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Two sandstone caves on the southern edge of the Meghalaya Plateau, India.

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Abstract: Two caves developed in sandstone are described from southern Meghalaya, northeastern India. Krem (Cave) Pubon is a fault-oriented sub-horizontal, sub-rectangular cave maze containing an active rivulet. Krem Lymbit is a relict horizontal cave, with a form that testifies to the former existence of a more extensive system, now largely eroded. Because both caves are unusual for this region, being developed in sandstone host rock, they are presented in support of the case for future exploration and scientific investigation in this important northeast Indian karst region.

Keywords: India, Meghalaya, sandstone caves

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Background

In April 2009 several members of the Speleoclub of Berlin (SCB) mounted an expedition to investigate known and new caves in Meghalaya, northeastern India, with the intention of collecting samples and data related to PhD research into palaeoclimate reconstruction of monsoonal rainfall regimes (Breitenbach, 2009). The scientific program for INSPEMO (acronym for Indian Speleological Monitoring) included sampling and maintenance of data loggers that were installed in Meghalayan caves in 2007. Monitoring of climatic parameters is now acknowledged as one path towards gaining an understanding of climatic variables that allow insights into the dynamics of cave microclimate and, ultimately, past climate changes that are recorded in speleothems (Mattey *et al.,* 2008). Alongside the scientific program, the speleological goal was to find and survey caves that were previously unknown to the caving community. The Expedition does not, however, claim 'discovery' of the caves described here, because local inhabitants have known about these 'holes' since time immemorial. Meghalaya has been inhabited by the Khasi, War and Garo peoples for many hundreds, probably even thousands, of years, and proof of this is provided by the presence of menhirs (standing stones) called *maw-shyngrang* in the Khasi language, meaning *male stone* (Chowdhury, 1998), which are found in many parts of Meghalaya State.

The Meghalaya Plateau is well known for the extensive karstification that is found along its southern margin, where limestone is abundant (Gebauer, 2008; Kharpran Daly, 2006). Heavy and markedly seasonal monsoonal rainfall and a subtropical climate support chemical weathering and valley incision. The Plateau is dissected by gorges, including some more than 1000m deep, that are undoubtedly guided by tectonic faults.

Two caves, Krem (cave) Pubon, and Krem Lymbit, are described below. A third cave (Krem Lymbit 2) is discussed more briefly because it belongs genetically to Krem Lymbit and is shown on the plan of the latter. These caves are relatively unusual in that they are developed in sandstone, rather than being parts of a classical limestone karst, but they are also typical of features related to the region's sandstone morphology. Plan and profile views of both caves are presented, together with some geological and geographical background information.

Environment and climate

The Meghalaya Plateau, lying in northeastern India on the northern border of Bangladesh (Fig.1), is a mountainous region with a tropical to subtropical climate. More than 8000mm of rain falls at Cherrapunji (Sohra) during India's summer (June to October) monsoon (Prokop and Walanus, 2003), currently the world's highest recorded rainfall. Despite such enormous rainfall levels, marked seasonality of precipitation commonly leads to water shortages during the dry season (late October to mid-May). This in turn has led to an extensive use of caves as freshwater reservoirs (Gebauer, 2008; Breitenbach and Gebauer, 2007). In the lower lying areas of the Meghalaya Plateau, the temperature fluctuates little during the course of the year, whereas somewhat cooler temperatures prevail during the boreal winter conditions experienced in the higher regions. The vegetation reflects the different climate conditions in the valleys and on the Plateau. Evergreen forests cover the valley floors, where high humidity is the dominant year-round influence. Pine (*Pinus kesiya*) forest is found on the Plateau. Commonly the influences of agriculture and mining activities (coal, quartz-sand and limestone) have led to rapid deforestation. Nevertheless, evergreen rainforest is still preserved near Krem Pubon and Krem Lymbit.

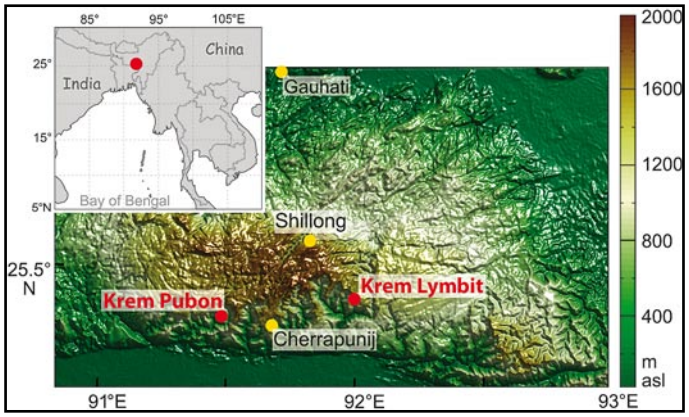


Figure 1: *Map of Meghalaya, northeastern India. Krem Pubon and Krem Lymbit lie near the southern fringe of the Meghalaya Plateau. N Marwan (PIK Potsdam, Germany) provided the digital SRTM elevation data, available at http://seamless.usgs.gov/ (U S Geological Survey).*

The Meghalaya Karst is developed mainly within a small strip of Tertiary limestones along the southern fringe of the Plateau, with some features developed locally in sandstone/conglomerate successions (Oldham, 1859; Gebauer, 2008; Biswas, 2009). At least 1239 caves, including India's longest (Liat Prah Cave, 29.8km; Arbenz, 2007; Gebauer, 2009, pers. comm.), are currently registered (Gebauer, 2009, pers. comm.), and new caves are added to the registry every year. Each year the Meghalaya Adventurers Association organizes caving camps that are attended by international cavers. Almost certainly many caves remain unexplored and unrecorded due to their remote locations. The cave names used here are in the *Khasi* language, translations from which were provided by H D Gebauer.

Krem Pubon (cave near Mawkawir)

History of exploration and geography

Krem Pubon (Pubon = another word for cave in *Khasi*, which makes this the Cave Cave) is located southsoutheast of the village of Mawkawir (25° 15′ N and 91° 40′ E). A GPS receiver was not available on the expedition but some GPS coordinates of local villages are provided by Gebauer (2009, pers. comm.). Altitudes were measured using an uncalibrated wristwatch altimeter; therefore their absolute values are almost certainly incorrect but the relative altitude differences between individual places are likely to be credible.

Initial information about "a cave" was passed to the expedition team by Canadian tourists (Valery Adams, Dylan McKernan and Rodrigo Cid, from Montreal) who also provided a sketch map (reproduced as Fig.2), which proved invaluable in relocating the cave. Starting from the road from Cherrapunjee Holiday Resorts (25° 13′ 10″ N, 91° 39' 46″ E, 825m asl (above sea level)) to Sohra, and heading for Tyrna village (25° 14′ 22″ N, 91° 40′ 52″ E), steep tracks, like stairways of stone slabs, were followed down to Nongriat village (25° 14′ 42″ N, 91° 40′ 02″ E), which is known for its living rubber-tree (*Ficus elastica*) bridges. Nongriat lies on the Umpynjngithuli River in the rainforest at about 150m asl, and provides a tiny tourist guest house. It was hoped that a guide from the village would facilitate finding the cave. The walk is quite strenuous, but the beautiful scenery and vegetation compensate for the steep and arduous tracks (such trails are a typical feature in the Khasi Hills).

The local guide helped to identify the correct route to follow uphill to Pyndemkhar village (at 900m asl) and onward past a splendid outlook point (c. 1045 to 1155m asl). Shortly before this village was reached the guide turned left (southward), climbing through bamboo thickets along narrow ledges on a vertical sandstone/conglomerate cliff face (probably Medlicott's (1869) "basal conglomerate") supposedly leading to Krem Pubon. This hunters' trail leads to several grottos in the cliff, not much deeper than 2m, with an average height of 0.8 to 1.5m. After some fairly exposed climbing a return had to be made along the same ledges without Krem Pubon being located. Back on the main track Mawlakhieng village was reached, at which point the guide decided to return home. The team went on without him, pushing further uphill to the village of Mawkawir, about 30 minutes walk beyond Mawlakhieng and at about 1200m asl. Here another guide willing to show the way to Krem Pubon was found, and the eager villager led the team to the cave in about 10 minutes. It lies a few dozen metres below a road that is apparently under construction (though actually appearing to be suffering active destruction).

Cave description and geology

Krem Pubon is situated about 100m below and a 10-minute walk from Mawkawir village on the southeastern escarpment of the East Khasi Hills. The main cave entrance is surrounded by jungle and bamboo vegetation. A rivulet flows out of this entrance, and its water is collected in a man-made basin about 1.2m wide and 0.5m deep. A second entrance was found a few metres northeast of the first one. The cave is used as a freshwater reservoir and the c. 1.80m-high entrance leads into a first chamber containing the remains of a low dam (Fig.3). Beyond the entrance chamber a number of fissure-like passages that intersect almost at right angles to form a short maze were explored, but not pushed to any definite conclusion (Fig.3). The dimensions vary from c. 3m width to narrow crawls of only c. 0.5m. Large breakdown boulders are found in the larger passages.

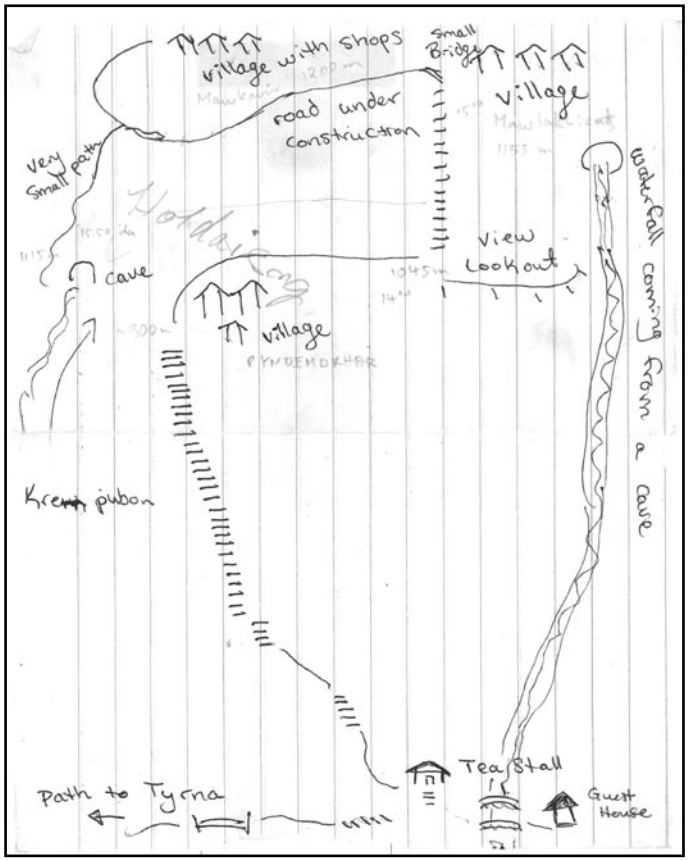


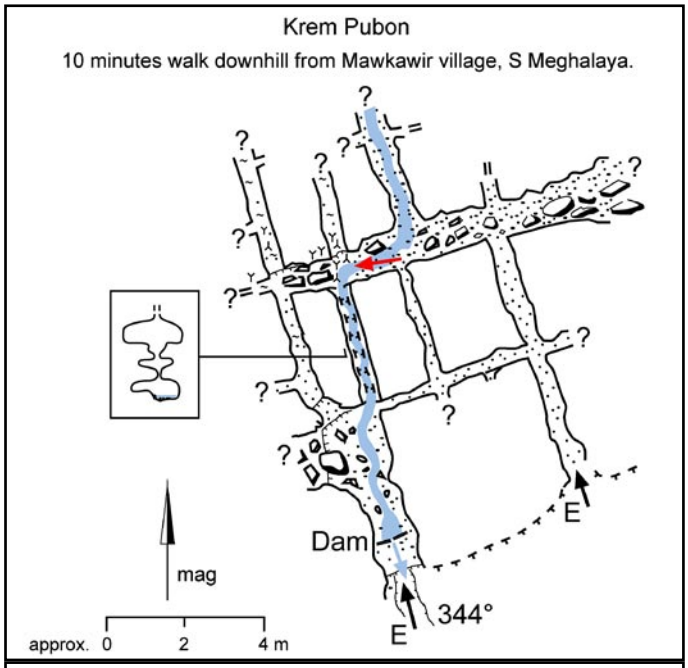
Figure 2: *Copy of the original sketch provided by Valery Adams of the path to Krem Pubon. Additional names and altitudes (Pathfinder wristwatch) added by S Breitenbach. Although a second (resurgence) cave is shown on the map (upper right) this site was not visited and surveyed. The sketch is not oriented, but the left-hand side approximates to south.*

Although the horizontal cave is largely abandoned by water, the surviving rivulet marks it as a still-active system (Fig.3) that is most likely very wet and partly inaccessible during the summer monsoon. Some limestone is probably located above the cave-bearing sandstone, as stalagmites and stalactites 5 to 30cm long are found in some parts of the cave (Fig.4). However, Oldham (1859) described calcareous sandstones, which might provide an alternative or additional carbonate source rock. Whereas the speleothems are clean and white in colour, the passages themselves are covered with quartz sand. In some inactive areas the sandy sediment is actively overgrown by small stalagmites. The rivulet enters from a passage offset from but on the same trend as the entrance chamber. Though the inlet passage was not pushed there is still reasonable potential, as the river discharge probably shows rapid seasonal changes, and hence significant erosional enlargement would be expected.

It appears obvious that cave development was guided by a rectilinear set of tectonic faults and/or joints, which were initially widened under phreatic conditions. To enlarge the resulting cracks to cave-size passages the corrasion of undissolved quartz grains under subsequent vadose conditions was probably crucial (the vertical cave cross-sections show characteristic keyhole profiles). The parent rock is reddish-brown conglomerate/sandstone, containing large pebbles. As described by Oldham (1859) this rock type is typical of the escarpment. Possibly the sandstone belongs to the uppermost part of the Weiloi Conglomerate Beds (also called basal conglomerates and belonging to the Jadukata Formation, Khasi Group, of the Upper Cretaceous) or to the lowermost part of the overlying Mahadek Beds (Oldham, 1859; Medlicott, 1869; Gebauer, 2008, Gebauer, pers. comm.). On the ascent towards Krem Pubon, the basal conglomerates are visible, exposed in the very steep cliff face. The clasts in the conglomerate are up to cobble-size.

During exploration of the cave, various bats, frogs and hand-sized spiders were observed in the passages. However, none of the animals were trapped or collected to allow species or genus to be ascertained.

On the basis of the observed grottos and another cave resurgence mentioned on the Valery Adams sketch map (Fig.2), more sandstone caves of similar type are expected to occur in this area.



Explored but not surveyed during the INSPEMO 2009 Expedition (S Breitenbach and J Donges). Explored length approximately 50m. Altitude c.1100m asl. Vertical range c.3m. Drafted by S Breitenbach. BCRA Gd. 2B sketch; not to scale.

Figure 3: *Sketch map of Krem Pubon. The cave's estimated length is 50m, but several leads were not pushed due to lack of time. The red arrow shows the direction of view of Figure 4. The main entrance opens on a trend of 344°.*

Krem Lymbit and Krem Lymbit 2

History of exploration and geography

Another two caves – Krem Lymbit and Krem Lymbit 2 – were visited a few days later (16 April 2009). Information on Krem Lymbit had been obtained previously, but there had been no earlier opportunity to explore. As 16 April was a Meghalaya-wide election day (election of the Indian national Parliament) everything was closed, including some of the roads. The authors, together with Gregory Diengdoh, Brandon Blein, Ksan Kupar Mawlong and Lindsay Diengdoh squeezed into two cars and headed southwards to Lyn(g)shing village in the Lum Lyngdoh area. Thanks to the various road closures and a lack of information this nominally short drive was extended to three hours, passing through a very "Scottish" landscape with several scattered megalithic menhirs whose age and history remain buried in time, before finally reaching a point near the steep southern rim of the Meghalaya Plateau.

At Lyn(g)shing, two locals, Bantreilang and Bistai Mukhim, were recruited as guides to the cave entrance. Finding it without them would probably have been impossible. Krem Lymbit (Bat Cave) is located at 25° 24′ 3.3″ N and 92° 00′ 01.9″ E (WGS84, ±4m) at an altitude of 1524m asl (western Jaintia Hills, Fig.1). However, when these coordinates are cross-checked using Google Earth® they appear to be too far south, and 25° 24′ 39.14″ N and 91° 59′ 59.49″ E is closer to the

Figure 4: *Stalactites in Krem Pubon. (Photo: J Donges.)*

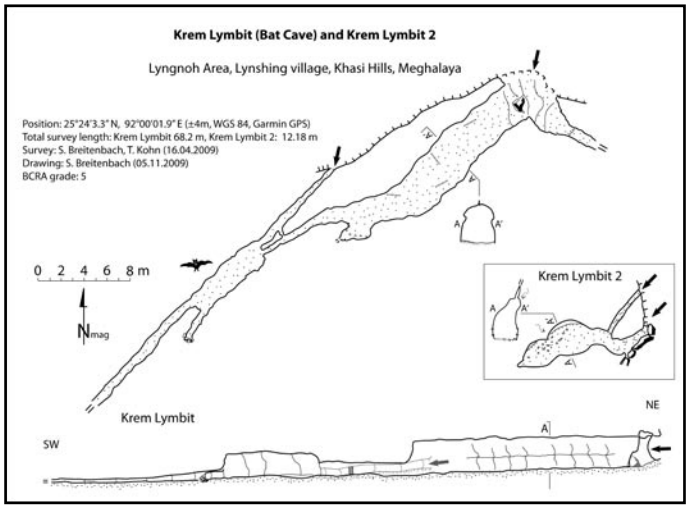


Figure 5: *Plan of Krem Lymbit and Krem Lymbit 2. The main entrance of Krem Lymbit is shown in Figure 6.*

Google Earth® coordinates. The vegetation immediately around the cave consists of evergreen jungle, commonly with dense bamboo thickets, although grassy pasture dominates the landscape in the general area, the latter possibly human-induced. Another cave entrance was found very close to Krem Lymbit (Krem Lymbit 2; Fig.5), and the two caves are genetically related, originally forming parts of a larger cave system.

Cave description and geology

Krem Lymbit's entrance is a c. 2.5m-high opening in a sandstone cliff. It is a relict cave, aligned and developed along tectonic faults and/or joints in the sandstone, which consists of fine- to coarse-grained (0.2 to 1mm diameter), relatively clean quartz sand. The sandstone's whitish-yellow colour might point to it being the Langpar Sandstone (Late Maastrichtian to Early Paleocene) of Medlicott (1869), lying just below the Cherra Beds. In both caves, several centimetre-thick ribs of harder, well-cemented brown sandstone have resisted erosion better than the main sandstone mass, and these now protrude from the cave walls, reflecting the original bedding (see profile in the Fig.5 inset). Erosion has produced beach-like sand deposits, which cover the caves' floors.

These two small caves are clearly remnants of a cave of originally far greater extent that has been eroded away by the Umiar River, which drains into the Um Thangphor River. However, it remains problematical to attempt to assign a date to the cave collapse without additional geological and geomorphological investigation in the valley of the Um Thangphor. By its surviving shape an overhanging rock shelter indicates its origin clearly, as part of a much larger (and now unroofed) cave. Several additional grottos are also found along the rock cliff, and these must all have belonged to one and the same cave system in the distant past. Further evidence for this assumption is provided by large blocks and boulders of sandstone, probably remnants of the collapsed ceiling of the great ancient cave, now lying strewn at the foot of the sandstone cliffs.

Figure 6: *View from the main passage to the main entrance of Krem Lymbit. The picture corresponds roughly with the (reversed) profile A-A' in the cave plan (Figure 5). (Photo: T Kohn.)*

Figure 7: *A bat (?Horseshoe bat;* Rhinolophus pusillus) *in Krem Lymbit (Photo: T Kohn). This species is also found in Krem Mawkhyrdop (Krem Mawmluh) near Sohra (Biswas, 2009).*

The main passage of Krem Lymbit stretches almost horizontally from the main entrance in a southwesterly direction (Figs 5 and 6). It has developed along a fault and opens into a chamber about 3m wide. From there a second passage leads northeastwards and ends as a second entrance/exit. Another narrow passage leads southwestwards, but after a few metres it becomes too restricted for human access. The total length of Krem Lymbit amounts to 68m. Bamboo sticks with burned ends and leaves are strewn across the sandy floor, indicating that the cave is occasionally visited by the local people, who use the bamboo sticks as torches. The cave is also inhabited by bats and large spiders (Figs 7 and 8).

Krem Lymbit 2 (Fig.5), which lies just a few metres southeast of Krem Lymbit, certainly belonged to the eroded large cave system mentioned above. It shows traces of an episodically active small waterfall and is also inhabited by bats and spiders. The fine-grained sandstone shows traces of root channels, now coated with iron oxides. Both caves show signs of standing and running water from the latest monsoon season. No speleothems are deposited, pointing to a limited carbonate content in the sandstone and to undersaturation of the infiltrating waters with respect to $CaCO_3$. Two other caves in the vicinity were mentioned by the local guides, but shortage of time precluded their location and exploration.

Summary

Meghalaya hosts the most important karst of the Indian subcontinent. Despite there being more than a thousand explored and registered caves, only a few sandstone caves have so far been described. The caves described here provide examples of active sandstone karstification on the southern plateau of Meghalaya. Because of their remoteness and rather small size many Meghalayan sandstone caves remain unexplored and, elsewhere in Meghalaya, the extraordinary karst of Shnongrim Ridge remains as yet unrivalled.

Krem Pubon provides an example of a cave in Meghalaya being used as a freshwater reservoir. Additionally the sandstone karst in Meghalaya has potential importance in the biospeleological context, as the fauna in these caves has so far been only poorly investigated. In a similar way to the quartzite karst in the Tepui of Venezuela (Aubrecht *et al.*, 2008), the sandstone karst of Meghalaya might furthermore prove important in terms of its microbiology.

More detailed exploration of the sandstone caves could help to provide an understanding of the regional hydrology and geomorphology. The remnants of the large cave system near the Lymbit caves give some indication of the formidable rate of erosion in this region, which currently experiences the world's highest rainfall. Detailed survey of the sandstone karst could help in modelling regional erosion rates and provide pointers to the momentum of ongoing river incision.

Figure 8: *A typical spider in Krem Lymbit (Araneae: Sparassidae: Heteropodidae, conf.* H. robusta *Fage 1924, or* H. fischeri *Jaeger 2005), the span between the leg tips is c. 20cm (Photo: T Kohn). It is most probably the same species as found in Krem Lawkhlieng (Breitenbach and Gebauer, 2007).*

Acknowledgements

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