard the roaring sound of a distant swirling river: we finally arrived at the underground Qingjiang. Mission completed. Our precious companion 'Little Hou' (the adjective only indicates his low origins) danced as in ecstasy. To our great surprise we were not the only ones there, so far from the entrance: Jos and Rik had just completed their share of undergroundriver exploration and returned to Longu cave entrance, passing the junction on the opposite side of the river. It was really an unforgettable moment!

WHITE CAVE, THE CONTINUATION OF THE FOSSIL GALLERY.

The main Touristical circuit in Tenglong Dong follows the mostly dry fossil gallery from the sinkhole to Maojiaxia (Mao canyon), with a diversion to Stone Forest, covered with the large speleothems described in the section on radiometric dating. This was mapped over 7 km by the Academia Sinica in 1987, preceeding our expedition. A continuation of the fossil gallery to White Cave, overlooking the canyon in the dry valley downstream of Milk Way Cave, was already established by the Tenglong guides. This part was mapped by a belgian- chinese team, together with the most conspicuous sidegalleries. These could possibly lead to parallel cavesystems or to higher levels. Some with enormous dimensions, such as Man Dong (75 m wide, at least 30 m high, but after 300 m abruptly ending in a blind wall, hence its chinese name which means: Blind Cave). Man Dong of course was explored by Koen.

Tunnelsections, excavated by flowing

Stone Forest.



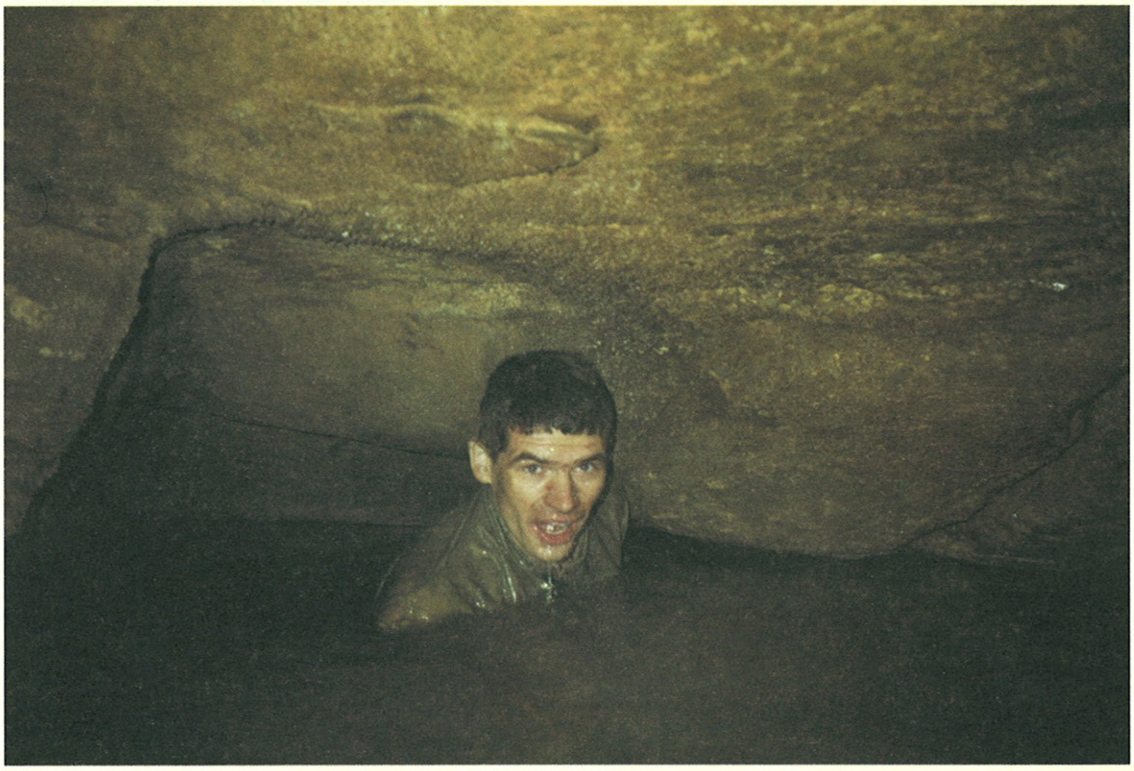
rivers, always ended filled up with sediments, a development to be expected after changes in the rivercourse. Several small rectangular networks were created by percolating water along fracturesystems in the rock. The most notorious labyrinth, Puzzle Palace, caused a lot of headaches to our chiefcartographer Wim. Here the exploration required no technical means. The most dangerous situation occured whith flash floods resulting from heavy rainfall. Backflooding of the White Dragon valley (a small tributary streaming through part of the fossil gallery) kept us from returning to our underground campsite and forced us to escape via White Cave. Well after midnight we stumbled in a farm, tired and drenched. We were offered a meal and a canopybed by the extremely friendly and inquisitive peasants. Nevertheless, work had to continue! However we failed to find real important lateral extensions of the Tenglong system, proving once more that the cave is created by the Qingjiang river. We still have to search for connections with the underground river or a prolongation of the fossil cave. Apparently the main fossil gallery is passing through White Cave-entrance, from where it is undercut by the development of the canyon in the dry valley.

Indeed, one pitch in a contorted fracture finally brought us down more than 70 m, where we arrived in a meandering gallery containing a very small stream and some lakes. This finally ended in a sump. Strange enough the water was clearly warmer in this sump, indicating a mixing with the underground river, which should be very close. This exploration showed that there is hope for new discoveries and for a continuation of the Qingjiang in downstream direction of Shuntan Dong.

BLACK CAVE, KOENS PASSAGE.

In the lower third of the Tenglong system, down to Black Cave, no equivalent of the fossil gallery is known. Shuntan Dong, located at the end of the canyon and collecting the overflow from Milk Way Cave during floods or Shuijing Dong, give access to the undergroundriver. These rather moist caves were particularly rich in cave fauna. Koen

Koens passage, the way to fox gallery.



will especially remember the very agile long-legged centipedes, feared for their venomous bites. They often escaped from the sampling boxes; one of them found an almost perfect hidingplace: Koen's shoulders!

Black Cave itself almost looked like a Swiss cheese with many large galleries which unfortunately all lead to the Qingjiang river (some galleries on the right bank remain to be explored). One gallery suddenly ended, its roof bathing in the muddy water of a sidestream. But it was not a real sump: air was blowing from a small crevice a few centimeters above the water level. Intrepid Koen did not hesitate and disappeared under the roof, to discover a new gallery, named after an unfortunate fox which dug a hole too deep only to find a miserable end. Its trail was conspicuous on the mud banks all along the walls of the gallery. Fox Gallery developed for about 600 m in thinly bedded impure T1d limestone, characterized by frequent breakdowns and low roofs. Regrettably a new siphon choked with soft mud, as experienced by our divers, put an end to our hopes. However, Koen's passage got a lot of attention and became one of the highlights of the expedition.

LONGU DONG.

September 6th. After several attempts, Jos finally reaches a small platform at the bottom of a beautiful 50 m pitch, just at the place where the Qingjiang river gives upon a big underground lake. Around the platform we see plenty of fish so we'll never die of hunger. The heavy roaring of the river makes it almost impossible to talk to each other. The river, at one place only 4 m large, is a steaming mass between two vertical slippy canyonwalls. What a difference with the calm atmosphere of the lake. We put on our safety- jackets and decide to explore the river upstream. Could this really be the main river? It looks so small, although the amount of water passing by is very impressive. Anyway, we start bolting the very flat wall on the left bank. We have to bolt almost continuously in a rather terrifying but fascinating atmosphere: the noise and the power of the water join the idea that one false step could be fatal.

The continuous efforts of bolting in very difficult positions and the care that has to be taken as to life- lining, makes that we progress very slowly. Only after two days and 60(!)m. of river- exploration, some small platforms appear. Because of the overhanging wall we have to attack now and which would need even more difficult bolting, we decide to try passing through the river, since the water seems to be calmer here. Jos secures me. I'm really surprised that I can walk on a step only 1.50 m under the waterlevel. But the force of the water doesn't leave much time for surprise, I'm smashed against the wall and only after a hard struggle, I can reach a small platform. Jos follows, but he is also smashed against the wall and I have to take much care as to the life-lining. Anyway, we decide to try continuing through the water. If it works, it will take us much less time: instead of 4 m/ hour, we can perhaps reach 10 to 2O m/hour. After a couple of days of this kind of waterexploration, one manages to use the forces and counterforces of the water in one's advantage. Now we can make faster progress, but we get far more tired, since we have to struggle continuously with and in the water.

At night, I dream about the day we'll manage to explore more then 200 m in Longu Dong in one day. That day comes ... but is the last day of our stay in Lichuan. That day, we explore over 500 m until we are stopped again by overhanging walls and a furious river.

Descending the pitch on Longu Dong.

FROM SHUNTAN DONG (DEEP LAKE CAVE) TO THE RESURGENCE OR HEI DONG (BLACK CAVE).

At the end of our stay in Lichuan, we tried to make the connection between Deep Lake cave, an entrance situated in the dry canyon, and the resurgence. In Deep Lake Cave, the exploration starts with the traversing of a big entrance lake. A little bit further we meet the underground Qingjiang river. Koen and Michiel, who already did a lot of explorations in this area, told us that it probably would be possible to follow the river to Shuiting Dong, a cave-entrance somewhere halfway between Deep Lake Cave and the resurgence. Indeed, Rik and I were able to reach this entrance. The exploration was rather easy, though we had an almost continuous swim, but the river is rather calm here and very large (up to 30 and 40 meters). We only had to let us go with the stream. The biggest problem was to make a topography of this part (almost one km long) simultaneously. Rik and I explored a bit anxiously every sidegallery to find Shuijing Dong. Since we didn't put any ropes at all, it would have taken many, many hours to go back the same way. But Shuijing Dong was found. Indeed, it is a very large and high gallery, with enormous boulder slopes. So we could get out. We are now halfway to the resurgence.

Next day Jan and I tried to continue. We had 'permission' to work extralate, as it was our last day in Lichuan. Again, most of the day is spent in the water. We can use the boat from time to time, sometimes it is easier to swim, now and then we have to make rope-traverses. It gets late and we used almost all our tackle. The next passage is a little waterfall where the current becomes so strong, that it is sure we won't be able to pass it upstream (on an eventual return) if we don't leave a rope here. Yet we have not enough rope left. We then decide, since we can see the river continue, and as we estimate the resurgence can't be far away anymore, to go ahead, let us go with the water and accept the impossibility of a return in case.... But we are lucky. A couple of hundred meters behind the waterfall, the river becomes calmer, the atmosphere colder, and then we see the entrance of the cave, lightened against the clear night. We explored the last km. of Tenglong Dong. The connection between Deep Lake cave and the resurgence is now a fact.

Tenglong Dong, Black Cave.

CAVE DIVING.

The reconnaissance of Tenglong Dong in 1986 had made it clear that we could be expecting different sumps along the undergroundtraject of the Qingjiang river. The undergroundstreamway can be entered at different places. In most of the cases we soon met a sump, rather surprising in view of the enormous dimensions of the galleries. We found at least 6 sumps (the dye-test at the end of the expedition lets us suppose that these sumps can not be very long or very deep).

Therefore we took a minimum of divingequipment to the '88-expedition: bottles (2 x 4l, 2 x 7l), the smallest Bauercompressor. But many circumstances prevented us from actually diving: logistic problems, lack of time because of the variety of goals, an enormous flood and, because of the very strong current, the impossibility to enter (or leave) the water nearly both upstream- and downstreamsumps. There might be a way when waterlevels are extremely low. Just after the highest flood of September, when we could not explore the river at all, we tried to dive a small sump in the fossil gallery near the resurgence. We had hoped to join a parallel system, but the sump was blocked by a mudslot at -3 m.

At the end of the expedition, during a short visit to Shangzi in Guizhou Province, we dived in the resurgence of Jiutiang Dong. The first sump was passed (30 m, -1), the second one was blocked by a boulder shoke at 3 m, -2. Lack of time kept us from further diving. Yet it is doubtless that the areas we visited offer plenty of possibilities, either for diving in resurgences as for diving in sumps in function of the exploration of cavesystems. But as there were logistic problems (no compressors, no medical support in case of decompressionaccidents, difficulties for transporting the divingequipment through China and through the cave), as well as the impossibility and inopportunity to mobilize expeditionmembers during a long time for the carries, it seemed all but evident to organize an expedition were the means are in proportion to the goals. An expedition, exclusively dedicated to diving, would probably be the best solution. Anyway, the potential remains enormous.

Getting ready to dive the sump of fox gallery.

CAVE SCIENTIFIC RESEARCH

MORPHOLOGY: MAPPING THE GENESIS OF THE FLYING DRAGON.

Of course Tenglong has a complex history, including the excavation by a river, other actions of the water and breakdowns. Some of the latter could have been reworked by subsequent riveraction as well. The final process which contributed to cavedevelopment is not the same everywhere. This is why we mapped the erosion agents which shaped the cave on a part of the groundplan of Tenglong (fig. 4).

We distinguish first those portions of the cave whose present morphology is due to a fluvial action. This shows that most of the upper fossillevel of the cave was also created by the underground Qingjiang.

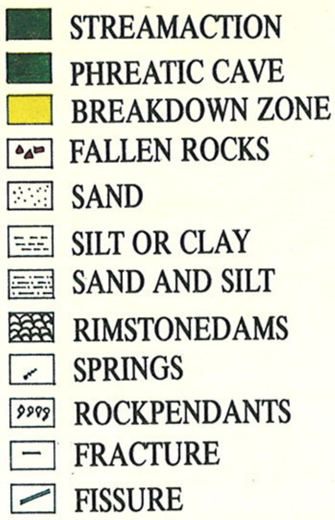
Secondly we distinguish the sections shaped by water, but not necesarilly a river. In one place, East of Yaowushan, the roof is incised by a deep meandering trench, remnant of a flow passing over the sediments which totally blocked the cave at some earlier epoch. In another place, West of Yaowushan, the stream has been flowing in a sump, thus presenting a rather tubular section, convex downward. In other places, all along the river- made gallery, pits, chimneys and small annexes definitely show the mark of wateraction, but not of a true river.

Finally, collapse zones are indicated on the map: these collapsezones generally enlarged some of the riverpassages, sometimes at the crossing of two galleries. This is easy to show on the map. In some places, the breakdowns only affected the roof of the gallery, increasing the altitude of the ceiling.

If most of the breakdowns struck the cave after the fluvial stage, some of them, though not many, were remodelled by riveraction: the collapsed blocks show erosionmarks (flutes, stream scallops,...). In some other places, the fallen blocks have disappeared and only the shape of the roof tells us about a breakdown. The blocks could have been removed by dissolution or covered by a subsequent sandy alluvial mat.

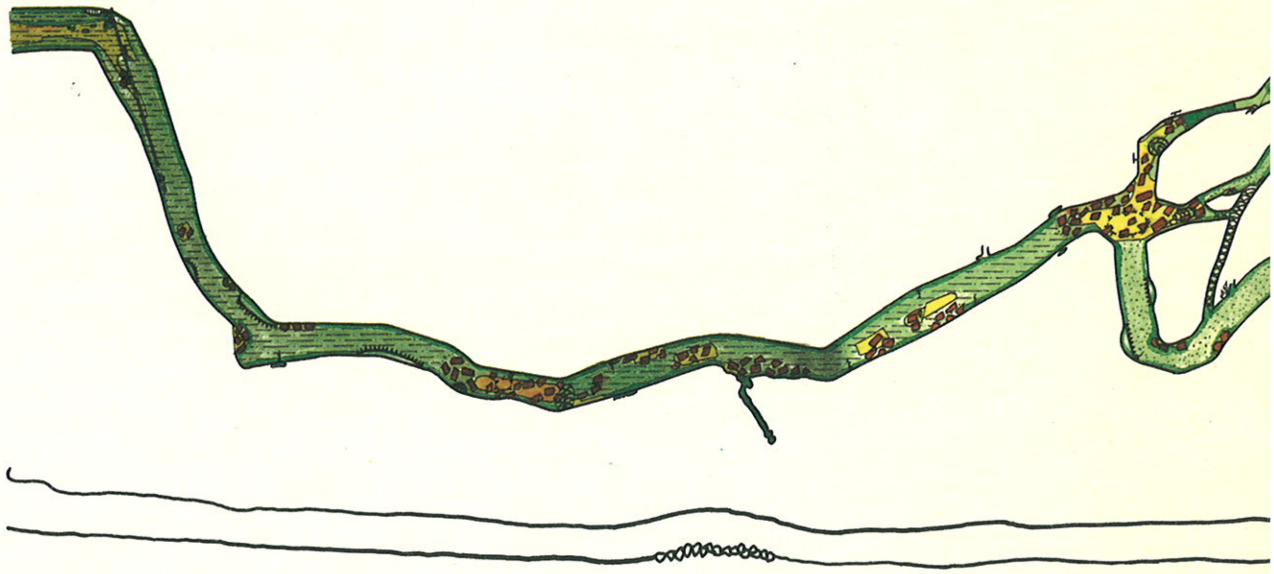
In some places at last, big fallen blocks appear under a roof, displaying no trace of breakdown. This can be because of a later remodelling of the walls by riveraction; but then one wonders why the blocks themselves eroded. In some cases, it is likely that some blocks were displaced, carried away during floods.

Let us finally stress upon the titanic sizes of some of the fallen blocks : some of them, at the foot of Yaowushan, measure no less than 12 m x 10 m, the third dimension being unknown.



TENGLONG DONG THE FOSSIL GALLERY MORPHOGENETIC MAP

Fig 4. Tenglong Dong The fossil gallery morphongenetic map

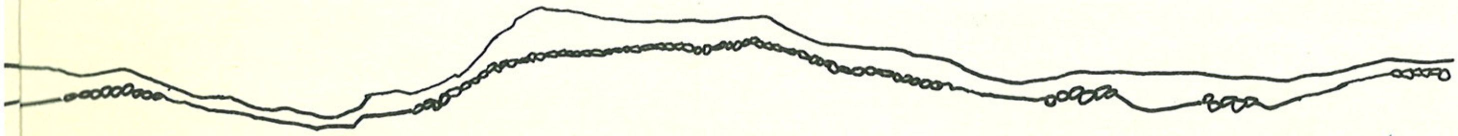


GEOLOGICAL INFLUENCES, CONTROLS ON THE CAVE LOCATION

Tenglong cave developed in the transitionbeds between T1d or Daye Formation and T1j or Jialinjiang Formation, composed of rather thick limestonebeds at the north eastern slope of the Jinzishan synclinorium, striking N60E. In the north, the T1d beds are updoming in several secondary anticlines belonging to the Lichuan anticlinorium. This T1d-T1j transition has also a marked impact on the regional karstmorphology. In this way the location of the Tenglong Dong system is stratigraphically controlled.

Differences in bedding and jointing form a structural control on the type of karstic dissolution and erosion. The mostly vertical joints are widened as fissures by percolating water allowing corrosion of the limestone. A network of open fissures or diaclases was preserved in the Puzzle Palace along the White Dragon gallery. The major galleries also tend to follow joint- and fracturedirections. They increase in height as a result of roof collapse in the jointed rock units which will halt when a massive unit is reached.

The increase in frequency of joints and shalepartings in the lower T1d beds will diminish the average dimensions of the cavities in these beds, cause obstructions by collapse and accumulation of insolubles, form traps for allochtonous sediments and eventually prevent accessibility to the karstsystem. This is best noticed in the zones where T1d beds are updoming in small secondary anticlines, probably of limited geographical extension and tapering out upwards in the more massive T1j units.

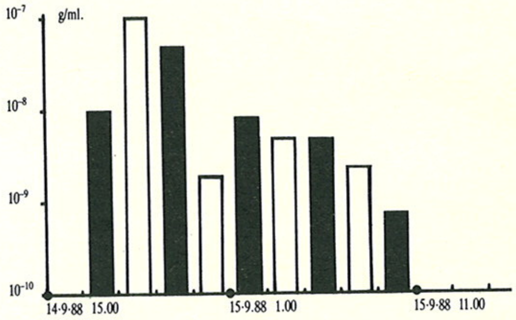


Whereas the average dips in the Lichuan limestones are 10-20°, these can increase to 50-75° in anticlinal structures. Fracturing and faulting are also associated with these anticlines. As a consequence, tectonic style exerts an additional control on cavedevelopment: the anticlinal zones deflect cave development and induce rockfalls and reduction of gallerysize. Thus, these parts of the Tenglong Dong system are less developed and seriously complicated the exploration.

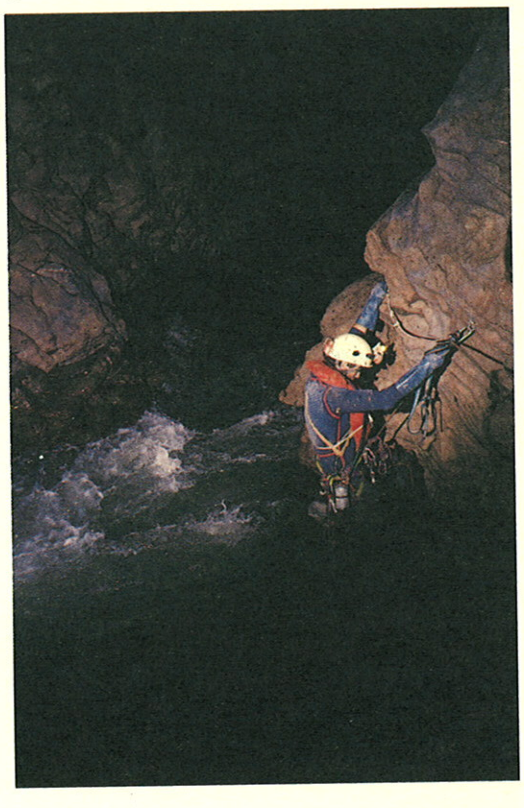
CAVE HYDROGEOLOGY: A STRAIGHTFORWARD RIVER.

The water course of the Qingjiang river in Tenglong is almost a straight line, a major conduit about 10 km long running along stratification of the dissolved limestonebeds, occasionally overflowing into normally dry galleries during floods. Many tributaries or outcrops of water have been noticed between the entrance and the outlet. By the means of tracingexperiments and wateranalyses, an attempt was made to distinguish the real tributaries and the diffluences of the river itself. Because of an extended catchmentarea covering mainly poorly permeable rocks or deeply corroded limestones in the polje, the discharge of the Qingjiang river at the cave entrance is largely fluctuating, ranging from 1.33 m3/s to more than 50 m3/s. As a consequence, the watertable may rise more than ten meters in smaller passages. No lakes, nor extensive phreatic volumes are large enough to reduce the amplitudes of these variations, as is confirmed by the results of the tracingexperiment carried out from the entrance to the resurgence (fig. 5). The uranine (10 kg) put in the Qingjiang river took less than 5 hours before coming out at the resurgence. The maximum was reached two hours later and the total time of restitution was only 17 hours. Also Milk Way, Water Well Cave (Shuijing Dong) and a shaft in the canyon were reached by the tracer, being on the way of the undergroundriver. It was clear that some vadose springs, like the one in Fish cave or Koens passage, were not connected with the main stream. Other connections (Xiangshui, Longu, Guancai) were not confirmed owing to sampling problems. Some temporary streams go through the huge dry gallery of Tenglong. They are infiltrations of percolating rainwater observed on the right bank and joining the river through phreatic conduits. One must distinguish these from the tributaries to the north or left bank which directly drain more diffuse aquifers. An attempt was made, to show a connection between Cold Wind cave river and Oxnose Cave through the dry valley. This connection is probably only effective during higher waters. The injected rhodamine B allowed us to measure the discharge of this river using the dilutionmethod. These preliminary hydrogeological investigations according to the established flow pattern, are likely to lead to a better understanding of the groundwaterresources of the Lichuan area.

Fig. 5: Variation of concentration of uranine in extracts of active charcoal, sampled every two hours during the tracingtest from Tenglong sink to the Black Cave resurgence. The injected quantity was 10 kg just at the end of a flood event.



Sportive caving in Longu Dong.



HYDROCHEMISTRY: DISTINCTIVE WATER FLOWS.

Physico-chemical analyses like temperature (T), conductivity (K25), pH, dissolved oxygen (O2), total hardness (TH), calcium (Ca++), magnesium (Mg++), total iron, nitrate (NO3-) and sulphate (SO4--) were carried out on karstwaters of the Tenglong hydrological system. About 100 water samples were taken in 40 sampling sites in the cave, representing more than 1000 analyses and measurements. Most of them were carried out in the field, using a HACH DREL/5 portable laboratory unit with spectrophotometer and pHmeter. A WTW conductimeter and oximeter were also used for the measurement of conductivity, temperature and dissolved oxygen. All the data, collected during the expedition were computed every day, using a ZENITH ZWL 183 portable computer.

The mean physico-chemical composition of waters, collected during August and September in Tenglong Dong are summarized in figure ..., in relation with a schematic crosssection along the hydrological system.

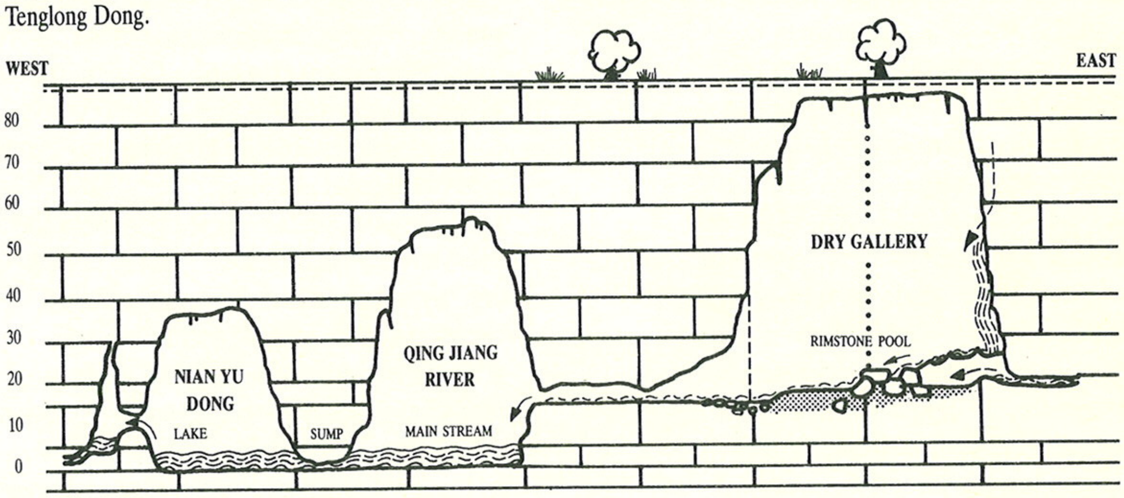
The waters in the cave are caracterized by a distinctive composition (mainly temperature, conductivity, TH, calcium and sulphate) and on this base one can recognize various types of water.
- Underground river (Qingjiang main stream): temperature 18 - 19°C (3 - 4°C less than the mean Septembertemperature), relatively low conductivity and hardness and high sulphate content. Water at the resurgence (Black Cave) contains a little more CaCO3 and has a higher pH than at the ponor (sink). Undersaturated at the ponor, water becomes supersaturated at the resurgence, after a 10 km undergroundtravel. Curiously enough the riverwater alos becomes supersaturated with oxygen, resembling bubble water! - Undergroundtributaries (percolationwater stored in the watertable and flowing in the cave through springs and then forming vadose collectors) : low temperature (near 13°C) due to a long residence time and corresponding to the mean annual airtemperature in the area (12.98°C); higher conductivity and hardness. Dripping water from the roof and water forming big rimstone pools, with the highest total hardness (around 175 mg/l CaCO3). The hydrological system becomes more complex during floodevents when mixing of water of different origins occurs : during floods, the water level of the main stream can easely rise

Hach Drel/5 portable laboratory in Cold Wind Cave.

8 to 10 meters and overflow in some tributary collectors. This was observed in the gallery west of Nianyu Dong and in the Yenhe Dong (Milk Way) gallery.

Very low pollutionlevels with nitrate (fertilizer or manure) were detected in all the analysed waters, with exception of two waterdrips near the entrance and far inside the cave (21 and 17 mg/l NO3- respectively).

Fig. 6. Physico-chemical composition of waters, collected during August and September 1988 in Tenglong Dong.



	SPRING/COLLECTOR		LAKE	PONOR	RESURGENCE
Tw (°C)	12.9	14.6 ± 1.3	18.8 ± 1.7	18.9 ± 1.4	17.9 ± 1.1
K_{25} (μS/cm)	260	269 ± 21	222 ± 54	217 ± 49	249 ± 26
O_2 (%)	–	96 ± 4	108 ± 4	89 ±11	108 ± 3
pH	–	7.5 ± 0.4	7.5 ± 0.4	7.5 ± 0.3	8.1 ± 0.2
TH (mg/l)	152 ± 14	144 ± 5	101 ± 26	113 ± 27	115 ± 16
Ca^{++}(mg/l)	132 ± 11	115 ± 8	87 ± 17	94 ± 23	97 ± 14
Mg^{++}(mg/l)	20	29	14	19	18
NO_3^-(mg/l)	1 ± 2	1 ± 1	3 ± 3	4 ± 3	3 ± 4
$SO_4^=$(mg/l)	9 ± 2	13 ± 4	25 ± 14	27 ± 13	23 ± 12
n	2	4	4	6	19

	VADOSE COLLECTORS	DRIPPING WATER CAVE	ENTRANCE	RIMSTONE POOLS	SPRINGS
Tw (°C)	13.4 ± 0.6	14.6 ± 2.3	17.4 ± 0.3	13.5 ± 0.8	13 ± 0.4
K_{25} (μS/cm)	285 ± 27	296 ± 26	230 ± 13	319 ± 36	326 ± 58
O_2 (%)	99 ± 2	–	–	98	94
pH	7.9 ± 0.4	8.1 ± 0.8	8.2 ± 0.6	8.1 ± 0.3	7.6 ± 0.5
TH (mg/l)	152 ± 24	143 ± 19	117	175 ± 18	167 ± 36
Ca^{++}(mg/l)	132 ± 12	118 ± 19	113	155 ± 24	146 ± 23
Mg^{++}(mg/l)	20	25	4	25	21
NO_3^-(mg/l)	2 ± 2	6 ± 8	21	4 ± 1	3 ± 1
$SO_4^=$(mg/l)	7 ± 7	8 ± 6	1	7 ± 3	8 ± 4
n	15	4	4	3	9

CAVESEDIMENTS: A CHANGING DECORUM.

The cave contains different kinds of fills, which in most places cover and hide the rock floor. The most impressive of these fills certainly are the numerous and huge fallen blocks, sometimes measuring over one thousand cubic meters. The rockfalls ("eboulis") formed by these fallen blocks are sometimes very high : up to 120 m, in Yaowushan.

The blocks display two different types : most of them are very angular, like freshly broken rock; some are locally rounded, corroded or eroded: they underwent the action of water since their fall. In some cases it is clearly the river that flew over these rockfalls and eroded them : these blocks come from breakdowns, more ancient than the last passage of the river in the upper gallery.

The cave encloses many other clastic deposits. Among them, the most noticeable are the sediments, sand and clay, which cover large parts of the floor. The sand is a fluvial sediment, very well sorted; it is siliceous and thus comes from outside, not from the cave itself; the clay was deposited in quiet water, slowly subsiding after floods; these overflow deposits have a phreatic character (cf glossary).

But the most beautiful deposits are certainly the stalagmites, rimstone and other speleothems which decorate a few passages of the cave. In this huge cave, speleothems are apparently sparse and not a prominent feature. There are exceptions. In some places, stalagmites are high, numerous, and beautiful. This is the case for instance, in Qianfoyan (the Hall of Thousand Buddhas) and in Baiyushilin (Stone Forest), where many stalagmites exceed 5 m in height and 1 m in diameter. We selected a series of speleothem samples, carefully chosen, for radiometric dating. The first results indicate that some stalagmites are rather old: 156 to 229 thousands years B.P.

There are also flowstones on some walls and many rimstone, around undergroundsprings or along the main streamlets which wander through the uppergallery. Cavepearls, cavecoral and other kinds of caveconcretions are also present.

One of the most curious of the precipitates in the cave is the thin calcite crust which covers the sandy deposits in the higher parts of the dry galleries, such as at Yuantangguan (the passages west of Fog Mountain, where we had an undergroundcamp at the end of our stay). This crust, sometimes covered by a black varnish, perhaps comes from the carbonatecontent of the condensationwater, falling from the roof. In some cases however, the crust is not carbonated and a study to determine its composition is in progress.

URANIUM SERIES DATING OF SPELEOTHEMS, A RESPECTABLE AGE.

Stalagmitesamples from Tenglong Cave were collected for agedetermination by the 230Th/ 234U-method, in order to reconstruct the cavehistory. Minimumage of big collapse- episodes will be inferred from the U-series age of stalagmites, growing on the huge rockfall of the Stone Forest chamber.

The first results, obtained at the Belgian Nuclear Research Center (SCK/CEN Mol), on a large fallen stalagmite (1.5 m diameter) from this chamber, give U-series ages of 229 q 32 ka (*) for the inner oldest growthlayers (sample LSM26) and 156 q 16 ka for the outer youngest growthlayers (sample LSM25). Uraniumconcentrations are quite low (0.364 to 0.372 ppm) and calcite is free of detrital components (230Th/232Th > 800). Initial (234U/238U)0 ratios calculated with 230Th/234U ages display high figures (4.45 to 4.52). From those results can be inferred that the stalagmite has grown during about 73 ka, with maybe some growthhiatuses. As this speleothem was formed on the top of the rockfall, the collapse of the blocks at top of the Stone Forest Chamber is older than 229 ka. Similarly, the event provoking the downfall of the stalagmite took place after 156 ka and is thus younger than this date.

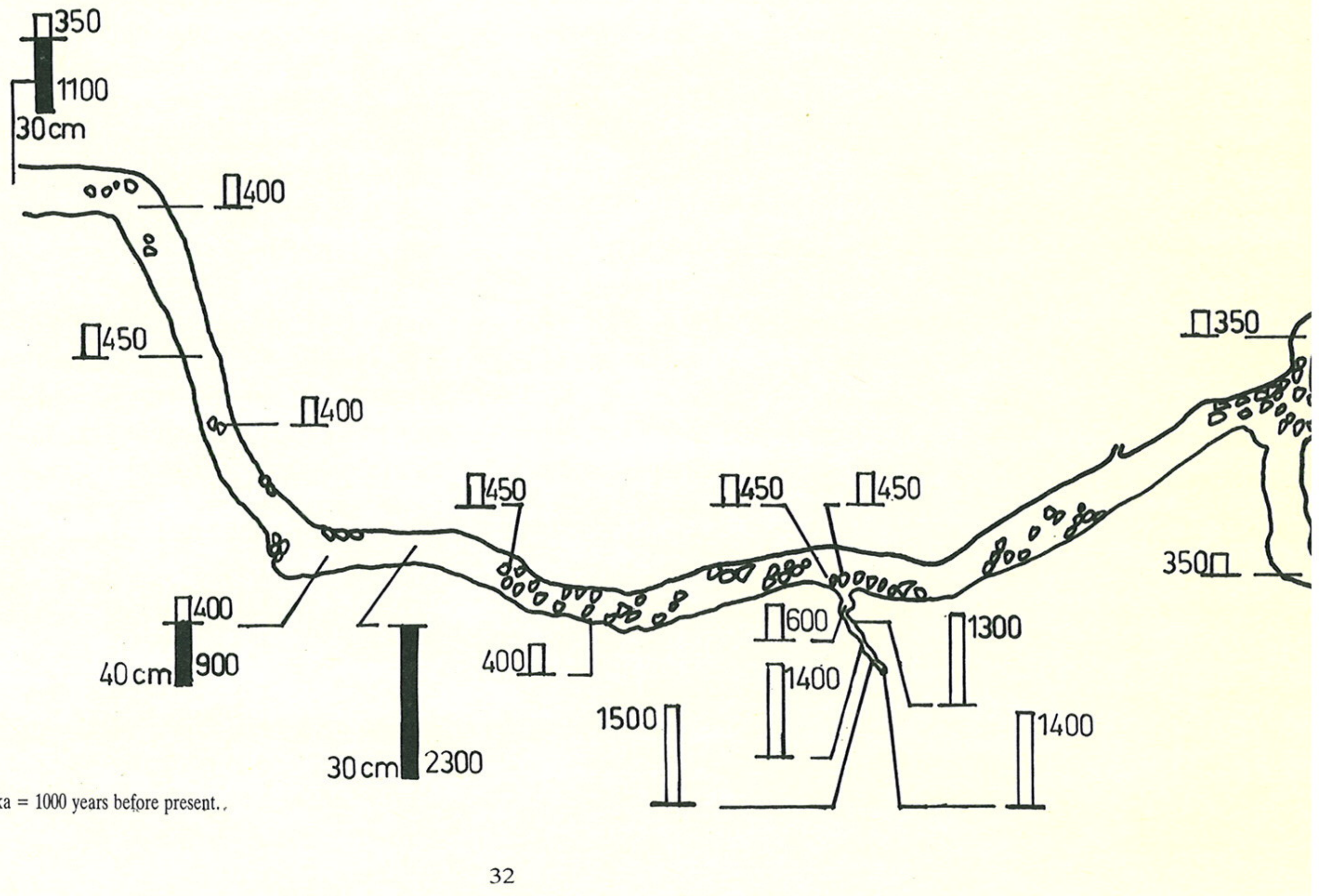
Other stalagmites, growing on roof breakdown blocks were collected in order to obtain more data in relation to the formation and evolution of this part of Tenglong dong. Analyses of those samples are still in progress and results will be published later on.

CARBONDIOXIDE IN THE CAVE-ATMOSPHERE: NO LACK OF FRESH AIR.

We carried out about 80 measurements on CO2 in the cave-atmosphere and in the vicinity of the cavity (fig. 7). It showed that - except in very cold areas - undergroundatmospheres are richer in CO2 than the outside surface-atmosphere. But in Tenglong Dong, the passageways are so large that they let the outside air enter almost everywhere in the cave. The air is permanently renewed, not only by diffusion but by actual winds, which

Fig. 7. Tenglong Dong : CO_2-measurements.

TENG LONG DONG
THE FOSSIL GALLERY

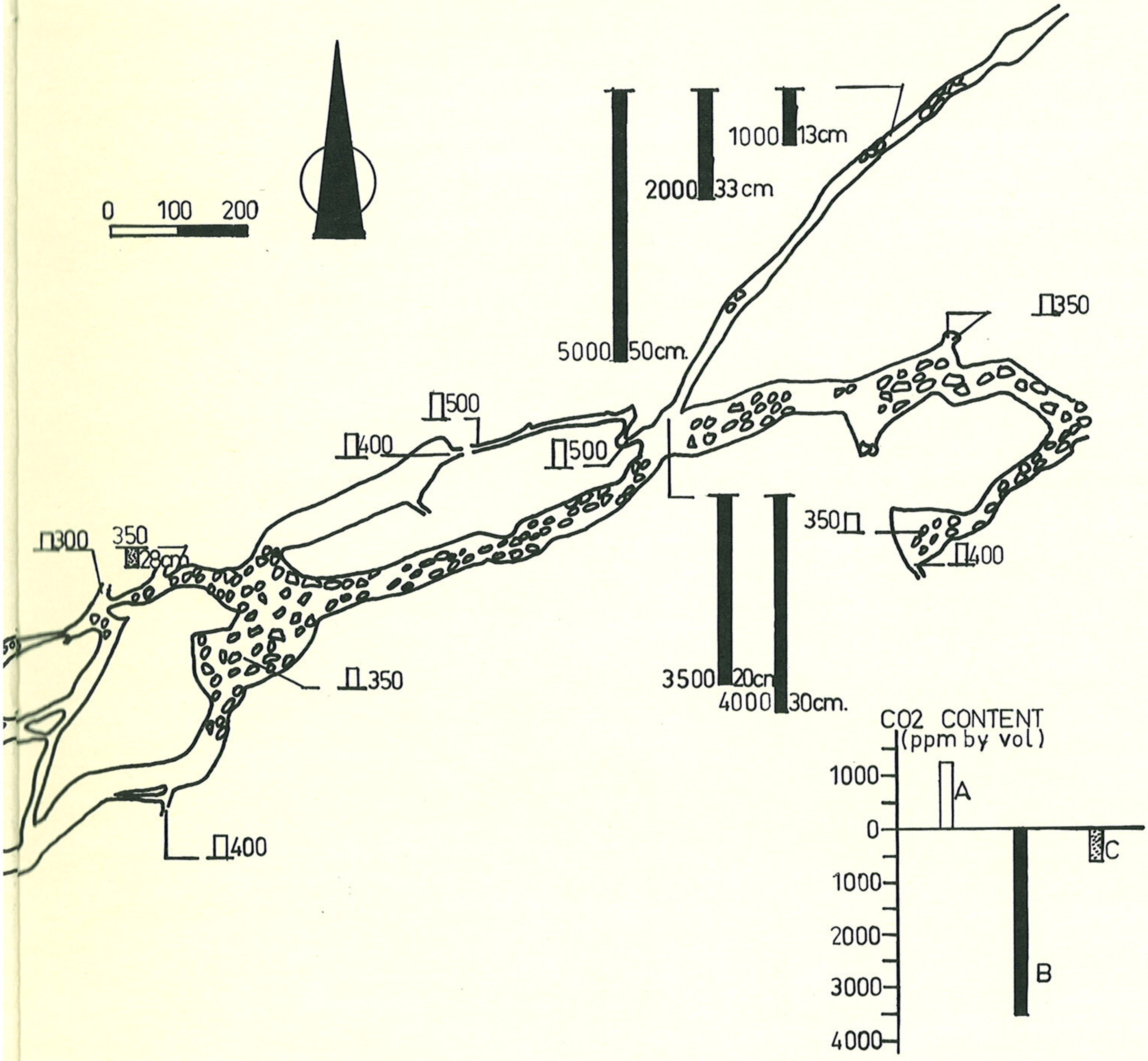


(*) 1 ka = 1000 years before present.

are very perceptible in some places. Thus the air in Tenglong Dong is much more similar to the outside free atmosphere than to a typical cave-air.

For the first time to our knowledge the aircontent of the sediments was also analysed, in order to measure the CO2 contained in it. We were surprized to find 3500, 4000 and even 5200 ppm CO2 in the air contained in the sediment of the clay deposits: the last figure represents more than 17 times the normal CO2-content of the air. The maximum values measured in the cave were indeed very similar to the maximum values we observed in the surfacesoil of the dry valley above the cave (3000, 3800 and, as a maximum, 6500 ppm, in a wet pasture).

We believe that, considering the humid environment of the cave, the degradation of fine organic debris by bacteria and inferior plants is the main source of this gas, so much related to life. Thus the sediments of the cave are as rich in CO2 as the cave-air is poor : this is one of the paradoxes of Tenglong Dong.



SIMULATIONTEST MODEL OF CAVEFORMATION: 'CAVES GROWING IN THE LAB'.

The Karst and Groundwater Research Laboratory of the Academia Sinica in Beijing has tested a simulation karstdevelopment. With gypsum, salt and water as basic ingredients, various geological and hydrogeological structures could be modelled and exposed to simulated rainfall. These models could be tilted to simulate runoff and waterdrainage. Especially karstification phenomena in the phreatic (water saturated) zone were observed as these will have the highest impact on cave formation.

Preliminary results are avaliable for models of carbonate rocks, displaying a low inclination of stratification (15°) with both dense and widely spaced fissures, with both multilayer and singlelayer aquiferes (water bearing rock units).

- Even in the single-large aquifercase, no homogeneous karstification was observed: dissolution was at maximum and cave formation started at the top and in the uppermost part of the phreatic zone (top of water-table).
- Cavedevelopment was controlled by the intersection of fissures on bedding planes, without watercirculation through massive rock.
- In case of dipping aquifers, karstification increased downdip, in the sense of final wateraccumulation.

Testresults clearly correspond to natural cavedevelopment. In this way simulation tests may allow to quantify the impact of different parameters on cavedevelopment.

GEOPHYSICAL INVESTIGATIONS: PROBING THE INVISIBLE.

The speleologist, working in a cave, will normally observe size and configuration of the open spaces, type and form of their boundaries: roof, walls, floor. Geophysical methods allow him to probe inside the surrounding rocks, sediments or speleothems, or to gather information on the distance or direction to other open spaces, inaccessible from his point of observation. Several of these methods were tested in Tenglong Dong: magnetometry, natural gamma ray-radiation and an electromagnetic transmitter/receiver. These geophysical tools were not originally designed for cave exploration. Application to caveresearch is rather unusual and interpretation of the results is hindered by the irregular environment: a systematic study combined with other research is essential to yield fruitful results. Nevertheless, they were only tests, but they did give some insight in the value of the used methods: magnetometry and gammarayradiation tell something on the clayinfilling of the caves, whereas the electromagnetic method can be used as an independent control for positioning the caveplan on the surfacemap.
(fig. 8a, fig. 8b, fig. 8c)

Fig. 8a. Localization of the sections.

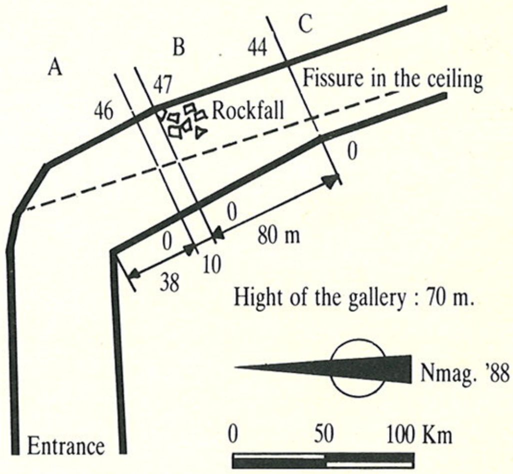


Fig. 8b. Results.

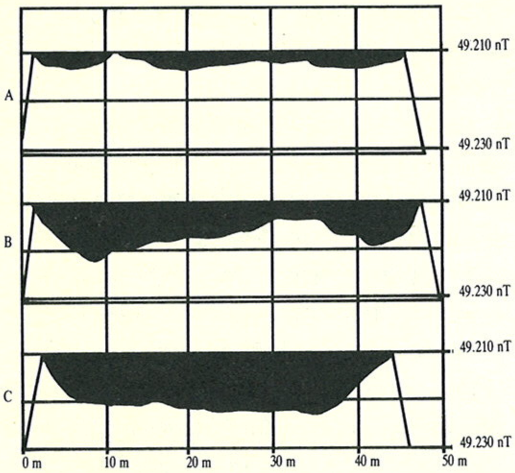


Fig. 8c. Results after differential treatment.

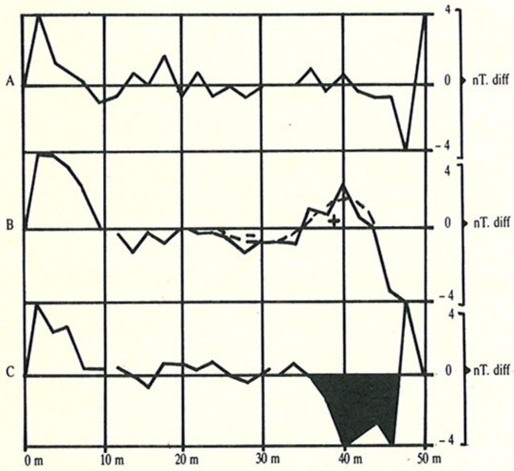


Fig. 9. Electromagnetics, the localisation of "Fog Mountain".

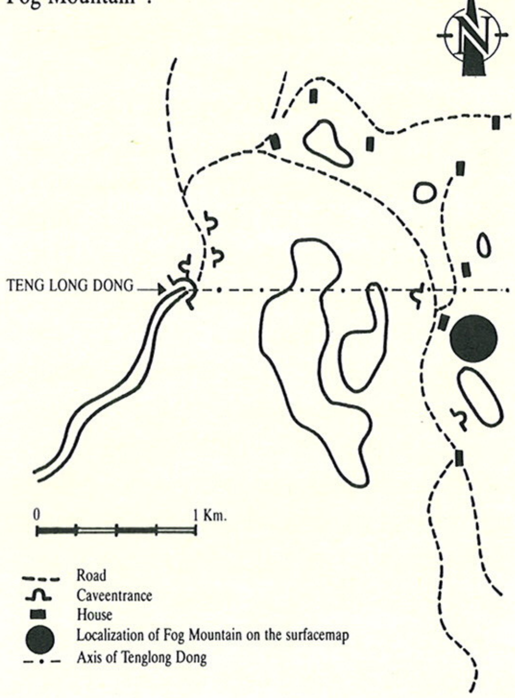


Fig 8: Magnetometry and radiation. Three traverses were made in the entrance hall of the fossil gallery. These indicate a progressive increase in the thickness of the claysediments, hence a lowering of the rock floor when proceeding inside the cave. Another traverse deeper inside the fossil gallery did not yield any clues for a meaningful interpretation.

Fig 9: Electromagnetics. This method was used to localize the top of "Fog Mountain" at two kilometers from the caveentrance. The received signal was very weak, which might be due to deformation of primary magnetic fields around the enormous chamber enclosing "Fog Mountain". As a result, localization was precise within a 300 m. radius only. As can be deduced from an altimetric survey on these points, the roof, covering "Fog Mountain", still attains to a thickness estimated at minimum 40 m, which may form a sufficient protection against a catastrophic rockburst and a new caveentrance.

CAVEBIOLOGY:THE MYSTERIOUS TADPOLES.

Caves are no biological deserts. Life is continuously adapting to seemingly harsh conditions of permanent obscurity, leading to the absence of green plants (no photosynthesis possible) and thus of a major element in the foodchain. Limited variations in temperature and moisture provide unique ecological niches, colonized by life forms evolving at a slow rate. In this way, the cavebiologist can study undergroundfauna, being a remnant of a fauna that once thrived on the surface. Shifting climates and a steady competition between life-forms at the surfaces might be the cause that this ancient fauna disappeared from the earth surfaces and were only preserved at depth. The biologist can also study the morphological or physiological adaptations of animal species to the particular conditions reigning in their undergroundhabitat. Tenglong Dong is no exception. A diverse fauna developed in this cave. Faunadiversification was controlled by different morphological and hydrogeological factors.

- Very large accesses bring in animals and climate from outside deep into the cave.
- The Qingjiang river conserves its fauna when rushing through the cave.
- Regular floodconditions of the Qingjiang, overflowing into normally dry galleries, prevent the colonization of those galleries by slowly moving fauna.
- The undergroundtributaries of the Qingjiang, characterized by their own hydrochemical composition, contain a unique cavefauna.
- Cavelife is richest where a normal foodchain was established, based on an outside supply of organic detritus, or soil brought in by floods or through the roofs where these approach the landsurface, or based on bat dung.

In the first place we made an inventory of the cavefauna with limited technical equipment (funnels, sieves, nets, traps). Bats and swifts, living far inside the cave, were not disturbed. Anyway, the enormous heights of the roofs in the major galleries would have prevented serious study.

The underground Qingjiang river contained outside fish: edible catfish was caught halfway between sink and resurgence at Longu Dong. Overflowbasins near the cave main entrance ("Fish cave") and the upwelling "Rainbow gorge" lake were favourite places for local fishermen. Myriads of flies dancing above the watersurface of the undergroundriver in the temporarily damp warm climate (in fact the Qingjiang warmed up its passageway to an agreeable 19°C, which can be expected to fall far below the average of 13°C in winter). These ubiquitous flies were a pest: they entered everywhere, they sticked on the topographic notebooks and made the exploration of the river often unpleasant.

The small cavedwellers form a rich fauna, though not present everywhere: food supply is essential. They live in areas with dripping water or clayaccumulation or below batcolonies. This fauna is composed of insects, amphipodes, spiders, centipodes, myriapedes, based on fungi. At least 9 species of myriapedes were sampled. Fierce longlegged and hardbiting centipedes were difficult to catch: they were fast, rather dangerous, and hardly fitted in the sample pots. Cavecrickets had the widest distribution; there was not one gallery without them. This special fauna is apparently not unique in Central China. It shows a close resemblance to cavefauna, described in tropical areas in South East Asia. This is not unlikely, since there exists an almost continuous development of karst from Central China down to the equator, and there has been no interruption of cave development during the iceages.

The fauna of the undergroundstreams outside the allochtonous Qingjiang is not rich, but very intrigueing. Virtually all streams or springs, surrounded by mudbanks contain, next to some amphipodes and possibly microscopic organisms, large (up to 4 cm) transparent tadpoles with reduced eyes. On the contrary, no frogs were observed. Local caveguides confirm that these tadpoles (called cave- "fish") persist all year round. This could mean that we are facing an exceptional adaptation to a caveenvironment: tadpoles may not pass into adult stage but reproduce at the tadpole stage, i.e. a local version of the famous axolotl. Needless to say that we eagerly await the confirmation of this hypothesis!

A CONCEPTUAL MODEL OF THE DEVELOPMENT OF TENGLONG CAVE: A CAVE GENERATED BY A POWERFUL RIVER.

Tenglong Dong is not only an enormous cave - almost 40 km surveyed often along extremely large galleries - but also an intrigueing one. No other cave dominated to such an extent by a river is known. Yet the cavedevelopment is very classical: it comprises both active and fossil part, formed by normal physico-chemical processes, underlying a dry valley with a length of 10 km.

Tenglong Dong is located in a region, characterized by an extensive slowly evolving qiufung - uvala mountain karstlandscape at the intersection between a karstic plain (polje) on the upstream side and a plateau - canyontype morphology overlying the caves. This morphological change is controlled by the stratigraphy: T1j limestone which consist of very pure carbonates is deeply corroded in the polje while T1d limestone which consist of silty carbonates with shalepartings are more resistant to erosion. The complete Triassic limestone sequence exceeds 1000 m in thickness and mostly occurs in gently dipping beds, thus allowing considerable development of cavesystems.

The Tenglong Dong karstsystem is mainly formed by an allochtonous river, originally flowing at the surface. The upstream drainagebasin of the Qingjiang covers 1000 km2, providing an average discharge of 15 m3/s. Both active and fossil zones are equally dominated by riveraction. The erosive force of the floodwaters is very impressive, as we could notice at the equipment we left in the cave during a flood. There is not much evidence left of the initial creation of an open fissuresystem subsequently widened by the river.

Typical characteristics of this river-dominated cave.

- Principal formation in the upper phreatic zone (top of water saturated zone).
- Unidirectional: one entry, one conduit (under normal discharge).
- Vertical access remains limited, indicating that cave genesis does not result from percolationwaters.
- Roofcover can be very thick.
- Strong downcutting action prevailing over lateral extension of the galleries.
- Rockfalls result from riverdowncutting in jointed limestone.
- The limited supply of percolationwater in the cave cannot produce wide-spread concretions; existing concretions may be prone to flooding.
- Tributaries along the dry valley section could not match the rapid incision of the Qingjiang; no continuous cavesystems have developed between the main river sections and the drainagesystems of these tributaries.
- Rapid passage of the water along the undergroundsection: colourationtests prove that no more than 5 hours are needed to traverse the Tenglong Dong complex.

However, the undergroundwater flow is quite complex and varying in time. Several sumps occuring in the active undergroundriver section have a limited discharge capacity, retaining the floodwaters and increasing the upstream waterlevels enormously. Raising waterlevels cause an overflow of the main river into galleries normally dry or utilized as drainagepaths for percolationwaters. This could be proven by the different chemical compositions and temperatures of water of different origins and by the presence of allochtonous sand and pebbles in the normally dry galleries. It is assumed that all large galleries joining the main active and fossil drainage axis, have been formed by the major river, even if they are only temporarily used as an overflowwconduit. Also the dry valley bottom does not represent a single riverbed, but is composed of a series of different structures of surfaceflow formed at varying levels and times. The dry valley canyon section between Milk Way Cave and Deep Pool Cave may partly result from roofcollapse over the undergroundriver.

The cave appears to have developed in three main stages. The first one occurred at 1140- 1150 m above sealevel, and continued with a slight entrenchment of the undergroundstream to 1100 m a.s.l., the altitude of the present floor of the main dry entrance of Tenglong.

The second stage was caused by the huge breakdown of Yaowushan ("Fog Mountain"). This breakdown provoked a displacement of the galleries towards the North, diverting one part of the flow through Maojiaxia and the other part to Sanyuanmen. During that period the stream entrenched from 1100 to some 1060 m a.s.l. Radiometric datings of a fallen stalagmite in Baiyushilin ("Stone Forest") show that a first huge breakdown occurred before 229. 000 years B.P. and a second breakdown took place after 156.000 years B.P.

The third stage is the one of the lowest level, which is the stage of the present-day stream. Elevation along the undergroundchannel is 140 m. Active erosion along the fast flowing current shows that the caveevolution is not yet terminated.

There are a lot of small cavities, galleries, at varied altitudes, above the main uppergallery of the cave and between the upper and the lower levels. But these cavities seem unrelated to the development of Tenglong Dong. They look as remnants of older stages, much more related to definite lithologies than to definite levels; there is no genetic relation between these cavities and Tenglong Dong.

CONCLUSIONS

Without any doubt one can say that China is a caver's paradise that offers a fantastic potential regarding depth and length of caves, river explorations, traverses, ... Some impressive systems, like Tenglong, were discovered and explored, but it is clear that this is only the beginning. Even though our chinese hosts make many efforts and always try to help, there are still different circumstances which create difficulties as for the organization of expeditions. There are the problems of permit, since many of the interesting areas are situated in closed and/or rather inaccessible regions. There is the problem of transport for people and equipment. We covered the long distances (more than 2000km) by rail and by steamer, which was very comfortable and enjoyable. In the explorationareas however, we used small busses and 4x4 (and of course our feet). The lack of vehicles, the bad road conditions or simply the non-existing roads meant that we spent a lot of time just waiting. Further, one can mention the rather unwilling attitude towards camping, both on the surface and underground. We were guest of local farmers twice and had two undergroundcamps, but in general we were housed in hotels where we had more or less fixed hours for the meals, so that sometimes the real time spent on exploration was little. Otherwise, one must admit that such a housing has considerable advantages. Besides the physical and psychical comfort, offered by regularity, good food, bath and other facilities, we consider the total time that can be really spent for exploration during the expedition should be longer.

We worked practically every day with several teams on different places. Our expedition was a 'big' one with several different goals (scientific research, cave-exploration and topography, making a film, photography, cave-diving) and was composed of a heterogeneous party (scientists, cavers, a cineast, a medical doctor and a professional photographer). The advantages are obvious: the costs are less for the participants, it is easier to find sponsors, it is possible to work with different teams simultaneously on a variety of objectives, it is easier to explore big and complex systems and when someone has to rest or becomes ill, this does not threaten the continuation of the exploration.

Although the expedition was very successful, one should not be blind for the disadvantages of such a 'big' expedition. First, it is almost impossible to realize all the objectives and to give a chance to all the aspects. Further, it is clear that the bigger the party is, the more transport and organization problems increase: more difficulties to obtain reservations on boats and trains, more cars needed simultaneously for the transport to the different objectives, more lodging-accomodations needed and more peopel accompanying and interpreters. Next: the great variety in objectives means a lot of equipment. In our case (1500 kg) the greatest part had to be transported separately, meaning we spent almost one week waiting for it, since the transporting truck was blocked as the road was washed away by heavy rainfall.

At last, much time is often spent making arrangements and in general it becomes more difficult to adapt plans to changing circumstances.

In any case, in the future we will try to work with smaller parties (4 or 6 persons, accompanying people included). These parties should be working completely autonomously in different areas, which should be facilitated by less and more specific equipment and by less transport- and organization problems. Moreover we would separate exploration and topography activity on one side and field scientific investigations on the other. In that way, we hope that the time spent on the organisation decreases and time for exploration increases.

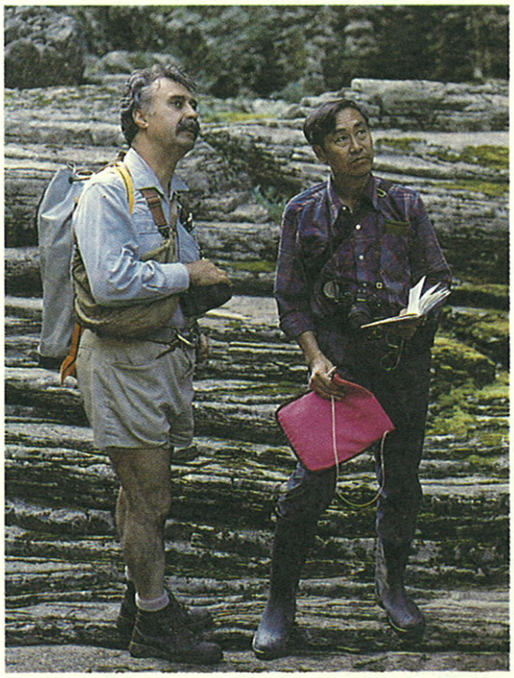
Anyway, patience remains a chinese virtue for quite some time, and waiting will remain, as in every expedition, great part of the game. This, of course, will not keep us away of the extraordinary and fascinating undergroundworld of China.

Tenglong Dong : the entrances.

APPENDIX

At the end of our campaign in Tenglong, we were eager to see some other karstic scenes. Karstzones and caves are certainly not limited to Lichuan county but abound throughout Western Hubei and neighbouring provinces. However, the degree of exploration and the potential uses are similar. We split up in two groups to visit two other sites. One group, with Michiel, Camille, Roger, Koen and Prof. Zhang went to the area of Wufeng, the others to the surroundings of Sangzhi.

Professor Zhang and professor Ek.



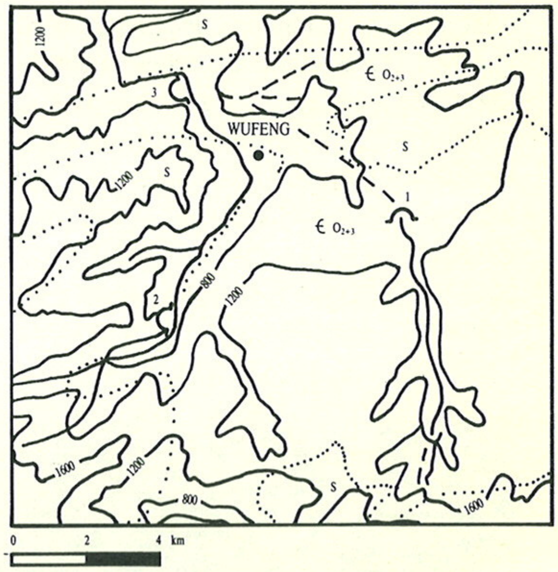
WUFENG AREA

Wufeng (altitude 550 m, average temperature 13,6°) is located 165 km east of Lichuan and was opened to visitors at the end of 1988. It is situated in the Tujia Nationality autonomous region in Western Hubei. Wufeng city is located in a deeply incised valley, protected all around by steep hills linked with a wall - a miniature version of the Great Wall. One prominent feature is formed by five teeth-like peaks on one of the hills which gave the city its name: 'Wu feng' or 'five peaks'. Wufeng county also belongs to the drainage bassin of the Qingjiang and the city is located on a north flowing tributary (fig. 10).

There are many caves around Wufeng. Several developed as touristical showcaves, whereas others produce small amounts of hydroelectric power. In this county we visited three caves in the immediate surroundings of Wufeng: Da Dong, Changsheng Dong (Long life Cave) and Shiniupin Dong (Rhino Pool Cave) of which Da Dong was the most important one. Da Dong or 'Big Cave' really deserves its name. The entrance hall at the head of a blind valley is enormous: its height is estimated at 120 m over a width of 45 m. Dimensions inside the cave are equally impressive and comparable to those of Tenglong. The agents responsible for the principal caveforming processes are the same as the ones of Tenglong: undergroundriver and roofcollapse.

At the time of our visit the blind valley

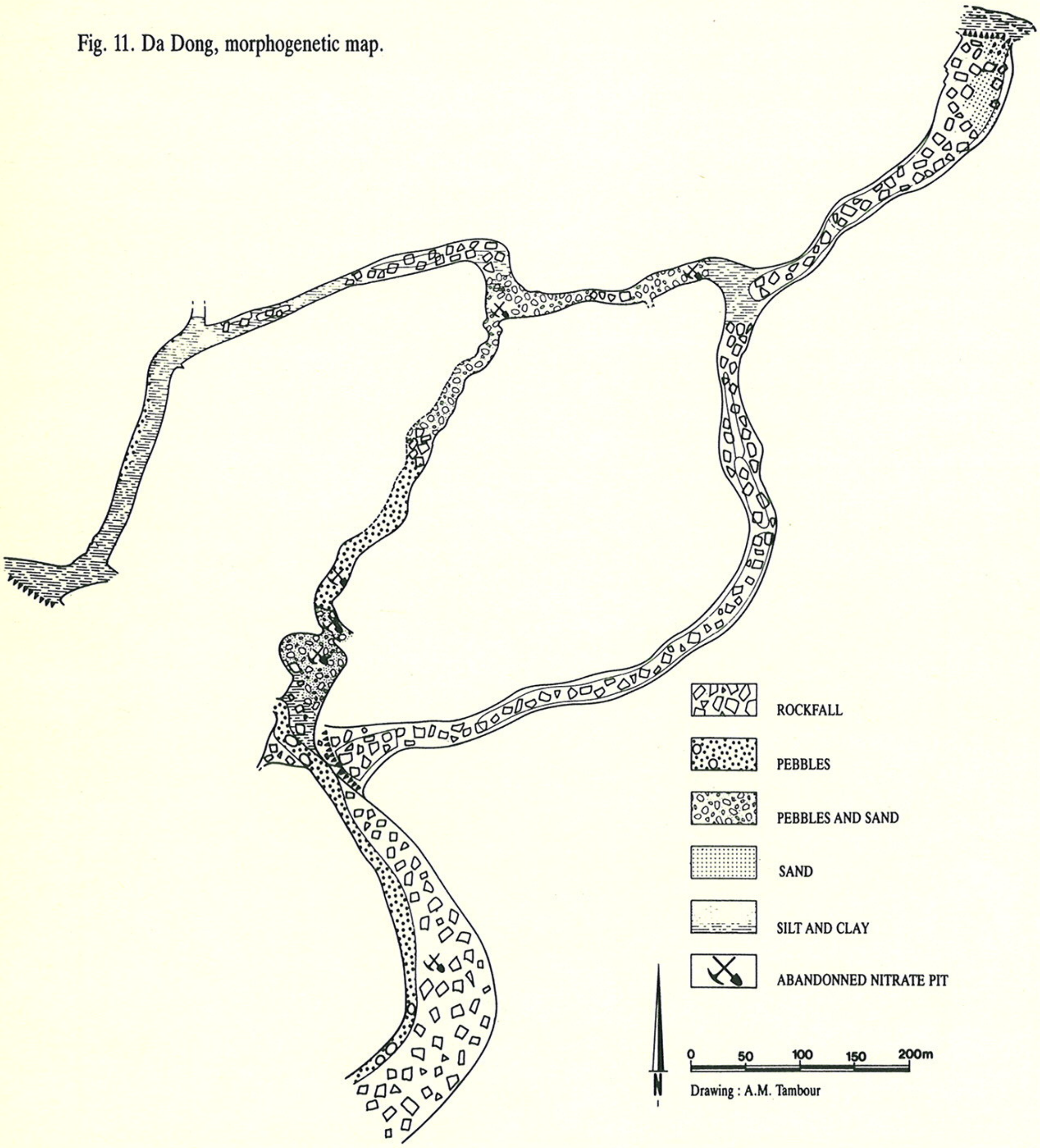
Fig. 10. Wufeng and surroundings.



P : PERMIAN
S : SILURIAN
O : ORDOVICIAN
€: CAMBRIAN
1 DA DONG
2 CHANGSHENG DONG
3 XINIUPEN DONG

riverbed was dry, the undergroundriverbed contained only a trickle of water. At floodconditions the picture may be very different. This must have been realized by the old nitrate-miners as well, who left many remnants of their activity deep into the cave: a passageway was dug over several hundred of meters in a sedimentblocked gallery linking the entrance gallery to the main fossil gallery containing the nitrate-deposits! However, this large cave is only very partly explored by the local inhabitants. There are only guesses about the resurgence of the undergroundriver. And we were there just for one day. This brought us in a frenzy: more than 3 km of this cave were explored and surveyed in a single day by a single team, completed by a summary morphologic description (fig. 11). The area is certainly interesting enough to be worth a further visit and investigation.

Fig. 11. Da Dong, morphogenetic map.



JIUTIAN DONG

Sangzhi town is located in the Hunan province, south of Hubei. We spent three days to visit Jiutian Cave which is located at Shuidong village, 17 km from Shangzi fig. 12). This cave had already been visited and partly measured by the Institute of Geology at the end of 1987, since 1988 a part of the cave became a showcave.

The cave is situated at the southeastern limb of a syncline and developed in lower Permian limestone (with chert concretions). The underlying Devonian sandstone is regarded as the impervious base. The entrance of the cave is a 40 m deep ponor (380 m above sea-level) which leads into a succession of large and very beautiful chambers. There are some special kinds of speleothems such as bottle brush-like stalactite, broom stick like stalagmite, rimstone with calcareous rafts and fried egg-like stalagmites. There are also several sky-light-caves, hence the name of the cave: Jiutian Dong which means Heaven Cave (fig. 13). In fact the cave consists of a fossil part, the actual showcave, and an active part where a small underground river can be followed over several km. We explored this river upstream, following the river into a chamber were many possibilities existed. We only explored one, which ended in a slot after a hundred meters. The exploration is more of the french type: rather small galleries, but very sporting and wet. Downstream we bypassed some sumps, until a final sump stopped us. Lateron we dived the resurgence: the first sump was passed(30 m, -1), the second one was blocked by a boulder choke at 3 m, -2.

We also had a quick look at different shafts located north-east of Jiutian, but in the same syncline. One of these offered a fantastic 124m pitch (fig. 14). At the bottom Wim and Philippe found a small river they only followed for a few hundred meters downstream to a sump, which is supposed to connect with Jiutian. There was no time left to explore upstream. Anyway, it is clear that the area around Shangzi is worth a further visit as well.

Fig. 12. Shuidong and surroundings.

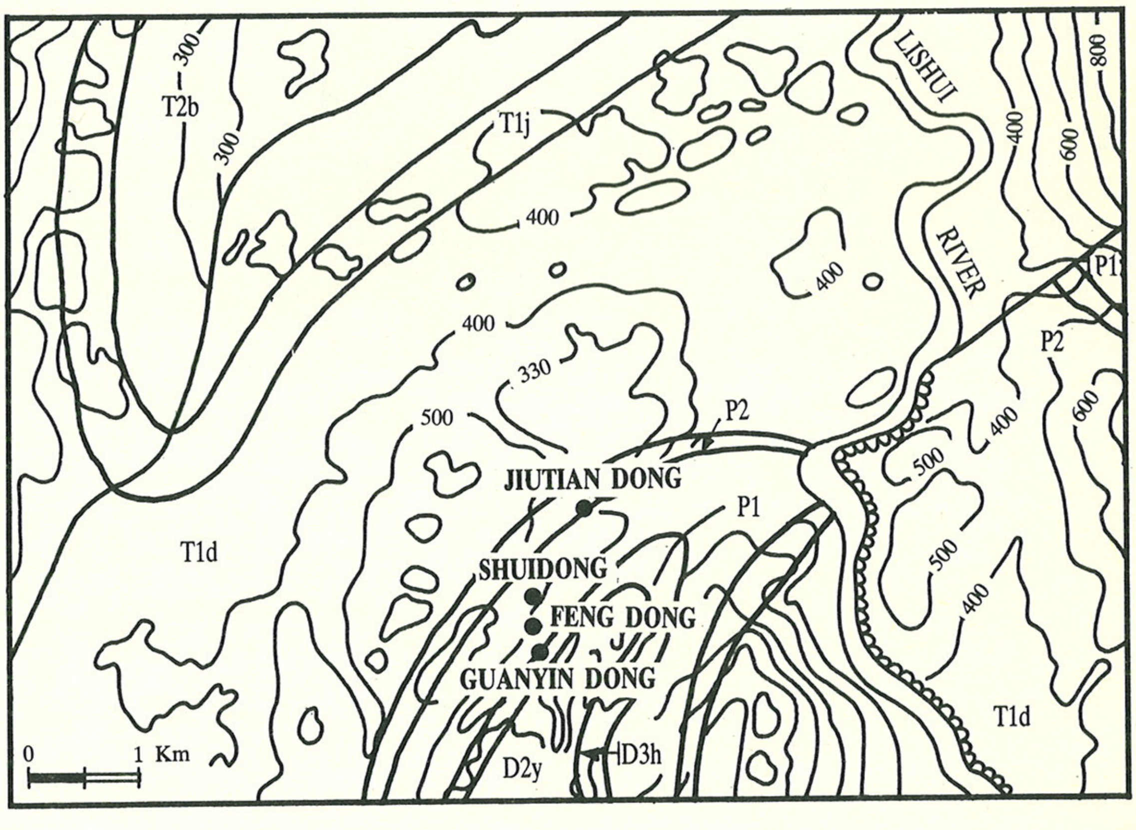
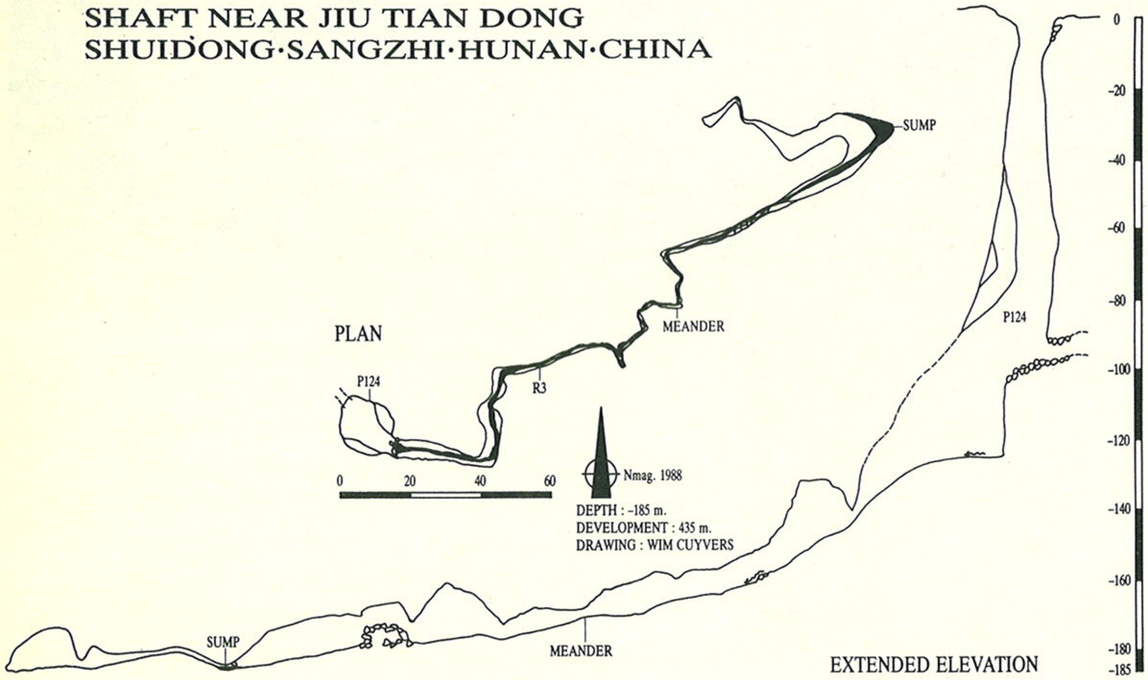


Fig. 13. Jiu Tiang Dong, PLAN.

Fig. 14. Shaft near Jiu Tian Dong, PLAN AND EXTENDED SECTION.



EXPLORATION TEAM '88

JOS BEYENS
WIM CUYVERS
FRANK DECLERCK
MICHIEL DUSAR
CAMILLE EK
MICHEL GEWELT
FRANÇOIS GUINAND
JAN KENNIS
RIK KEUNEN
KOEN MANDONX
JAN MASSCHELEIN
PHILIPPE MEUS
ERIC SACRÉ
ANDRÉ SLEURS
ROGER VANDEVINNE

CHEN SHICAI
HUANG WEI
JIN YUZHANG
LIU MINGLIN
PEI JINGXIAN
QI ZHONGLIN
SHI MENGXIONG
SONG SHIXIONG
ZHANG SHOUYUE
ZHAO SHUSEN
ZHANG DACHANG

The '88 team.

Aknowledgements

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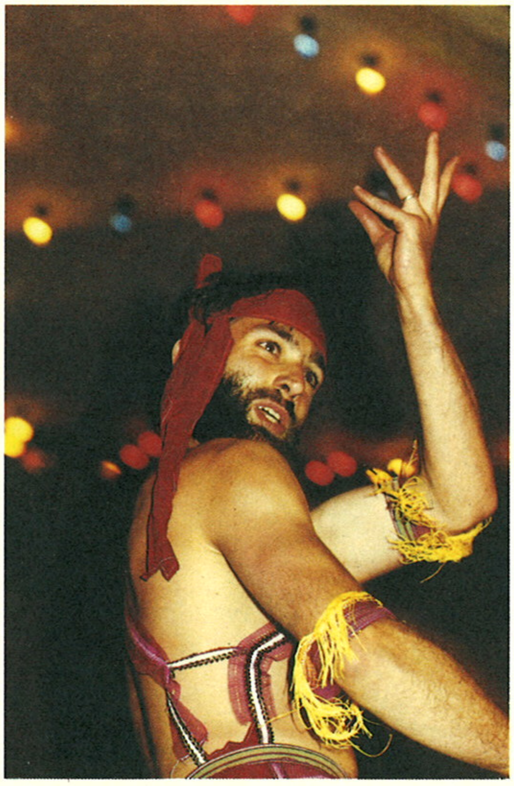
A SUCCESFUL PERFORMANCE

Banquet in Lichuan.

Our Chinese hosts of the municipality of Lichuan treated us generously. They prepared for us very varied meals, they supplied rich picknicks for our cavetrips, and they offered us more than one banquet. And we were invited twice to an intimate party in the lobby of our hotel. All this was very informal. So when we were invited to a show in the city, we thought it would be the same. We were kindly asked to prepare some sketches or songs from our country. Our common stock of songs was extremely restricted; so some of us prepared a beautiful scenario for a sketch... but none of us had the air of a producer, and we decided to improvise on the spot.

We went to the performance. We were guided to a large music hall in the center of Lichuan; there were at least 600 seats, all occupied; the passages were crowded; some people were sitting at two on one seat. This was far from being the 'family'-party we expected and our project of a boy-scout sketch definitely died : it was unthinkable to play there without a careful preparation and a serious rehearsal. What to do ? We sat in the honour seats in the first rows and admired local songs and dances. We saw an exotic wild dance from the south cost of China. Four young men were performing under the leadership of an old and venerable dancer, almost naked, as his pupils. The dance had a "primitive" dash; it was as much acrobatic as art. This piece finished; the next began. Rik and Koen suddenly got up and disappeared backstage, while we admired a girls-dance. After this dance, the same wild tam-tam as before sounded again, and two wild dancers jumped again, like devils, on the stage, performing astonishing stunts. It were Koen and Rik : they had borrowed the stage-costumes of the southern dancers. Very rudimentary costumes indeed : some ribbons around the arms and legs, and not much more. Our two savages performed a risky break- dance. After a while, the venerable master joined them on stage : he accepted the playback show as an homage - as it intended to be - not as a parody. Our honour was saved. Rik and Koen became local heroes for some time.

The performance.



GLOSSARY

ANTICLINE:	upward bending of the rocks.
ANTICLINORIUM:	large updoming of older rocks through combined effect of secondary anticlines.
AQUIFER:	groundwater-reservoir.
CLASTIC:	detrital generally transported components of sediments (pebbles, sand, clay).
PIEMONT:	hilly plateau at the foot of a mountain range.
PHREATIC:	below the watertable.
POLJE:	very large closed depression, in some places many kilometers long and wide and having a flat floor.
QIUFUNG:	cone karst with gently sloping hills.
SYNCLINE, SYNCLINORIUM:	downward bending of younger rocks, as opposed to anticline, anticlinorium.
T1D, T1J:	different types in limestones occuring over the Tenglong Dong karstsystem: - the upper T1j unit or Triassic Jialinjiang formation is composed of thickly bedded limestones, attaining a thickness of 300 m. - the lower T1d unit or Triassic Dage formation is composed of thinly bedded limestone, attaining a thickness of 700 m. (See also chapter 'Geological Influences'.
UVALA:	large closed depression formed by the coalescence of several dolines.
VADOSE:	zone with percolating water above the water table (opposed to phreatic).