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Seri Thai System, a large cave in the quartz sandstones of North-east Thailand, geology, morphology and genesis

Liviu Valenas[1, 3], Martin Ellis[2], Maliwan Valenas[3]

1 TU Bergakademie Freiberg, Institute of Geology, Chair of Hydrogeology and Hydrochemistry, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany. liviu.valenas@gmail.com

2 Shepton Mallet Caving Club, Somerset, BA4 5TT, UK. thailandcaves@gmail.com

3 Speleological Club "Z" Nuremberg, Germany. maliwan.valenas@gmail.com

Abstract

North-east Thailand was considered relatively uninteresting from a karst and speleological point of view until a few years ago, as 90% of its area is quartz sandstone, which was wrongly considered to lack karst. In 2011, systematic research began in North-east Thailand, noting that the entire area contains large caves in these sandstones, as well as other karst phenomena such as karren, sinkholes, blind valleys, ponors and karst springs. Since 2023, the research has been supported by the Technical University of Freiberg, Germany.

One of the caves studied for the first time was the Seri Thai System. This is a highly labyrinthine underground complex, 1,124 m in total length, comprising three parallel branches, connected either by extremely narrow joints or low galleries and has 28 entrances. The System is a good example of a karst on sandstone, which may also be called "silicate karst". It is a dendritic labyrinth, active only during the monsoon season when it exhibits a complex hydrogeological organization, complete from sink and resurgence. The formation of this system is the result of a combination of factors, primarily the process of arenisation of quartz sandstones under monsoon climatic conditions, accentuated by corrosive processes due to tropical vegetation. The Seri Thai System is also a lithological contact cave, as it occurs between different layers of quartz sandstones and clay.

Introduction

The Seri Thai System is located in Sakon Nakhon province in North-east Thailand (Figure 1), within the Phu Phan National Park, near the Seri Thai historical monument. The surrounding area is 90% forested with various tropical and subtropical trees (Figure 2). Because this area is strictly protected, the vegetation has remained intact. The most common tree species are *Dipterpcarpus tuberculatis, Dipterpcarpus obtusifolius, Shorea obtuse and Shorea siamensis*. However, Dipterpcarpes predominate. In the area the predominant soils are ferarsoils, acrisoils and laterites (Figure 3).

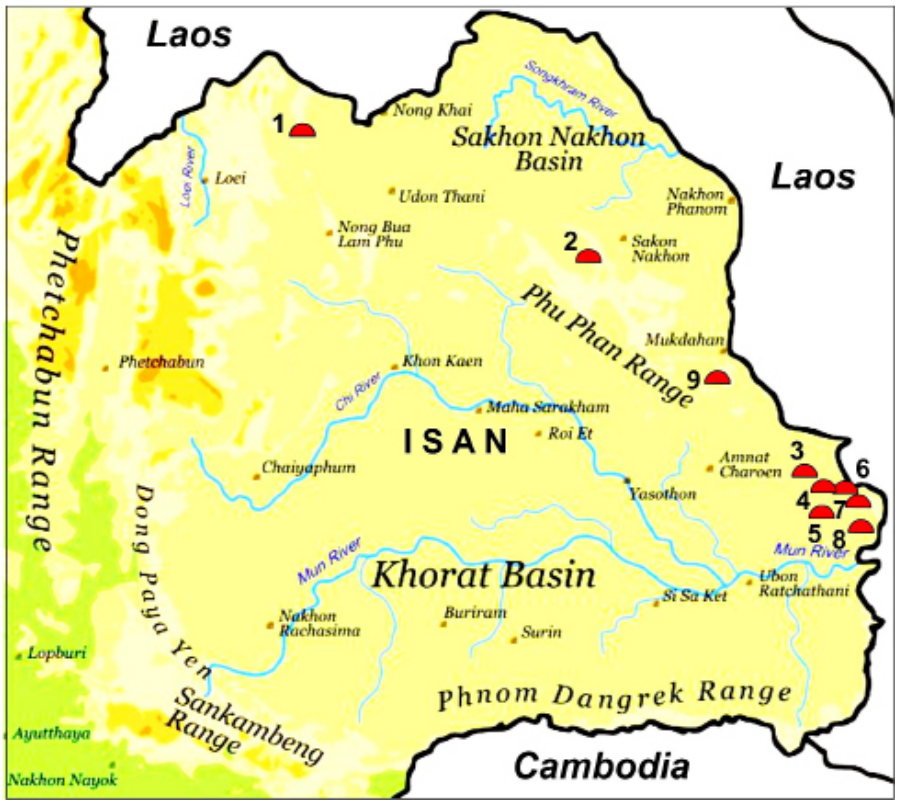


Figure 1. Map of North-east Thailand showing the main sandstone caves. 1 Tham Din Pieng, 2 Seri Thai System, 3 Tham Phu Pom No. 1, 4 Phu Phanom Di System, 5 Tham Nam Lot, 6 Tham Ghia, 7 Tham Meut, 8 Tham Patihan, 9 Tham Phusi Kew.

Figure 2. Forest in the immediate vicinity of the lower entrance to the Seri Thai System (entrance No. 20).

Figure 3. Typical landscape in the Seri Thai System area.

The upper (or "historical") entrance is located at 17.099°N, 103.972°E at an altitude of 318 m asl.

North-east Thailand consists mainly of the Khorat Plateau, the altitude of which varies from 140 to 180 m asl with several mountain ranges, such as the Phu Phan Range, rising to more than 666 m asl (Pfeffer 2013). Geologically, the plateau and the mountain ranges are mainly composed of quartz sandstones and, in some places, volcanic rocks (Figure 4).

The quartz sandstones are currently known to contain 290 caves (Ellis 2017), three of which exceed 1 km in length. The Seri Thai System is a dendritic labyrinth, active only during the monsoon. The system has a total length of 1,124 m (for comparison with other similar caves in the country, see Table 1) accessed through 28 entrances, 25 of them in the form of potholes (Figures 5, 6, 7 and 8). The cave was formed from the Middle Pleistocene, mainly by the process of arenisation of the quartz sandstones, but also by other processes (e.g. accelerated corrosion due to tropical vegetation and active tectonic processes). The System well illustrates a karst on quartz sandstone, sometimes called "silicate karst".

Sandstone Karst Research in North-East Thailand

The first speleological explorations of the sandstone caves of North-east Thailand were carried out by French geologist and caver Claude Mouret. He had field trips to the region between 1992 and 1994, together with Louis Deharveng, Lien Mouret and Philippe Leclerc. The caves they explored and surveyed included Tham Patihan (Ubon Ratchathani province), Tham Cham Pha Tong (Sakon Nakhon province) and Tham Wat Sila At (Chaiyaphum province). None of these cave surveys have been published, but geological and geomorphological observations have been published (Mouret 2004, 2017, Mouret & Mouret 1994). Australian caver John Dunkley had four trips around the north-eastern region looking for sandstone caves between 2011 and 2017. The caves researched on these trips included Tham Din Pieng (Nong Khai province) and Tham Nam Tok Saeng Chan (Ubon Ratchathani province) while other caves visited included the Seri Thai System and Tham Wat Sila At. Some observations from these visits were presented at conferences (Dunkley 2011, Dunkley & Bolger 2017) and published (Dunkley and others 2018).

No.	Cave Name, Province	Length (m)	Explored by	Date of exploration
1.	Tham Din Pieng, Nong Khai	2,747	Valenas/Speleological Club "Z"	2024-2025
2	Seri Thai System, Sakon Nakhon	1,124	Valenas/Speleological Club "Z"	2023-2025
3.	Tham Patihan, Ubon Ratchathani	1,029	Valenas/Speleological Club "Z"	2024-2025
4.	Tham Meut, Ubon Ratchathani	525	Valenas/Speleological Club "Z"	2020-2025
5.	Air Raid Shelter Cave No. 1, Phitsanulok	361	Dunkley, Ellis & Bolger. 2018	2011
6.	Tham Phu Pom No. 1, Amnat Charoen	284	Valenas/Speleological Club "Z"	2019-2020

Table 1. The longest sandstone caves in Thailand, 2025

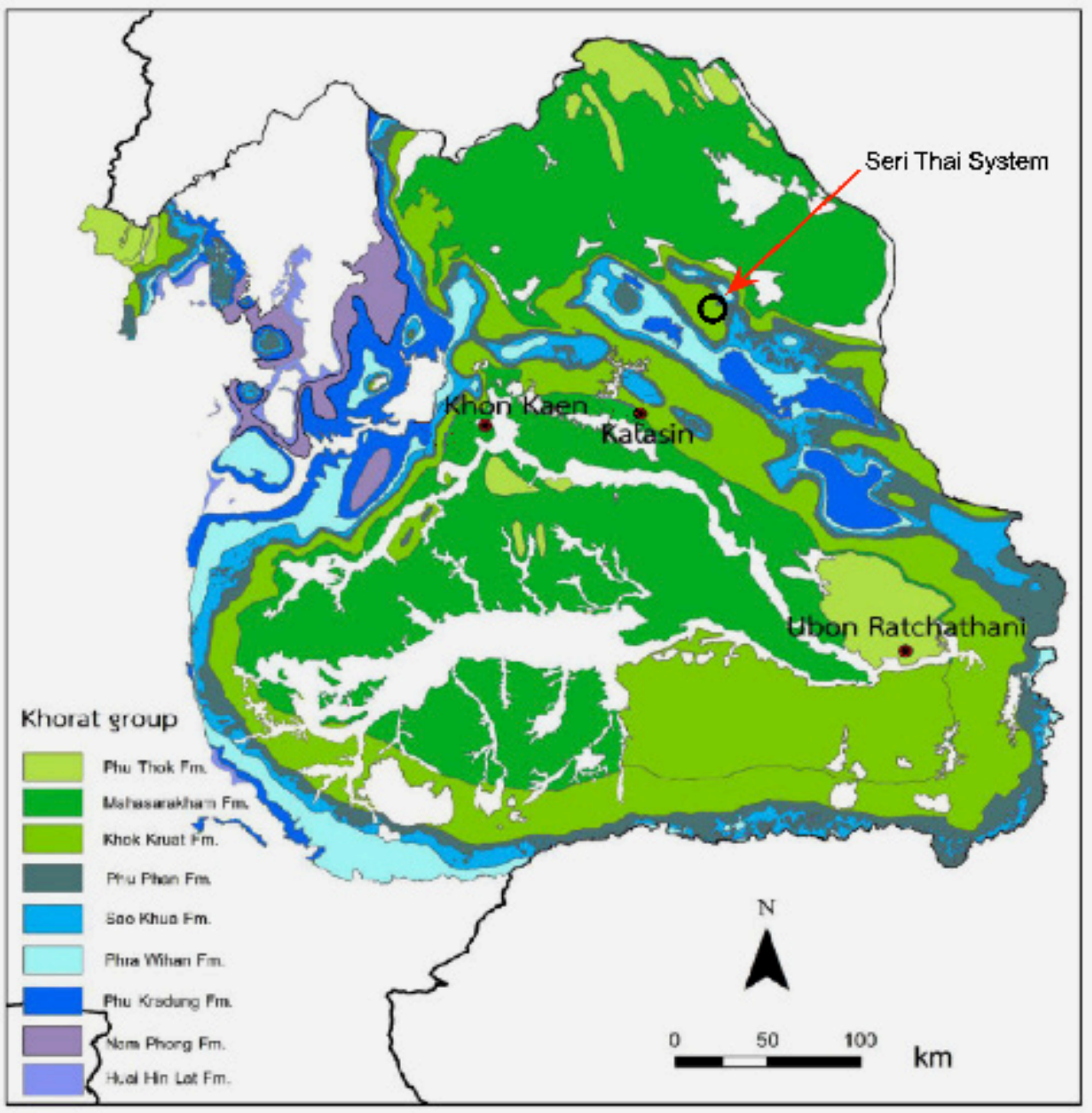


Figure 4. Geological map of Khorat Plateau, from Wongklo and others (2019).

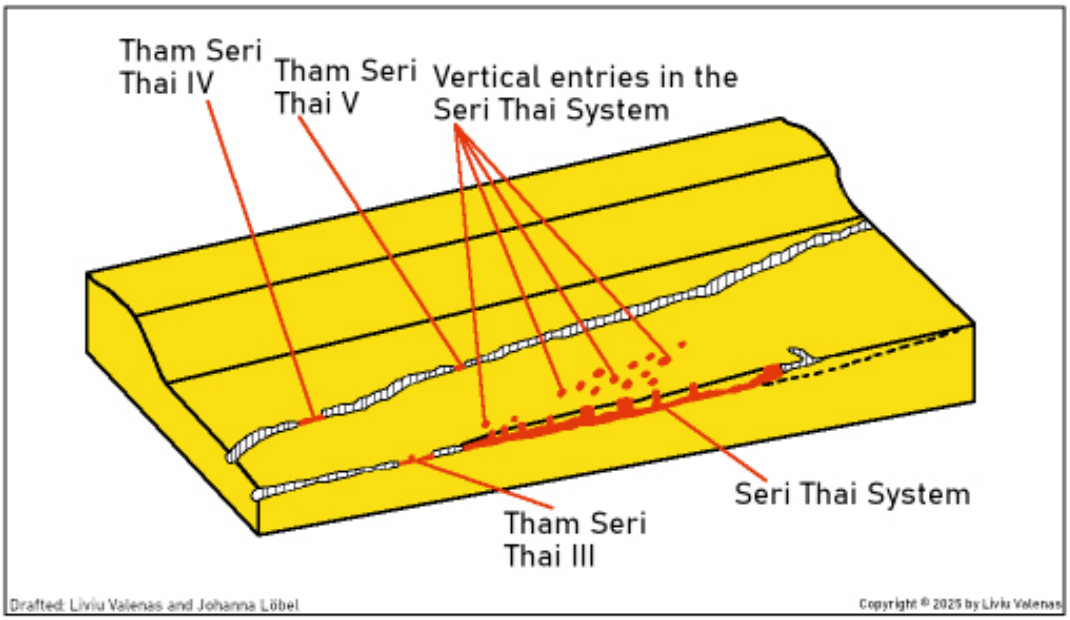


Figure 5. Block diagram of the relief in the vicinity of the Seri Thai System, showing the caves in the area:

Seri Thai System, 1,124 m long;
Tham Seri Thai III, 55 m long;
Tham Seri Thai IV, 32 m long;
Tham Seri Thai V, 16 m long.

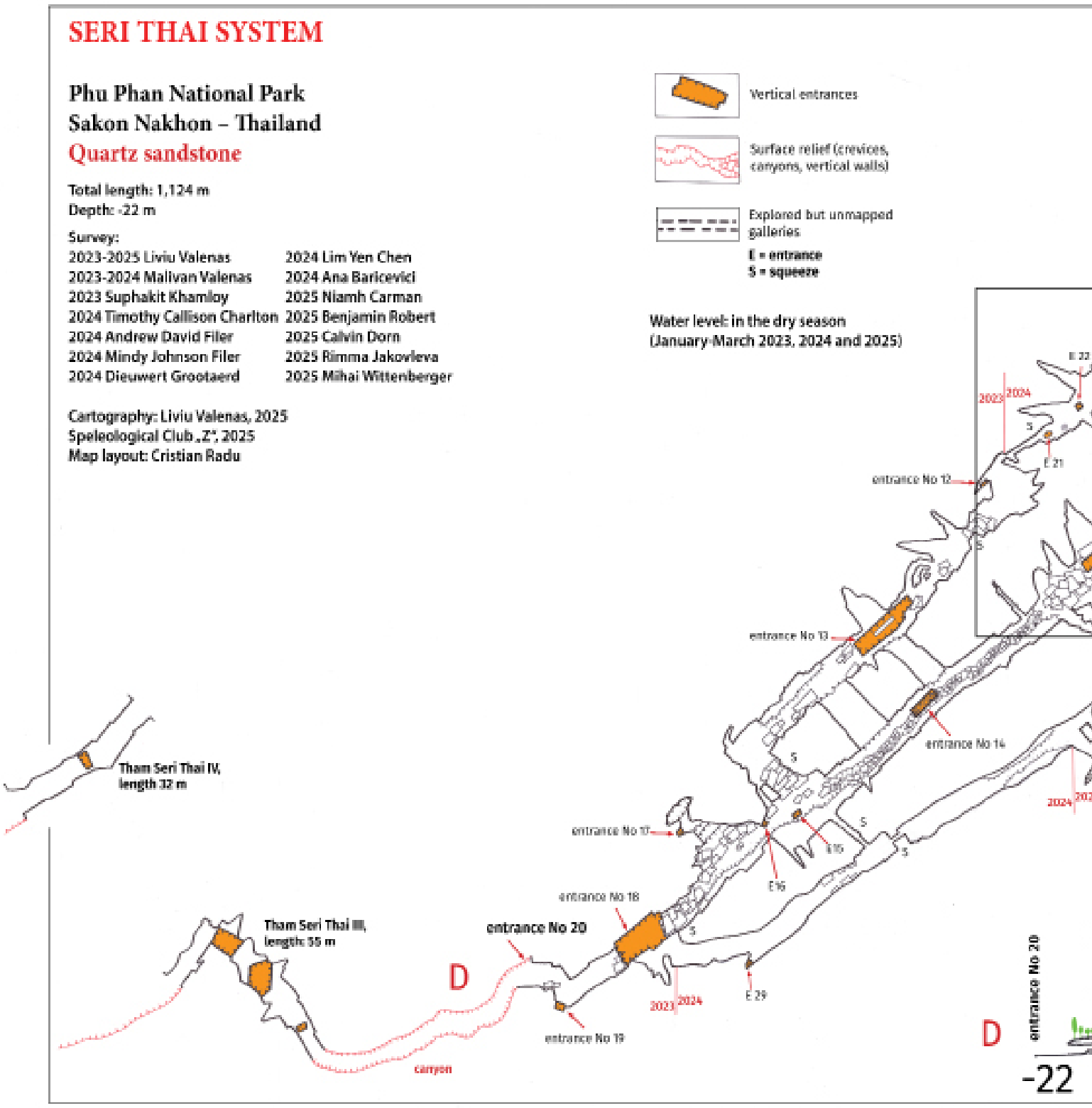
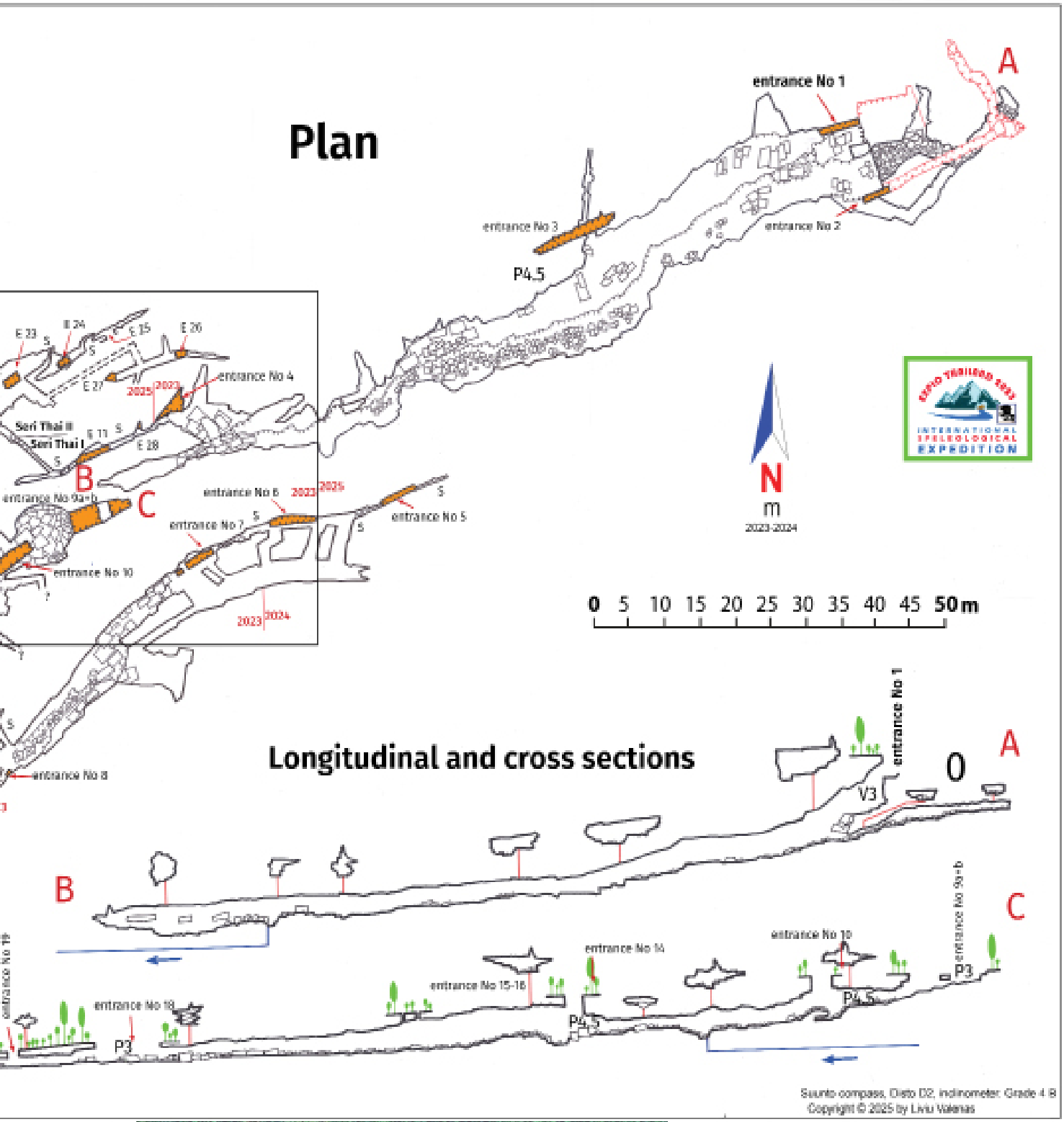


Figure 7. Plan and sections of the Seri Thai System, cartography by Liviu Valenas, 2025

Between 2016 and 2018 the cave research team of the Department of Mineral Resources (DMR) surveyed and investigated the geology of Tham Din Pieng (the results have not been published) and the long sandstone caves in Ubon Ratchathani province - Tham Patihan (Wilungkit and others 2021) and Tham Meut and Tham Ghia (Nakhiya 2020). In a review of the caves and karst in Thailand published by the DMR, Sattayarak (2021) summarised the geology of the Khorat Plateau, without mentioning the long caves, while Siripornpibul (2021) gave an overview on the origin of the sandstone caves, with surveys of Tham Patihan and Tham Din Pieng.

Since 2011 Liviu Valenas, together with members of the Speleological Club "Z" from Nuremberg, Germany, has been systematically exploring and surveying the most important caves



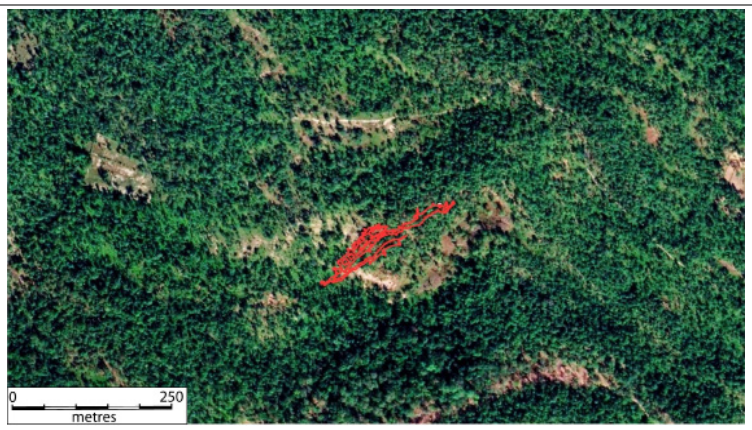


Figure 6. The Seri Thai System (in red) and surrounding area. As can be seen, the area is 90% forested (from Google Earth).

Figure 8. Entrance No. 27 of the Seri Thai System. The cave has a total of 28 entrances, the vast majority of which are vertical.

in the sandstones of North-east Thailand (Valenas 2019). This has resulted in the discovery or rediscovery of 95 caves, with detailed exploration and documentation. Prior to 2016 the longest known sandstone cave in North-east Thailand measured only 660 m in length, whereas currently three are known to exceed a kilometre in total length, one of which is approaching 3 km. Through these speleological explorations, the surface karst has been scientifically researched, with water samples from the sandstone karst in this area of Thailand being collected and analysed for the first time – at the Technical University of Freiberg, Germany. The results of these analyses have shown that the genesis of sandstone caves is much more complex and complicated than previously thought.

Research and Exploration of the Seri Thai System

The upper cave (Tham Seri Thai I) has been known to the region's inhabitants for centuries. Between 1941 and 1945, the cave was used as a weapons and food depot by the Seri Thai ("Free Thai") organization during the Japanese occupation and between 1965 and 1983 it was used by the People´s Liberation Army of Thailand, a guerrilla organization of the Communist Party of Thailand. It was not until 2011 that John Dunkley visited Tham Seri Thai I and estimated it to be (only) 150 m long (Dunkley and others 2018, Ellis 2017). In 2023 Liviu Valenas, Maliwan Valenas and Suphakit Khamloy conducted the first detailed speleological investigations of the cave, mapping 857 m of galleries (Valenas 2023a, 2023b, 2023c, 2024a, 2024b, 2024c). In that year, the Seri Thai System became the longest known sandstone cave in Thailand. In 2024 and 2025, Liviu Valenas organized two international caving expeditions, resulting in the cave's known length reaching 1,124 m (Valenas 2025b, 2025c, 2025d).

Methods

The Seri Thai System was surveyed with Suunto compass, Disto D2 and inclinometer. Cave entrances were positioned with a Garmin 62s GPS and later plotted on Google Earth. The underground photos were taken with a Nikon D 5200 camera, Tamron 18-155 mm lens, Metz 58 and Metz 62 flashes. The thin sections of sandstones were taken first with a reflected light microscope and secondly with double-polarized light. The pH value and temperature were determined at the sampling locations in Tham Patihan using a HQ40D digital dual-channel multimeter from Hach Lange GmbH. The pH electrode (Hach Lange GmbH) was calibrated with pH buffer solutions with pH values of 4.01 ± 0.02, 7.00 ± 0.02 and 10.01 ± 0.02 (25°C). The silica concentration was measured photometrically by DR890 colorimeter from Hach Lange GmbH, using the silicon molybdate method (measuring range: 1.0-100.0 mg/l SiO_2). Chemical analyses and photomicrographs of the sections were performed in the laboratories of the Technical University of Freiberg, Germany.

Lithology and Tectonics

The description of the Cretaceous formations of North-east Thailand by Meesook (2011) (Figure 4), indicates that the Seri Thai System is most likely located within the Khok Kruat Formation and this is confirmed by the stratigraphic column (Figure 9).

The Khok Kruat Formation is widely distributed in the outer parts of the Phu Phan mountain range (Veeravinantankul and others 2018). In general, the formation consists of brown to fine to medium-grained reddish-brown sandstone with some conglomerate layers, siltstone and reddish-brown claystone (Figures 10 and 11). Plant remains, bivalve fragments, and vertebrate fossils have been recorded in the formation (Meesook 2011). In the southern part of the Khorat Plateau the formation is widespread in Muang, Prathum Ratchawongsa and Phana districts of Amnat Charoen province; Trakanputphon, Kutkhaopum,and Si Muangmai districts of Ubon Ratchathani province, and parts of Patiu district of Yasothon province. The Khok Kruat Formation overlies the sandstones of the Phu Phan Formation (Meesook 2011).

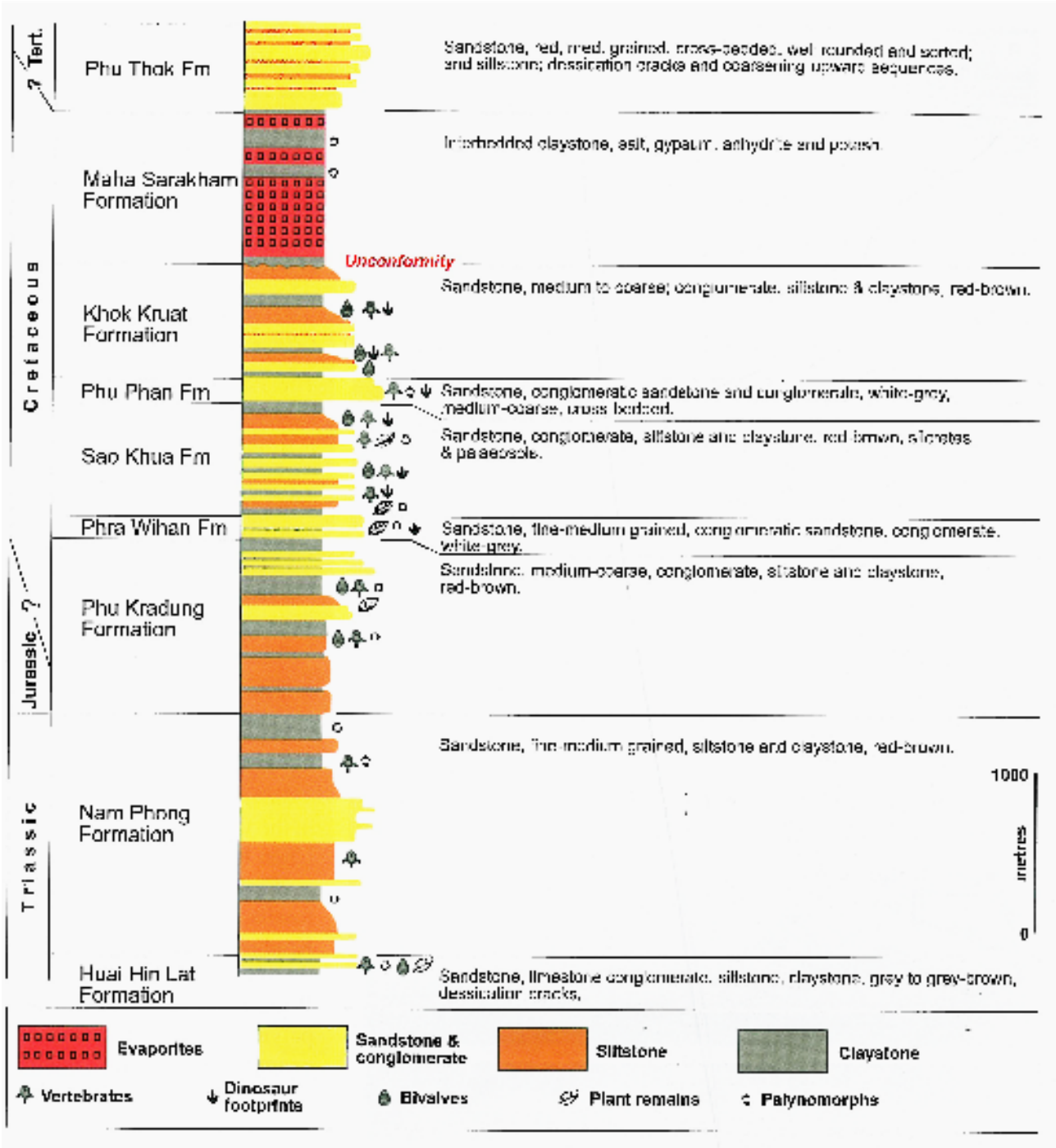


Figure 9. Mesozoic stratigraphic column for North-east Thailand, after Meesook (2011).

Plant remains, bivalve fragments, and vertebrate fossils have been recorded in the formation (Meesook 2011). Quartz sandstones are detrital sedimentary rocks in which the mineralogy is dominated by quartz (De Waele & Gutiérrez 2022), they should contain 95% quartz and <5% feldspars and lithics (Pettijohn and others 1987). Quartz is one of the most resistant minerals to chemical weathering. However, this resistance decreases significantly in tropical areas with high temperatures and heavy rainfall.

Although none of the authors cited above mention the presence of calcium carbonate in the cement that ensures the cohesion of the sandstones of the Khok Kruat Formation, this carbonate exists. Its presence is proven by chemical analyzes of the waters from the streams in the caves of this formation, and also by the speleothems (drapes, stalactites, rimstones, etc.) of calcium carbonate (Figure 12) that appear in the large caves in the Khok Kruat and Phu Pha formations. In the area of Tham Din Pieng, in the underground streams in the cave and in the main karst spring, the concentration

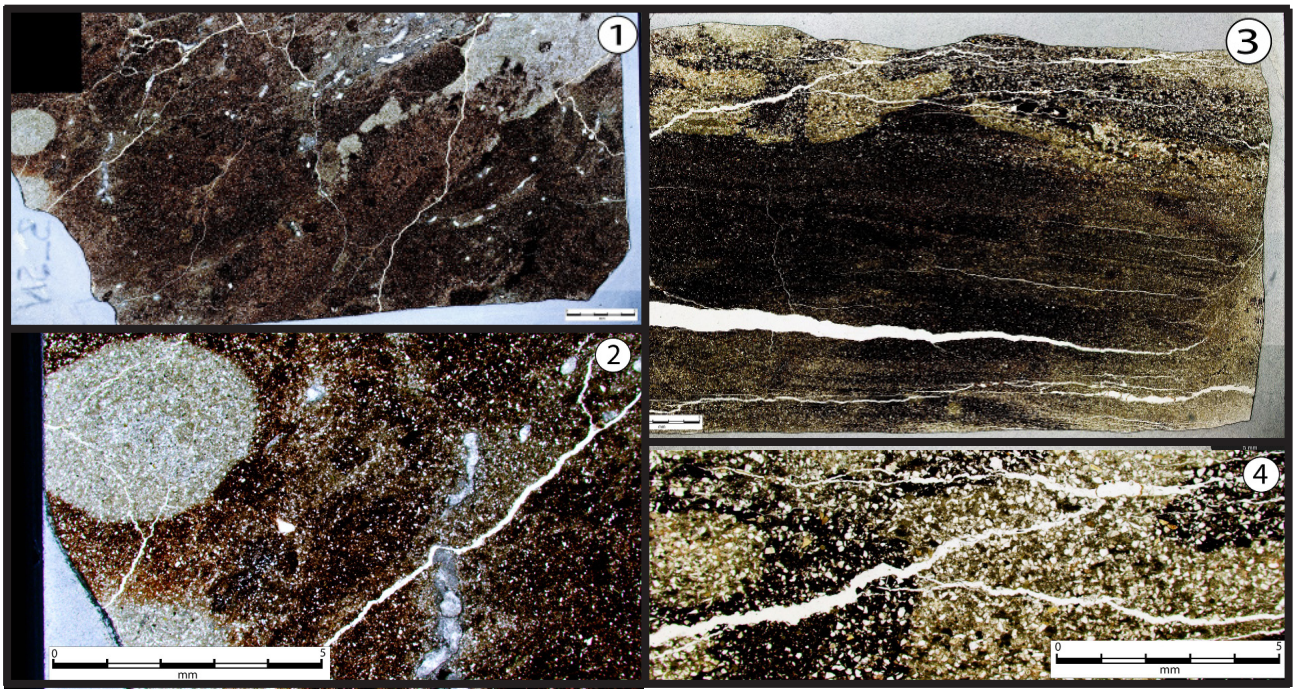


Figure 10. Photomicrographs of different layers of sandstones in the Seri Thai System. The sandstones contain varying percentages of feldspar, quartz, various rock fragments and calcite inclusions, cemented by syntaxial overgrowths. All quartz sandstone samples contain calcite veins. Photos by TU Bergakademie Freiberg.

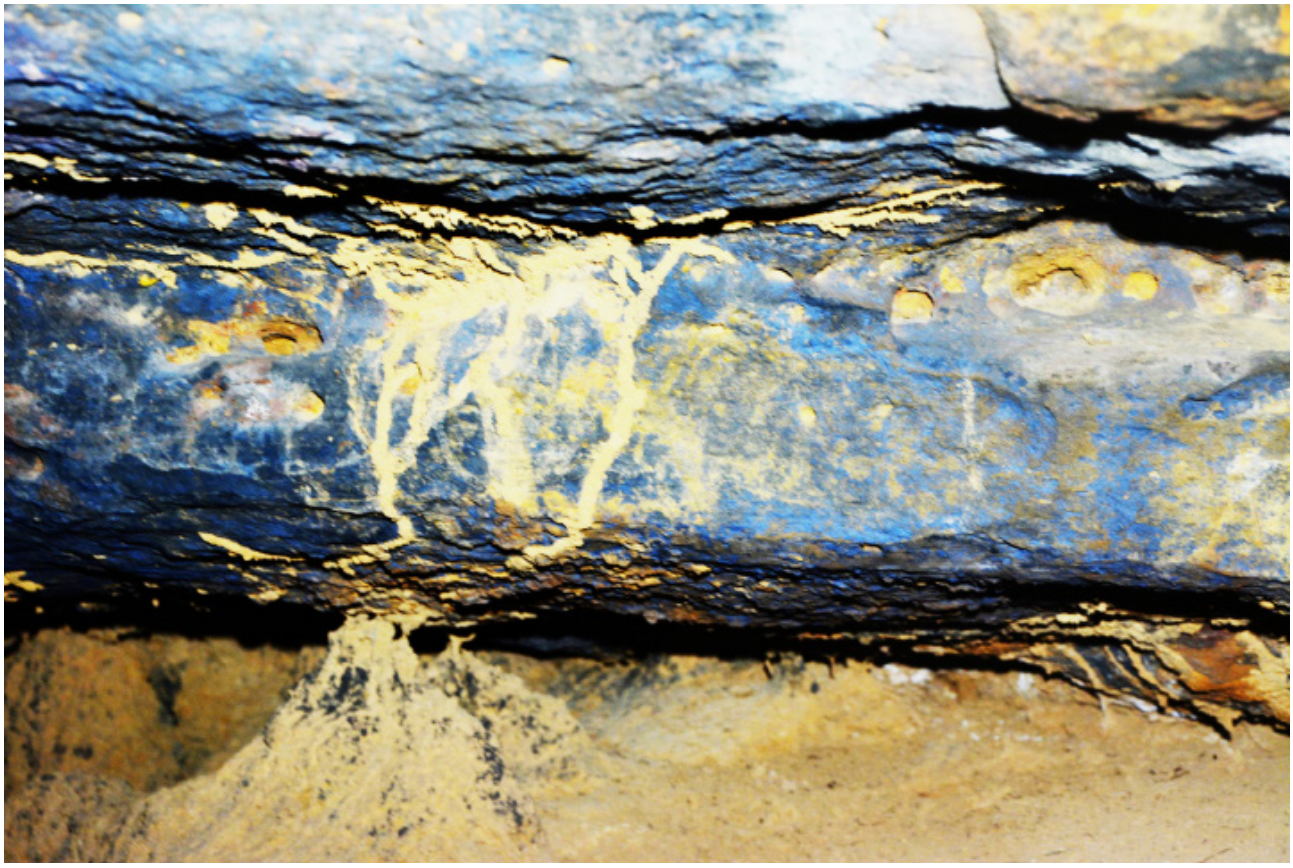


Figure 11. Top, quartz sandstone layer with manganese mineralization; bottom, clay layer.

Figure 12 (upper and lower). Examples of calcium carbonate speleothems in the Seri Thai System.

of calcium carbonate exceeds even the waters of the limestone resurgences. When we refer to calcium carbonate, we are mainly talking about the cement that ensures the cohesion of sandstones and only secondarily about the calcite veins in quartz sandstones. The Seri Thai System is developed on a major fault, oriented north-east to south-west. At a distance of 10 to 15 m from this fault are two secondary, compressional faults, along which the parallel branches of the Seri Thai System are formed. Between these faults are several perpendicular joints on which the connecting galleries are developed. In other words, the Seri Thai System is formed on a "chessboard" tectonic system, that is, in a system of perpendicular faults. The cave system has been significantly affected by active tectonics. Many galleries are vertically cut by "micro-faults" with throws of between 5 and 10 cm. Gravitational distension cannot be taken into account because the sandstone package of the cave roof is very thin: from two to four metres. We believe that active tectonics is also directly responsible for the 25 vertical inlets (e.g. Figures 13 and 14) in the Seri Thai System. As several seismic movements have occurred, staggered over time, under some vertical inlets the collapse cone is almost intact, while under others these collapses have been completely eliminated, by the process of arenisation and also by mechanical transport carrying out the debris by the underground stream during the rainy season. Similarly, only 70 km to the east, in Laos, the karst area near Thakhek has been and is affected by active tectonics. The caves here show sectioned columns and pillars, and massive cave collapses occur periodically (Valenas 2024d). The regional tectonics affect both areas.

The Seri Thai System Description

A sinkhole descending a 3 m vertical drop leads to the "historical" entrance of Tham Seri Thai I, 4 m wide and 2.5 m high (Figure 15). After another 3 m vertical drop, the main gallery (Figure 16) is intercepted. To the north-east, it can be followed for 27 m. Downstream, to the southwest, the gallery is initially very wide (up to 11 m) and 3-4 m high. After 40 m, ascending a slope to the right, the second entrance is reached, in the form of a 5 m deep pit. The main gallery continues downhill, begins to narrow, and 120 m from Entrance No. 1 the gallery becomes impenetrable. Before the gallery ends, by climbing up a vertical slope, one encounters

Figure 13. A vertical entrance to the Seri Thai System. Almost all of these are the result of active tectonics. (Photo by Calvin Dorn.)

Figure 14. Entrance to the Seri Thai System produced by collapse generated by active tectonics.

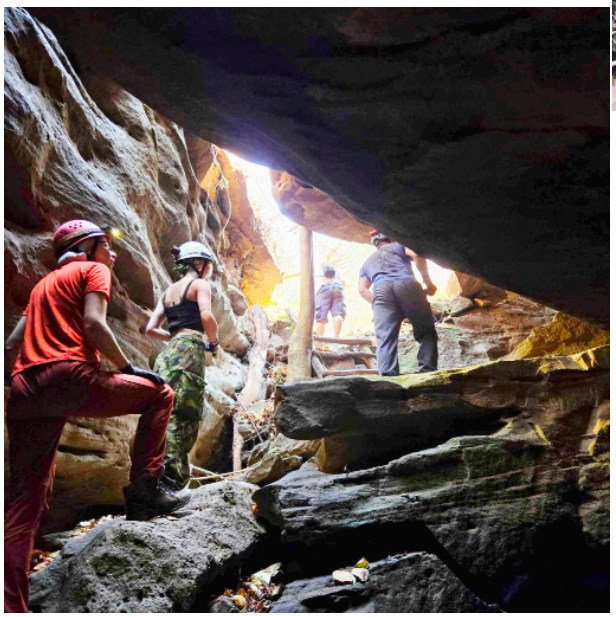


Figure 15. The "historical" entrance to Seri Thai I Cave. (Photo by Benjamin Robert.)

another exit through a 3 m pit (Figure 17). At the base of this vertical slope is the start of an extremely narrow gallery, shaped like an inverted T. The north-east branch provides the morphological connection with Tham Seri Thai II. In Tham Seri Thai II the main gallery begins just a few metres

Figure 16. The main galleries in the Seri Thai System are relatively wide and in many places wall flows of calcium carbonate occur.

Figure 17. Entrance No. 3 (P 3) to Seri Thai I Cave. (Photo by Andrew David Filer.)

from the end of Tham Seri Thai I, through a 3 m pit (Figure 18). It runs straight in the same general direction, southwest. It is generally a gallery 5 to 10 m wide and up to 4 m high. Along its entire length it has seven vertical entrances, shaped like potholes and up to 5 m deep. These are windows into the main gallery (Figure 19). After 149 m it opens to the surface with a horizontal entrance which, during the monsoon, has the character of a high-flow resurgence. From the traces left by a large flood on the walls of the main gallery of the Seri Thai System, we estimate that in the monsoon season the maximum flow of the main stream at the exit of the cave is 500 l/sec, exceptionally reaching about 1000 l/sec.

From the middle section of this gallery, through three relatively wide galleries, each no more than 1 m high, the connection is made with the northern branch of Tham Seri Thai II Cave. To the north-east, another parallel branch begins, 141 m long,

Figure 18. Entrance No. 9 (P 3) to the Seri Thai II Cave. (Photo by Maliwan Valenas.)

Figure 19. Vertical entrance in Seri Thai II Cave.

which includes several entrances, seven of which are potholes, up to 4.5 m deep. To the south lies the southern branch of the system, with a main gallery 147 m long. It begins with three letterbox-shaped potholes (that is, rectangular in shape, 5-10 m long, but with a very small width, between 20 and 100 cm), up to 6 m deep. The gallery then includes wide sections, but also three difficult squeezes. At its end, a bedding plane only 25 cm high provides a direct connection with the middle main gallery of Tham Seri Thai II Cave. The system has a total length of 1,124 m, a vertical range of 22 m and the distance between extreme points is 257 m, giving a branching coefficient of 4.4.

Climatic Data

Climate has played and plays an extremely important role in the formation and functioning of this cave. The Seri Thai System is located at a latitude of 17° north, so it is in the tropical zone. However, the dramatic climate changes in recent decades have resulted in North-east Thailand starting to have a slightly subtropical climate. The characteristic of a climate strongly influenced by monsoon cycles remains. Global climate change has also manifested itself in the areas with water pits in North-east Thailand. The relatively dry months, December to April, have become extremely dry, with practically no rain at all in these months. Global climate change, characterized in the northeast of Thailand by 4 to 5 extremely dry months, transforms the plateaus into something similar to African savannas during these months. On the other hand, in the monsoon season, starting at the end of May, there are extremely heavy rains which have been the driving factor in the formation of the Seri Thai System. The average annual precipitation in the past was never high in North-east Thailand: 1399 mm in Khon Kaen province and 1515 mm in Surin province (Pfeffer 2013). In comparison, in Eastern Thailand, in Chanthaburi province, the average annual precipitation was 3235 mm, and in Southern Thailand, 2466 mm in Phuket province (Pfeffer 2013). With respect to average annual temperatures, we have data only for the neighbouring provinces: Khon Kaen (166 m altitude), average annual temperature 26.8°C and Udon Thani (178 m altitude), average annual temperature 26.7°C. These average data are only for the period 2003-2013 (Pfeffer 2013). Currently, with global climate change, temperatures are higher; in the hot and dry season they frequently exceed 40°C.

Geomorphology and System Genesis

The Seri Thai System is complex, with a complicated genesis. Three major faults and their intersections with bedding planes initiated the dissolution process of the quartz sandstones. This process of arenisation (Martini 1979, Doerr 2000, Wray & Sauro 2017) is accelerated in a tropical monsoon climate. The first to use the term "arenisation" (Figure 20) was Martini (1979), based on his study of karst in sandstones in the Eastern Transvaal of South Africa. The term subsequently gained international circulation. It is a concept that attempts to explain the dissolution of rocks considered insoluble. The concept aims to "reconcile" two quite contradictory concepts, related to the occurrence of well-developed karst in rocks characterized by very low solubility and slow dissolution kinetics. Slow dissolution along crystal and grain boundaries reduces the coherence of the rock and increases its porosity. After that, the loose particles and crystals are eroded and transported by surface and subsurface flowing water. So, it is a mechanical erosive process. According to the concept developed by Martini (1979), dissolution is not responsible for the removal of a significant rock mass, but plays a critical preparatory role (De Waele & Gutiérrez 2022).

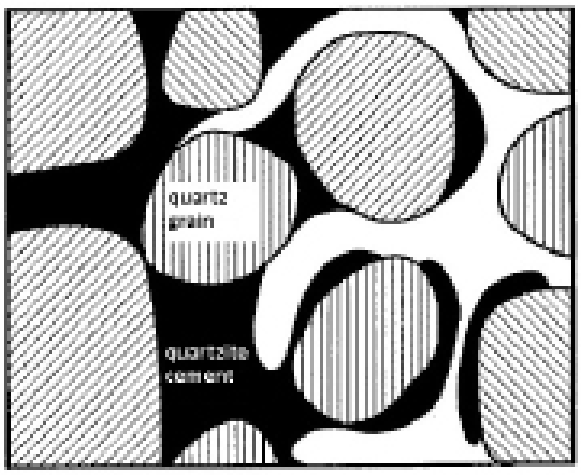


Figure 20. The arenisation process (after Doerr 2000).

The extremely humid and hot climate is the main driver of cave formation in the quartz sandstones of North-east Thailand, including the Seri Thai System. However, factors other than arenisation come into play. First, biocorrosion produced by organic acids released by tree roots (Figure 21). Initially, we assessed that biocorrosion caused by bats played a minor role (Valenas 2023b). However, after observing a radical change in the pH of the Tham Patihan (Ubon Ratchathani province) underground stream, caused exclusively by bat droppings and urine in 2025, this view was discarded. Over a length of only 110 m the pH of the underground stream in Tham Patihan changes from 6.9 to 3.6, exclusively because of bats. Biocorrosion makes the groundwater even more acidic, which accelerates the dissolution of quartz sandstone cement.

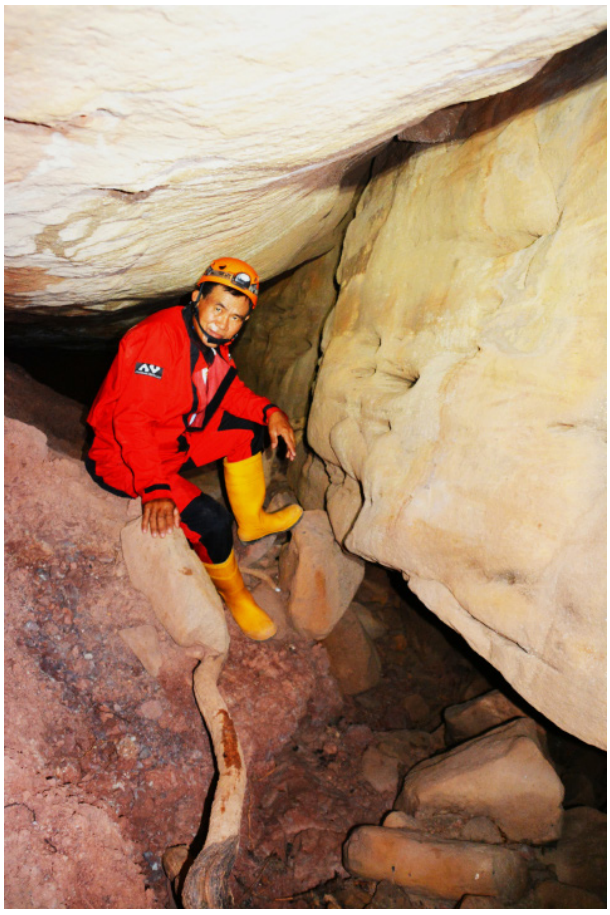


Figure 21. Massive root that runs horizontally through a sector of the main gallery in the Seri Thai System.

At this point we must make some clarifications. Almost all authors see a direct relationship between the dissolution of silica (quartz) and high and extremely high temperatures and alkaline pHs (De Waele & Gutiérrez 2022, Wray & Sauro 2017), (Figure 22). But it is about silica, not quartz sandstones as a whole. With the exception of the water samples collected by us in 2023-2025 in Tham Din Pieng Cave, where the pH was alkaline, the rest of the dozens of water samples from quartz sandstones in North-east Thailand have a lowered pH; i.e. the waters are acidic or extremely acidic. Under these conditions why are quartz sandstones dissolved? The explanation lies in the nature of the cement that ensures the cohesion of these sandstones. Both the quartz sandstones of

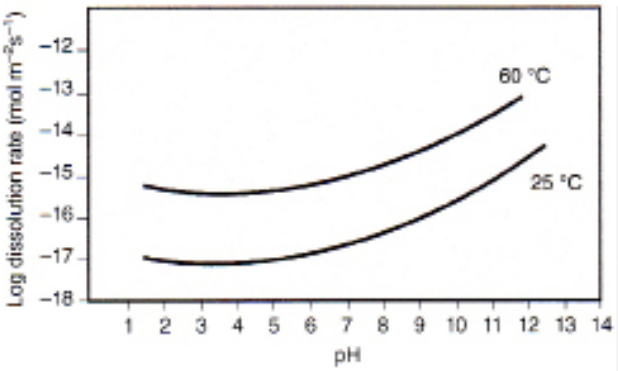


Figure 22. Dependence of quartz dissolution rate on the pH at 25°C and 60°C. (Source: De Waele & Gutiérrez 2022, adapted from Wray & Sauro 2017).

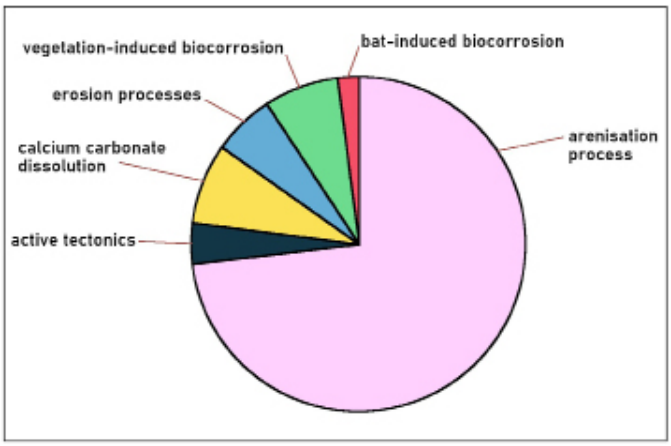


Figure 23. Theoretical model showing the six factors that created the Seri Thai System.

the Khok Kruat Formation and those of the Phu Phan Formation contain a significant percentage of calcium carbonate in their cement, and waters with an acidic pH act predominantly on this cement. Not only is the dramatic change in pH noteworthy, but also a substantial change in chemical composition. At the appearance of the underground stream in Tham Patihan, the calcium concentration was only 1.14 mg/l and that of calcium carbonate only 20 mg/l, after 110 m downstream the calcium concentration reached 74.4 mg/l and that of calcium carbonate, 175 mg/l (Table 2). The only explanation is the extremely acidic nature of the underground water, directly influenced by the large colony of bats in this gallery of Tham Patihan. It is certain that the same phenomenon occurs in the Seri Thai System during the rainy monsoon season.

Intensive research over two years (2023-2025) of the Seri Thai System has allowed, for the first time, the development of a theoretical model (Figure 23) for the formation of caves in quartzite sandstones in North-eastern Thailand. There are 6 factors that contributed to the formation of this large cave: (1) the arenisation process, (2) active tectonics, (3) mechanical erosion processes, (4) dissolution of calcium carbonate, (5) biocorrosion produced by vegetation, through organic acids released by plant and tree roots and (6) biocorrosion induced by bats.

The arenisation process remains the main factor in the formation of this cave. Active tectonics produced most of the cave ceiling collapses, which led to the appearance of 26 entrances in the form of potholes. Active tectonics also acted massively due to the fact that the sandstone roof in the entire Seri Thai System is only 2-4 m thick. Erosion has been fully manifested in the deepening of galleries (Figures 24 and 25) in the vadose flow system, during the rainy season. Chemical analyses of karst waters from other caves in sandstones in North-east Thailand have shown a significant percentage of calcium carbonate. The explanation lies in the fact that the siliceous cement that fixed the quartz grains also contains calcium carbonate. There is no pure cement, composed only of silicates, in the sandstones of North-East Thailand. In addition, the sandstones also contain veins of calcite, which in the Seri Thai System are visible to the naked eye. Finally, the biocorrosion produced by bat colonies (and the Seri Thai System contains a relatively large colony) plays a not inconsiderable role in the dramatic change in the pH of the groundwater

Name	T (°C)	pH	Cl (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	Na (mg/l)	NO_2 (mg/l)	K (mg/l)	Mg (mg/l)	Ca (mg/l)	$CaCO_3$ (mg/l)	SiO_2 (mg/l)
Tham Patihan The Upstream Underground Course	24.5	6.9	1.40	3.61	1.4	0.99	0.16	0.77	0.26	1.14	20.0	7.2
Tham Patihan Downstream Underground Course	26.2	3.6	4.30	< 0.1	0.55	0.64	< 0.1	3.03	7.29	74.40	175.0	4.1

Table 2. Physicochemical values of the underground stream in Tham Patihan Cave show the massive influence of biocorrosion produced by a large colony of bats.

Figure 24. The main gallery in the Seri Thai System, remodeled by erosion in the vadose flow regime.

Figure 25. Another part of the main gallery in the Seri Thai System, also remodeled by erosion in the vadose flow regime.

in this cave during the monsoon season. Through the excrement and urine that reach the flowing waters of the cave, these become extremely acidic. Unfortunately, we lack chemical analyses of the waters directly from the Seri Thai System, because during all periods of our research in this cave (January - April), it was completely dry. Of course, these six factors acted on an adequate stratigraphic and tectonic framework (contacts between different layers of sandstone, between sandstones and clays and favourable tectonics: major faults and a network of joints).

We do not yet know whether this model can be applied to all quartz sandstone caves in tropical and subtropical regions. It may remain, at least for the time being, a valid model only for the quartz sandstone caves of North-east Thailand.

Returning to the structural factors, an important role in the formation of the Seri Thai System is played by the alternation of sandstones and claystones (Figures 26 and 27). Thus, the cave can also be considered to be a lithological contact cave.

Figure 26. Alternating sandstone and clay layers in the Seri Thai System.

Figure 27. The Seri Thai System can also be considered a lithological contact cave, not only between sandstones and clays, but also between different sandstone layers.

The Seri Thai System initially formed in an epiphreatic regime, starting in the Middle Pleistocene, and was then remodelled into a vadose system with the erosion levels fully demonstrating this. At the present stage of karst research in North-east Thailand, the age of the caves can only be established in correlation with the river and stream terraces in the studied areas. The Seri Thai System can be extrapolated as terrace 1 of the hydrographic network in the area and this terrace cannot be older than the Middle Pleistocene.

Are the Seri Thai Landforms True Karst?

The findings of recent research involving the Seri Thai System have raised questions in some quarters as to whether these landforms can properly be classified as "karst". Until recent times there were those who would consider only caves and surface relief on highly soluble rocks (such as carbonates, magnesites and halites) to represent karst. Similar landforms on much less soluble rocks (such as sandstones and quartzites) were termed by some, effectively following Knebel (1908 - cited by Halliday 2004) as "pseudokarst". There has been considerable controversy around the use of this term but Eberhard and Sharples (2013) rejected it. They showed that it

(a) [is] poor classification practice in principle;
(b) unnecessarily duplicates mainstream approaches to landform classification; and
(c) is a karst-centric terminology for non-karstic phenomena.

In 2010 Pfeffer concluded: *Siliceous rocks can form a true karst under conditions of intensive climate (precipitation and high temperatures)*. Wray & Sauro (2017) observed: *... limestone and similar highly soluble rocks were long believed the sole host for large karst drainage systems ... Quartzose caves and dolines are similar in size, though, to the vast majority of smaller limestone caves and dolines, and are thus significant, and often very impressive, sandstone karst features.* More recently, Brazilian researchers (Pereira and others 2022) confirmed that *Karstification in quartzitic sandstones is a reality demonstrated worldwide by the exploration and research of caves in sandstones.* At an international symposium in Karlow, Poland (May 2023), there was a heated discussion about whether the term "pseudokarst" had any scientific basis and most participants disputed the validity of the term. Bearing these studies in mind, it is clear that the landforms developed on quartz sandstones in North-east Thailand, documented by Valenas (2023a, 2023b, 2024a, 2024b), should be considered a true karst.

Conclusions

The Seri Thai System is an extremely complex underground network and is so far unique in Thailand among the sandstone caves. It is unique due to the arrangement of the galleries in a dendritic system. Large or relatively large caves in the sandstones of north-east Thailand (Table 1) are very different from each other. Tham Nam Lod (Valenas 2016, 2023a) is a tectonic cave, because the primary role in forming this cavity was a major rectilinear fault. Of course, this cave was also later remodeled through the processes of arenisation and subsequent erosion. Tham Meut and Tham Ghia (Valenas 2023a) are tunnel caves with a single, large, relatively straight gallery, developed on bedding faces. Tham Patihan is also unique among the sandstones of Thailand because it has two levels, the lower level being permanently active. Tham Phou Pom (Valenas 2023a) is a maze cave with narrow galleries developed along both bedding planes and tectonic joints. The maze caves of Tham Din Pieng (Valenas 2025a) and Tham Phusi Keuw (Valenas 2025c, 2025d), developed in sandstone with carbonate cement, are unlike any others. The former, with a length of 2,737 m, is also the longest sandstone cave in all of South-east Asia. This brief list alone demonstrates the complexity of the subject. The Seri Thai System is formed on three parallel faults and on bedding discontinuities. It is also a lithological contact cave, between different layers of sandstone and claystone. Its formation is a direct consequence of the tropical monsoon climate, characterized in north-east Thailand by high rainfall and temperatures. The Seri Thai System is part of a true karst, albeit one developed on sandstone – hence it may be termed a silicate karst (Valenas 2023a), mainly due to the arenisation process of quartz sandstones, or a sandstone karst (Mouret & Mouret 1994).

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Photographs, unless otherwise attributed, are by Liviu Valenas.

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