Chapter 30
Guangxi Karst: The Fenglin and Fengcong Karst of Guilin and Yangshuo

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Abstract The limestone karst of southern China is among the most extensive and spectacular in the world. Large blocks of fengcong karst consist of clustered conical hills with large caves draining beneath them and their intervening dolines. Isolated towers in the fenglin karst may evolve from the fengcong where input of allogenic sediments maintains alluviation of the base-level plain and hence permits undercutting of the limestone hills. This process appears to take more than 10 million years, and only occurs in areas of slow tectonic uplift.

Keywords Cave • fengcong • fenglin • Guangxi • karst • limestone

30.1 Introduction

Southern China consists of the world's largest area of mature limestone karst, which is perhaps the best known for the spectacular landscapes of limestone towers, most widely developed within the province of Guangxi. Most of the lowland karst is densely populated, with towns and villages, alongside rice paddies and market gardens, on almost every bit of alluviated ground that is near to flat. But it is also a hugely dramatic landscape with the limestone towers of the fenglin karst that feature so strongly in traditional Chinese art. Guilin (Fig. 30.1) is now a major tourist destination, and millions of visitors take the famous boat trip down the Li River (Li Jiang) from Guilin to Yangshuo every year – passing vistas that are classics of geomorphology.

30.2 Karst Terrains in the Guilin Basin

A succession of nearly 10,000 m of Devonian to Triassic carbonates lie at outcrop across around half the area of Guangxi, and erosional evolution of this huge mass of limestone has allowed development of what is arguably the world's finest karst terrain. Within this, the karst of the Guilin basin is formed in about 2,600 m of Devonian and Carboniferous limestones. These occupy a complex syncline between anticlinal mountains of Devonian sandstone, which are critically important in supplying allogenic drainage and sediment into the karst (Fig. 30.2). The limestones are pure, strong, and massively bedded, so are ideal for the development of cavernous karst.

Overlying the limestone around Guilin, scattered outliers of Cretaceous red beds lie at various elevations, resting unconformably on what appears to be the remnants of a pre-Cretaceous karst landscape (Zhu 1988). Their distribution is unrelated to the modern karst, which therefore dates them to no earlier than the Cenozoic. Notable among Pleistocene deposits in the karst are coarse and poorly sorted diamictons that appear as many low mounds on the dissolution plain. These have commonly been described as "boulder clays," which is very descriptive of their lithology, but is an inappropriate term when Pleistocene ice sheets never reached this far south in lowland China. Their origins, whether fluvial, glaciofluvial, or as mudflow deposits, remain controversial. Most of their cobbles are sandstone derived from the pre-Devonian outcrops in the adjacent hills; they generally have diameters of 10–30 cm, although boulders up to 1 m across are not rare.

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Fig. 30.1 The northern suburbs of Guilin spread across the alluviated plain between the steep limestone hills of the fenglin karst (Photo T. Waltham)

Alluvial sediments form both floodplains and various terraces along the modern Li River and its tributaries. Most are well-sorted gravels covered by silty sand. The modern alluvium is mostly less than 10 m thick, but is thicker over buried dissolutional fissures. Recent drilling for new bridge sites along the Li River has revealed that there is usually a trough, 30–50 m deep, infilled by the Pleistocene diamicton beneath the Holocene alluvium (Yuan 2004). This trough may originate from erosion to lower sea levels during the Pleistocene ice ages, and may have influenced development of the karst that is now beneath the dissolutional plain.

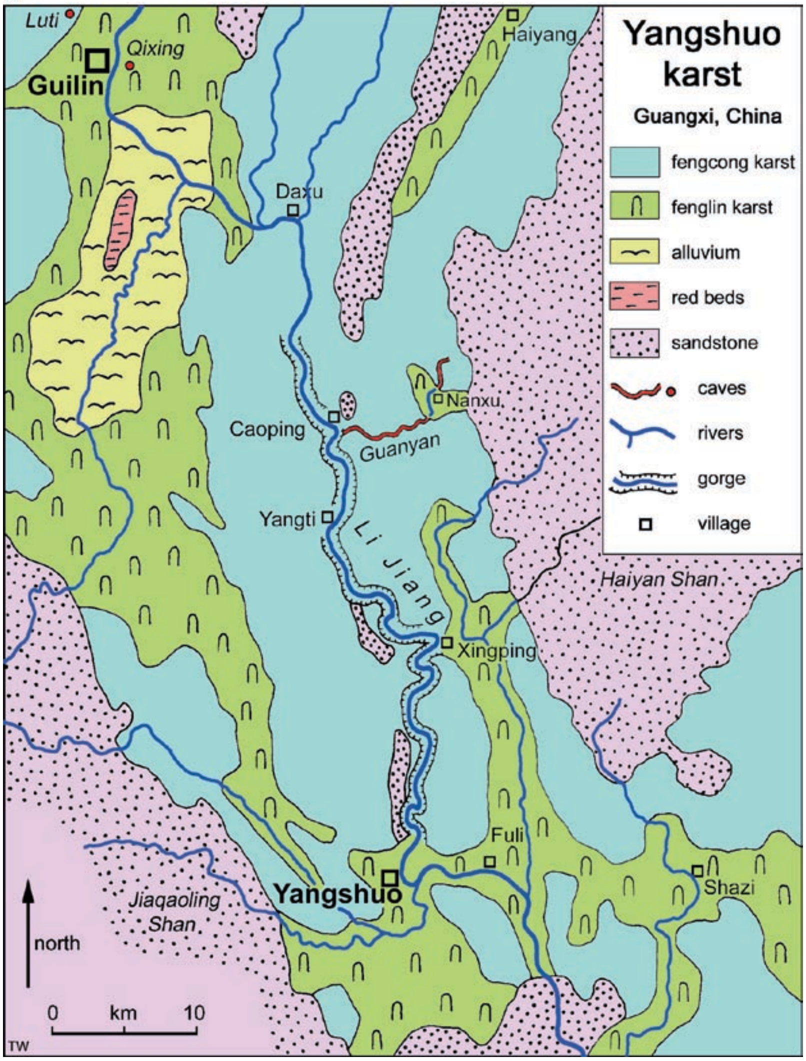
Guilin's climate is humid tropical with a dry winter. Mean annual precipitation ranges from 2,000 mm at Guilin to 1,500 mm at Yangshuo, with 62% of the total falling in the rainy summer from April to August. Mean annual temperature is 18–19ºC.

The Li River forms the trunk drainage route with a mean flow of 215 m^3/s past Guilin; it defines local base level at 141 m at Guilin, descending to 103 m at Yangshuo. With the huge rise in tourism, groundwater abstraction from the karst has risen to around 150,000 m^3/day. New wells are now controlled by local environmental regulations. Karst collapses are frequent, and most are subsidence dolines within the alluvium induced by water table decline in areas of overpumping.

Show caves complement the major tourist appeal of the karst scenery. The abandoned chambers and galleries of Qixing Dong and Luti Dong, both near Guilin, are long-established, along with various culturally significant caves within the city. Guanyan is newly developed as a major show cave at Caoping, and there are smaller caves open to tourists around Yangshuo, where rock climbing on the limestone towers is also a popular new sporting attraction.

Mature tropical karst landscapes may be broadly divided into the two main types: fengcong and fenglin (Zhu 1988; 1991; 2005). In China, these are distinguished by either dolines or an alluviated plain between the hills, and not by the hill profile as in Western terminology. Fengcong karst has clustered limestone hills with intervening dolines; its name translates as peak cluster, and it may be known in the West as a variety of cone karst, though its profiles are much steeper than the often described cone karst of Gunung Sewu on Java (Lehmann 1936, Balazs 1973). Fenglin karst has isolated limestone hills rising from an alluviated karst plain; its name translates as peak forest, and it is popularly known in the West as tower karst. Each type accounts for about half the karst in this area, with fenglin dominant around Yangshuo and also south of Guilin, while fengcong dominates along the course of the Li River (Fig. 30.2).

Fig. 30.2 Outline map of the karst between Guilin and Yangshuo (above) and the location of Guilin karst within China (below) a


Yangshuo karst
Guangxi, China
fengcong karst
fenglin karst
alluvium
red beds
sandstone
caves
rivers
gorge
village
Luti
Qixing
Guilin
Haiyang
Daxu
Nanxu
Caoping
Guanyan
Yangti
Li Jiang
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Yangshuo
Shazi
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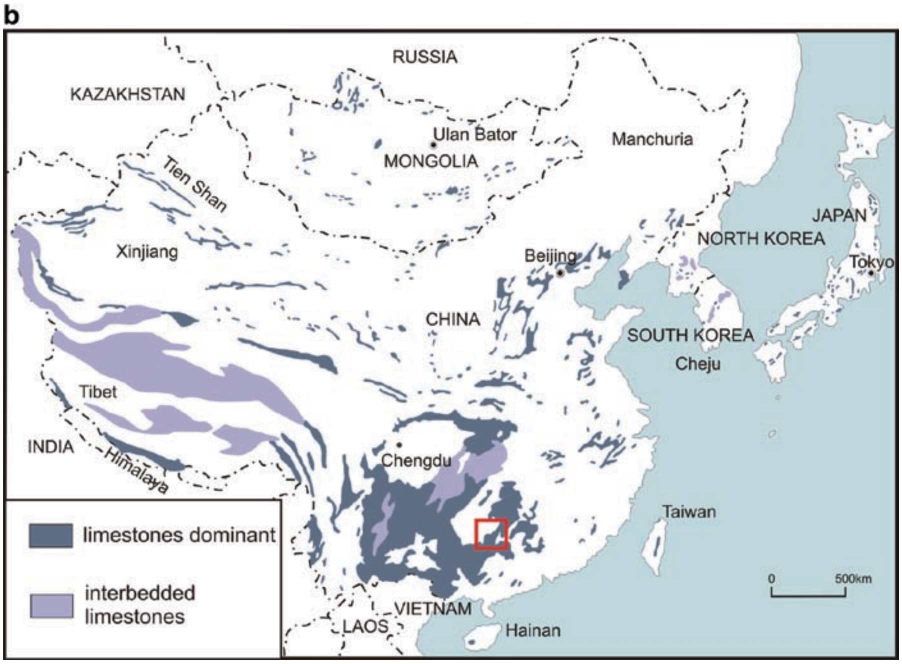
b


RUSSIA
KAZAKHSTAN
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CHINA
SOUTH KOREA
Cheju
Tibet
INDIA
Himalaya
Chengdu
Taiwan
limestones dominant
interbedded limestones
VIETNAM
LAOS
Hainan
0 500km

Fig. 30.3 Limestone hills of the fengcong karst east of Caoping, and underlain by the Guanyan cave system; the alluvial flat in the foreground is a terrace of the Li River (Photo T. Waltham)

30.3 The Fengcong Karst and Its Caves

Fengcong is defined as a group of limestone hills with a common limestone base. Deep closed depressions lie between the peaks, so the integrated landscape is sometimes described as peak cluster depression karst. Some internal depressions are alluviated, but these are mainly those that are entered by sediment-laden allogenic streams. The fengcong forms large blocks of deeply dissected highland (Fig. 30.3). The largest block extends along the center of the basin, and is entrenched by the gorge of the Li River. This appears to be an inherited feature whose course was established early in the evolution of the terrain and has been maintained by the large allogenic flow of the Li. Local relief in the fengcong on each side of the Li River is typically 100–300 m, but rises to over 500 m in places. Hill profiles are mostly steep cones. Individual beds of strong limestone create cliffs that break these profiles, but there is a limit to how steep hill slopes can be when they continue down into conical dolines; vertical-sided towers cannot exist within fengcong karst.

With the intervening dolines reaching down to various levels that are mostly well above base level, fengcong has a deep vadose zone with considerable seasonal fluctuations in water table elevation (Zhu 2005). This allows the development of large and extensive cave systems. There are hundreds of caves within the fengcong karst. Most are not yet fully explored and mapped, but there are 23 known river caves each with a passage length of more than 1 km, along both sides of the Li River gorge.

The longest single series of caves is the Guanyan system between Nanxu and Caoping (Fig. 30.4). Its headwaters drain off the sandstones of Haiyan Shan and descend rapidly towards a graded profile, through the Xizhen caves and across the alluviated Nanxu basin. From there the route is underground through a sequence of large cave passages, broken only by one small surface basin, as far as the open resurgence cave on the bank of the Li River. Along much of the cave, the modern vadose canyon is entrenched in the floor of old, high-level, phreatic passages, though old and new passages separate in parts. A total length of over 14 km of cave passages has been mapped along this route (Waltham 1986), while a central flooded section remains unexplored through a phreatic loop. Flows range between 0.3 and 8.0 m^3/s, from a catchment of 80 km^2.

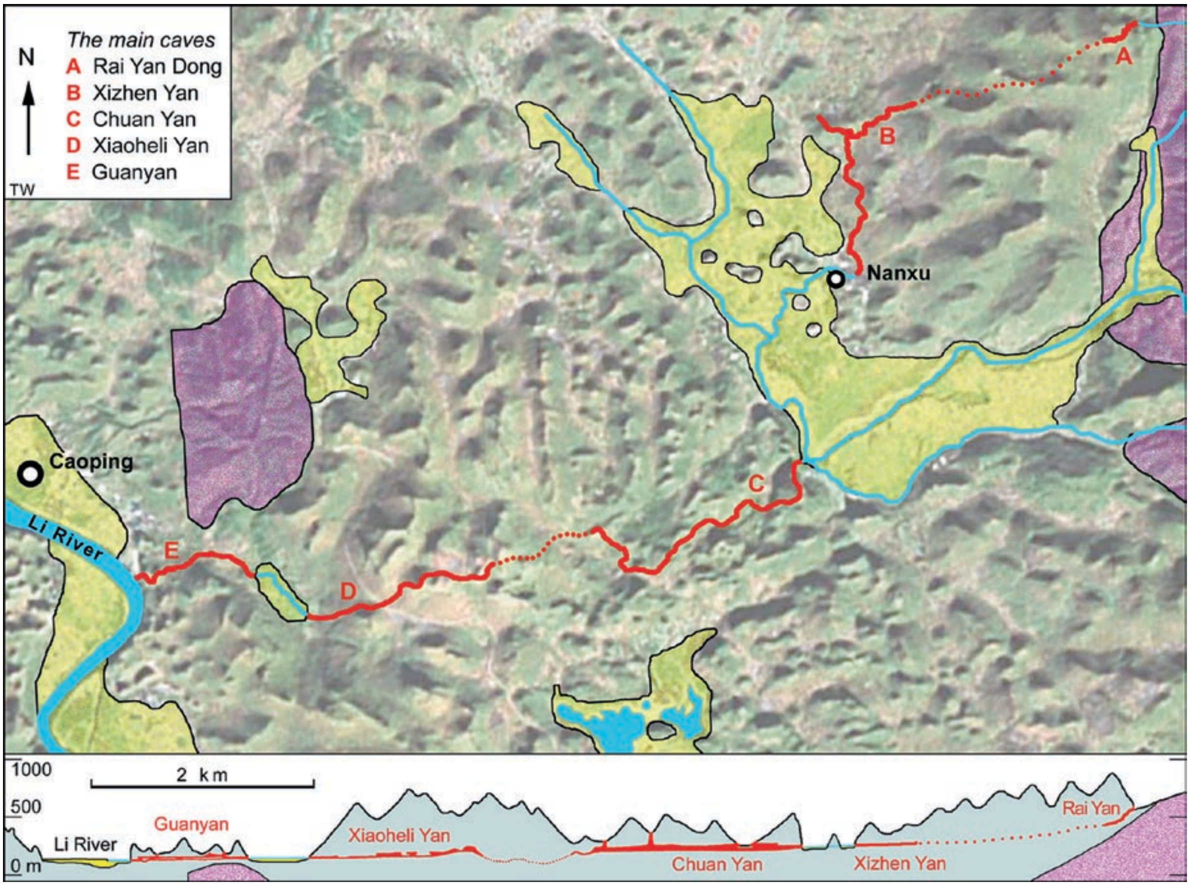

Fig. 30.4 The main line of the Guanyan cave system through the fengcong karst east of Caoping. The sandstone inliers are tinted purple and the main areas of alluvium are yellow. On the plan, only the main streamway is shown, and passage width is exaggerated for clarity; high-levels are included on the profile. Satellite imagery is from NASA, cave surveys, and geology are from China Caves Project (Waltham 1986)

It is significant that the cave route bears no relation to the fengcong surface topography (Fig. 30.4), but takes almost a direct line from the sandstone outcrop to the Li River. It now has a mature graded profile that hides most of the early stages of phreatic looping within the limestone. The cave passes beneath both hills and dolines, and locally breaks out into the floors or margins of some dolines (Fig. 30.5). There are some collapses of doline floors into the cave passage, but the limited local relief means that none of these is as large as the tiankengs (giant collapse dolines) elsewhere in the Guangxi karst (Zhu and Waltham 2005).

30.4 The Fenglin Karst of Yangshuo

Fenglin is defined as a landscape of limestone hills that are isolated from each other by a flat limestone surface that is generally covered by a thin layer of loose sediments. As the hills are usually surrounded by a plain, the integrated landscape may be called a peak forest plain. The hills may be steep-sided towers or lower conical hills, as its definition in China is based on the intervening flat plain, but the best known fenglin is the spectacular tower karst, especially that around Yangshuo (Fig. 30.6).

Fig. 30.5 The main passage of Chuan Yan, with daylight entering where its roof breaks into the floor of a doline within the fengcong karst (Photo A. Eavis)

Fig. 30.6 The classic fenglin karst east of Yangshuo, where limestone towers rise more than 200 m from the thinly alluviated karst plain (Photo T. Waltham)

Fig. 30.7 An almost perfect fenglin tower with vertical walls of limestone largely shrouded in vegetation, beside the Jingbao River on the outskirts of Yangshuo (Photo T. Waltham)

Within the karst of Guilin and Yangshuo, local relief (i.e., the height of the limestone towers) is generally around 30–80 m in the central part of the basin, but may be over 300 m in areas adjacent to the blocks of fengcong. Profiles of the individual peaks may be almost perfectly columnar where the limestone is gently dipping, and the fenglin around Yangshuo is the classic of its type with many towers having almost vertical sides (Fig. 30.7). Profiles tend towards asymmetrical cuestas where dips are steeper on the flanks of the syncline, notably to the west of Guilin. Towers may or may not have steep aprons of bedrock or talus around all or part of their bases, and there is almost every profile transitional to the steeper cones of the fengcong.

This is the type area of the Yangshuo type of tropical karst defined by Balazs (1973), with a base diameter of the tower being less than 1.5 times its height. Balazs used this ratio to distinguish the Yangshuo type towers from the other types of tropical karst hills – the Organos type mogotes of Cuba (ratio 1.5–3.0), the Sewu type hemispherical cones of Indonesian (ratio 3–8), and the Tual type of lower cones on some Indonesian islands (ratio >8). The contrasts in hill morphology are notably dependent on the limestone lithology. The Yangshuo towers are formed of strong and very massive limestone, while the hills of both Organos and Sewu are formed of weaker and more fractured limestones; the lowest cone profiles are formed on young reef limestones at Tual and are mimicked in thinly bedded dolomitic limestones elsewhere in Guangxi (though not in the Guilin basin). Geomorphological evolution also has an impact on the tower profiles in these different karst types, as there are other karsts in similar limestones with very different topographies, but the geological factors cannot be ignored.

In the fenglin karst, the deep vadose zone of the fengcong is replaced by a thin zone of seasonal fluctuation of the water table (Zhu 1988). Numerous foot caves within the fenglin towers are a significant component in the processes of lateral planation, slope undercutting, and cliff retreat. Long caves cannot fit inside the isolated towers, and while some extent of flooded caves must exist beneath the intervening karst plains, none has yet been explored and mapped. High-level caves lie abandoned within many of the towers, and these include old foot caves and also fragments of larger trunk passage that pre-date the modern landscapes.

30.5 Evolution of the Karst

The karst of Guangxi, and even just of the Guilin basin, is immensely complex and contains every variation in detail, including all intermediate morphologies between fenglin and fengcong and hill profiles between a cone and a tower.

Within the Guilin basin, there is no clearly recognizable pattern, either in plan view or in profile, in the distribution of fenglin and fengcong. Across the whole basin, the two types are very mixed in their lateral distribution. So it is possible that the fenglin and the fengcong are contemporary variants of the karst (Zhu 1991). With respect to all the Guangxi karst, there is considerable debate over the origins of fenglin, but it

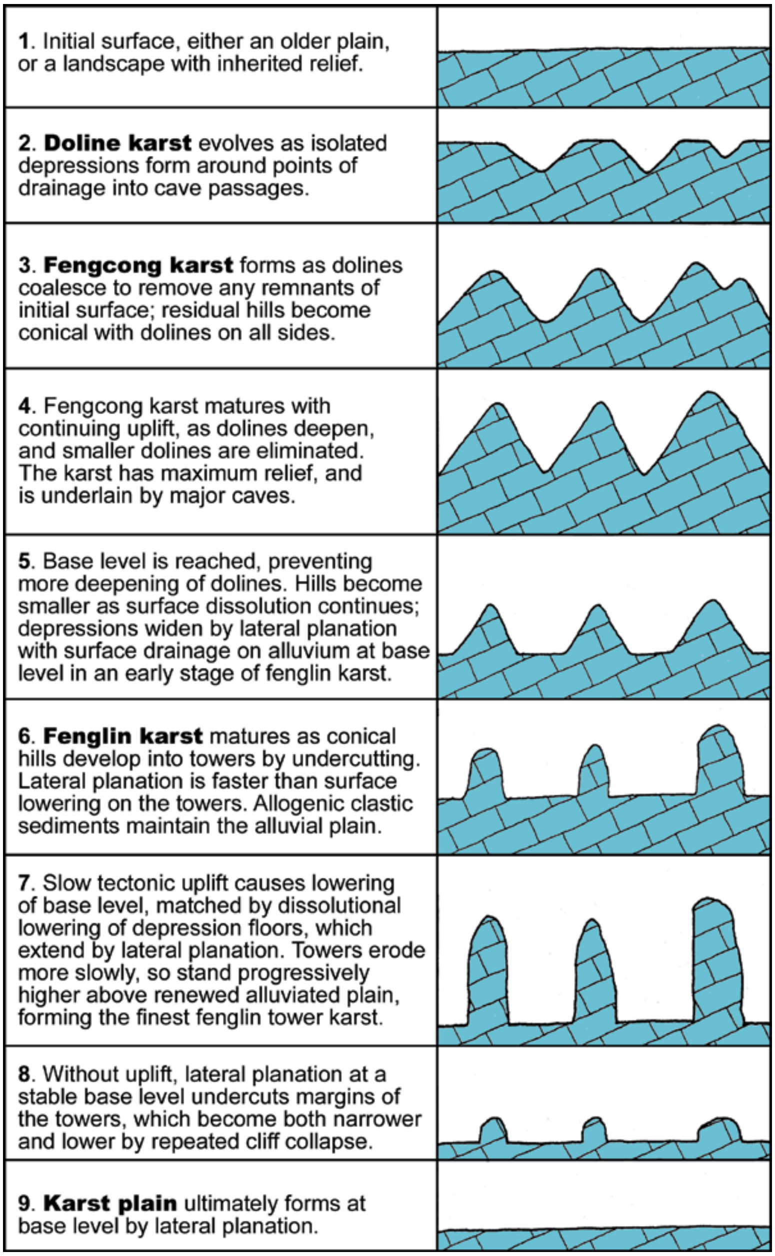

Fig. 30.8 A simplified sequence of stages in the development of fengcong and fenglin karst; details and critical factors are described in the text

appears that the more likely alternative is that fenglin evolves from fengcong, and this certainly seems to be applicable in the Guilin basin.

A greatly simplified evolutionary path for the fengcong and fenglin karst is summarized in Fig. 30.8. Whether starting from a newly exposed outcrop, from an uplifted karst plain, or from an inherited topography; a limestone terrain in a wet tropical environment first develops as a doline karst. This may then evolve into fengcong, as the dolines enlarge to occupy the whole land area, leaving only residual hills that assume conical profiles. With or without an early stage where valleys are entrenched before they break up into dolines, this process is recognized in cone karsts across the world.

Unless a thin limestone is totally removed, base level is ultimately reached, and lateral planation then proceeds to undercut, and reduce the residual hills. The isolated cones or small towers are fenglin in the Chinese sense of the word, and perhaps the best example is seen in the mogote karst of Cuba (Panoš and Štelcl 1968). Ultimately, the hills are removed (as evolution proceeds directly from stage 5 to 8 in Fig. 30.8).

The key factor for the development of mature fenglin karst, as in the Guilin basin, is slow and almost continuous tectonic uplift (Zhang 1980). Where dissolutional lowering of an established plain between the hills can keep pace with a declining water table, lateral planation erodes the bases of the towers faster than their upper surfaces that are reduced by direct rainfall. In effect the towers therefore grow, as the plain declines between them, and this is the key stage in the development of the tall fenglin tower karst of the Yangshuo area (as well as at other sites around Guilin and elsewhere in Guangxi). Important to continuation of the fluvial erosion and limestone planation is maintenance of the alluvial plain by continued replenishment of the clastic sediment from allogenic sources. In the Guilin basin, most of the fenglin stands in areas where streams from adjacent sandstone mountains provide this supply of clastic sediment into the karst (Yuan 1987). This excludes the course of the Li River, which carries little clastic material so far down its course and has simply entrenched its gorge through the main block of fengcong karst.

Development of the fenglin karst requires a delicate balance of processes, which is made possible in southern China by the humid tropical climate and tectonic uplift associated with the nearby Himalayas. With more rapid uplift, the water table may never reach the surface even in the wet seasons, so new dolines develop, and the karst ultimately reverts to fengcong. Too little uplift allows the karst to degrade into a karst plain. There is endless scope for interruptions and repetitions within the simplified sequence of Fig. 30.8, and these can account for a host of multiphase landscapes where fenglin is only one variant (Smart et al. 1986). Fenglin takes time to evolve, and this accounts for the juxtaposition of blocks of fengcong that have not yet reached the fenglin stage within the Guilin karst.

The last factor critical to the development of the mature fenglin of the Yangshuo area is an enormous thickness of limestone. The stages in Fig. 30.8 evolve only during overall surface lowering through perhaps 1,000 m or more of unbroken limestone. Guangxi has this thickness of limestone; its combination with the tectonic uplift, and with tropical weathering unbroken through the Pleistocene, leaves its fenglin karst unmatched in the world. Elsewhere, the only towers that approach the morphology of those in Guangxi are in the Phang Nga and Ha Long Bays of Southeast Asia, both of which have been modified by marine erosion.

An unresolved question concerns the age of the karst around Guilin and Yangshuo. Most of the caves are richly decorated with massive deposits of calcite, and stalagmite in the caves of Maomaotou Hill, in the suburbs of Guilin, has dates ranging from 41,000 to >350,000 years ago, with deposition in both warm and cold stages through the Pleistocene (Wang 1986). The karst is clearly much older. There is a range of data on rates of surface lowering in the Guilin basin. Zhang (1980) cites 80–120 mm/ka[1] based on dissolution measurements, Williams (1987) deduces a maximum rate of 23 mm/ka from palaeomagnetic studies of clays in tiered caves within a single tower near Guilin, Zhu (1988) cites around 100 mm/ka from data on fossils in the high-level caves, and Yuan (2004) cites 90 mm/ka from multiple studies. Lu (1986) estimates denudation rates at 100–300 mm/ka, and compares them to tectonic uplift rates of 50 mm/ka in the Pleistocene, increasing in the Holocene. Very approximate figures of 50–100 mm/ka for surface lowering, through somewhere in the order of 1,000 m of limestone, extend evolution of the karst to around 10–20 million years ago; these places origin well back into the Cenozoic, and appear to be a very reasonable concept until more precise chronological data is available.

30.6 Conclusions

The huge range of morphologies and the spectacular extreme variants make the karst of China, and particularly of Guangxi, the most important in the world. No study of karst, nor any concept of its development, can be complete without reference to the fenglin karst that is so magnificent in the area around Yangshuo. The fenglin appears to evolve under a very narrow suite of

[1] ka stands for 1,000 years

environmental factors, and this is what makes it so unusual and so special.

The Author

Dr **Tony Waltham** recently retired from many years as a university lecturer in engineering geology in Nottingham, UK. His main research interest was in karst and specifically in engineering problems of construction on cavernous ground. He is the author of the popular textbook *Foundations of Engineering Geology*, and of many other books. He has travelled widely, mainly to areas with great caves or active volcanoes.

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