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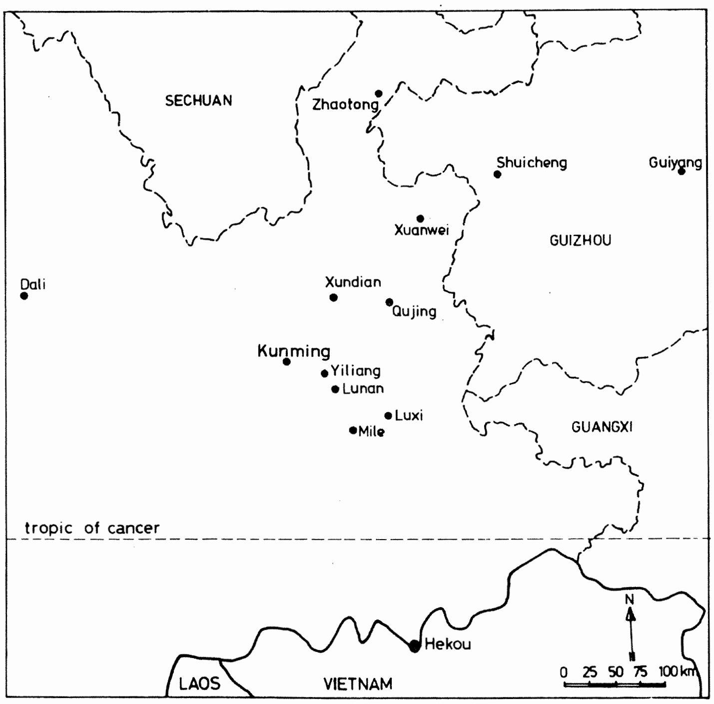

PROFESSIONAL PAPER 1991/4-N° 248

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BELGIAN GEOLOGICAL SURVEY
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Summary: A speleological reconnaissance trip on the high plateau of East Yunnan (China)- (average altitude 1900 m) revealed the presence of a highly diversified karst. The geological substratum consists of Sinian (Upper Precambrian) to Jurassic sedimentary rocks deposited near the western margin of the Yangtze platform. Carbonates are widespread and variable in composition and texture. Karst phenomena are developed in Sinian, Devonian, Carboniferous, Permian and Triassic strata. Modern karst evolution has been determined by two factors: Himalayan uplift and climatic differentiation. The uplift and subsequent erosion has resulted in the destruction of the original tropical tower karst landscape and the replacement by a karst plain-hilly plateau karst on the East Yunnan plateau or by a mountain plateau-canyon type of karst on the Yunnan-Guizhou border region. The former karst type shows a transition to the karst plain-tower karst developed in tropical Southeast Yunnan. Several cave systems on the East Yunnan plateau were selected for further exploration and study. These generally correspond to allogenic multistorey underground rivers with marked differences in maturity and represent a transect between varied climate-induced karst morphologies.

Key words: Yunnan (China), karst, caves, speleology, carbonates.

1. Introduction

The province of Yunnan located in the southwest of China "to the south of the clouds" as is the meaning of its name, possesses many attractive sides. It contains the greatest diversity of ethnic groups in China. In addition to the Han and the Hui or Muslim chinese, twenty-one minority groups, are present in the province, many of whom have well preserved their traditions. Because of its latitude Yunnan belongs to the southern tropical belt in China but the altitude (1900-2000 m on the eastern plateau) renders the climate exceptionally pleasant. In fact, the capital city Kunming is famous as the city of eternal spring.

The geological constitution of Yunnan is quite complex as well. Karstified rocks occur throughout the province but have not yet been the subject of a general study. A noteworthy exception is the Stone Forest, a spectacular example of a denuded karren field, which is known as one of the touristical wonders of China. In fact many similar but unknown Stone Forests exist in the surrounding area. Furthermore the province of Yunnan presents a unique cross-section from karst development typical for temperate climates to tropical cone karst, similar to the famous examples of Guilin in the eastern Guangxi province. The present project will bring a contribution to the study of this karst on the East Yunnan plateau.

Belgian participation in the study of Chinese karst already led to the 1988 Tenglong Dong speleological expedition in west Hubei province (Fig. 1), a joint organisation of the Academia Sinica, Institute of Geology, Karst and Groundwater Research and the Belgian-Chinese Karst and Caves Association, uniting sportive and scientific interests for Chinese karst studies in Belgium (Masschelein and Zhang Shouyue, 1990). As a result of this expedition, 37 km in this cave system were explored and mapped. In addition pluridisciplinary studies were conducted on cave morphology and genesis, host rock geology, cave air and hydrology, speleothem formation and dating, remote sensing (Ann. Soc. géol. Belg. t. 114, in preparation).

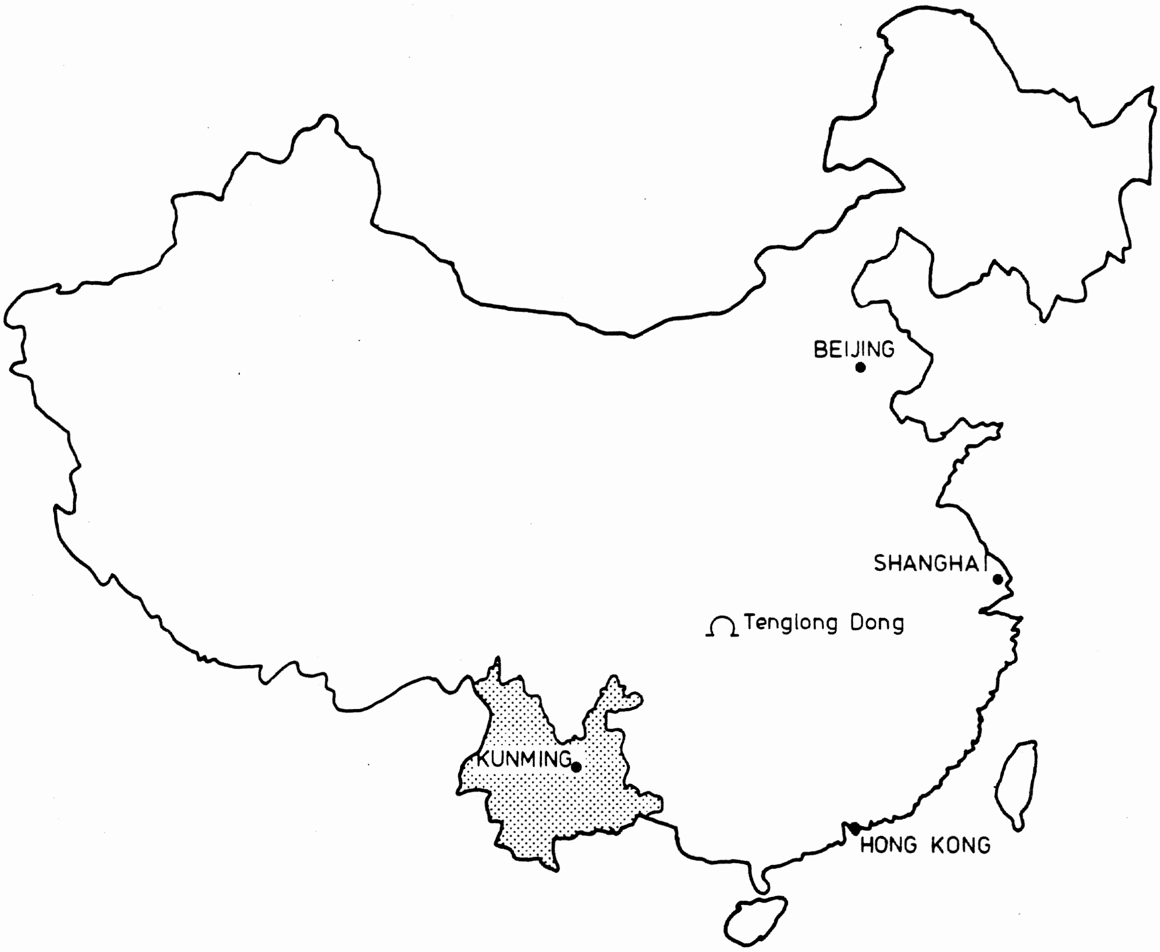

Fig. 1: Location map of Yunnan province in China (conterminous part only)

The same group intends to conduct further studies in China, starting with a new project in East Yunnan. Because the local field conditions and the speleological prospects were not yet known, a small reconnaissance group was set up, composed of Prof. Zhang Shouyue, director Karst and Groundwater Research Division, Academia Sinica, Qi Zhonglin, foreign affairs division of the Institute of Geology, Academia Sinica, Jan Vloeberghs, president of the Federation of Flemish Speleologists, acting president of the Belgian Union of Speleologists, and Michiel Dusar, Belgian Geological Survey. The field trip was conducted between 17.12.1990 and 3.01.1991 in the dry season, allowing the easiest access both above and underground. A larger scale speleological expedition to the same region is foreseen for the period 15.03.1991 - 15.04.1991.

In fact the objectives of this new project are manifold:

- appraisal of the East Yunnan karst in a zone of climatological transition and under different host rock conditions
- exploration and mapping under difficult physical conditions
- multidisciplinary study invoking the cooperation between different Belgian research institutes, Academia Sinica and local offices responsible for water resources, geological mapping and construction.

Moreover it is intended that this project will bring a significant contribution to the 1993 International Speleological Congress in China by adding a field excursion to the programme of this congress.

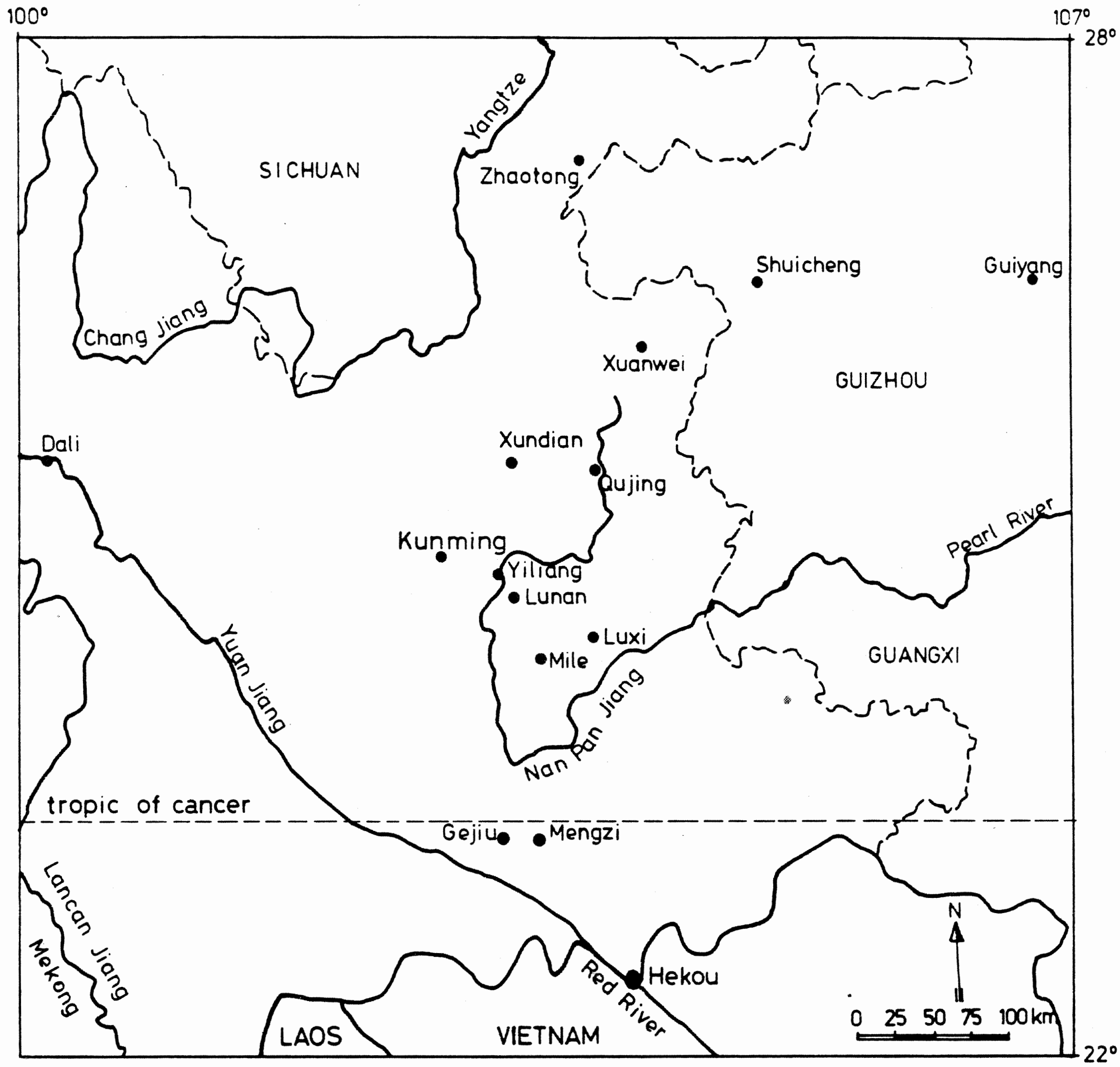

Fig. 2: East Yunnan geographical map

Prior to the field trip, district authorities of eastern Yunnan counties containing carbonate rocks, were informed on our mission and requested to indicate the presence of interesting caves. The response was very favourable. Many caves with complex development and underground rivers were selected (Table 1). In this way we were assured of the highly appreciated assistance of the authorities and local people who have investigated much of the underground space in their area and who show some economic interest in our study for the development of tourism by opening new showcaves or for the protection and better knowledge of precious water resources. Unfortunately one area more to the north (Zhaotong, fig. 2) could not be visited because of local frost conditions, rendering the access by road very hazardous. The efficient assistance and guidance we received were very encouraging; they already indicate that our study will certainly contribute to the regional development and to a pronounced image mark of Belgium in this region of growing importance.

Cave name	Village	District	Coordinates	Distance to district seat	Altitude entrances	Depth water level	Top karst massif	Type of cave	Stratigraphy	Interest	Known length
1. Tiansheng Qiao Natural Bridge cave	He Ga	Xuanwei	26°37'N 104°29'E	60km NNE	ponor 1425 m middle 1610 m top 1690 m	1400 m	2303 m	Multistorey underground river	Permian	Depth min 335 m	3 km
2. Long Dong Dragon cave	--	Xuanwei	26°23'45"N 104°13'15"E	22km NNE	res. 1935 m middle 1990 m pitches 2040 m	1935 m	2354 m	Multistorey underground river	Permian	possible show cave	1.5 km
3. Source of the river Pearl	Maxiong Mtn	Qujing	25°56'N 103°57'30"E	55 km NNE	res. 2045 m pon. 2065 m	2045 m	±2135 m	underground river	Triassic	historical	(1.5 km)
4. Unnamed cave	Huashan reservoir	Qujing	25°47'30"N 103°59'30"E	40 km NNE	pon. 2005 m end 1975 m	?	2035 m	Inactive underground river	Triassic	possible show cave	0.8 km
5. Tiansheng Dong Natural cave	Cave park	Qujing	25°40'N 103°48'E	17 km N	---	---	---	Multistorey surgence	Devonian	show cave	1.5 km
6. Da Dong water cave	Fu Tian	Qujing	25°12'30"N 103°48'E	33 km S	exs. 1940 m	1940 m	±2140 m	Exsurgence	Devonian ?	water course	0.1 km
7. Gan He Dong Dry River cave	---	Xundian	25°49'N 103°30'E	52 km NE	res. 1720 m upper 1750 m	1720 m	2140 m	Multistorey underground river	Permian	possible show cave	4 km
8. Ancient Alu caves	Luxi	Luxi	24°33'30"N 103°45'30"E	5 km N	entr. 1705 m	1695 m	±1750 m	cone karst	Triassic	show cave	2.5 km
9. Bailong dong White Dragon cave	cave park	Mile	24°12'N 103°21'E	32 km S	low 1450 m upper 1475 m	1390 m?	±1600 m	cone karst	Carboniferous	water level below showcave	2.5 km
10. Da Qiao Dong	cave park	Mile	24°12'N 103°21E	30 km S	1410 m	1390 m	±1475 m	exsurgence	Carboniferous	water level	0.9 km
11. Ying Cui Shan Gorge shadowy with vegetation	Jiuxiang park	Yiliang	25°6'N 103°25'E	44 km NE	pon. 1760 m res. 1680 m	idem	1820 m	Multistorey underground river	Sinian river	showcave	3 km
12. San Jiao Dong Three feet cave	Jiuxiang park	Yiliang	25°8'N 103°25'E	44 km NE	res. 1820 m	idem	±1950 m	underground river	Sinian	scenic spot	(2.7 km)
13. Da Dong	Jiuxiang park	Yiliang	25°7'30"N 103°24'E	44 km NE	pon. 1815 m	idem	±1950 m	underground river	Sinian	scenic spot; connection	0.6 km
14. Da Kuo Dong Big dry hole	Jiuxiang park	Yiliang	25°7'N 103°25'E	44 km NE	pitch 1815 m bottom 1760 m	?	±1950 m	Collapse on water passage	Sinian	vertical type cave	1.5 km
15. Da Sha Ba Big Sand barrier massif	Jiuxiang park	Yiliang	25°8'N 103°26'E	44 km NE	1870 m	1840 m	±1950 m	Complex meander cutting	Sinian	lateral development	2 km

Table 1: Overview of visited caves.

2. Geographical and geological setting

2.1. Topography

Yunnan province, 390.000 km^2 for 33 million inhabitants, forms a southwestern border province, limited by Laos and Vietnam in the south, Burma in the west, and the Chinese provinces or autonomous regions Guizhou and Guangxi in the east, Sechuan in the north and Tibet in the northwest (Fig. 1-2).

The study area in East Yunnan is located between 24° and 27°N and between 103° and 105°. It forms a high plateau strongly affected by karst, with average altitudes between 1900 m and 200m (Fig. 3). Toowards the east this high plateau passes into the Guizhou karst plateau at a lower altitude (±1400 m).

The western half of Yunnan possesses a more complex topography, controlled by a NNW-SSE trending structural grain. Altitudes decrease from over 6000 m in the NW to a mere 67 m in the south. Rivers descending from the Tibetan plateau with deeply incised canyons are responsible for the rugged and inaccessible topography: the Yangtze or Chang Jiang returning NE into Sechuan, the Lancanjiang (or Mekong) and Nujiang (or Salween) flowing towards the south, and the Yuanjiang (or Red river in Vietnam) flowing towards the southeast.
The study area is drained by the Zhujiang or Pearl river, turning eastwards towards Guangzhou (Canton). Measured by annual discharge, the Zhujiang is the second most important river in China (after the Yangtze). Its source located in a karst zone to the north of Qujing (Fig. 4) is a venerated spot for Chinese visitors.

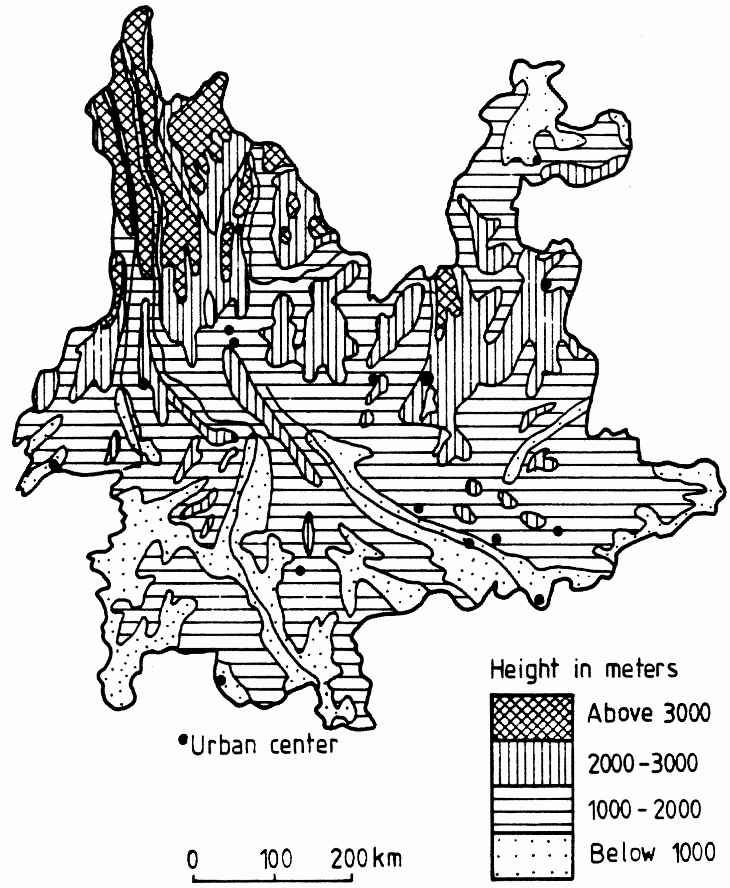

Fig. 3: topography in Yunnan (modified after Hsieh, Atlas of China)

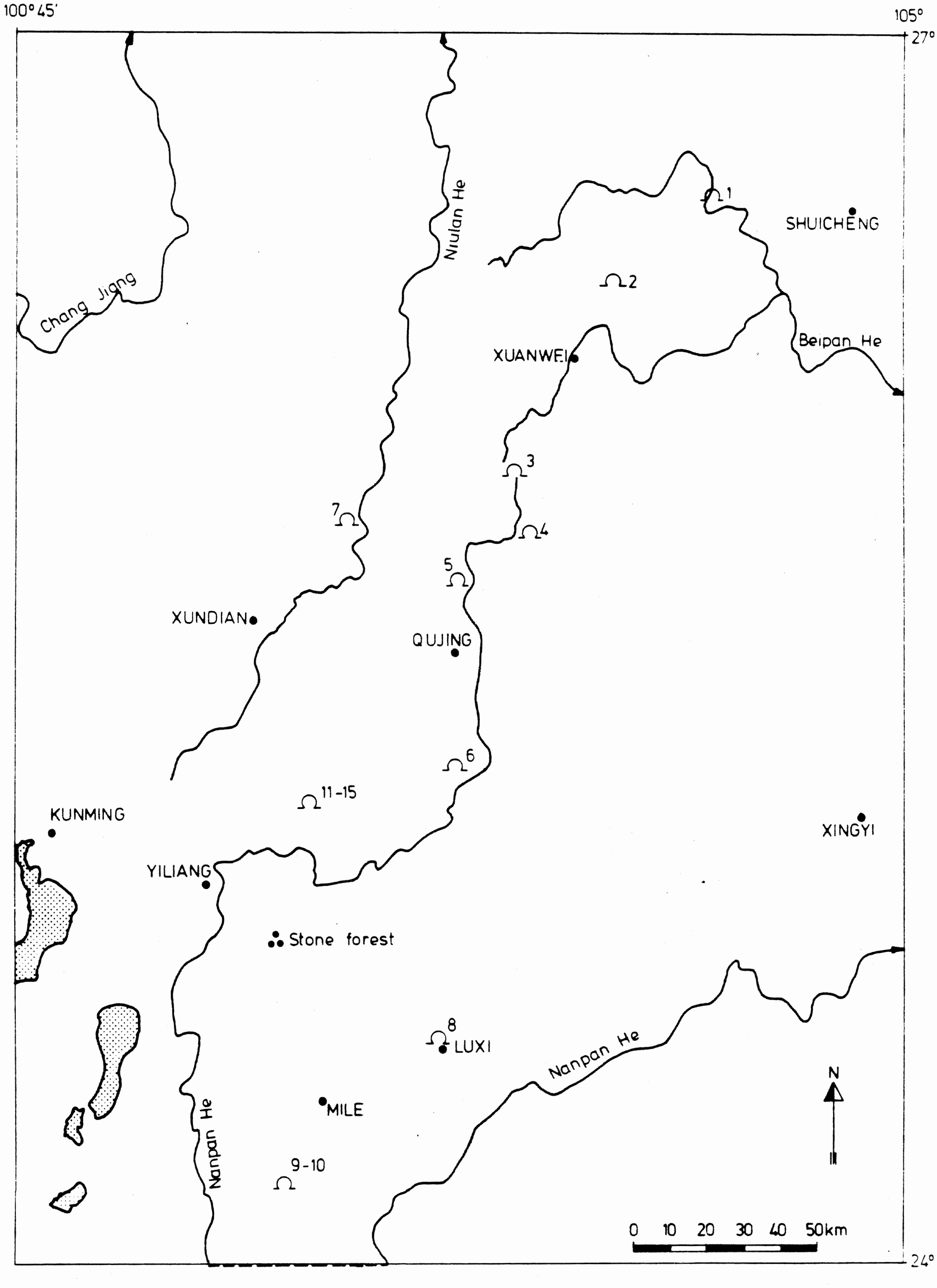

Fig. 4: *East Yunnan caves and drainage pattern (1 Tiansheng Qiao dong, 2 Long dong, 3 Source of the River Pearl, 4 Huashan reservoir, 5 Tiansheng dong yuan, 6 Da Dong Fu Tian, 7 Gan He dong, 8 Ancient Alu caves, 9 Bailong dong, 10 Da Qiao dong, 11 Ying Cui Shan, 12 San Jiao dong, 13 Da dong, 14 Da Kuo dong, 15 Da Sha Ba)*

2.2. Climate

As in other parts of China, the seasonal variations in climate are caused by the monsoon regime. The winter monsoon brings cold dry northeasterly winds from the Mongolian-Siberian anticyclone into Yunnan, interrupted by short-lived humid westerly depressions. The summer monsoon, starting in May and lasting till October, brings warm moist air in from the south. However rainfall, humidity and even temperature variations remain moderate on the sheltered East Yunnan plateau. Also the annual variation is very limited and thus the reliability on rainfall very high. Whereas the winter isotherms run east-west so that Yunnan experiences the same mild conditions as the tropical coastal areas of South China (to be corrected for elevation above sea level, with a January minimum of 8-9°C in Kunming), the summer isotherms run north-south, indicative for the fresh mountainous conditions of the Chinese interior (June maximum of 22.2°C in Kunming) - (Fig. 5).

The resulting climate is delightful and almost ideal, and can best be typified as an eternal spring. For Kunming, which is representative for the study area, average annual rainfall is 1053 mm, with a clear summer maximum and annual variations of less than 15%. The average temperature range varies between 8.9°C in January and 22.2°C in June, or a difference of only 13.3°C, which is the lowest in China (Treagar). No wonder that this region is famous for its year round flowers and is endowed with sufficient and variable food production, centered around a rice-culture.

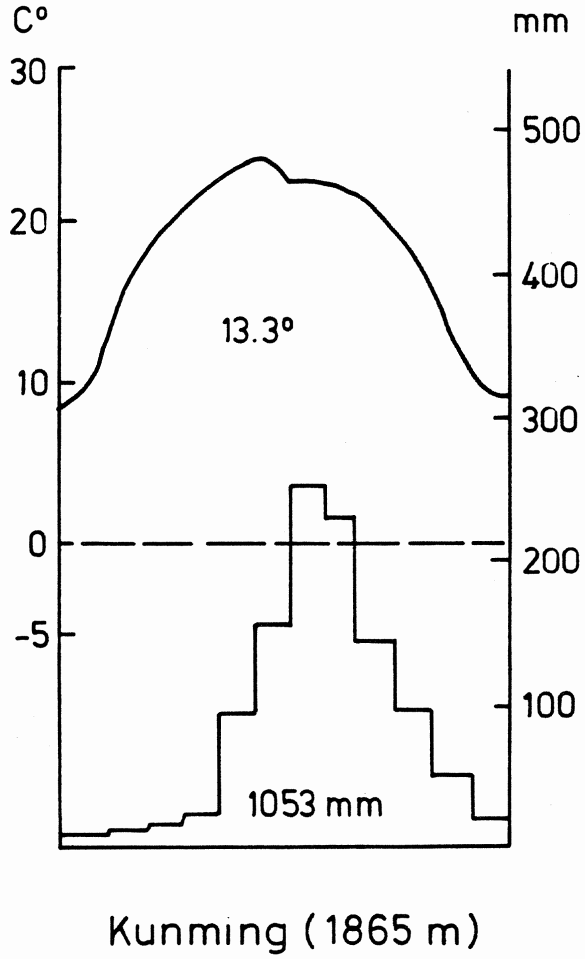

Fig. 5: Monthly temperature and precipitation variation in Kunming (from Treagar, China, A geographical survey)

2.3. Soils

The Yunnan plateau is generally characterised by strongly podzolic yellow soils which are reasonably fertile under appropriate cultivation techniques, by introducing organic fertiliser on a regular basis. On the limestones terra rossa occurs to great depths as is shown by karren denuded over 30 m in the Stone Forest. The deforested hillslopes have been subject to rampant sheet and gully erosion but vigorous measures are actually taken to minimise further erosion. The widespread use of coal stoves for cooking and heating fortunately has reduced the demand of wood, so that reforestation plans have some chance of success. On the barren limestone plateaus, the Yunnan pine has been introduced succesfully. Few hillslopes still preserve the natural vegetation of deciduous trees, intermingled with broad-leaved evergreens and bamboo.

2.4. Geology

2.4.1. Structural outline

East Yunnan is underlain by rock formations of various composition and age. This is also reflected by the diversified karst, developped on carbonate rocks ranging in age from Late Proterozoic to Triassic. Although carbonate distribution maps of China (Jennings, 1981) mark the East Yunnan-Guizhou plateau as completely karstic, carbonate rocks cover generally less than half of the total surface. The proportion of carbonate formations increases towards the south however (Fig. 6). Unlike the Triassic carbonates in West Hubei no formation is really preponderant in this region. Nevertheless East Yunnan presents a comparable geological history as West Hubei (Dusar, Swennen & Zhang, 1991). The East Yunnan-Guizhou plateau forms part of the Yangtze platform covering much of South China and the Middle and Lower Yangtze basins. The western accretionary boundary of the Yangtze platform with the Himalaya foldbelt crosses Yunnan province in a NNW-SSE direction to the west of Kunming. On the East Yunnan plateau a NNE-SSW structural trend is strongly dominant and responsible for a similar trend in the topographic expression. The Sinian (Upper Proterozoic) to Jurassic sedimentary cover of the East Yunnan part of the Yangtze platform underwent relatively minor deformation. Gentle folding accompanied by normal and shear faulting accommodated the Yanshanian tectonic phase, time equivalent of the Upper Jurassic Cimmeric deformation stage. Despite the presence of several unconformities in the sedimentary cover of the Yangtze platform even Sinian rocks do not show much stronger deformation in the study area: average dips stand at 30° to the NW in the Jiuxiang parkzone. Local compression or shear events however may increase the folding and faulting as was observed near Tiansheng Qiao in Xuanwei district (Fig. 4).

2.4.2. Stratigraphic and paleogeographic framework

The sedimentary cover of the Yangtze platform developed already in the Proterozoic with the onset of the Sinian system some 850 m.y. ago. The Yangtze platform has been covered with shallow epicontinental seas or inland basins for most of its subsequent history (Table 2). The great extension of this platform and the remoteness of source rocks for clastic sediments resulted in widespread carbonate sedimentation starting in the precambrian Upper Sinian (Fig. 7) and lasting till the Middle Triassic. The carbonate sedimentation was interrupted by periods of tectonic instability associated with tectonic pulses, respectively occurring after the Lower Ordovicium and lasting till the Lower Devonian ("Caledonian"), during the Carboniferous - Permian transition ("Hercynian") and during the Upper Jurassic ("Yanshanian" or "Cimmeric"). Sea level fluctuations locally affected the platform margins, allowing the influx of siliciclastics. This was especially the case in the Kunming region which frequently underwent some relative uplifts. Although marine conditions prevailed during most of the sedimentary history, a tenden-

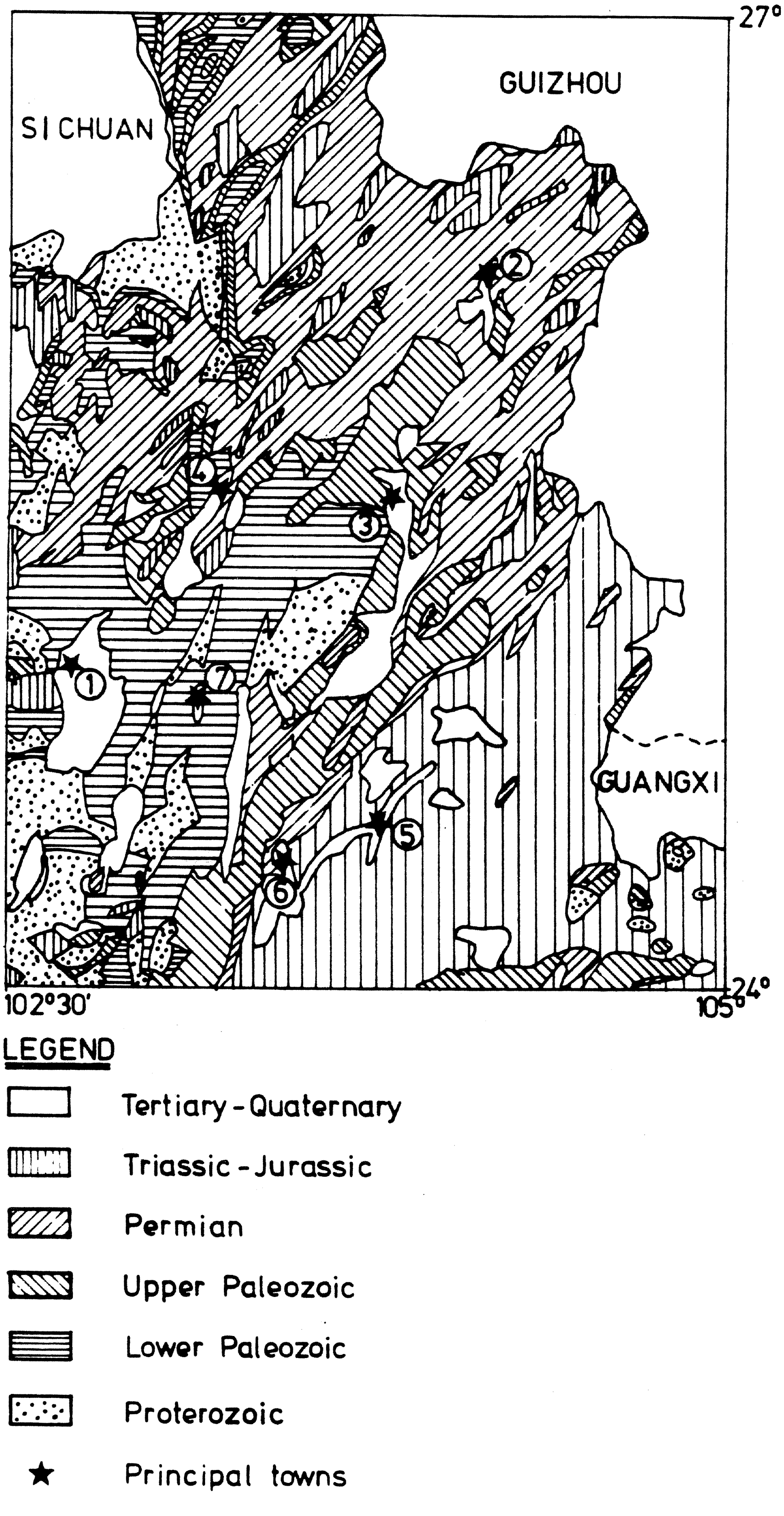

Fig. 6: Simplified geological map of East Yunnan, modified after Geological Atlas of China (1 Kunming, 2 Xuanwei, 3 Qujing, 4 Xundian, 5 Luxi, 6 Mile, 7 Yiliang)

PERIOD	SEDIMENT TYPE	DEPOSITIONAL ENVIRONMENT	THICKNESS RANGE
Quaternary	alluvial sands and lacustrine clays	inland fault basin	0 - 126 m
Neogene	alluvial sands and clays; lignite; basal conglomerate	inland fault basin, humid subtropical to tropical	0 - 160 m
Paleogene	clastic infill (mudstone, sandstone)	inland fault basin, arid	
Jurassic 2	clastic red beds	Red Basin border zone (Sechuan basin)	
Jurassic 1	lacustrine deposits	inland open basin (Sechuan basin)	
Triassic 3	deltaic clastics with basal conglomerate; fining upwards	paralic basin (uplift in Kunming area)	814 - 1579 m
Triassic 2	marl with mudstone intercalations, limestones and dolomites which predominate towards SE	epicontinental carbonate shelf	153 - 773 m
Triassic 1 yn	limestones and dolomites	epicontinental carbonate shelf, very extensive	361 - 671 m
Triassic 1 f + Permian 2	mudstone with sandstone; coal towards base, marine towards top	paralic basin, uplift in the West	596 - 954 m
Permian 2β	basalt, some sedimentary intercalations	plateau basalt	273 - 609 m
Permian 1	massive carbonates	carbonate shelf	405 - 968 m
Permian 1 1	sandstone and shale with thin coal towards base P1	continental influx on shelf	80 - 187 m
Carboniferous 3/ Permian 1	sandstone; limestone towards top and base	sea level drop; Hercynian uplift	0 - 890 m
Carboniferous 2-3	limestones	South China sea carbonate shelf	304 - 2433 m
Carboniferous 1 + Devonian 2-3	limestones with siliciclastics	edge of Upper Yangtze oldland in W; transition to South China sea in E	172 - 1197 m
Devonian 1	no deposits	Upper Yangtze oldland	0 m
Silurian/ Ordovician 2-3	some sandstone - shale - carbonate deposits	Dian Qian Gui oldland with bays; Caledonian uplift at base	0 - 305 m
Ordovician 1/ Cambrian 2-3	littoral clastics and shales in W; also carbonates in E	Upper Yangtze epicontinental sea	0 - ? m
Cambrian 1	shale - sandstone - dolomite	Upper Yangtze sea	550 - 580 m
Sinian 2	dolomites and clastics; tillite at base	Upper Yangtze sea	170 - 260 m
Sinian 1	clastics	piedmont paramolasse on Kham Dian oldland	200- 400 m

Table 2: Sedimentary cover of the East Yunnan plateau (stratigraphic information derived from geological and hydrogeological maps, and from Atlas of Palaeogeography of China).

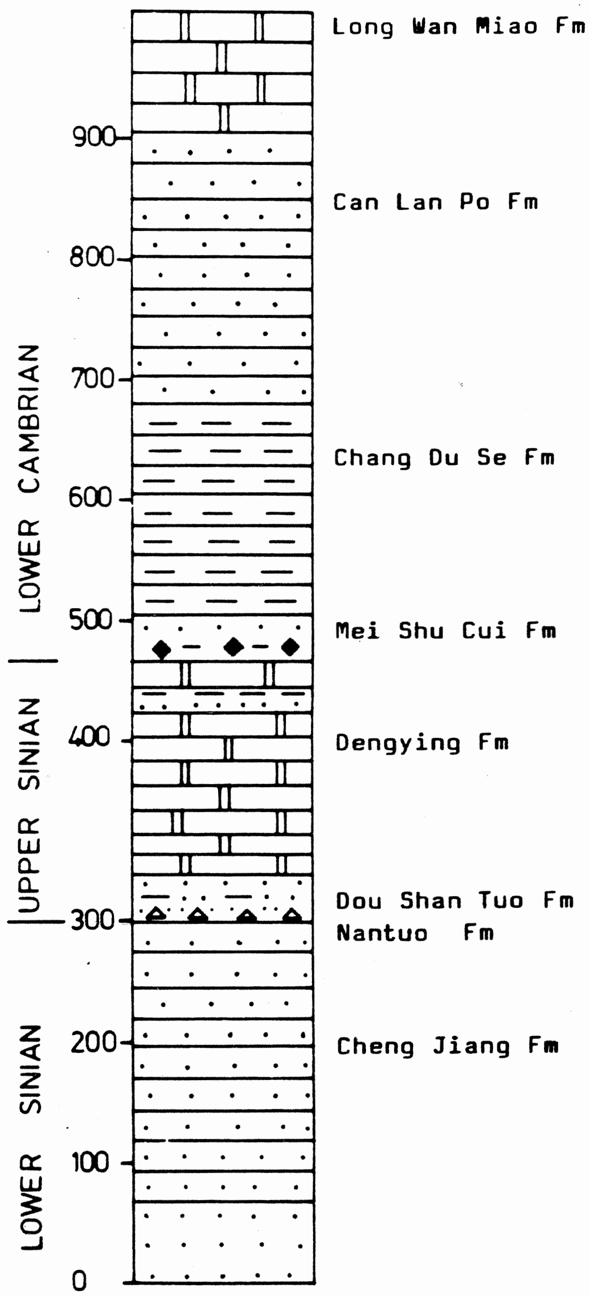

Fig. 7: Sinian to Lower Cambrian stratigraphic succession in the Kunming region (information by Mr. Rao Qing Yun, Yunnan Bureau of Geology and Mineral Resources)
Long Wan Miao Fm: dolomite, 100m;
Can Lan Po Fm: medium to fine grained sandstones, ±225m;
Chang Du Se Fm: shale ±175m;
Mei Shu Cui (Yuhucun) Fm: siltstone and shale with phosphatic nodules, 50-80m;
Dengying Fm: thin bedded dolomite, near top siltsone and shale with phosphatic nodules, 150-200m;
Dou Shan Tuo Fm: siltstone and sandstone, 20-50m;
Nantuo Fm: tillite, <10m;
Chengjiang Fm: fine grained quartzitic sandstone, 200-400 m

cy towards basin closures becomes apparent when moving upwards in the stratigraphic time scale. This is marked by the appearence of paralic conditions with associated coal deposits in the Lower Permian and the Upper Permian - Lower Triassic transition or the development of inland basins from the Upper Triassic onwards (cf. Atlas of the Palaeogeography of China, 1983). The Yanshanian deformation associated with the closure of the Paleotethys terminated the sedimentation on the Yangtze platform (Sengör, 1987). Instead a highland developed on this platform. On this South China Highland some strongly subsiding inland fault basins occur along NNE-SSW trending faults which essentially developed since Neogene times. They now form intensively cultivated flatland areas but do not cover much more than 5% of the East Yunnan countryside. Otherwise the gently folded platform cover is well exposed because of a strong erosion on the East Yunnan plateau.

3. The karst phenomena

3.1. History of investigations

Agriculture still forms the most important economic activity in Yunnan. However local natural resources are increasingly used to support rapid industrial growth and to provide adequate housing and communications. Therefore detailed and reliable geological and hydrogeological maps exist. Unfortunately their circulation is restricted and subject to approval by the responsible authorities. In this way the contribution of previous stages of fieldwork, geological mapping and hydrographic observations to the present study is rather limited.

Although the distribution of carbonate rocks and water circulation patterns are fairly well known in East Yunnan, the inventory of underground water resources in karst zones has all but started and no investigations have been made of the regional development of the different karst morphologies nor of its dependency on lithology and structural geology. The famous tourist attraction Shilin or Stone Forest near Lunan (Fig. 4), a denuded karren field, up to 30 m deep, developed on gently sloping massive Permian Maokou limestones, forms the only notable exception (Zhang, 1984a).

In order to obtain a more comprehensive view of the karst development and to start a study of the most spectacular karst features, district authorites in East Yunnan were requested to provide information on the most interesting cave systems known. The information gathered in this way and the enthousiastic cooperation thus obtained, proved that a combination of scientific goals and local interest is an excellent way to start such studies.

3.2. Karst development

The karst terrains observed in the East Yunnan plateau form part of the Proterozoic to Mesozoic carbonate rock karst developed on the Yangtze craton which covers much of south and central China. The carbonate rocks are several thousand meters thick, interrupted by non-carbonate rock units, and range in age from Sinian to Triassic. Mainly as a result of the Yanshanian Orogeny are all these rocks well exposed and accessible for karstification in the East Yunnan plateau. The composition of the carbonates encountered is variable. The average dolomite content is increasing with age, from 8% in the Permian over 20% in the Carboniferous to over 75% in the Devonian and the Sinian. This has to be related to the paleogeographic evolution: the shallow carbonate platform reached its greatest extension in Permian times. In the Triassic the average dolomite content is again increasing to almost 30% (Zhang, 1984b).

Bed thickness and purity is also an important factor in karst development and has influenced the size of karst features. The pure thick-bedded Maokou limestones of Permian age are responsible for the largest karst features and for the deep karren fields of Stone Forest type (Zhang, 1984a).

Actual karst morphology is but a passing stage in a long evolutionary sequence. Different phases in paleokarst development can be recognised since the establishment of the basic tectonic framework modelled by the Yanshanian orogeny during the Jurassic (Zhang Zhigan, 1980). More ancient paleokarsts have also affected the carbonate rocks (e.g. differential landscape morphology on the P1m Maokou limestone below the P2β Omeishan Basalt) but their role in the development of the actual karst morphology is rather passive (Zhang, 1989). "Recent" paleokarst development started with the Pre-Eocene Shishan peneplanation phase, evolving in the Zhaolu phase of Eocene to Pliocene age, associated with the oldest inland fault basins on the East Yunnan plateau. Before the Pliocene tropical conditions led to the establishment of a tower karst landscape. The last evolutionary phase of "modern" karst development known as the Jinshajiang phase, started in the Pliocene and continued into the Quaternary.
Two factors have determined the modern karst evolution: 1- the Himalayan uplift, and 2- climatic differentiation and weathering. The uplift has been very intense, attaining several kilometers, and could not be matched by denudation. It is responsible for the climatic differentiation and possible glaciation in mountain zones. Downcutting by rivers has been destroying the original hydrographic network. Plateau-canyon type of karst has been created where river incision is very rapid as on the Yunnan-Guizhou border region; elsewhere karst plain-hilly plateau karst has resulted from intensive corrosion accompanying the erosion (Waltham, 1984).

A regional classification of different karst morphological types has been established by the Karst Research Group of Academia Sinica (1979). On the East Yunnan plateau a distinction can be made between: 1- type IA2 "Karst plain-hilly plateau karst", typical for most of East Yunnan, and generally characterised by low gradients of the hydrographic net; 2- type IA3 "Uvala qiufung(1) mountain plateau karst" of West Guizhou, also encountered in the Xuanwei area, generally characterised by deeply incised rivers; 3- type IB1 "Karst plain-funglin(2) plateau" karst, developed in tropical Southeastern Yunnan, to the south of Mengzi and best known from Guilin in Guangxi province.

The present study concentrates on the IA2 karst landscape and its transition to the IA3 type in the Yunnan-Guizhou border mountains. Previous speleological expeditions were already carried out in the adjoining Guizhou province (Waltham, 1986; Zhang & Barbary, 1988). The IB1 type karst morphology is not so interesting for deep speleological investigations. Therefore prospections did not extend into the tropical part of Southeast Yunnan.

1- Qiufung: a type of cone karst that is characterised by gently sloping, hemispherical limestone hills, the diameter being several times the height.
2- Funglin: tower karst and cone karst.

4. Regional distribution of selected karst features

4.1. Xuanwei district

4.1.1. Geographical introduction

Xuanwei county in northeastern Yunnan, depending on Qujing prefecture, and still closed for foreigners, has a surface of 6.050 km^2 and 1.170.000 inhabitants. This county holds the highest population in Yunnan, the capital city Kunming not counted. The east Yunnan plateau levels at around 1900 m with peaks to 2500 m and some deeply incised rivers draining into the Guizhou plateau at an elevation of ±1300 m (Fig. 4). 95% of all the land is considered as mountainous, 40% is considered as karst area. Nevertheless land use is intensive. Tobacco forms the main cash crop. The natural resources are widely used, most on a small artisanal scale. These do not increase substantially the wealth of the county however. For instance local coal mining brings 3 million yuan in revenues, but costs 9 million yuan in subsidies. Brickmaking and pottery production are common activites, and limestone kilns also abound.

Major karst development in the Xuanwei district is on Lower Permian limestones which are very massive and well developed, often forming prominent outcrops deeply affected by karstic dissolution. These are also the oldest beds exposed. The stratigraphic series further comprises P2β basalt, P2-T1 siliciclastics with coal, T2 marls, T3-J1 mudstones and sandstones and a Neogene to Quaternary inland basin with clastic fill around the district seat (Tab. 2, Fig. 8, 10).

4.1.2. Tiansheng Qiao cave system

4.1.2.1. Location

Tiansheng Qiao or Natural Bridge cave system is located on the Ke Du He river, a tributary of the Bei Pan He, right at the Yunnan-Guizhou border, some 60 km to the NNE[3] of the Xuanwei district seat (Fig. 4, Tab. 1). The Ke Du He river locally forms the border line between both provinces; the cave system encompasses the underground course of this river. The geographical coordinates for this cave system are 26°37'N and 104°29'E.

The main Kunming-Guiyang railway line crosses the river and thus the province boundary at the dry valley right on top of the cave. Approach of the cave by road transport from the district seat is very time consuming and takes about 3 hours: 30' on tar road, 1h15 on dirt road till the last railway station, 30' on dirt road descending to the chief village Shung He, situated along a tributary of the Ke Du He at 1550 m, 20' on dirt track to the village He Ga, situated on the interfluvium to the Ke Du river at 1730 m, followed by a foot walk of at least 15' to the most proximal cave entrance.

3- Magnetic declination is acutally less than 2°W. Therefore no distinction has been made in this report between true north and magnetic north when indicating directions. True north appears on the map-figures however.

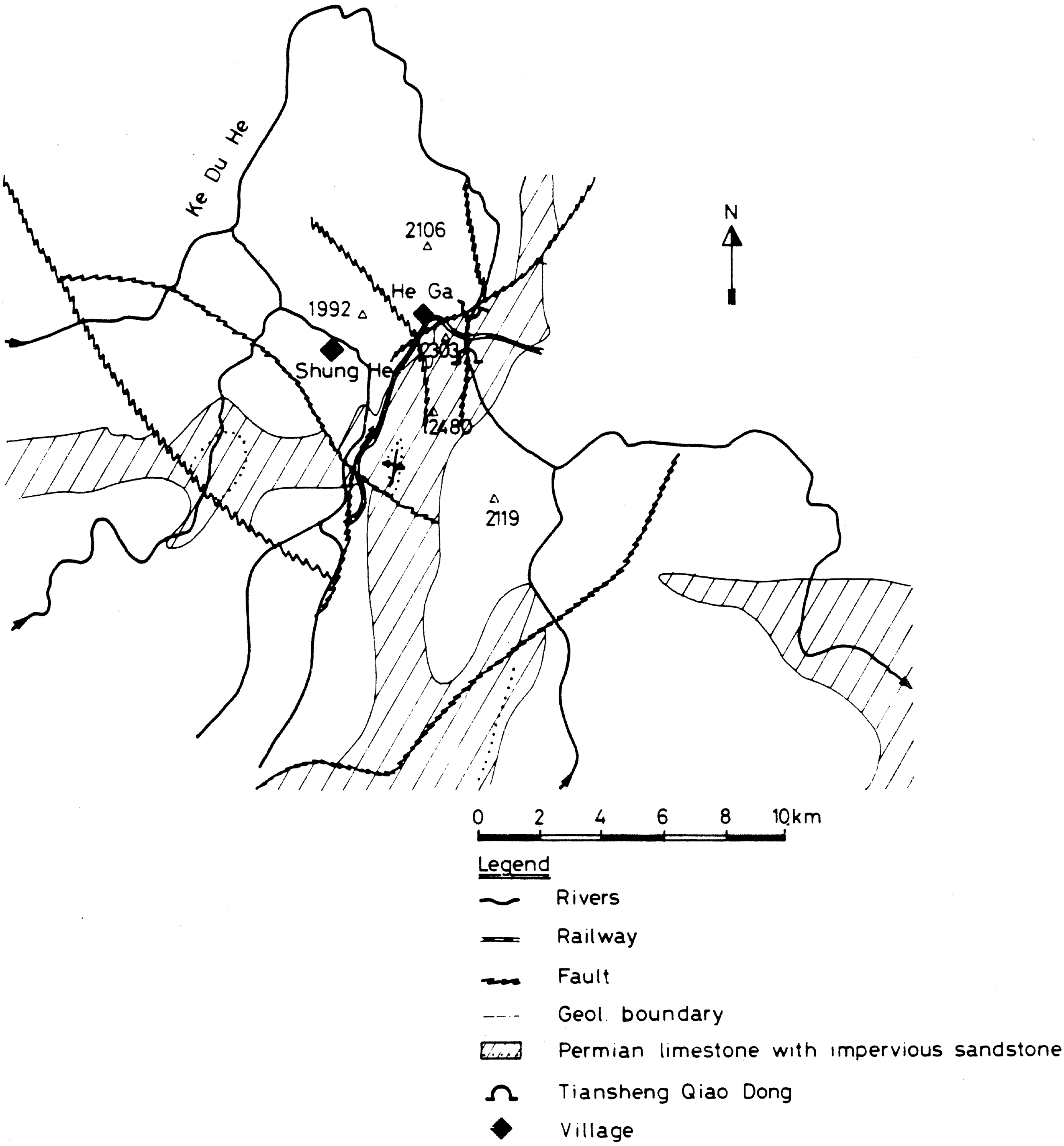

Fig. 8: Geological sketch map of the Tiansheng Qiao cave system in the Xuanwei district (based on the 1:200,000 hydrogeological map)

4.1.2.2. Geology

The cave system developed in massive Lower Permian Maokou limestones, generally composed of blue-grey recrystallised bioclastic wackestones. This limestone is folded in a north-south directed anticline with limbs dipping 30 to 60°. Folding is associated with normal and transversal faults. One of such faults trending ENE-WSW, delimitates the limestone massif to the north, right at the cave entrance where an abnormal contact with overlying P2β Omeishan basalts is observed. In the contact zone the limestone is strongly veined and brecciated, presenting some disharmonic folds (Fig. 8).

4.1.2.3. Hydrography

The Ke Du He river has shaped this cave system. It enters the cave at an altitude of 1425 m and leaves the cave some 2 km further to the south at an altitude of 1400 m. The dry valley in between lies at an altitude of ±1690 m or almost 300 m higher; an intermediate fossil river course is found at ±1610 m or ±200 m above the actual river level. The karst plateau surrounding the dry valley culminates at 2303 m or ±900 m above the valley bottom (Fig. 9). This extremely deep incision is unusual for the East Yunnan plateau; it is related to its proximity to the lower lying Guizhou plateau which forms the destination of the Bei Pan river joined by the Ke Du He.

The Ke Du He river discharge pattern shows strong seasonal fluctuations with peaks of 1000 m^3/s, fed by occasional torrential rains. The average discharge is ±10 m^3/s, and the minimal discharge observed in the dry season from October to April is ±5 m^3/s, supplied by perennial springs (figures kindly supplied by the Shung He village officials). At the cave entrance (ponor), which is at least 40 m high and ±15 m wide, flood levels marked by brown silt and clay staining on the cave walls were observed some 12 m above the dry season river level. A coarse gravel bed stood at 1 m above the dry season level, coarse sand banks at ±8m.
Temperature measurements on 20.12.1990 gave 13.4°C for the river water, 14.4°C for the air and 16.3°C in the upper cave level at 1720 m.

4.1.2.4. Karst morphology

The Tiansheng Qiao cave system is essentially composed of a multistorey underground river system with an active lower level and two abandoned fossil levels. The underground course of the Ke Du He river attains 3 km, according to local sources. The straight distance between ponor and resurgence is only 2 km. The underground river tract is overlain by a dry valley at an altitude of 1690 m[(4)] which is about 300 m above the actual river level at 1400 m. The underground incision thus is very deep compared to its length and to the importance of the river. Geological structure might provide an answer to this phenomenon.

Altough the general elevation of the East Yunnan plateau in the Xuanwei district is 1900 m, the Lower Permian limestone anticline and the succeeding P2β basalts form a NNE-SSW stretching ridge culminating at 2480 m. On the west side of the dry valley an altitude of 2303 m is reached, or 900 m above the river base level. The Ke Du He river first follows a subsequent north to south direction through more easily erodable P2-T1f sandstones and mudstones.

4- Altimeter readings have to be interpreted with caution, since pressure changes during the day affected all readings with systematic drifts in the order of 10 to 35 m each day. Readings for the same point generally increased by such an amount between morning and afternoon on sunny days. Also the altimeter was set arbitrarily at fixed readings for the district seats which might not be completely exact at all places.

It is then compelled to traverse the limestone massif normally stretching to the east of theriver, because of a lateral shift in the outcrop of this limestone due to a ENE-WSW trending normal fault. The uplifted limestone is also cut by two north-south trending shear faults, accompanied by intense fracturation. Preferential dissolution of the limestone along one of these faults is probably at the origin of the underground river course (Fig. 8). Predominant north-south lineaments in the Permian limestone either structural (fault lines) or stratigraphic (impervious sandstone and shales in the anticlinal core) may direct further subsurface karst development along parallel paths.

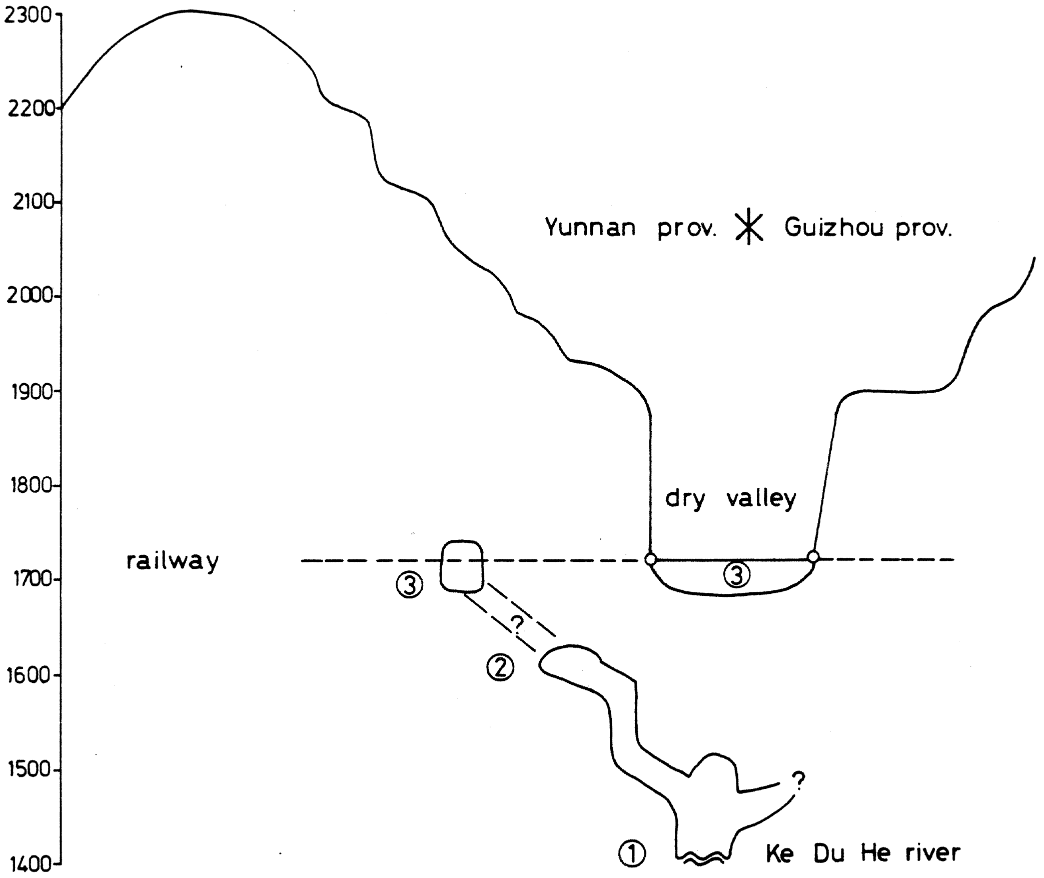

Fig. 9: Geological sketch map of the Tiansheng Qiao cave system in the Xuanwei district (13: cave development phases)

The dry valley is surrounded by vertical walls showing signs of superficial dissolution. They are at least 200 m high and may correspond to an ancient underground gallery exposed by roof collapse. An upper level in the cave development, probably related to the formation of the dry valley, was encountered in a railway tunnel to the west, between the dry valley and He Ga village (Fig. 8). In the original railway tunnel at altitude 1720 m and direction NNE-SSW a large chamber was encountered (approximate dimensions 20 m wide, 25 m high, 35 m deep) with apparent prolongation towards the east (direction of ponor). Due to the discovery of this cave this part of the railway tunnel was abandoned and the railway line was relocated to the south.

At ±1610 m a new cave development level was noticed, observable on both ends of the dry valley. Part of the caves corresponding to this level have collapsed; ancient cave chambers have become exposed. On the other hand a connection with the lower active gallery exists. Thus three main levels of cave development are present with signs of lateral extensions and vertical connections (Fig. 9). Vertical drainage of the karst plateau overlying the Tiansheng Qiao cave system is likely but may be directed towards the outer margins of the narrow limestone anticline (average width 3-4 km for a length of 6 km possibly connected with the Tiansheng Qiao system. Nevertheless in the dry winter season no percolation waters seem to drain into the underground river. A fourth cave development phase may for instance be linked to the 1900 m peneplanation level.

4.1.2.5. Interest of the Tiansheng Qiao cave system

The Tiansheng Qiao cave system is a good example of a rapidly incised underground river with three main development phases. The vertical development is much more important in this cave system, situated close to the transition of the East Yunnan high plateau to the Guizhou low plateau, than in other cave systems situated more to the west. Although it could be observed that degradational effects were important in the middle level (breakdowns, precipitation), there exist good prospects for underground connections between the different levels. Furthermore preferential drainage patterns from the top of the karst plateau may be accessible for further exploration. Unlike the other karst areas investigated, this cave system may thus show some characteristics of karst development in temperate mountainous areas. Some morphological features of the higher mountain ranges are indeed indicative for Quaternary mountain glaciation in the Xuanwei district.

4.1.3. The Long dong cave system

4.1.3.1. Location

Long dong or Dragon cave is located 22 km to the NNE of Xuanwei; it is close to an important lime-kiln and pottery centre and easily accessible by car. The geographical coordinates are 26°23'45" N and 104°13'15"E (Fig. 4, Tab. 1).

4.1.3.2. Geology

The Long dong cave system develops in massive Lower Permian Maokou limestones gently dipping on the south flank of an elongated anticline (width varying between 1 and 2 km) stretching in a SW-NE direction. The axis and the northern flank of this anticline are faulted. The anticlinal axis is composed of impervious P1l sandstones and shale with thin coals. On these beds a central depression is formed in the ridge-like anticline. Coal is mined from small horizontal galleries on the north flank of the anticlinal axis. The Long dong cave system is situated where the subsequent drainage system in the isolated anticlinal core breaches through the massive limestone ridge of the south flank of this anticline. However extensive cave development mostly occurs in a east-west direction more corresponding to the strike of the limestone beds (Figs. 10-11).

4.1.3.3. Hydrography

Long dong cave is formed by a small stream draining the southwestern part of the anticlinal depression along a subsequent course till the ponor. An underground course developed in a NW to SE direction perpendicular to the strike of the anticline. The straight distance between ponor and resurgence is only 0.5 km. The stream has received the appropriate name of Long dong He (Dragon cave river) but is renamed Qing Shui He shortly after leaving the limestone massif.

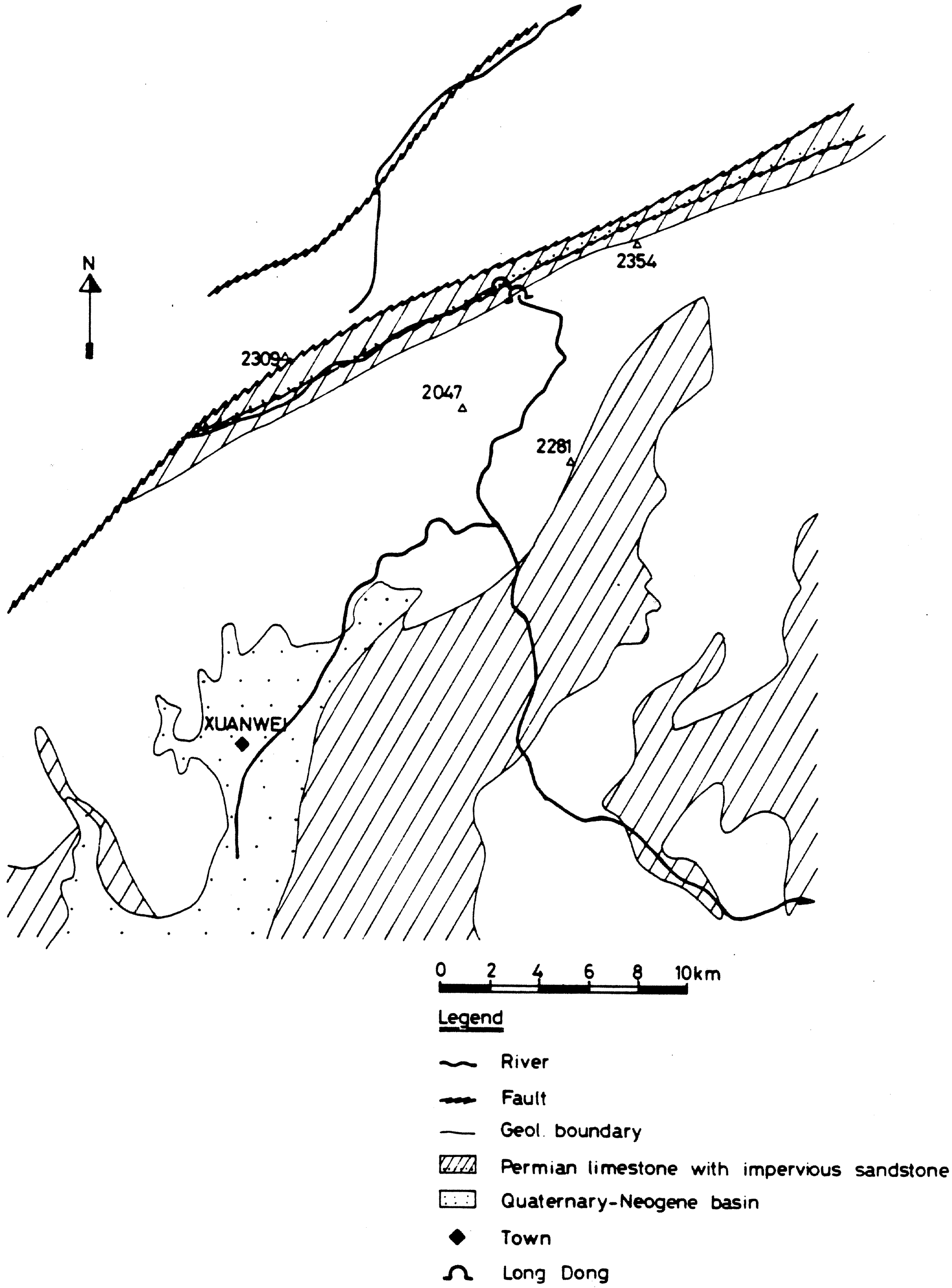

Fig.10: Geological sketch map of the Long dong cave system in the Xuanwei district (based on the 1:200,000 hydrogeological map) River flow then continues in a southward direction till, after the confluence with the stream draining the Tertiary-Quaternary basin around Xuanwei, it becomes the Beipan river which also receives the waters of the Ke Du He (cf. 4.1.2.3.) on its way to the Zhujiang (Pearl) river.

At the resurgence the minimal discharge of the Long Dong He in the dry season is 17 l/s which already indicates the purely local importance of this stream. The water temperature at the resurgence was 12.7°C on 21.12.1990 whereas the cave air temperature was 16.5°C. This testifies of the short underground stay of the water flow which was unable to equilibrate with the average annual temperature inside the cave. However it is not possible to follow the underground river course: the ponor is full of mud and siphoning, the resurgence also leads to a siphoning pool after a short distance. Altitude of the water course at the resurgence was 1935 m. The culminating points on the anticlinal ridge (generally at the contact between the Lower Permian limestones and the overlying basalts) were 2354 m to the NE and 2309 m to the SW.

There exists another resurgence at only 37 m besides the Long dong He resurgence. Flow to this resurgence is from the opposite direction (east). So underground flow converges to a transversal axis on the anticlinal ridge. Altogether six caves belong to the Long dong karst system, covering an area of 4 km^2 (Fig. 11).

4.1.3.4. Karst morphology

The Long dong cave system, which consists of two levels, has been thoroughly explored and its length measured by the municipal authorities. The total measured length of the Long dong He resurgence attains 940 m. The water passage itself is largely inaccessible. Therefore the major part of this length was surveyed in a dry gallery, extending towards the west. The dimensions reflect the local drainage: the gallery is on the average 15 m high and 8 m wide, with some side loops such as a pressure conduit with 2 m diameter and lateral developments along bedding planes or joints. The gallery is flat, with a very low gradient of 2%.
Although this gallery is just slightly above the water level is is no longer active for water drainage. Precipitations in the form of vertical speleothems and rimstone pools decorate this passage, replenished by dripping water during the wet season. Concretions block this gallery at ±500 m from the entrance. At this place the CO_2 content in the cave air was a normal 300 ppm for a temperature of 16.5°C (measurement on 21.12.90).

The upper fossil level of this cave system has been split into two major parts by recession of the limestone ridge and roof breakdowns. An eastern section at ±1995 m altitude with a measured length of 375 m is accessible from two window caves. The western end of this cave inside the limestone massif ends with a shaft descending ±20 m; the part beyond this shaft is not explored. The gallery itself presents a tunnel section with 8 m width; clay infilling and flowstones have reduced the height to 3-4 m. This part is located on top of the second resurgence, unrelated to the Long dong river.

The western section of the upper level is located on top of the Long dong He resurgence. It is accessible at 2040 m from a window on a large gallery which quickly terminates on both ends because of roof breakdowns. However a side gallery descends 50 m on the rockfall cone below this window in a northward direction, giving access to a series of high chambers at altitude 1980 m separated by rockfalls and concretions. The total length of this descending gallery was 400 m for an average width of 15 m and variable heighth, locally exceeding 30 m (Fig. 11).

4.1.3.5. Interest of the Longdong cave system

The Longdong cave system is considered as the second most important cave development in the Xuanwei district. Because of its location close to the district capital, the rich ornamentation and the limited risk of floods, it has some potential for development as a showcave.

The presence of more spectacular showcaves or potential showcaves in the adjoining districts of East Yunnan will reduce its impact to the local district population only.

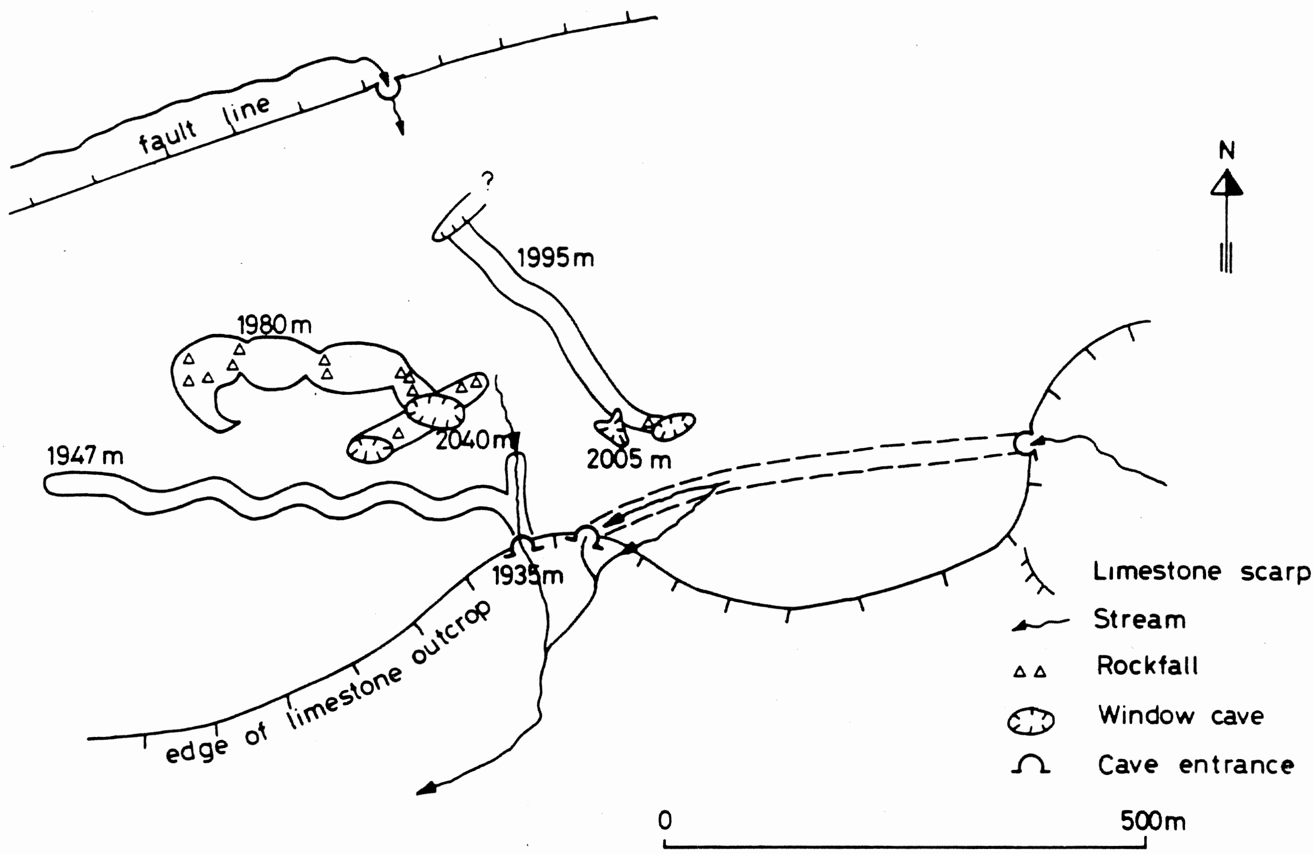

Fig. 11: Sketch map showing 2 level cave development at the Long dong cave system, Xuanwei district (scale is approximate)

Although the exploration and mapping of the Longdong cave system is not completed, its position inside a narrow ridge and the proximity of the upper galleries to the surface, greatly reduce the prospects for further important discoveries.

4.2. Qujing district

4.2.1. Brief geographical outline

Qujing is the most important city in northeastern Yunnan, and forms its gateway to the eastern provinces. It is an important cultural, economic and commercial centre with 300.000 inhabitants, presiding over a district with 790.000 inhabitants for 4318 km^2. The Qujing prefecture also controls the Xuanwei and Xundian districts which are normally closed areas for foreigners.

The city has a long chinese history, which is reflected in the many monuments, sculptured in black marble. A local showcave exists at Tiansheng dongyuan (Natural Cave Park), situated some 17 km to the north of Qujing city (approx. coordinates 25°40'N and 103°48'E)-(Tab. 1). This cave was already known more than 200 years ago, when it was described in the county annals. It is an active cave with 3 dry levels above the unaccessible water gallery. Two of these levels have been equipped for tourist tours. They host a lot of speleothems and some water-ponds, attracting 80.000 visitors per year, who mainly come from the surrounding area (Qujing city). Competition from more famous showcaves and Stone Forest park prevent further growth.

Qujing district equally forms part of the East Yunnan plateau at an average altitude of 1900 m. The proportion of karst areas is somewhat less in Qujing district than in adjoining areas. This is partly caused by the presence of Tertiary basins and Quaternary alluvial deposits, especially along the north-south trending Nanpan river. The major karst exploration area is situated in the north of the district in the less populated but scenic area between Maxiong Mountain and Huashan water reservoir (Fig. 4, Tab. 1).

4.2.2. The Source of the River Pearl cave system

4.2.2.1. Location

The "Source of the River Pearl" or Zhujiang cave system is located in the north of Qujing district some 55 km to the NNE of the district capital near Maxiong Mountain, famous for its wild flowers in spring but also known as the watershed between the Beipan and Nanpan rivers which form the headwaters of the Zhujiang.This unpopulated area, depending on Yan Fang town, consists of a very scenic landscape with rolling karst hills reforested with Yunnan pines. A typical resurgence 12 km off the main Qujing-Xuanwei road, is honoured as the spring of the Zhujiang or Pearl river, which is the most important river of South China. Discharge is minimal in winter but may increase enormously by torrential rains in summer. The resurgence is marked by many historical inscriptions but tourists cannot venture more than a few dozen meters in the cave. Needless to say that this resurgence cannot be considered as a real source, but this dispute will not be on the order here. Its altitude is 2045 m (as measured from Xuanwei district seat; its approximate coordinates are 25°56'N and 103°57'30"E.

4.2.2.2. Geology

The karst massif is composed of grey fine grained wackestone and dolomites showing variable textures and grainsizes, and containing geodes. Beds are approximatively one meter thick and frequently separated by more shaly laminations. These are responsible for the angular bedding structures observed in the caves. Surrounding hillocks are composed of more resistant white to rose finely recrystallised dolomite with chert like cleavage. Stratigraphic age determinations are not yet fixed, but they strongly resemble Middle to Lower Triassic carbonates. The karst massif forms the centre of a flat lying syncline, surrounded by the Upper Permian to Lower-most Triassic coal basin. It is very weakly deformed here: beds are almost in subhorizontal position with dips averaging 5 to 10°. Cave development is mainly in a downdip direction.

4.2.2.3. Karst morphology

The "Source of the River Pearl" cave system results from an underground river course. Only one level is present in this region of low hills. A peneplanation level is indeed observed at 2085 m (40 m above the resurgence water level) whereas the surrounding hilltops are some 50 m higher. The ponor is situated at the end of a large polje about 1.5 km to the NNE at altitude 2065 m. On the plateau in between ponor and resurgence several deep dolines and uvalas occur. Some of these form window caves on the underground system. One doline, located some 300 m to the NNE of the resurgence showed a stretch of the undergrond river ±50 m long. In the rainy season the floor of this doline is completely flooded (Fig. 12).

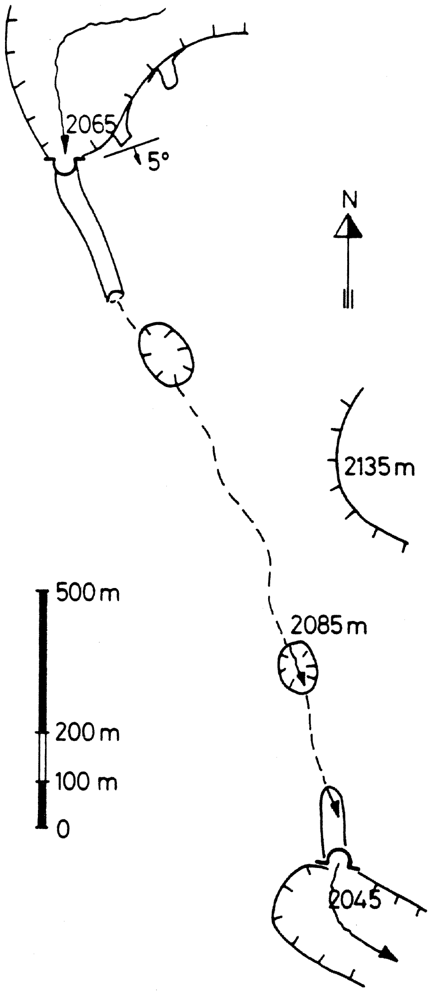

Fig.12: Sketch map showing development of the "Source of the River Pearl" cave system, Qujing district (scale is approximate)

Several siphons may be present on the underground water course. These do not slow down the underground residence time of the water sufficiently to adapt the mean annual temperature measured as 15.6°C inside the resurgence (the outside temperature on 22.12.1990 was 6°C). Nevertheless the water temperature increased from 7.3°C at the ponor to 12.9°C at the resurgence.

The ponor is known as Da Guo Dong or Big Waterpassage cave. The section of this cave is rectangular, ±10 m high and 7 m wide, but gradually diminishing. The stream bed is strewn with fallen limestone blocks. This shows the importance of mechanical breakdown in this karst massif where limestone beds are separated by shaly laminations. After a section of 300 m in a SSE direction the waterpassage narrows to flowin 1 m^2 presenting a temporary siphon.

The resurgence is also siphoning after ±100 m. The stream is flowing on a fine gravelbed. During floods the entire cave may be waterfilled, as is testified by gravel fixed to the flat roof of the resurgence cavity. The water exit is divided in two ledges; in winter water flows out of the lower ledge only, whereas in summer, during the rainy season, water leaves the cave from the upper ledge in the form of a waterfall.

4.2.2.4. Interest of the "Source of the River Pearl" cave system

The major interest of the regional authorities in the "Source of the River Pearl" cave system is the management of the water resources. Flooding of the upper polje by damming the ponor is unlikely to succeed because other ancient ponors or fissure systems will be reactivated. On the other hand damming of the lower ledge at the resurgence may effectively result in a more steady flow from the upper ledge to the tourist's delight. Penetration of the cave thus may be hindered but this is not considered as a priority.

4.2.3. Unnamed cave near the Huashan reservoir

4.2.3.1. Location

An inconspicious ponor, located in a wide doline some 40 km NNE of Qujing and ±5 km south of the main road from Qujing to Xuanwei, proved to be the access to a cave of bewildering beauty. Its location in reforested land north of the Huashan reservoir, and at the food of Huashan (or Flower) mountain, make it a potential tourist target, increasing the attraction of Qujing district. Landscape and vegetation resemble the previously described area (Source of the River Pearl). The altitude of the ponor in the doline floor was 2005 m, beneath a rolling plateau at 2035 m. The approximate coordinates of the cave entrance are 25°47'30"N and 103°59'30"E. The cave has not yet received a proper name.

4.2.3.2. Geology

The same hard brittle and compact whitish to reddish limestones as found in the vicinity of the Source of the River Pearl, are found at this location. It is thus presumably Middle to Lower Triassic as well.

4.2.3.3. Hydrography

No water is flowing to this cave in the dry season. In the rainy season, drainage from the doline completed by percolation water, finds its way to the cave and forms a small collector, increasing in importance when proceeding downwards. Several huge speleothem barriers make that even a limited flow will produce some lakes with increasing volume and depth downwards, however not exceeding the 2 m depth marker level for the lowest part of the cave. This testifies of the purely local importance of the actual drainage into the cave. Nevertheless the major part of the cave has been formed by an important underground river, flowing underneath the doline in a westerly direction and still marked in the landscape by a linear depression. However the hydrographic pattern has now been altered and no trace of any important superficial drainage system was found in the vicinity. The air temperature measured in the cave was 16.6°C; there was considerable agile cave fauna found on the humid and smooth walls (crickets, spiders and bats). On the contrary, on the mud flats very few fauna was found (centipedes).

4.2.3.4. Karst morphology

The entrance is very narrow. One descends ±20 m on a rockfall cone. Most of the blocks are composed of, or covered by speleothems. This passage gives way to a cave, formed by river passage of rather important dimensions, 10 to 20 m high and wide. The ornamentation of this cave is really impressive. Most speleothems which occur in giant and in minute forms are very fresh and active, yet unspoiled by visitors. The bottom of the cave is covered by sticky red clay, probably derived from terra rossa flooded in from the ponor, and deposited at water standstills behind speleothem barriers. Besides the entrance gallery no or few breakdowns were observed.

The gallery descends to a level 1980 m at ±150 m from the entrance by a series of small chambers separated by cascading flowstones. From this point real speleothem barriers block the the passage. The flood water passage below the speleothem barriers is mud filled. It was though still possible to traverse 3 of such barriers by climbing up and down the speleothems. Between these barriers a flat mud floor occurred. In this way the end point of the cave at ±800 m from the entrance was only at 1975 m depth. In this last speleothem barrier, no passage was round. These was however an air current passing.

4.2.3.5. Further use of the cave

The cave was thoroughly investigated by the personnel of the Qujing Construction Dept, making use of bamboo ladders. Further continuation requires digging and cutting a passage. Tourist infrastructure can be placed without technical difficulties; it should remain above the flood levels which are easily recognisable. The Maxiong Mountain (with the Source of the River Pearl cave) and the Huashan reservoir areas will probably be developed as a major tourist resort area for northeastern Yunnan.

4.2.4. Da Dong water cave

4.2.4.1. Location

A cave located some 32 km due south of Qujing along a hillslope overlooking the Nanpan river alluvial plain, was signalled as an example of an active water passage cave. The entrance is found at altitude 1940 m at the foot of a cliff 10-30 m high, above pittoresque Fu Tian village, located at 1860 m (Qujing centre is located at 1860 m also). This cliff was observed at the southern margin of an elongate ridge striking north-south to the outskirts of Qujing city. The approximate coordinates are 25°12'30"N and 103°48'E.

4.2.4.2. Geology

The limestone cliff containing Da Dong water cave is composed of grey finely dolomitised limestone with yellow porous dissolution vugs of presumably Devonian age. The dolomitic limestone is strongly karstified, presenting many irregular joints and small cavities on the cliff surface. The rock composition changes uphill, probably including non-carbonatic strata. Structural deformation is very limited and dips are less than 10%. As a result the same formations crop out along the ridge for long distances.

4.2.4.3. Hydrography

A perennial stream leaves the cave. Its discharge was estimated at 20 l/s, which is rather much for an exsurgence not formed by an allochtonous river. It supposes a considerable drainage on the plateau converging to this cave. On the plateau ±200 m higher sinkholes are mentioned. It is however also possible that water is diffusily drained from an overlying aquifer in porous dolomite or sandstone. This may explain the limited variations in discharge and the absence of mud in the riverbed.

The water is very clear and used for drinking water supply to the nearby villages. The cave entrance was walled to protect this water supply. The water temperature was 16.1°C; the outside air temperature 15.1°C.

4.2.4.4. Karst morphology

The exsurgence is located in a steep (65°) widened joint crossing the limestone cliff. At about 20m above the water passage, a similar opening was observed in the same fissure, going inside the cliff over several tens of meters. Intermediate passages must have existed but were filled with sediments. Inside the water passage some pipes may lead to these higher leves.

The water passage is generally 3 m wide and 7 m high with some higher channels. The floor is constituted either by rimstones or covered by medium grained yellowish sand, without clay admixture. Cave morphology indicates formation under phreatic conditions. The name Da Dong, given by the local population, is thus rather exaggerated. After proceeding ±100 m inside the cave the rising water level prevented further investigation without proper equipment. The local people had not ventured deeper into the cave anayway. But this cave clearly continues, and should form an interesting exploration target for a small team of speleologists. Indeed further exploration is required to establish the type of cave system and water drainage.

4.3. Xundian district

4.3.1. A brief geographical introduction

Xundian district is a Hui-Yi minority autonomous region, to the west of Qujing and depending on Qujing prefecture. It is a rather poor mountainous area with the exception of a fertile Tertiary basin, stretching south of Xundian town. Major drainage is by the Niulan river, flowing north as a tributary of the Changjiang (Yangtze) river. This river is confined to the west of Maxiong mountain (Fig. 4).
Carbonate rocks are predominant only to the northeast of Xundian town in the Wumeng Shan mountain range. The altitude of Xundian town, also of the Tertiary basin and the Niulan river flowing out of this basin, is 1860 m.

4.3.2. Dry River Cave

4.3.2.1. Location

Dry River Cave (Gan He Dong) also known as Tiansheng Qiao dong or Natural Bridge cave, a multistorey underground river course which has not yet received a proper name, is situated on the Gan He or Dry River, an important tributary of the Niulan river, at 52 km to the NE of Xundian. This represents a 2h drive along rugged roads in the Wumeng Shan. The first half is essentially ENE directed till leaving the Niulan river valley at altitude 1825 m and mounting uphill in a NE direction until reaching a peneplanation level at 2140 m. The drainage pattern on this karst plateau then remains chaotic over 5 km before descending in a NNE direction towards the Dry River, which streams in a SE direction at altitude 1720 m in a winding canyon type valley with cliffs of 200 m heigth.
The walk down from the end of the road to the cave entrance takes 15'. The approximate coordinates of the resurgence are: 25°49'N and 103°30'E (Fig. 11, Tab. 1). It should be noticed that the karst plateau on the between the Niulan and Gan He rivers (altitude 2000 to 2140 m) presents many deep dolines possibly descending into steep pitches.

4.3.2.2. Hydrography

Gan He Dong is an impressive example of a multistorey cave created by an allogenic river, Gan He or Dry River, a tributary of the Niulan river. The Gan He follows a WNW to ESE direction. The ponor of the underground river course is situated at the eastern termination of a large polje. Downstream of the resurgence the meandering river bed is surrounded by high cliffs, showing many remmants of abandoned cave sections, indicating that the resurgence has been receding in time. Small inactive ponors are also present at the foot of the cliffs ±12 m above the actual river level. Small tributaries reach the Gan He canyon in steep dry gorges, undercut by caves, ending in small resurgences close to the Gan He riverbed (Fig. 13).

The river passes a weir at 250 m below the resurgence. The minimal discharge is 3 m^3/s, its actual discharge was estimated at 4 m^3/s. The river is apparently polluted by organic components, though fish is still thriving. The outside temperature (in the shadow) was 14.7°C, mounting to 17.5°C after midday on 25.12.1990.
In the descending fossil gallery a cold air current was flowing in, reducing the temperature to 12.7°C at ±500 m distance from the cave entrance.
The temperature inside the active cave was 17.5°C whereas the water temperature at both ends of the underground river was 15.2°C. Close to the waterfall colder air was flowing in, reducing the temperature to 14.9°C.

4.3.2.3. Geology

Massive limestones assigned to the Permian Maokou Formation are outcropping in thick subhorizontal beds. They are composed of light brey-blue finely recrystallised bioclastic wackestone with large molluscs and crinoids, slightly veined. The massive beds shows frequent signs of intensive dissolution. This type of limestone attains at least 200 m in thickness, as shown by the cliffs, surrounding the valley, continuing downslope into pointed karren fields.

4.3.2.4. Karst morphology

The Gan He dong multistorey cave system is composed of three major levels: the active underground river course at 1720 m, a fossil river passage at 1750 m, and a dry valley above the underground river at ±1820 m (fig. 13).

The fossil gallery is located at 1750 m altitude on the south flank of the valley. The huge entrance (±60 m high and 40 m wide), corresponding to an old resurgence is hidden by a rockfall cone of 40 m height. The fossil cave continues inside the rock massif fairly straightforwards in a NW direction and can be followed over ±2 km with several rockfall cones. We followed this gallery over half its length till level 1775 m. The average dimensions of the gallery were 40 m high and 50 m wide. It was superbly ornamented, its floor covered by flowstones (also cave pearls in rimstone pools). The gallery did not show much lateral development; towards the end some side galleries should be present. It is not clear whether this gallery was completely prospected by the local people who produced relatively minor amounts of nitrate from this cave.

Dry valley: a dry valley, surrounded by high cliffs overlies the water passage, known by the local people as Natural Bridge Cave. Its length is ±1.5 km, its width ±300 m and its elevation above the water level ±100 m. Towards the resurgence this level is lowered almost to the roof of the cave by a strong subsoil dissolution (karren formation) and erosion. Along the southflank of the dry valley several shallow caves, originally ornamented, and widened diaclases were observed. Above the resurgence a small hole gives access to the water passage. Otherwise no connections between the different systems are known.

Water passage: access to the underground river course is by boat from the resurgence side, where the water level is stabilised in the dry season by a small dam (weir). At the resurgence the free passage is very narrow (2-3 m) and winding through huge, probably fallen blocks. Water flow should extend underneath these blocks since no notable increase in current was observed in the narrow passage. This lasted for 50 m, ending in an open and wide passage with SE-NW direction. This section was mainly a tunnel form, 25 m wide and 25 m high. A large part of the water passage showed a narrower lower section (keyhole) on the average ±7 m wide and ±7-8 m high above the water level. Towards the resurgence and over 250 m inside the cave richly ornamented upper levels were easily accessible over ancient rockfalls, stabilised by flowstones.

The entrance of the water passage is by waterfall ±10 m high thus resembling the Tenglong dong situation. At this part of the cave river current erosion has scalloped all walls. No side galleries were observed except near the entrance close to the waterfall at ±10 m above the water level.

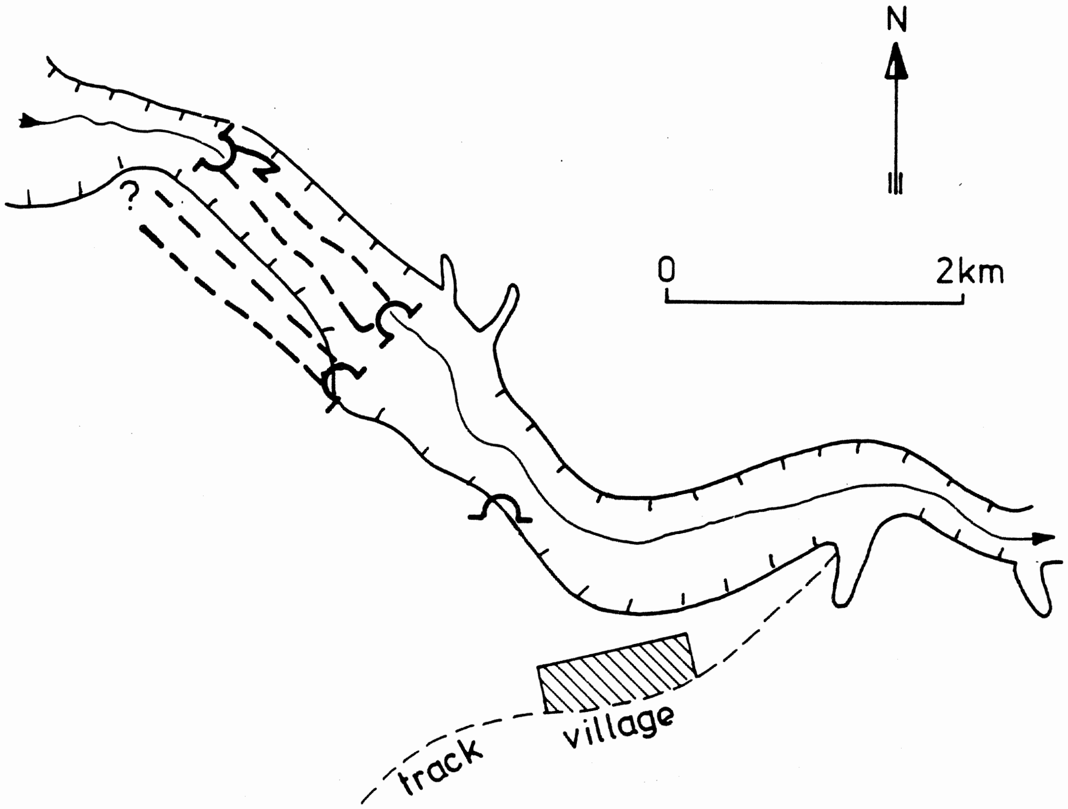

Fig.13: Sketch map showing location of the Gan He dong cave system, Xundian district (scale is approximate)

A peculiar feature of the water passage was the presence of a barrage made by wood at ±150 m in front of the resurgence. At this place some fallen blocks partly obstructed the narrow lower passage. Tree trunks transported by floods were held back by these blocks, in their turn witholding finer drift wood, and after lowering of the flood discharge, also silt. In this way a barrage 4 m high and 15 m long was formed above the dry season waterlevel. Behind of this high barrage an accumulation of finer wood about 50 cm high and 30 m long marked the low waterlevel. The high barrage was strong enough to allow a dry passage of the river. Finer detritus marks the highest flood levels at 8 m above the dry season waterlevel.

4.3.2.5. Interest of the Gan He cave system

The Xundian construction department had temporarily illuminated both fossil gallery and water passage by placing hundreds of candles and tens of electric bulbs. Electricity was supplied by a small transportable generator. They made use of 2 wooden boats for transport along the underground river passage. This light show has confirmed the potential for a real touristical exploitation of these magnificent caves which are remotely located but of easy access.

The Gan He cave system is also interesting for further morphological observations and morphothematic mapping. A great variety of speleothem forms are present in addition to active dissolution features along the underground river course. Furthermore the different stages of cave development related to the evolution of the hydrographic system can be compared to the development of vertical dissolution on the karst plateau.

4.4. Luxi district

Luxi district belongs to the Gejiu prefecture of Southeastern Yunnan. Nevertheless it still belongs to the Nanpan riverbasin. Luxi town is famous for its showcave, known as the Ancient Alu caves after a legend of the local Yi minority group. This cave is situated at only 5 km to the northwest of the city, with coordinates 24°33'30'N and 103°45'30"E (Fig. 4, Tab. 1). The tourist part of the caves attains a length of 2500 m, divided into four parts on two levels, of which the lower one is artificially flooded, allowing an agreeable boat trip. The Ancient Alu showcave is well managed and clean, attracting already great numbers of local tourists. A tourist guide book including a cave map is provided.

This cave is located in a low karstic hill, not more than 50 m above the plain level at 1695 m (Luxi town at 1705 m). Several window caves are present, as well as active and fossil resurgences, allowing easy access to the different parts of the cave. A small stream is draining this karst area. The cave's origin however is far more complex. It shows good examples of different cave morphologies, clastic sediments and spelothems.

The limestone hill containing the Ancient Alu caves, as well as the surrounding hills which are exploited for cement production, are composed of pure, light blue-grey recrystallised limestones with variable but mostly gentle structural dip, of Middle Triassic age (T2).

Carbonate rocks are widespread in Luxi district. In fact over 70% of its total surface is karst area. The carbonates display different environments. They occur in elongated narrow mountain ranges and in deeply corroded floodplains with cone karst. Subtropical morphologies become more evident in the southern districts of Luxi and Mile. To the south of these districts, South of Mengzi, but well before reaching the tropic of cancer, floodplains with tower karst (mogotes) which are similar to the scenic Guilin region, are well exposed (Karst Research Group, 1979). To the north of Luxi, in direction of Lunan and Stone Forest, many deeply eroded karren fields occur, which can be considered as incipient Stone Forest formations (Zhang, 1984a, b). Unfortunately no further investigations of Luxi district are foreseen.

4.5. Mile district

4.5.1. Introduction

Mile district is the southernmost district investigated. Luxi and Mile districts both depend on the Gejiu prefecture of Southeastern Yunnan. Bai Long Dong lies a mere 100 km north of the tropics (Fig. 2). The southerly position and the lower altitude have a profound effect on the karstification which results in stronger superficial weathering and surface expression, important precipitation and less profound caves. South of Mengzi steep tower karst, typical for tropical conditions in the very south of China, prevails (Waltham, 1986).

Mile district also forms parts of the Nanpan river basin. The district seat is less developed but it is located on the strategic main south road from Kunming to Hekou (Vietnam border)-(Fig. 2). Elevation of Mile city is 1420 m.

Bailong Dong or White Dragon Cave is the districts showcave. In its vicinity several other important caves are found. The Bailong dong karst massif is composed of conical limestone hills, virtually devoid of vegetation and soil cover, but presenting a strong scenic impact.

4.5.2. The Bailong dong karst massif

4.5.2.1. Location

Bailong Dong is situated in the southern part of an important cone karst massif, stretching NNE-SSW to the west of Mile. The cave is located 32 km south of Mile, and can be reached by driving 20 km along the main south road from Kunming in the Nanpan river valley, and 12 km to the southwest along a new road. Its approximate coordinates are 24°12'N and 103°21'E (Fig. 4, Tab. 1).

Bailong Dong cave was measured for the first time in 1988 by the Environmental Protection Bureau of Maitreya county (Mile). The tourist tour extends over 2000 m. The cave was opened for tourism in January 1989. 90% of the visitors make the bypass on the south road from Kunming, 10% visit the cave in combination with Stone Forest near Lunan and Ancient Alu Showcave in Luxi. Tourist accomodation is developed in a similar way to the latter cave which is more popular. In January 1989 a group of Bulgarian speleologists toured the place and measured also Da Xiao Dong (Jalov, 1990). They were invited by the Geographical Institute of Yunnan.

4.5.2.2. Geology

The karstified limestones are presumably of Carboniferous age. They are composed of light grey recrystallised wackestones and packstones. Important sections are composed of intensively fractured wackestones, which are rather soft and brittle and represent crackle breccias (Morrow, 1982). At the southeastern border of the limestone massif a thick bedded rubble packbreccia is found (thickness possibly in the order of 100 m), with heterogenous limestone clasts up to 20 cm in diameter, and with red or grey coloured matrix. This breccia strongly resembles the Grande Brêche in Belgium. Several strongly recrystallised and veined red stained heterogenous limestone beds underly this unit. The limestone beds are strongly folded and occasionally steeply bedded (70°SE at the southeastern margin of the massif). The contact with the younger Red Beds occurring to the south and east of the limestone massif is abnormal. Several poljes developing along this contact complicate its structural interpretation. To the west, the limestone massif passes into older non-carbonatic formations which equally form a positive relief. In this way the major drainage patterns are to the east, possibly deflected along the main NNE-SSW lineaments.

4.5.2.3. Karst morphology

Bailong dong showcave completely developed in a single karst cone. Its measured length approximates 2500 m, divided in two fossil levels at 1450 m and 1475 m. A lower active level has not been found. Access to this cave is by intersection of the large galleries on the north slope of the karst cone, which is receding by superficial weathering and roof collapse. The southern termination of the showcaves, at the opposite side of the hill, is marked by two windowcaves with depths of 15 to 30 m. A rudimentary cave map is included in the tourist folder.

Bailong Dong presents many interesting speleothems which especially abound in the upper level. Corrosion features on these speleothems are particularly well developed. Traces of original cave forming processes (river passages) and clastic sediments infill, now partly eroded, can be distinguished occasionnally.

The karst cones are fairly rounded, except where they are intersected by subsurface dissolution phenomena producing karstic collapse. Their diameter averages 1 km; their heigth above a base level at ±1450 m is ±200 m. Most cave openings occur near this base level or in the lower part of the cones. Openings due to roof collapse of the underlying caves may be quite large and steep: openings 300 m wide and 50 m deep are by no means exceptional. Only part of these caves have been explored; some of them are certainly connected. In an east-west traverse of the Bailong dong karst massif it thus was possible to find several large caves with sufficent dimensions to allow the passage of an allogenic river (Fig. 14).

No surface drainage exists in the Bailong dong karst massif anymore. Furthermore the presumed major outlet for the percolation water, the Da Qiao dong exsurgence, situated 3 km to the east of Bailong showcave at the margin of the karst massif, does not contain flowing water in the dry season. The water level underneath the showcave is not known. Lack of drinking water impelled the showcave managers to drill a waterwell beside a "water vapour" cave, 1.5 km to the south of Bailong dong at 1460 m altitude. The well was drilled till a depth of 220 m and encountered a water filled passage at 150 m depth. The water vapour cave descended effectively to the water level, encountered after 70 m at 1390 m depth. The latter information, provided by the Bulgarian prospecting team, could not be checked for its reliability however. It is anyway plausible that the waterlevel underneath the Bailong dong karst massif, well below the base level of the karst cones, is fairly stable at least between the Water vapour cave and Da Qiao dong which are 3.5 km distant.

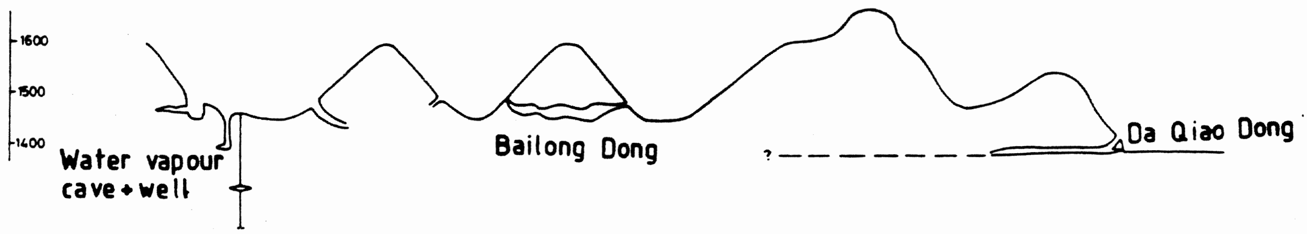

Fig.14: Sketch map of a west-east traverse of the Bailong dong karst system, Mile district (traverse represents 5 km)

4.5.3. Da Qiao dong

Da Qiao dong cave is the supposed drainage outlet from the Bailong Dong area. It can be reached by driving ±3 km to the NE of Bailong Dong in direction of Mile (till altitude 1450 m) and then 1 km further to the SE, along a small track. Several cave entrances occur in a fissured massif at altitude 1410 m, overlooking a dry exsurgence at 1390 m. The cave entrances give access to a rockfall cone descending towards a very muddy gallery at 1390 m depth (as is the exsurgence) heading into the massif in a SW direction (thus towards Bailong Dong). No water was flowing in this cave, which probably gathers the percolation waters from the rainy season. The mud which seems derived from terra rossa erosion, was freshly deposited in a 40 cm thick layer. Since the karst massif is composed of strongly fractured almost bare limestones, underground water transport must be very rapid, withering in the dry season. The gallery is about 8 m wide and 10 m high, decorated with many speleothems and ending in a sump at 890 m, according to a Bularian measurement (Jalov, 1990).

The temperature in the cave is high, at 17.5°C. The exsurgence is overlooking a small polje at the probably faulted edge of the limestone massif. To the SSE of this polje, slightly dipping Red Beds are present in a lower lying massif containing the Nanpan river.

4.5.4. Importance of the Bailong dong karst massif

The Bailong dong karst massif presents many features of superficial and underground karstification in subtropical conditions. It is virtually unpopulated and not covered by vegetation. A general landform analysis and elucidation of drainage patterns are essential for the recognition of the main dissolution phases and possible underground drainage patterns.
Many caves exist in this area. Most observed cave entrances are intersections between the base of the karst cones and major cave formation levels at 1450-1475 m. Their horizontal development may be interrupted by roof breakdowns or by sedimented or precipitated passages. The depth range is limited between the high plateau at altitudes of ±1600 m (which is not the top of all peaks) and the probable water level at ±1390 m. Horizontal cave development above the 1450 m level will of course not exceed the dimension of the karst cones in which they are contained.

The major objective for further investigation of the Bailong dong karst massif thus is the recognition of the waterlevel underlying all of this massif and its relation to the overlying karst development.

4.6. Yiliang district

4.6.1. The Jiuxiang nature park

4.6.1.1. Location

Yiliang district is situated between Kunming and Stone Forest and depends on Kunming prefecture. In the north of this district, the area around Jiuxiang is developed as a natural park including caves as scenic spots. The development of the Jiuxiang scenic area started in September 1988. The first tourists were admitted on 1 October 1989 (information by cave manager Mu Jie Yung). The most important cave system known, and basically the only one which is touristically developed, Ying Cui Shan, or "Gorge shadowy with vegetation", near Feng Jing Qu, at 44 km from Yiliang, attracts on the average 1000 visitors per day and employs 70 people. Ethnic minority arts and dance festivals are held here (e.g. in March 1991). The Jiuxiang park area has a wooded appearance, fairly unusual for this part of China. Strict measures to control pollution of its main river, the Maitian, and waste treatment are foreseen in view of the steady flow of visitors from the nearby Kunming metropolis (at 97 km distance), or touring to Stone Forest (Zhen, 1989)-(Fig. 15).

4.6.1.2. Karst investigations

For all these reasons Chinese interest in the study of the Jiuxiang park area exists already since several years. The Yunnan Bureau of Geology and Mineral Resources is inventoring scenic spots including caves since 1976. In 1982, 97 caves have already been located, about 30 of them important ones, in an area of 200 km^2. They have been classified in different categories:
- underground stream
- ancient riverbed
- dry cave
- multistorey cave
- collapse type.

Two more investigations carried out in May 1988 and in February 1989 (12 days altogether) in an area of 30 km^2 centered around the Ying Cui Shan show caves, led to the following conclusions (Rao, 1989)-(Fig. 16):

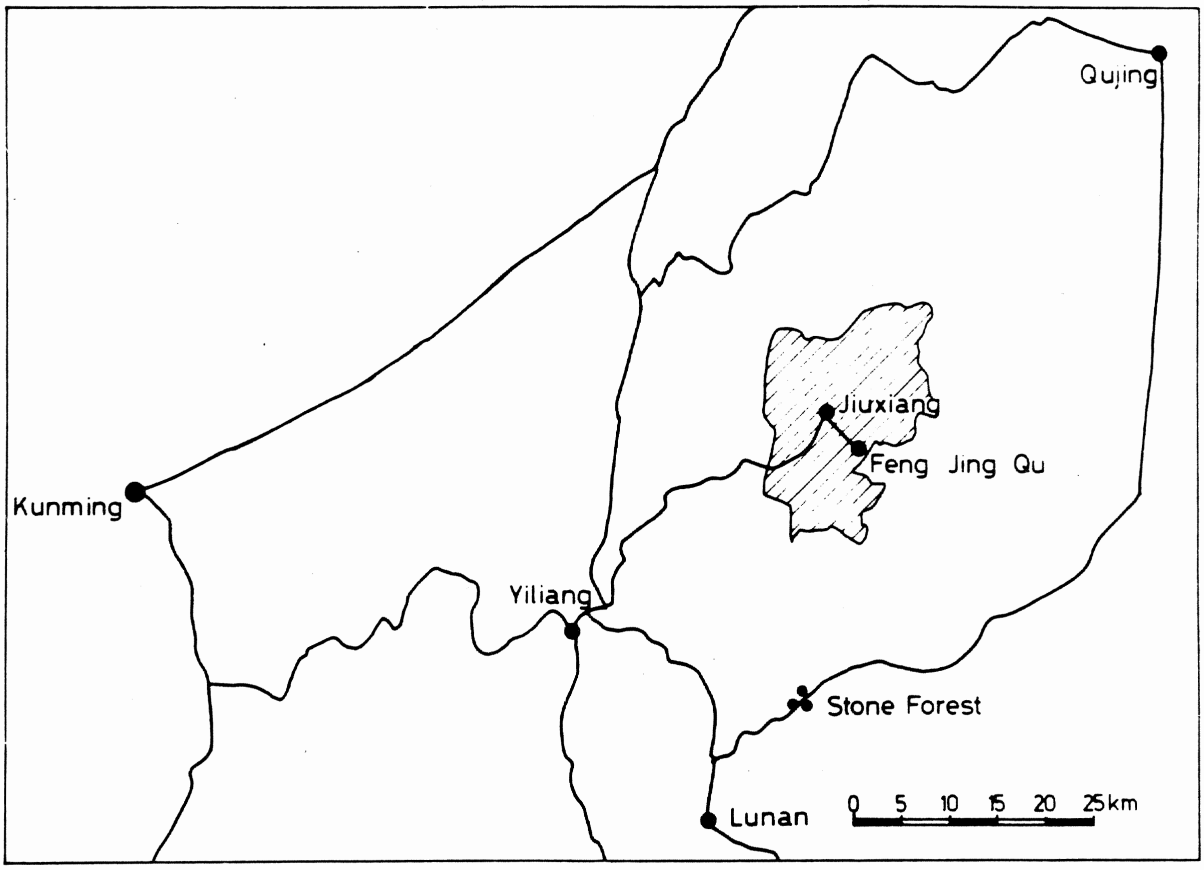

Fig.15: Location map of Jiuxiang nature park, Yiliang district (modified from tourist brochure)

- too many caves occur in this area; they cannot all be surveyed
- the highest cave level is 1900 m and the lowest 1750 m, as derived from the topographic maps
- 4 types of cave development can be distinguished:
  * strike type: caves elongated in a NNE-SSW direction, like the main surface structure or the Maitian river
  * vertical fissures extending to the water level
  * inclined type, following bedding planes
  * horizontal and vertical development superimposed.

4.6.1.3. Geology

The carbonate rocks producing the karst in the Jiuxiang area are very particular with respect to their age: Proterozoic Upper Sinian. They are composed of bedded siliceous dolomites, mostly grey coloured and fine grained, in a sequence of 200 m thickness, named the Dengying Formation (Fig. 7). Especially in the lower part, stromatolitic beds are present. In the middle part some shaly beds are intercalated which can negatively influence tichk vertical karst in this formation. Stratabound differences in lithological and chemical composition also profoundly affect the karstification. Easily dissolvable beds of several meters thickness generally guide beginning karstification which can further proceed by mechanical breakdown or fissure widening in over-and underlying beds.

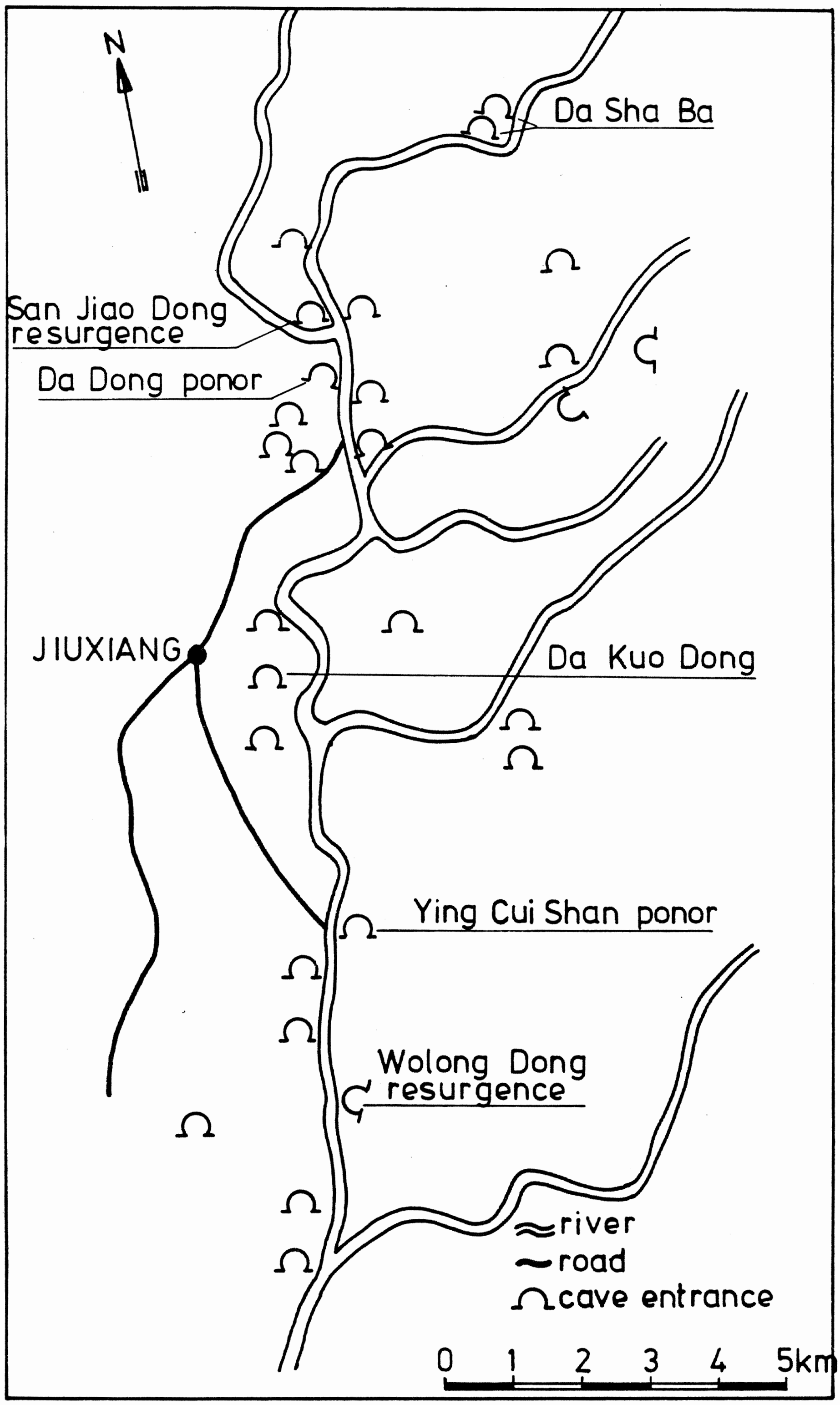

Fig.16: Cave location sketch map in the Jiuxiang nature park, Yiliang district (established by Rao Qing Yun, 1989)

The Dengying Formation forms part of a large transgressive sequence covering the Upper Sinian and Lower Cambrian time span occurring in the Kunming area (Tab. 2). All these beds have been deposited on the Yangtze craton or paraplatform, covering much of southern China, including eastern and central Yunnan. These beds underwent relatively minor deformation in the studied area: gentle open folds with limbs up to 30° generally strike NNE-SSW. In this way the Dengying dolomites are found throughout the area but do not cover it entirely. Cave systems spanning large areas similar to Tenglong dong, cannot be expected in this area. Caves will rather show much more lateral development.

Note: *A geological map exists on scale 1:200,000. The Bureau of Geology and Mineral Resources prepares a new map for the Jiuxiang area on scale 1:50,000 (personal communication by Mr. Rao Qing Yun).*

4.6.1.4. Hydrography

The Meidian river which is a tributary of the Nanpan river, flows through the Jiuxiang area from NNE to SSW. Its discharge may vary between 0.37 and 1800 m^3/s averaging 5.85 m^3/s as measured below the Jiuxiang park area (personal communication by Mr. Rao Qing Yun). On a relatively short distance (±8 km) this river takes 2 underground courses, the longest over more than 2 km. Several underground courses along tributaries are also known rendering the hydrographic network quite complex (Fig. 16).

4.6.2. Ying Cui Shan

The Ying Cui Shan cave complex on the Meidian river, is the most spectacular scenic spot in the Jiuxiang nature park, close to Feng Jing Qu village Narrow. Ying Cui Shan gorge (Fig. 17, point 1), with vertical walls of 60 m high, once belonged to the adjoining cave system, composed of the Bai Xiang Dong, or White Elephant Cave (so named because of a large light-coloured fossil river entrance, Fig. 17 pt. 2), the Shen Mi Gong, or Fairy Palace (a decorated dry cave, Fig. 17 pt. 5, separated from the former and latter caves by natural bridges), and the Wolong Dong, or Sleeping Dragon cave on the downstream part of the underground river (Fig. 17, pt. 7-8). The approximate coordinates are: 25°6' N and 103°25'S.
This cave complex covers the Meidian river over 2 km. Four levels were recognised, the lowest of which is formed by the underground river; the highest level yielded some 350 artifacts and mammal fossils.

The touristical visit starts in a low portion of the dry river bed above Wolong Dong (alt. 1765 m). Access to the caves is via an abandoned ponor leading to a vertical shaft which at 1725 m communicates with a huge chamber "Banna Hall" (long ±200 m, high ±50 m, wide ±75 m)-(Fig. 17 pt. 7). The Meidian river enters this cave at altitude 1720 m by a 30m waterfall, and leaves Wolong Dong in a quiescent way at altitude 1680 m-(Fig. 17 pt. 8). At the three natural bridges "Dile Hong Qiao" or Rainbow Bridge section the riverbed is exposed and superb examples of phytokarst can be observed here (Fig. 17 pt. 6).
Bai Xiang Dong contains a small part of the underground river and some fossil sections (Fig. 17 pt. 4), well visible because of penetrating daylight. The underground canyon is of the same dimensions as the open air canyon (about 50 m deep and 7 m wide), but still shows many signs of active river erosion (Fig. 17 pt. 3). In this way its resembles the wild water sections at Tenglong Dong cave in Lichuan (Masschelein & Zhang, 1990).

The Ying Cui Shan canyon is indeed shadowy and cool: on 31.12.90, the water temperature was only 11.6°C while the air temperature was 17°C and the air temperature outside the canyon 19.3°C. The large watermass contained in the canyon (average depth 9.25 m) has certainly contributed to the local cooling effect. Its waterlevel altitude is 1760 m, while the land surface outside the cave system is 1820 m. This cave shows many attractions for tourists, including a boat trip on the open-air canyon. For speleologists and karst researchers, this cave with very limited speleothem overgrowth shows many fine textbook examples of stratabound dissolution features and incision by erosion. Also transitional phases from underground to superficial karst are present. Furthermore the boat trip in the canyon allows the observation of well exposed stromatolitic beds ("Collenia") in the precambrian Dengying Formation.

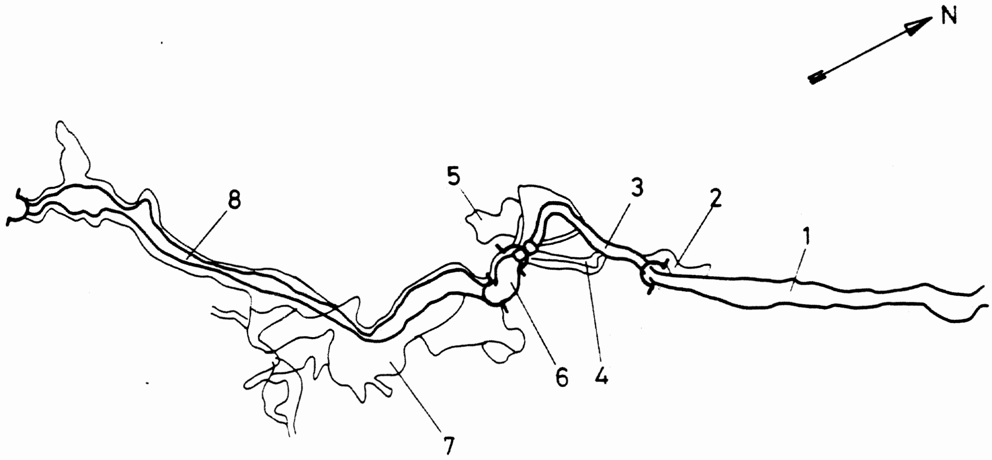

Fig.17: Ying Cui Shan cave complex map (modified from tourist brochure).

4.6.3. Other cave systems

4.6.3.1. San Jiao Dong

"San Jiao Dong", or Three feet cavern is an example of a water passage cave, created by an allogenic stream. It is named after local Yi folklore, seeing in the three natural bridges occurring at the resurgence, the feet of a giant. This cave is located at ±6 km NE of Jiuxiang along the Meidian river at altitude 1820 m (coordinates 25°84N and 103°25'E). It is the resurgence of a tributary of the Meidian with an underground length of 2.7 km, according to the topographical map (Fig. 16). The dry season discharge of this tributary was estimated at 25 l/s. The horizontal riverbed has respectable dimensions however; it is on the average 25 m wide and 12 m high, its form a flattened bell-shape, deformed according to differential solution of the siliceous dolomite beds (bedding is very gently dipping). The direction of the cave is meandering along a general N-S line, corresponding to the strike of the Sinian strata. Large concretions develop linearly on vertical fissures striking N-S, NW-SE and NE-SW. Some side galleries have developed at ±8 m above the riverbed. A complex cave with abandoned ponor entrance, located between the resurgence and the Meidian river is joined to the San Jiao cave.

This cave has also been investigated from the ponor side. The junction has not been made however because of the presence of flooded zones. Nevertheless a concrete path 1.5 m wide and crossing the river many times has been constructed over more than 1 km length inside the cave. Reaching this point the water temperature attained 15.6°C, while the air temperature was 16.3°C on 29.12.1990.

4.6.3.2. Da Dong

The Meidian river disappears underground in a large ponor about 1 km south of the San Jiao Dong resurgence (approx. coordinates 25°7'30"N and 103°24'E) at level 1815 m (Fig. 16). The dry valley bottom starts at 1840 m but rises steadily showing some deep collapse dolines. Dolines were still observed at 1920 m altitude, going in the direction of Jiuxiang village which lies at 1950 m. Peneplanation levels were clearly observed at altitudes 1850 m and 1940 m. The NNW-SSE altitudes striking dry valley is drained by a small stream but the main river was deflected westward at the ponor. Unfortunately it was not possible to obtain reliable information on the length of the underground river section in this cave but it must have been explored at least partially by local people.

4.6.3.3. Da Kuo Dong

"Da Kuo Dong" or Big Dry Hole is a typical example for a comprehensive cave with sections created by underground streams, vadose water percolation and vertical collapse. It is located at a few kilometers to the southeast of Jiuxiang near Maitian village (elev. 1860 m, overlooking towards the south the junction between the Meidian river and an important tributary (approx. coord. 25°7'N and 103°25'E, Fig. 16). Access is by a deep and large collapse doline opening at 1815 m. Nevertheless this doline passes almost unnoticed in the landscape. At 30 m below the surface (1785 m) the top of a large breakdown cone is reached, which is sloping down till 1765 m. The opposite wall of the collapse doline has a vertical wall of ±30 m above ±20 m of open space before reaching the bottom of the breakdown cone. The cave presents tunnel sections produced by an underground stream, crossed by narrower passages developed along joints. Speleothems abound except in the lower portions of a cave wich still drains the percolation water (water temperature, at altitude 1760 m, 16.9°C; air current temperature 16.3°C, in high level gallery at 1775 m, 17.5°C, outside temperature 20.7°C on 30.12.1990). The total known development of this cave is reported to reach 2 km. A sketch map, produced by the Yunnan Bureau for Geology and Mineral Resources, subdivides this cave into 5 zones with different morphological development. Except for the hydrogeologists, using a rope ladder, this cave has been entered at several occasions by the local people, not withstanding the partly vertical descent !

4.6.3.4. Da Sha Ba massif

The "Da Sha Ba" or Big Sand Barrier limestone massif, containing at least a dozen of caves is located in a meander of the Meidian river at altitude 1840 m (approx. coordinates 25°8'N, 103°26'E, Fig. 16). Access is by rugged roads from Jiuxiang, passing Dianxe village along a tributary of the Meidian and crossing the interfluvium on foot.

The Da Sha Ba limestone massif is separated from the adjoining limestone massifs by a structurally controlled dry valley, striking NS and cutting the meander. In one cave (no cave has yet received a name)on the north slope of the meander, entrance altitude 1870 m, a dry underground streambed was observed, reputed to cross the hill according to a local peasant (distance less than 1 km). The temperature at the entrance pitch, with descending cold air currents, was only 12.1°C on 30.12.1990. Another cave along the north flank of the meander at ±300 m to the SE (alt. 1880 m) reputedly reaches an underground river. On the south flank of the massif a dry inaccessible resurgence (alt. 1850 m) was noted, underlying two caves at entrances 1870 m and 1880 m. These give access by pitches (depth ±15 m), yet unexplored, to rather large (width ±15 m) and continuous galleries with tunnel sections.

Probably connections could exist between all these caves, extending its length over many kilometers. The Da Sha Ba massif is not explored by the hydrogeologists team although it constitutes a scenic spot. It is one of many examples of unexplored sites in the Jiuxiang nature park.

4.6.4. Interest of the karst features in the Jiuxiang nature park

The karst morphology of the Jiuxiang nature park is unique for East Yunnan. There are two possibly related seemingly controversial explanations: the karst develops in very old rocks but presents a rather immature character.

The geological substratum is composed of Late Proterozoic (Upper Sinian) siliceous and stromatolitic dolomites assigned to the Dengying Formation. The Dengying dolomites which attain a thickness of 200 m, are intercalated in an important siliciclastic succession. Sinian strata are exposed in scattered outcrops on the East Yunnan plateau, especially in the area around Kunming (Fig. 6). They are surrounded by younger strata which may also contain carbonate rocks but do not show more intensive deformation structures. Karst development thus is limited to zones where these dolomites are exposed or prone to vadose water circulation. Apparently karstic dissolution is less easy in the siliceous dolomites. It is strongly controlled by structural fissure patterns and confined to the most soluble strata. Further development is often based on the collapse of overlying less soluble strata.

The morphological impact of the karst is limited and mainly restricted to subsurface water circulation. There are no signs of intensive subsoil or superficial dissolution as could be expected in a subtropical environment. Peneplanation levels are not much disturbed by dissolution of the carbonate rocks because cone karst or karren fields are generally absent. On the other hand river downcutting with the subsequent development of underground water circulation patterns and caves seems to be an active process. It is not sure whether this is related to recent uplift and exposure of the Sinian rocks in the Jiuxiang nature park in particular, or to the generalised uplift of the East Yunnan plateau associated with normal erosion processes equally affecting the neighbouring areas. Anyway the resulting landscape and cave development is immature for the geographical position and is reminiscent of cave development in temperate environments because of its juvenile character.

5. Conclusions

The East Yunnan karst landscape forms a very diversified part of the huge Chinese karst as a result of its exceptional geographical position and the variable composition of the carbonate rocks. The Tropic of Cancer crosses the southern part of the province of Yunnan but the high altitude of the eastern plateau (±1900 m) guarantees an equitable and mild climate ensuring to its capital Kunming the charming title "city of eternal spring". Nevertheless past climatic fluctuations and the differential effect of weathering and erosion processes have led to a rapid gradation from temperate to tropical karst types in the eastern part of Yunnan. These also result from the interaction with different carbonate formations in the geological substratum. The Yunnan high plateau is situated on the Yangtze platform which covers most of South China and consists of mainly epicontinental Late Precambrian to Jurassic deposits. Marine carbonates ranging from Sinian (Late Proterozoic) to Triassic, are intercalated in this series and are all exposed due the gentle Yanshanian (Jurassic) folding and uplift with subsequent erosion.

Recent karst development in these carbonates has not yet been studied in any detail, with the exception of the famous Stone forest site, a denuded karren field which has become a major tourist attraction. In order to remediate this situation a preliminary field investigation was organised by the Karst and Groundwater Research Division of Academia Sinica for the Belgian-chinese Karst and Caves Association, grouping karst researchers and cavers in Belgium. From 17.12.1990 to 3.01.1991 a transect was made over 300 km in a north-south direction between latitudes 24°N and 27°N. In this area different karst types were encountered ranging from plateau-canyon karst to subtropical cone karst. Mogote tower karst, typical for tropical weathering occurs 100 km further to the south. The cooperation of local authorities made it possible to select and visit 15 different cave systems in East Yunnan, developed in different carbonate host rocks and presenting variable morphologies. Most caves represent parts of multistorey underground river systems, often of impressive dimensions. Galleries abandoned by the rivers generally display complex infill sequences and superb concretions.

Interest in these cave systems is equally diverse. Local authorities want to promote tourism and recreation, but also to protect the natural resources or to investigate the water resources potential. The elucidation of cave genesis and karst development in a transitional zone between temperate and tropical climates has certain applications in Global Change study programmes. The Belgian contribution to such study can be directed towards both practical achievements such as the exploration and cartography of extensive cave systems, even under difficult physical conditions, and towards pluridisciplinary research, progressing from the Tenglong cave and Lichuan karst research project started in 1988. Such cooperation will be beneficial for the further improvement of the relations between both countries; moreover it will mean a small Belgian presence in a region which is rapidly developing and opening to the outside world. The present report intends to be a partial introduction to this promising land and the onset of renewed cooperation.

6. Acknowledgements

The present field investigation could not be realised without the support of our companions Jan Vloeberghs, acting president of the belgian Speleological Federation and Qi Zhonglin, Foreign Affairs Dept of Academia Sinica. Administrative difficulties were skilfully resolved by Zhang Hanyun and Wang Shide of the Kunming Branch of Academia Sinica. We greatly benefited form the profound geological knowledge and experience of Rao Qing Yun and Zhao Yinlong of the Yunnan Bureau of Geology and Mineral resources.

We were warmly welcomed by the district authorities and by local authorities who ever again impressed us with their sound insight in the subsurface environment and their readiness to assist us during the field trips. Local inhabitants were of great help because of their familiarity with the caves. We also appreciated the enthousiasm and care of the showcave managers in Tiansheng dongyuan (Qujing), Ancient Alu caves (Luxi), Bailong dong (Mile) and Jiuxiang Nature Park.

Our stay thus was made most agreeable and rewarding by the efficiency and interest of many people, among whom Mrs. Guo Hui-Qiong and Mr. Wang Fangguo, Vice-Mayors of Qujing, Mr. Ni, Vice-Major of Xundian, Mr. Li, Vice-Major of Mile, Mr. Xiang Zhang and Cai Chung Zi, vice-Mayors Yiliang, Mr. Zhou, Li Hao and Mrs. Fan Liang Zhi of the Foreign Affairs Office Qujing, Mr. Liu, Science and Technology Dept. Xuanwei, Mr. Li Shaoan, Construction Dept. Qujing, Mr. Ma Ting Jiao, Environmental Protection Bureau, Mile, Mr. Li, Construction Dept. Xundian.

We acknowledge grants to the Belgian participants from the Belgian National Fund for Scientific Research (NFWO), the Sports and Outdoor Life Administration (BLOSO) and the Ministry of Economic Affairs.

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