

DISTRIBUTION AND CHARACTER OF KARST IN THE LAO PDR.

RAZPROSTRANJENOST IN ZNAČILNOSTI KRASA V LAOSU

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Abstract

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Kevin Kiernan: Distribution and Character of Karst in the Lao PDR

The extensive karst areas of the Lao PDR are poorly documented but are known to include extensive limestone mountain plateaus; isolated ridges including towerkarst; hillslopes that are locally underlain by limestone; and alluvium-covered limestone plains. Palaeokarst phenomena attest to a very long history of karstification while sediments in some caves offer insight into environmental change during the Quaternary. Limited financial and technical resources, political factors and the dangers posed by massive volumes of unexploded ordnance that remain after decades of war are major impediments to karst area documentation, analysis, planning and management. Assessment of karst extent based on aerial photographs and other remote sensing techniques is complicated by very extensive pseudokarst formed due to bombardment during past military conflicts, including hundreds of thousands of closed depressions formed in both carbonate and non-carbonate rocks. Notwithstanding such practical difficulties, the extent and importance of the karst is such that improved inventory at the national, provincial and local levels is required if satisfactory environmental management and sustainable social and economic development are to be achieved.

Keywords: limestone geomorphology, caves, warfare impacts, bomb craters, sustainable development, environmental inventory.

Izveček:

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Kevin Kiernan: Razprostranjenost in značilnosti krasa v Laosu

O obsežnih področjih krasa v Laosu je malo objavljenega, čeprav je znano, da obsega velike kraške visoke planote, posamezna slemena s stolpastim krasom, pobočja, katerih podlaga je apnenec, in z aluvijem prekrite apnenčeve ravnine. Paleokraški pojavi so dokaz zelo dolgega razvoja zakrasevanja, sedimenti iz jam pa omogočajo vpogled v spremembe okolja tekom kvartarja. Omejene denarne in tehnične možnosti, politični dejavniki in nevarnost zaradi velike količine neeksploziranih teles, ostalih po desetletjih vojne, so glavne ovire pri zbiranju podatkov, analiziranju, načrtovanju in upravljanju. Ugotavljanje razprostranjenosti krasa na podlagi fotografij iz zraka in s pomočjo drugih tehnik daljinskega zaznavanja je težko zaradi izrednega števila pseudokraških oblik kot posledic bombardiranja med preteklimi vojaškimi spopadi, ki vključujejo stotine tisočev zaprtih depresij tako na karbonatnih kot na nekarbonatnih kamninah. Kljub takim konkretnim težavam sta obseg in vloga krasa tako pomembna, da je izboljšanje inventarizacije na državni, provincialni in lokalni ravni nujno, če želimo doseči zadovoljivo upravljanje z okoljem in trajnostni družbeni in gospodarski razvoj.

Ključne besede: površje na apnencu, jame, vpliv vojne, bombni kraterji, trajnostni razvoj, inventarizacija okolja.

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INTRODUCTION

Even in resource-rich western democratic countries many challenges arise in attempting to achieve genuinely sustainable long-term use of the environment, upon which humanity is dependent. Such challenges are greatly amplified in many economically less-developed coun-

tries where poverty results in immediate demand for natural resources that often impacts upon relatively marginal sources of supply; the expertise and finance necessary for compilation of the resource inventories essential for effective planning and sustainable management are

lacking; and environmental governance is deficient. The implications of such challenges are particularly serious where karst landscapes are involved, given the extreme sensitivity of many karst environments (Yuan 1988), and it is compounded still further where political instability or armed conflict is or has been endemic. The purpose of the present paper is to contribute to development of an inventory of the widespread but very poorly documented karst in the Lao PDR, as a contribution to the broader task of improving karst environmental management. This paper reports new observations concerning the apparent distribution and character of some karst areas, and it consolidates some of the presently scattered information on the karst geosystems known to be present (Fig. 1).

The topography over much of the Lao PDR is very rugged. The jungle-covered Truong Son (Annamite) cordillera stretches 1,100 km from Xieng Khouang in Laos to the Central Highlands of Vietnam with peaks at 1,500 - 250 m. The highest summit is Phu Bia, to the north of which lies the extensive Xieng Khouang plateau (1,200 m). For much of their length the Truong Son forms the border between Laos and Vietnam, but in the north it broadens into the wide Tran



Fig. 1: Localities mentioned in text.

Provinces: A. Phongsali; B. Oudom Xai; C. Lam Nam Tha; D. Bokeo; E. Sainyabuli; F. Luang Prabang; G. Houa Phan; H. Xieng Khouang; I. Saisombun Special Zone; J. Vientiane Province; K. Vientiane Prefecture; L. Bolikhamsai; M. Khammuan; N. Savannakhet; O. Salavan; P. Sekong; Q. Attapeu; R. Champasak.

Cited karst localities: 1. Oudom Xai; 2. Ban Mo; 3. Ban Peng; 4. Pak Beng; 5. Ban Houayhing; 6. Vieng Pheuka; 7. Phou Lek; 8. Hong Sa; 9. Pha Xang; 10. Nong Khiaw; 11. Muang Ngoi Neua; 12. Nam Bak; 13. Pak Ou; 14. Chompe-Chomngoua; 15. Luang Prabang (city); 16. Muang Nan; 17. Vieng Thong; 18. Sam Neua; 19. Vieng Xai; 20. Maung Sui; 21. Plain of Jars; 22. Ban Na Meun; 23. Xaisomboun (Long Chen); 24. Phou Khoun; 25. Kasi; 26. Vang Vieng; 27. Pak Chon (Thailand); 28. Lak Sao; 29. Na Hin; 30. Hinboun; 31. Thak Hek; 32. Mahaxai; 33. Ban Nongchan; 34. Phong Nga-Kebang (Vietnam); 35. Salavan; 36. Sekong; 37. Attapeu; 38. Si Phan Don; 39. Stoeng Treng (Cambodia).

Ninh plateau that separates northern Laos into eastern and western sectors that have been subject to different historical influences. To the east of the range crest in central Laos lies the karstic Khammuan Plateau and at its southern end lies the largely non-karstic Bolaven Plateau. The spectacular and difficult topography that can occur in tropical karst is epitomized in Laos, which is characterized by large tracts of remote and rugged limestone mountains and wild forests.

There are few roads and, as a result, rivers remain primary transport routes. The present population numbers around 6 million, comprising 49 different ethnic groups. The literacy rate is a little over 50% and GDP per capita is only about \$US 1,700. The difficult topography and often densely-forested terrain has long contributed to community isolation and a sense of separateness that has played a role in Laos having endured many decades of war, in which various factions have been sponsored by outside powers seeking to further their own interests or ideologies. During one campaign, known locally as the American War phase of the Revolutionary Struggle, the volume of bombs dropped amounted to half a ton for ev-

ery man, woman and child in the country, erasing entire towns and rendering post-war recovery impossible over vast parts of the country due to a massive problem with unexploded ordnance (UXO).

Most parts of Laos are now relatively at peace and, in a bid to raise living standards, the country has commenced to emerge from a perhaps understandable phase of largely self-imposed isolation from the outside world. Control of scientific and recreational activities is maintained by various levels of government, but as this national emergence progresses, there is growing recognition of the potentially important role that karst and caves may play in fostering tourism. However, the vast extent of karst in Laos means that it is inevitably of significance for much more than tourism. Careful stewardship of the soil and water resources in karst areas are particularly critical if overall economic and social development is to be achieved. Improved karst documentation and research is therefore imperative, together with a political will that is supportive of appropriate policy development and implementation, if the karst resources are to be managed in a truly sustainable manner over the long term.

KNOWLEDGE AND DOCUMENTATION OF LAOTIAN KARST

Karst figures prominently in the national psyche of the Lao PDR. Many mountain communities remain compliant to mountain and cave spirits and Buddhist statuary is abundant in and around some karst caves. There is also a social and physical legacy of warfare in the karst, including cave-based operations that played a critical role in the revolution that saw Laos declare itself an independent nation in 1975. An exhibit in the memorial and museum to the important Pathet Lao (PL) leader Kaysone Phomvihane includes a model of his base in "Kaysone Cave", Huaphan province, complete with his revolver, binoculars, radio and other personal effects (Cummings & Burke 2005).

However, until relatively recently the outside world's knowledge of Laotian karst was largely limited to that obtained during the years of French colonial occupation during which such sites as the culturally significant Pak Ou caves were reported; some awareness of the strategic significance of caves and karst by various foreign military protagonists, especially during the French War of the 1950-60s and the American War of the 1960s-70s when the key supply chain of the Ho Chi Minh Trail was a particular target; and later occasional reporting in the western media of the vast opium-growing industry that grew massively in the limestone areas during the American war in particular. In some

areas there remains a residual reluctance to reveal the location of caves that have provided sanctuary from conflict in the past and which might conceivably be required again.

Little reliable broad-scale geological information is readily available, the most detailed work being commercial-in confidence mapping by overseas mining companies that have established major operations in a few specific areas. The present investigation was initially informed mainly by an overview map of carbonate rock distribution in SE Asia provided by (Mouret 2004a), and by a map of some karstic zones explored by German cavers (SpeLAologie 2007). Additional field observations were obtained by the writer in November-December 2006 and December 2007, and this paper also includes interpretation of a series of topographic maps at 1:100 000 scale compiled from Russian aerial photography flown in the earliest 1980s. There are few karst features clearly indicated as such on the latter, and the general absence of any indication of caves, despite the maps being labeled "en secret", may suggest continuing sensitivity regarding overt documentation of sites that have repeatedly played a major role in armed conflicts. None of the various published information sources are definitive. In the absence of any reliable overall map of carbonate rocks in the Lao PDR, Fig. 1 is restricted to

a general depiction of broad localities in which karst is known to occur rather than attempting to define the margins of particular areas of limestone outcrop.

In northern Laos much of the limestone is of Permian-Carboniferous age but Jurassic limestones occur locally around Luang Prabang. The total carbonate sequence may reach 5,000 m thick but non-carbonate interbeds are common in some areas. In central Laos the Permo-Carboniferous Khammuan Limestone, ~1100 m thick with thin inter-bedded dolomites, and occasional Devonian carbonates, is often covered by thick siliclastic rocks. Post-Jurassic tectonism has produced structural lineaments that are orientated from N-S to NE-SW and has resulted in very steep dips, while metamorphism has reduced the solubility of much of the original carbonate mass (Mouret 2004a). A pronounced palaeokarst legacy has been recognized in the Khammouan area, where major karst that developed in the Middle Triassic has been buried under Mesozoic sandstone, then inherited and adapted during a new phase of karstification underway since uplift at the start of the Tertiary (Mouret 1997a, 2001b, 2004b).

Western cavers have contributed to documenting aspects of the karst only in some areas. One principal focus has been on the central province of Khammouan where results from a series of French expeditions undertaken since the mid 1990s, primarily at the instigation of Claude Mouret, a geologist resident in neighbouring Thailand, have been recorded in numerous reports (Brouquisse *et al.* 1999; Brouquisse & Cholin 2002; Gregory 1996 a, b; Mouret 1998, 2001a, b; Mouret & Vacquie 1993, Mouret *et al.* 1996, 1997 a, b; Waltham and Middleton 2000). Since 1999 Dutch cavers (Eskes & Damen 2000) and more recently the German Laos Cave Project have also initiated exploration in some northern provinces (Dreybrodt & Laumanns 2005 a, b, c; LCP 2004, 2006, 2007; SpeLAOlogie 2007). A French group has focused on the Vang Vieng area north of Vientiane (Hedouin & Reonuard 2000). Some additional information on caves is available due to initiatives by tourism interests (BLRGH 2007; Cummings & Burke 2005; Ecotourism Laos 2007). However, much of this activity has been recreational and focused on caves and caving rather than the broader attributes of the karst pertinent to overall karst environmental management.

KARST AREA DISTRIBUTION AND CHARACTER

Ideally, a management-oriented review of the karst in Laos would be structured on the basis of natural georegions, drainage systems and ecologically functional boundaries, but at this early stage in our knowledge the available data is insufficient to provide a reliable systematic framework of this kind. The adoption of arbitrary administrative boundaries typically results in an environmental inventory that can less readily be translated into ecological units for management purposes, but it does at least provide a structure of clearly defined spatial units, in which initial reconnaissance observations can be recorded and then elaborated upon until sufficient information is available to allow a more naturally integrated inventory system to be constructed. Hence, in the following review identified karst areas are addressed on a province by province basis, starting in the north and moving progressively southwards. Numbers in parentheses after locality names in the text are locations indicated on Fig. 1. However, it is clear from the fieldwork and reconnaissance of maps and satellite photography that the full extent of karst is likely to be considerably greater than is indicated below. Because the focus of this paper is on karst systems rather than merely caves it is not intended to present a comprehensive documentation of all known caves. However, reference to some caves is somewhat in-

evitable given the bias towards cave exploration among those who have, thus far, undertaken karst documentation, and it also usefully illustrates the character of some karsts.

The population of Laos comprises many different ethnic groups and the literacy rate is relatively low. Five basic dialects of the official Lao language are commonly recognized and a variety of transliteration systems are in use in Laos. Hence, nomenclature and spelling of place names differs between various published maps and in local use. The approach adopted in this paper has been to utilize those spellings contained in publications widely available and commonly used by overseas visitors, principally the International Travel maps series published by ITMB Publishing Ltd, Vancouver, Canada, and the Lonely Planet tourist guidebook to Laos (Cummings & Burke 2005). These names and spellings have been supplemented by some additional place names taken from the 1:100 000 maps held by the National Geographic Service of the Lao PDR in Vientiane, and by place names and spellings found to be in most frequent use at the local village level. In some cases neighbouring villages may utilize different names for the same feature. While every effort has been made to guard against duplicate references when referring to sites not visited personally by the writer, the pos-

sibility exists that this paper may contain rare residual duplicate references to the same cave by different names. Some key terms that recur in the following descriptive paragraphs include *tham* (cave), *nam* (water or stream), *phu* (mountain), *wat* (temple), *pha* (holy image), *ban* (village) and *muang* or *meuang* (district or town).

PHONGSALI PROVINCE

This northernmost region of Laos is sandwiched between Vietnam and China. No record or indication of karst has been identified by the writer, despite the presence of carbonate rocks not far to the south in Luang Namtha and Luang Prabang provinces. However, given that opium poppy cultivation is heavily focused on limestone areas elsewhere in this part of southeast Asia the particular persistence of poppy growing in Phongsali suggests that the possibility of karst in this province should not be entirely dismissed.

OUDOM XAI PROVINCE

This province stretches NNE-SSW from Phongsali to the Thai border south of Bokeo province. Carbonate rocks that often form very rugged topography are widespread along western Oudom Xai adjoining Luang Nam Tha province, and also occur in the southeast, adjoining Luang Phrabang province. Near the provincial capital *Oudom Xai* (Muang Xai) (1) the waterfall Tat Lak Sip-Et cascades over a limestone cliff. On the western bank of the Nam Tha about one third of the distance between Nam Tham (in neighbouring Luang Nam Tha Province) and Maung Pak Tha, at the confluence of the Nam Tha and Mekong, lies the spacious Tham Davadeung, a short distance from *Ban Mo* (2). It contains a large Buddha statue and there is a locked gate at its entrance. There are further caves near *Ban Peng* (3), 45 km NE of Maung Pak Tha. The carbonates reach south to the Mekong River in the Ban



Fig. 2: Karst of northern side of Mekong downstream of Ban Houayhang, southern Oudom Xai Province (Photo: Kevin Kierman).

Khuktha-Pak Beng (4) area (Fig. 2). Carbonate rocks are also present in the vicinity of *Ban Houayhing* (5), on the Mekong in the SE corner of Oudom Xai, where there are limestone bluffs emergent from steep hillsides.

LUANG NAM THA PROVINCE

Located SW of Phongsali Province, Luang Nam Tha shares borders with China to the north and Burma to the west. Carbonate rocks occur in all but the westernmost part of the province. The best known karst occurs near *Vieng Phouka* (6), 120 km west of Huay Xai. Tham Nam Eng (Aeng), about 12 km north of Vieng Phouka near Ban Aeng, consists of a fossil upper level cave system 3.1 km long and a lower resurgence stream cave of 3.5 km. At an annual ceremony each January a local shaman summons large fish from the cave that provide a feast for the crowd. Tham Phoulan in the same area contains a chamber estimated to be 250 m long, 80 m wide and 100 m high (Dreybrodt & Laumanns 2005 a) and LCP (2006) record several further caves up to ~400 m long near Tham Nam Eng, frequently ending in sumps and siphons. Tham Pasat is a 2.6 km-long system on three levels linked by vertical shafts. The caves in this area are seen as important tourism assets. Villagers harvest bats from Tham Ban Boolahn, an hours walk from Ban Boolahn 15 km from Vieng Phouka. Two further caves occur another 8 km north near Ban Nam Sing. Near Ban Nam Mai lies Tham Sam Hee See Nom, which provided a secret meeting place during the years of revolution. South of Vieng Phouka and accessible from Ban Nam Pha is a reportedly very large cave, Tham Phou Lek (BLRGH 2007). Caves up to 2.5 km long occur around *Phou Lek* (7), located about 1.5 hours west of Vieng Phouka, (LCP 2006). Others include Tham Nam Lot, a multi-entrance, 1.4 km long stream cave with passages up to 20 m diameter that crosses beneath a ridge, and Tham Phou Pasat (645 m) (Dreybrodt & Laumanns 2005 a). Villagers also harvest bats from at least one of these caves, Tham Ban Tung.

BOKEO PROVINCE

West of Luang Nam Tha Province and bordered by Burma to the north and Thailand to the west and south, the town of Huay Xai is readily reached by boat from across the Mekong in Thailand's Chiang Khong. The principal occurrence of carbonate rocks is in easternmost Bokeo. While karst is likely to have developed within it no information regarding karst in this area has been located.

SAINYABULI PROVINCE

Sainyabuli stretches down the western margin of northern Laos between the Mekong River and the Thai border (Fig. 3). Limestone of Permian age extends into northwestern

Sainyabuli near *Muang Ngoen*, south of Pakbeng on the Mekong. This is an extension of the karst that occurs in northern Nan Province, Thailand (Dunkley 1995). At *Hong Sa* (8), about 30 km SE of Pakbeng, the stone floor of Wat Simungkhun (Wat Yai) is reputed to cover a hole that “leads to the end of the world”. On the eastern side of Sainyabuli province the limestone *Pha Xang* (Elephant Cliffs) (9) extend parallel to the Mekong River. This area forms the northern end of a discontinuous limestone belt that includes the karsts of Loei Province, Thailand (Dunkley 1995) and further south forms the large limestone belt through central Thailand.



Fig. 3: Degraded forest, northern Xaignabouli Province (Photo: Kevin Kiernan).

LUANG PRABANG PROVINCE

Permo-Carboniferous limestone is very widespread in this province. The surface karst features include major ridges intersected by large streams and spectacular limestone cliffs such as those at Phaa Hen. To the east and south of the provincial capital, Luang Prabang city (LPBC), are two limestone plateaus 30 km long and 1,000 m high. There are also some massive tufa deposits, large stream caves and numerous smaller caves.

The Nam Ou is a deeply incised major tributary of the Mekong River that cuts through impressive karst peaks and massifs, at one point via a very deep limestone

gorge. Caves occur both close to present river level and at 50-100 m above it. The higher-level caves are often richly decorated, and sometimes have high atmospheric CO₂ levels (Dreybrodt & Laumanns 2005 a, b). The *Nong Khiaw* (*Muang Ngoi*)/ *Ban Sop Houn* karst (10) is centred around the confluence of the Nam Ou and Nam Houn. This karst area appears to be about 300 km² in extent and it contains numerous caves, of which the best known is Tham Pha Thok, another cave used as a refuge by local people during the American War.

The limestone mountains in the *Muang (Ban) Ngoi Neua* area (11) are cut by a spectacular gorge with vertical rock walls up to 600 m high, in which the village of Ngoi Neua is situated, at the Nam Ngoi-Nam Ou confluence. The steeper and more rugged mountains are formed of limestone with more subdued ridges of sandstone also present. A number of caves have been recorded but the literature is potentially confusing due to the adoption by some cavers of the local name Muang Ngoi for the town formally named Nong Khiaw which is located on the west bank of the Nam Ou. However, Muang Ngoi Neua, the area discussed here, is located one hour upriver from Nong Khiaw on the opposite (eastern) bank of the river. Cliffs up to 400 m high occur on the flanks of mountains that rise steeply from the Nam Ou and from other basins and valleys. The Tham Paho complex near the village of Sop Tiem provided sanctuary for the entire village, several hundred people, during two years of bombing (Dreybrodt & Laumanns 2005 b). Tham Pasang is used by fishers for overnight accommodation (Dreybrodt & Laumanns 2005 a). The mountains contain various other caves, including Tham Kang (Tham Kham, Middle Cave, 520 m long) which was used by soldiers for shelter and from which UXO has subsequently been recovered. This cave appears to be linked by drainage to Tham Pageo (Tham Pha Kaew?), which has been explored for over 1.5 km (Dreybrodt & Laumanns 2005c). The inconspicuous entrance of Tham Panoi contains the remains of sleeping platforms, hand grenades, land mines, batteries, tins and eating utensils. Caves up to 450 m length are also present near *Nam Bak* (12), 23 km west of Nong Khiaw near the junction of Routes 1 and 13 (Dreybrodt & Laumanns 2005 b).

About 50-60 km upriver from Luang Prabang city (LPBC) spectacular limestone mountains are visible east of the Mekong towards Phu Namgvang. Downstream of this point the Mekong forms a huge hairpin bend with a radius of 15 km where the river turns from a north-westerly to south-westerly course. The same mountains are visible from both reaches of the river but whether the limestone is continuous through the core of the hairpin is uncertain. The *Pak Ou* Caves (13) are located near the apex of this bend opposite the confluence of the Nam Ou

with the Mekong (Fig. 4), about 25 km upstream from LPBC. Two caves at this site contain large numbers of Buddha images and have long been utilized for tourism. South of Pak Ou are tower-like residual limestone hills that rise from non-carbonate basement rocks in the *Chompe – Chomngoua* area (14). Tham Khou Ha Sakhalin (120 m long) lies on the western side of the Mekong about 10 km upstream from LPBC in an area where the limestone relief is about 300 m. The archaeological site of Tham Hua Phu also occurs in this area. Further inland where some summits rise to over 1,000 m altitude there are further caves including Tham Long in the Huay Lom valley under Phoulouang, and Tham Nang Anh 2-3 km down-valley towards Ban Som. On the N side of the Huay Tan about 3 km WNW of its confluence with the Huay Lom lies Tham Pho Xae. Tham Xang lies under Phu Xang near the head of the eastern branch of the Huay Ghan, which joins the Mekong 2 km downstream of LPBC (Ecotourism Laos 2007). Several other caves also occur on the western side of the Mekong opposite LPBC, including the 100 m-deep Tham Sakkarin Sannakuha, which contains the cave temple Wat Tham Xieng Maen. At least one other small cave has been reported 1 km upstream from Chomngoua (Dreybrodt & Laumanns 2002).



Fig. 4: Limestone bluffs on lower Nam Ou near its confluence with the Mekong, Luang Prabang Province. Lighter coloured vegetation on ridge in background is regeneration of areas previously cleared for slash and burn agriculture (Photo: Kevin Kiernan).

Limestone hills are prominent on the eastern side of the Mekong around the ancient provincial capital *Luang Prabang city* (LPBC) (15) which was accorded World Heritage status for its cultural values in 1995. In the centre of the town lies the limestone hill of Phu Si, within which a small cave shrine is located. Caves also occur north of LPBC near Ban Man Phone Sai. About 6 km downstream from LPBC lies Tham Din, 280 m inside



Fig. 5: The ruggedly karstic northern end of Phu Longhuay, Luang Prabang Province (Photo: Kevin Kiernan).

which the remains of a bamboo ladder into a short shaft were encountered by Dreybrodt & Laumanns (2005 a, b), although their exploration was abandoned due to high CO₂ levels. The *Phou Longhuay plateau*, which reaches 1,606 m altitude (Fig. 5), lies about 14 km east of LPBC. It stretches NE-SW for about 30 km, its northernmost edge demarcated by the 900 m deep gorge of the Nam Pa, NW of which is an extension of the massif complex. Dreybrodt & Laumanns (2005 a, b) have reported some small caves on the NW margin of the Phou Longhuay Plateau



Fig. 6: Tufa cascades at Tat Sae, Phu Phaxang Noy area, Luang Prabang Province (Photo: Kevin Kiernan).

Only 3 km S of LPBC lies the northern tip of the *Phou Phaxang Noy massif*, which extends 30 km south-westwards and reaches 1,341 m altitude. At Tat Sae, near Ban Aen, a broad stream cascades gently over a series of tufa dams amid forest (Fig. 6). The present waterfalls represent only a fraction of the total expanse of tufa, in



Fig. 7: Cave formed in tufa above Tat Sae, Phu Phaxang Noy area, Luang Prabang Province (Photo: Kevin Kiernan).

which at least one small but fascinatingly decorated cave has formed well above the present stream level (Fig. 7). On the opposite side of the massif from Tat Sae and 32 km south of LPBC lies Tat Kuang Si, a 140 m high waterfall that cascades from the edge of a tufa accumulation which is at least several hundred metres wide, the top of which forms a very extensive topographic bench (Fig. 8). About 12 km SW of the Tat Kuang Xi near Longkhoay is Tham Loum (1.6 km long) (Dreybrodt & Laumanns 2005 a, c).

About 30 km SE of LPBC lies the *Phou Phaban* massif, which extends for about 20 km NE-SW and attains 2,212 m altitude. Its southern edge is incised by the Nam Khan, which joins the Mekong at LPBC. About 32 km up the Nam Khan from the Xiangngeun near the village of Ban Kengkoung, lies Crystal Cave (400 m long) (Dreybrodt & Laumanns 2005 a, c). Further afield, the *Muang Nan* area (16) is located about 1.5 hours drive south from LPBC in the SE corner of Luang Prabang province shortly before the road to Sainyabuli crosses the Mekong River. Several caves are known locally, reaching 1.4 km length and 106 m depth (Eskes & Damen 2000). Karst also occurs around the town of *Vieng Thong* (17), along Route 1 on the border of Luang Prabang and Xieng Khuang provinces, some of which has been investigated



Fig. 8: Tat Kuang Si cascading over a massive accumulation of tufa, western side of Phu Phaxang Noy karst area, Luang Prabang Province (Photo: Kevin Kiernan).

for its cave tourism potential. About 1.5 km of passage has been surveyed in Tham This Thong (LCP 2007). The *Phou Khoun* area is located near Muang Phu Khun, a former garrison town at the intersection of routes 13 and 7, about 3 hours drive south of LPBC or 30 minutes north from Kasi. The karst south of this town is discussed in the paragraphs on Vientiane Province.

HOUA PHAN PROVINCE

There are several discrete karst areas in this province, which forms a “peninsula” of Lao territory east of Luang Prabang province that is surrounded to the north, east and south by Vietnam. Although much of this carbonate terrane remains little documented it extends into neighbouring Vietnam where very extensive karst development has been recorded. Spectacular karst summits reach over 500 m above *Sam Neua* (*Xam Nua*) (18), located at about 1,000 m altitude in the narrow Nam Xam valley, within a major belt of intensely karstified upper Triassic limestone that trends NW-SE. This mountainous karst terrain continues along either side of Route 6B as it descends to Vieng Xai at about 700 m altitude and it appears to continue for perhaps 60 km to the south. It also appears to continue for 20 km or more northwards of Sam Neua.

Although the “en secret” 1: 100,000 map sheet of the area produced in 1985 acknowledges the existence of just two caves, over 100 caves are known in the narrow valley in which the town of *Vieng Xai* (19) is located. The caves were initially used by the Vietnamese during their campaign against the French but for nine years after about 1964 they became a major stronghold for the Pathet Lao (PL), and many of the caves are named after PL leaders (Kremmer 1997). Tham Xieng Muang was used as the site for a hidden underground hospital, while weaving mills, printing mills and other facilities including meeting rooms and weapons storage areas were established, as were relatively luxurious dwellings for senior political figures including a PL chief and later Prime Minister. At least one artificially excavated cave is also present. In 1971 a deputation from Cuba was received by an audience of 5,000 in an underground lecture hall. Although a long kept secret, the caves in this area are regarded as national memorials to the development and ascension of the Communist Party of Laos and about a dozen caves have now been developed for tourists (Cummings & Burke 2005). Among the many further caves that occur in the general area a few remain closed for “security reasons” which has raised the suspicion of some continued use of caves as detention centres (Tomory 2006). Nevertheless, some 10 km of cave passages, often massive and highly decorated river passages, were surveyed by an expedition in 2007, the longest caves being Tham Nam Long (4.5 km) and Tham Nam (3 km) (LCP 2007).

XIENG KHUANG PROVINCE

This province lies at the head of a deep re-entrant into the Lao border along the Ca River Valley, which discharges into the Gulf of Tonkin at the Vietnamese city of Vinh. This valley has long formed an important access corridor into Laos from the east. This province is dominated by the 1,200 m high Xieng Khuang Plateau. Rugged karst mountains and wide valleys and plains, some developed in limestone, are characteristic of this province, which is perhaps best-known for the large stone jars that are found at various points between the Vietnam border and westwards to Muang Sui.

The *Maung Sui* karst area (20) lies 35 km west of Phonsavan although the drive along Route 7 is considerably longer. Here limestone crops out as ridges and chains of lower hills orientated NE-SW, the relative relief in this area being up to 800 m. Karst landforms include the Nong Tang lake, about 19 km east of Maung Sui, which is surrounded by limestone cliffs, in which at least five caves occur. Other caves in the same area include the large and impressive Tham Pha, in which rudimentary lighting has now been established to facilitate tourist visits. Buddha figures were hidden in this cave during Haw invasions 200 years ago and more recently it was reput-

edly used by the NVA as a hospital during the American war. Nearby Tham That contains a small stupa. Another small cave in a nearby limestone cliff contains coffins carved from hollowed tree trunks (Cummings & Burke 2005), similar to those described from some caves in northwestern Thailand (Kiernan *et al.* 1988; Sidisunthorn *et al.* 2006).

The *Plain of Jars* karst (21) is characterized by a well developed doline field but many other pseudokarstic closed depressions are bomb craters. There are various springs present including some hot springs such as Baw Yai and Baw Noi. The main Plain extends SE from around the confluence of the Nam Gnouan and Nam Kho and up the valley of the latter. It measures about 15 km E-W and 10 km N-S, pock-marked with both sinkholes and bomb craters, and with small hills up to about 80 m high locally rising from parts of it. A smaller area with similar relief continues NE of the Nam Gnouan. A number of caves are known locally including Tham Piu and Tham Piu Sawng. At least one cave on the plain was used as a shelter by the PL which is said to have developed a considerable underground arsenal beneath the POJ by 1964 (Cummings & Burke 2005, 140). “Smoke-holes” in its roof have compounded a local traditional belief that it was an underground kiln, where some of the jars were produced, although the jars have in reality been carved from rock.

A substantial spring occurs at Ban Nong Pet, 27 km east from Phonsavan, and there are two hot springs near Maung Kham. A few kilometers east at *Ban Na Meun* (22) lies Tham Piu, where in late 1968 or 1969 an unmarked aircraft fired a single rocket into the cave mouth killing hundreds, who were sheltering inside (estimated death toll up to 400 people). There is some contention as to whether these were civilians or patients in an underground military hospital. Significant rockfall was generated in the cave mouth by this attack. Other caves are present in the same general area, including the well decorated Tham Piu Song. About 40 km SW of Tha Piu and 25 km SE of Phonsavn along Route 7B there are further hot springs near Muang Khoun (old Xieng Khuang).

SAISOMBUN (XAISOMBOUN) SPECIAL ZONE

This Special Zone of 7,105 km² was divided off from the provinces of Xieng Khuang and Vientiane in 1994 and placed under the control of the Lao military, but it is presently being phased out following an easing of tensions. It includes the highest peak in Laos, Phu Bia (2,820 m) 15 km NE of *Saisomboun* (Long Chen) (23). Little geological information is available, but ambiguous features on the topographic maps and a history of significant opium poppy production are suggestive that at least some karst may be present.

VIENTIANE PROVINCE

Maung *Phu Khun* (24) is a strategically important village located 100 km south of Luang Prabang along the road to Vietianne, at the turnoff to Phonsavan and the Plain of Jars. It is an area of high limestone peaks including the spectacular *Phu Phra*, a site considered holy by both animists and Buddhists (Figs. 9, 10). The first known systematic cave exploration occurred in 1995 during which *Tham Seua* and *Tham Lot* were linked underground with 2.7 km of passage surveyed, including a highly decorated upper level network. *Tham Dout* also exceeds 1 km length.



Fig. 9: *Phu Phra*, *Phu Khun* karst area, viewed from ridge leading to *Maung Phu Khun*. Security in this area has long been questionable due to numerous attacks on road traffic by insurgents and/or bandits (Photo: Kevin Kiernan).



Fig. 10: Karst spires in *Phu Khun* area, northern Vientiane Province (Photo: Kevin Kiernan).

A belt of rugged limestone hills over 15 km long forms the eastern border of the *Nam Ken Valley* NE and E of *Kasi* (25) (Fig. 11). Much of this terrain is well dissected with small farms present on the plains. The high-

est summits attain over 1,300 m altitude, about 500 m higher than the adjacent valley floors. The limestone belt is L-shaped, with a SE trending massif about 18 km long terminating in the *Pha Louang* ridge (1,310 m) (Fig. 13). About 8 km SW of *Kasi* lie the isolated *Pha Koi* (1,390 m) and *Pha Lay* (1,739 m), both of which appear likely to be limestone. These two elongate ridges are separated by a wind gap, through which flows the very small *Nam Kham*, but together they extend about 16 km SW.

Vang Vieng (26) is located about 56 km south of *Kasi* and 110 km north of Vientiane. Here dark-coloured, well fractured and highly karstified Permian limestone occurs over an area of about 30 km N-S and 15 km E-W. This limestone forms mountains along the western margin of



Fig. 11: Limestone summits along the eastern margin of the *Nam Ken Valley*, *Kasi* area, Vientiane Province (Photo: Kevin Kiernan).



Fig. 12: Limestone mountains overlooking the *Nam Song* near *Ban Phatang*, northern *Vang Vieng* area, Vientiane Province (Photo: Kevin Kiernan).

the broad *Nam Song Valley*, while schists and lavas form the highest summits slightly further west (*Hedoiin & Renouard 2000; SpeLAologie 2007*). In the north, upstream

of Ban Phatang (Fig. 12), the highest summits rise 1,200-1,400 m above the valley floor. Two major tributaries from the east, the Nam Xang Nua and the Nam Xang Tai, both with catchments of several km², sink in very large closed depressions on the lower slopes of these mountains. Further south craggy limestone summits of up to 1,480 m (Fig. 13) border the broad Nam Kha and Nam Koang valleys that drain eastwards into the Nam Song just south of Vang Vieng town (230 m altitude). Rugged karren is typically present on the steep hillsides, beneath which there are numerous caves.



Fig. 13: Limestone mountains NE of Ban Na Thong, Nam Kha valley, Vang Vieng area, Vientiane Province (Photo: Kevin Kiernan).

About 14 km north of Vang Vieng town and overlooked by the impressive Phu Nampin (1,736 m) lie some heavily-visited caves. They include Tham Nam, source of a tributary of the Nam Song and frequently penetrated for about 500 m by tourists who float through on inflated car-tyre inner tubes; the small Tham Sang, which contains Buddha images; nearby Tham Loup; and the extensive Tham Hoi (3 km long?) (Cummings & Burke 2005). Further south along the foothills west of the Nam Song are several other caves including Tham None and Tham Pha Puak. Several significant caves occur in the Nam Kha and Nam Koang valleys. Various caves, such as the large Tham Jang, have been used as sanctuaries against marauding armies, and some contain religious icons. A large reclining Buddha occupies the very large entrance chamber of Tham Pho Kham (Fig. 14) and its large inner passages are spectacularly decorated by large speleothems, but unfortunately these have been badly despoiled by traipsed mud (Fig. 15) and there is also abundant graffiti. Two very large resurgences occur at the foot of the nearby cliffs. Another well-known but less spectacular cave in this area is Tham Pha Jao (Hedoiin & Renouard 2000; SpeLAOlogie 2007).



Fig. 14: Entrance chamber, Tham Pho Kham, Vang Vieng, Vientiane Province. (Photo: Kevin Kiernan)



Fig. 15: Speleothems in Tham Pho Kham, Vang Vieng, Vientiane Province (Photo: Kevin Kiernan).

In far southern Vientiane Province limestone cliffs are visible across the river from the Thai town of *Pak Chom* (27) but no ground-level investigation was conducted during this study and nor has any published reference to karst phenomena here been located.

VIENTIANE PREFECTURE

The Vietiane Prefecture borders south-central Vientiane Province and stretches about 180 km E-W and 30-40 km

N-S bounded to the south by the Mekong River. Limestone is likely to be present at the western extremity of the Prefecture west of the previously-cited limestone cliffs present a few kilometers over the border in neighbouring southern Vientiane Province opposite the Thai town of Pak Chom.

BOLIKHAMSAI PROVINCE

Spectacular karst scenery occurs in the Lak Sao area (28), and there are hot springs and caves about 17 km NW of the town, the best known being Tham Mangkhnon (Cummings & Burke 2005). Further west the main belt of carbonates, up to 40 km wide, appears to extend north-south across central Bolikhamsai Province. The relatively pristine Nam Kading flows through some spectacular karst. Spectacular karst peaks surround *Ban Na Hin* (Khoun Kham) (29), the main construction town for the Nam Theun dam, located on Route 8 at 41 km from Route 13, and they provide an imposing backdrop to the Tat Namsanam waterfall, 3 km north of the town. In the SE corner of Bolikhamsai rugged fengcong (Fig. 16)



Fig. 16: Limestone summit at the southern end of the Phu Nokkok ridge system, Bolikhamsai Province (Photo: Kevin Kiernan).

with summits reaching over 900 m altitude commences 15 km north of the Nam Hinboun, which locally forms the provincial border. This karst extends southwards into Khammouan. Small elongate corridors that penetrate the fengcong are generally drained by surface streams. One small karst lake is perched over 100 m above the plains on a group of steep limestone peaks 3 km N of Ban Thonglom.

KHAMMUAN PROVINCE

The Khammuan Limestone forms a belt of karst 290 km long and 30-120 km wide that stretches NW-SE across the full width of Laos (Mouret 2004b; Brouquisse 2005; Brouquisse & Cholin 2002). The carbonates of Bolikhamsai Province are a relatively minor extension of this belt.

In Khammuan Province allogenic drainage into the karst is limited to runoff from some bordering sandstone uplands and from sandstone cores within incised anticlines (Waltham & Middleton 2000). Limestone cliffs up to 300 m high sometimes delineate the margins of karstic massifs that rise from alluvial plains, and limestone pinnacles and towerkarst are prominent. The area is characterized by well-developed closed depressions including massive poljes, and there are major stream sinks and springs, and large underground stream passages (Mouret 2001 c, 2004 a). Abrasion by river-borne allogenic clasts has contributed to formation of some caves, such as Tham Nam Con which crosses 5 km underground beneath a ridge and contains many large sandstone boulders (Mouret 2004b). Some very long caves are known, including Nam Non (22.1 km) and Tham Nam Hin Boun (12.4 km).

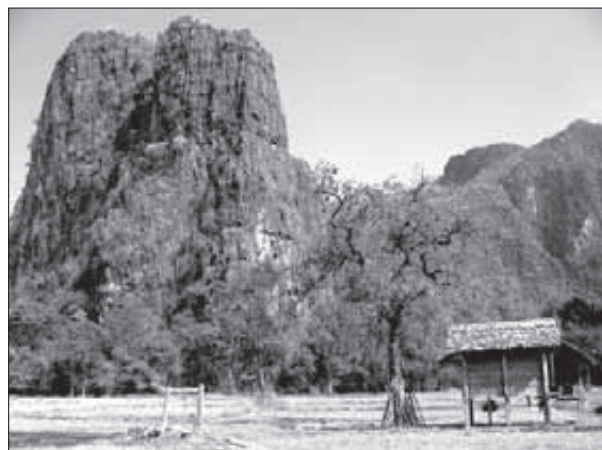


Fig. 17: Residual summit on the floor of the northern Hinboun polje, and the polje margin formed by the ridge of P. Namno, Khammuan Province (Photo: Kevin Kiernan).

The northern end of the karstic mountains lies in southern Bolikhamsai about 30 km NE from the confluence of the Nam Thon with the Mekong. About 12-15 km south along the karst and upstream from the town of *Hinboun* (30) the Nam Hinboun, which locally forms the provincial border, has incised a spectacular gorge 500 m deep that cuts 12 km through densely juxtaposed limestone summits, of which the highest is Pha Dang (762 m), a couple of kilometres south of the river.

A karst margin polje 30 km long and 8 km wide upstream from the gorge receives allogenic runoff from the neighbouring 1,000 m high Say Phou Ak escarpment of sandstones, shales and other non-carbonate rocks where the topography contrasts strongly with the rugged mountains on the opposite (SW) side of the polje. A few scattered residual summits protrude from the alluviated polje floor (Fig. 17), at the SE extremity of which the Hinboun emerges from Tham Hinboun (Tham Lot Kong



Fig. 18: Resurgence of the Nam Hinboun (Tham Kong Lo) at the upstream end of the northern Hinboun polje, Khammuan Province (Photo: Kevin Kiernan).

Lo) near Ban Kong Lo (Fig. 18). This cave passes beneath a 700 m high ridge via a river passage 6.3 km long that is regularly traversed by motorized canoes and fishtail boats in about one hour, providing a critical transport link to villages in a second karst margin polje.



Fig. 19: Riverbank agriculture beneath rugged karst peaks bordering the southern Hinboun polje near Ban Natan, Khammuan Province (Photo: Kevin Kiernan).

The karstic mountain chain in this vicinity is 32 km wide with summits reaching 700 m above the plains and polje floors (Fig. 19). Polygonal karst is well developed on the steep-sided limestone plateaus and spectacular karren pinnacles are widespread. The plateaus rise above other well-developed poljes that are sometimes bordered by cliffs over 300 m high, and the rivers that drain some basins have formed very spectacular karst gorges. The large Panthene depression, 26.5 km long and up to 9 km wide, and located SW of the Hinboun poljes, is a breached anticline where the basement rocks that have become exposed on the polje floor facilitate broadening of the basin by lateral planation. It is drained by the Nam Pathene, which maintains a surface course SW to the Mekong. Among the caves in the depression tributary to the Nam Pathene is 7.9 km long Tham Thon (Waltham & Middleton 2000). Smaller poljes up to a few kilometers in length occur to the south, one of the larger containing Ban Boumlou and being drained underground by the Nam Pakan. This stream flows through Tham Nathan, which also provides the only access between two villages (Waltham & Middleton 2000). Numerous small karst lakes occur on the floor of some poljes towards the eastern part of the karst in this area. Khoun Kongleng Lake, 30 km N of Thakhaek near Ban Nakheu, is fed by an underground stream and is noteworthy for its clear, emerald-coloured waters. Some of the higher summits in the extensive fengcong further to the south attain 900 m altitude.

The karst mountains occur to within 8 km of the Mekong near the provincial capital, *Thak Hek* (31), and from there extend eastwards right across Laos to the Vietnam border. Open linear depressions in this area include the corridor of the Nam Don, at the head of which lies Tham Phachan which extends 600 m through a major ridge from an entrance reported to measure 60 x 40 m. A number of notable caves occur in the ridge just east of Thak Hek and there is also spectacular karst with many caves eastwards along Route 12. About 14 km NE of Thakhaek near Ban Songkhone is Tham Xienglieb (Xieng Liap), a 300 m long through cave navigable by boat during the wet season. Tham Sa Pha In, which contains an underground lake and a major daylight hole, is located 16 km from Thak Haek, and Tham Nang Aen (Tham En), 1.3 km long and richly endowed with speleothems, lies about 18 km from the city. The latter is one of several river caves that receive drainage from the sandstone Phou Khiao, and it has been partly developed for tourism (Waltham & Middleton 2000). Its entrance is 215 m wide and 30 m high, possibly the largest cave entrance in the world, and it contains a chamber 260 x 240 m in area (Mouret 2001b, 2004b). North of Route 12 is Tham Pha Xang, the entrance to which is reportedly 60 m high and 100 m wide, and the large resurgence

of the Nam Don (Khoun Nam Dom), which nourishes a picturesque lagoon from which access is possible into a major cave said to extend over 3 km and from which an eyeless fish species has been collected (Cummings & Burke 2005). About 20 km north of Route 12 near Ban Na Kan lies Tham Pha Pa, celebrated for its many Buddha images. Among various other caves along Route 12 are Tham Pha Nya In, 17 km from Thak Hek, which contains Buddha images and a small underground lake. Tham Heup, located 1.5 km from Ban Nakhok, is a through cave just over 1.2 km long with sections up to 30 m high, that gives access to a secluded valley that contains the jungle-clad ruins of the ancient city of Aran. Local people walk through Tham Heup to reach villages. The entrance to Tham Phi Seu, 2.5 km from Ban Phon Ton, is 25 m high. This cave contains one chamber estimated at 40 m diameter, and accessible cave passages ascend 315 m (Mouret 2004b).

Further east the Xe Bangfai River flows through a spectacular limestone gorge to emerge onto the plain on which *Mahaxi* (21) is located. The southern margin of the limestone in the Mahaxai area is marked by fenglin-like residual peaks that rise from the non-carbonate basement, with some peaks further east rising over 400 m above the plains. More subdued residual peaks occur on the northern side of the karst further east towards the Vietnam border. In contrast to the karst in the Hinboun area the landscape here is far less rugged with open forested plains and relatively few limestone residuals. A belt of extremely rugged karst over 20 km wide with some summits over 1,000 m occurs between *Ban Nongchan* (32), and the Vietnam border, and this stretches southwards all the way into Savannakhet Province. The most prominent karstic mountains occur in broad belts that extend NW-SE east of the Xe Banfai-Nam Phanang confluence, east of Ban Naphang on the Nam Phanang, south of the upper Nam Phanang, and on the broad plain of the Nam Xe Noy north of the Say Phou Xan Ghe escarpment.

The karst in this westernmost part of central Laos is distinctive in comparison to that further east because the structural geology of the Annamite mountains has resulted in a regional drainage pattern, whereby some streams flow along the limestone massifs rather than simply cutting across them (Waltham & Middleton 2000). The largest karstic river on the Laotian side of the border, the Xe Banfai, initially flows northwestwards parallel to the mountain chain through remote forested karstlands which become progressively steeper, with peaks up to 1,397 m altitude rising above the narrow valley floor at less than 400 m. It then turns eastwards and passes underground for 5 km to a resurgence about 24 km SE of Ban Nongchan. Tham Xe Bagfai is 6.5 km long from streamsink to resurgence, the mean discharge of its

river being 50 cumecs and its minimum 2 cumecs, while its estimated discharge in flood is a massive 600 cumecs. The passage diameter reaches 40 m (Mouret 2004b, Mouret *et al.* 1996, 1997).

The extraordinary karst in this area is rugged, difficult of access and doubtless littered with UXO. Although aspects of the karst here and southwards along the Annamite chain were doubtless well known to those involved in military activities along the Ho Chi Minh Trail, for present purposes it can be regarded as essentially undocumented and unknown, except where intruded by illegal logging operations, particularly by loggers from Vietnam. This karst belt lies largely within the Hin Namno National Biodiversity Conservation Area, which is contiguous with the *Phong Nga-Kebang* World Heritage site (34) immediately east of the Vietnam border, and a transboundary protected area to encompass both the Vietnamese and Laotian sectors of this karst has been proposed.

SAVANNAKHET PROVINCE

The southern margin of the carbonates that dominate Khammouan Province occurs as a belt up to 40 km wide that extends for about 120 km across northeastern-most Savannakhet Province, continuing a short distance into Vietnam's Quang Tri Province. Karst is present in this area, but few details appear to have been recorded. The writer is presently unaware of any carbonates further south in Savannakhet.

SALAVAN PROVINCE

Salavan Province extends east-west across southern Laos. Limestone is of relatively restricted occurrence in this province although a small belt extends southeastwards from the town of Salavan, reaching into Sekong Province. The potential karst area is up to 60 km wide and 20 km wide. Much of this area comprises alluvial plains but mountains rise more than 500 m to either side, although the topographic relief of the limestone is not known.

SEKONG PROVINCE

Sekong stretches E-W across Laos and is dominated by the dissected eastern edge of the Bolaven Plateau but much of this terrain is sandstone. Apart from the carbonates that extend into the western part of the province from Salavan north of *Sekong (Muang Lamam)* (36) the writer is unaware of any limestone karst, although it is conceivable that some carbonate units occur towards the margins of the province.

ATTAPEU PROVINCE

Cummings and Burke (2005) indicate the presence of a small cave shrine, Tham Pha, 3 km NW from the pro-

vincial capital *Attapeu (Samakhi Xai)* (37). The author is presently unaware of any other evidence of possible karst in this south-easternmost corner of Laos.

CHAMPASAK PROVINCE

Northeast Champasak is dominated by the sandstone Bolaven Plateau, but topographic maps and some reports suggest limestone may occur in the Mekong Valley downstream of Ban Mounlapamuk and through the area of Muang Khong amid the *Si Phan Don* (Four Thousand Islands) (38). This area, where the Mekong broadens to 14 km in the wet season, lies upstream of Cambodia's *Stoeng Treng* karst (39). About 2 km north of Muang Khong on Don Khong (Khong Island) lies Tham Phu Khiaw (Green Mountain Cave) (Fig. 20) but this is not a karst feature and is formed in non-carbonate rocks.



Fig. 20: Statuary in Green Mountain Cave on Don Khong in the *Si Phan Don* (Four Thousand Islands) area, Champasak Province (Photo: Kevin Kiernan).

DISCUSSION

Karst landscapes are very widespread in the Lao PDR and they contain a considerable proportion of the nation's natural capital. Karst permeates many aspects of Lao society from the spiritual to the geo-political and economic. Its economic significance is not confined to the potential of karst landforms as tourism magnets, but also encompasses their resources for agriculture, water supply, forestry and both non-metallic and metallic minerals. However, the potential of the karst areas to contribute to social and economic development is in many cases compromised by inadequate understanding of their extent and distribution, their resources, sustaining natural processes, sensitivities and management requirements. This deficiency is particularly serious as Laos emerges from isolation and desperately seeks foreign exchange. The mixed success of cave and karst tourism admirably illustrates the dangers when exploitation outpaces the development of necessary management protocols. The tragic fate of some of the remarkable caves around Vang Vieng highlights such failings in a microcosmic reflection, of what is happening more widely in the Lao environment.

A significant role can be played by those in the karst community, who have the knowledge, experience and desire to usefully direct their energies to the betterment of a people, who deserve much better from the outside world than it has thus far delivered to them. Providing a more broadly-based holistic understanding of the karst areas, such as identifying patterns of underground drainage and recommending suitable protective management protocols for wider karst systems, would be beneficial

in at least some cases. However, karst documentation is made difficult by practical issues such as the extent of pseudokarst bomb craters that complicate karst identification using aerial photography, and the dangers posed by unexploded ordnance. There are few resources available locally to support environmental management and nature conservation initiatives, especially given the more immediate local priority of social and economic development. Under such conditions, for cavers to focus their attention merely on identifying new caves for tourism is likely to simply provide replacements for those caves perceived to have become worn out by inadequate management of cave tourism, and to facilitate progressive mining of the resource rather than its nurturing. On the other hand, focusing more attention on documenting values and improving management of those caves that are already known and under threat can only be to the good.

It is difficult to conceive of some areas of the Laotian karsts being sufficiently cleared of the scourge of UXO, that plagues every Laotian province, to again become available for safe utilization, or perhaps even safe exploration. But the Laotian karst estate is particularly extensive, and karst occurs in key geographical sectors of the country. Without a much better understanding of the karst in some areas, and of the requirements for its sustainable management, the potential for the myriad resources it can contribute to lifting the economic status of the people of this battered land will be very severely compromised.

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