Some Upper Palaeozoic fossil localities in the Vientiane Contract Area, Lao PDR, and their Geological Importance

Robert B. Stokes[1], Paul Lovatt Smith[2], Andrew Racey[3], C. Howard C. Brunton[†], Orapin Dawson[4], Andrew R.H. Swan[5], Michael F. Whitaker[6]

Received : 2 Febuary 2011 ; Accepted : 13 September 2011

Abstract

A reconnaissance geological mapping of parts of central and western Laos as part of a petroleum exploration contract led, amongst other results, to the discovery of several fossil locations which are important for the interpretation of the stratigraphy and structure of the region. Significant Upper Palaeozoic localities include (1) Early Carboniferous (?Late Visean or earliest Namurian) palynological flora from the Phatha Formation exposed on Route 8, Bolikhamxai Province indicating that the sediments are older than previous thought; (2) A Serpukhovian (Early Namurian) brachiopod from the Nam Thom Formation at Ban Bochan anthracite mine, Vientiane Province, shows that the coal-bearing sediments west of the Vientiane Basin are Early Carboniferous and not of Late Carboniferous or Late Carboniferous to Early Permian age as previously described; (3) Lower Bashkirian (Late Namurian) cephalopods most probably from the Nam Thom Formation on the Nam Ngom, Bolikhamxai Province indicate a northward extension of the Late Namurian/Early Bashkirian fauna of Ban Phit in Khammoun Province; (4) Early to Late Permian (Asselian/Sakmarian – Midian) foraminifera from core samples from an unrecorded exploration well at Gnommelat, Khammouan Province proves carbonate sedimentation of the Nalang Formation from the Early (Sakmarian) to Late (Midian) Permian; (5) Partially silicified Middle Permian (Murgabian) fusulinids from the Nalang Formation at Ban Chamngoua, Luang Prabang Province confirm that the overlying *Dicynodon*-bearing red-beds can be no older than Late Murgabian and may be no older than Midian; (6) Late Permian (?Dzhulfian – Dorashmian) fusulinids from the Nalang Formation on the shores of the Nam Ngum Reservoir, Vientiane Province prove one of the youngest marine Permian limestones in SE Asia. The exposure is in the core of a SE-plunging anticline in an area previously mapped as Mesozoic. It shows a south-easterly extension of Permian limestones of the Vang Vieng region and leads to the prospect that they may provide suitable reservoir rocks at depth even further along this trend.

Keywords: Carboniferous, Permian, palynology, brachiopod, ammonoids, fusulinids, foraminifera, algae.

---

[1] *Geoscience, Mahidol University, Kanchanaburi Campus, Sai Yok, Kanchanaburi 71150, Thailand,*

[2] *Foxwood, Cinderford Lane, Hellingly, Hailsham, East Sussex BN27 4HL, UK,*

[3] *British Gas, 100 Thames Valley Park Drive, Reading, Berkshire, RG6 1PT, UK.*

[4] *32, Culham Drive, Maidenhead, Berkshire, SL6 7PW, UK,*

[5] *School of Geography, Geology and the Environment, Kingston University, Kingston upon Thames, Surrey KT1 2EE, UK,*

[6] *Det norske oljeselskap ASA, Nedre Bakklandet 58c, 7014 Trondheim, Norway.*

** Corresponding author : E-mail: surbitongs@gmail.com*

Introduction

The Vientiane Contract Area of the Lao PDR covered 37.500 km^2. It was awarded for petroleum exploration in 1991 to a group of which Monument Resources (Overseas) Ltd (MROL) was the operator. Following an initial review of previous work, five field trips were made between November 1991 and December 1993, resulting in the production of a series of 30 geological maps at a scale of 1:100,000 corresponding to the topographical sheets of the *Service géographique*. A total of 549 outcrop localities were visited and described, and 422 samples collected for analysis. Here we present, in roughly stratigraphic order, the results of the palaeontological analysis of some Upper Palaeozoic localities which are important in terms of the stratigraphic and structural interpretation of the area. The field work was carried out by RBS and PLS with the assistance of staff from the Department of Geology & Mines and Geomining Enterprise (Vientiane). Unless otherwise stated, fossil identifications and their stratigraphic assignments were made by CHCB (brachiopods), OD (fusulinid foraminifera), AR (smaller foraminifera and algae), ARHS (cephalopods), and MFW (palynology), Subsequent interpretations are by RBS and PLS. The geographic locations below refer to the 1:100,000 scale topographic map series dated 1985, published by the Lao PDR *Service géographique d'Etat*.

Lithostratigraphy

The lithostratigraphic scheme used by MROL was based on the stratigraphic summary of the geology of the Vientiane region given by Pham Van Hung & Bountheung Phengthavongsa[1] (see also Lovatt Smith & Stokes[2]: figure 5 page 37). We adopted their Nam Thom and Nalang Formations but introduced the Phatha Formation (unpublished internal MROL reports) for the Early Carboniferous sediments which form a triangular outcrop at the northern end of the main Khammouan Uplift. Unfortunately the relationships of this unit to other Palaeozoic strata are not seen as it is always faulted ; it is overlain unconformably by the Cretaceous Nam Set Formation (equivalent of the Phu Kradung Formation of Thailand).

Phatha Formation (C_1pt). The unit consists essentially of indurated sandstones, conglomerates, claystones and coals. The sandstones are poorly-sorted, very fine-(laminated), fine-(fractured) and medium-grained (chloritised) and show severe compaction by their deformed clasts and sutured grain contacts. We recognise this unit East of 103°30' East. It may be a lateral equivalent of the Nam Thom Formation, but the high degree of induration and earlier biostratigraphic assignment suggest the possibility that it is older.

Nam Thom Formation (*Assise de Namthom*, C_{1-2}nt). This formation includes a wide variety of lithologies ranging in age from early to late Carboniferous. Common rock-types include dark grey, reddish or black shales, coals and siltstones ; locally massive grey limestones, sandstones and conglomerates may be developed. We recognise this unit West of 103°30' East.

Nalang Formation (*Assise de Nalang*, C_3-P_1nl). This unit occurs throughout the Contract Area and consists essentially of massive, grey to dark grey crystalline limestones with chert nodules, particularly in the upper part. Although the published age of this unit given by Pham Van Hung & Bountheung Phengthavongsa[1] showed it to extend no later than the Early Permian, we suspect this to be a typolographical error and regard the Nalang Formation as extending upwards into the Late Permian. All the Permian localities discussed below are attributed to this unit.

Carboniferous

1. Early Carboniferous (?Late Visean or earliest Namurian) Phatha Formation on Route 8, Bolikhamxai Province.

Location. 1:100,000 Sheet E-48-65 grid reference 355095 (locality 5.12.91-3) and 357099 (locality 5.12.91-4).

Geology. Outcropping along a new road cut for almost 2 km, approximately 16 km from the junction with Route 13, is a sequence of alternating sandstones and black claystones. The sandstones are red-brown to grey, buff-weathering, fine to coarse and conglomeratic with quartzite clasts, poorly sorted, and indurated. The claystones are grey to black, in beds 1 to 2 m thick. The sequence is deformed and locally

overturned, with dips ranging from 40° to 70° and strike varying from 070° to 130° probably due to faulting. **Biota.** Three samples were sent for palynological analysis. The results are as follows :

5.12.91-3A. The occurrence of *Tripartites vetustus, Tripartites mirabilis* and *Triquitrites marginatus* var. *comptus* indicate a Late Visean – Early Serpukhovian (= ? earliest Namurian age = VF/NC zones of Clayton *et alia* 1977). Associated palynomorphs, consistent with this age determination, include abundant *Lycospora* cf. *rugulosa* and *Lycospora pusilla;* common *Lycospora* cf. *rotunda, Leiotriletes* spp., ?*Granulatisporites* spp., *Punctatisporites* spp.; rare *Acanthotriletes* spp.; and single specimens of *Lycospora noctuina, Convolutispora* sp., *Discernisporites micromanifestus* and *Anapiculatisporites hispidus.*

5.12.91-3. The occurrence of *Diatomozonotriletes cervicornutus* together with *Raistrickia* cf. *nigra* and a single questionable specimen of *Rotaspora ergonulii* indicate a Late Visean – Early Serpukhovian age (= ? earliest Namurian age = VF zone of Clayton *et alia* 1977). Associated palynomorphs include abundant *Lycospora pusilla, Anaplanisporites* cf. *baccatus;* common *Lycospora noctuina, Punctatisporites spp., Knoxisporites* cf. *stephanephorus;*, rare *Lycospora priddyi, Raistrickia* cf*. clavata;* and single specimens of *Anapiculatisporites hispidus, Tripartites* sp., *Calamospora* spp*., Leiotriletes tumidus, Stenozonotriletes* sp., *Microreticulatisporites microreticulatus* and *Auroraspora cf. macra.*

5.12.91-4. Although no age-diagnostic palynomorphs were recovered, the lean assemblage is characterised by taxa forming the 'background flora' of the samples from locality 3, confidently dated as Late Visean – Early Serpukhovian. Therefore a similar age is assigned to this sample. Sporomorphs include common *Lycospora pusilla*, *?Lycospora rotunda*, rare *Leiotriletes* spp., *Granulatisporites microgranifer, ?Triquitrites marginatus, Lycopora rotunda* and single specimens of *?Cirratriradites/ Vallatisporites* sp., *Lophotriletes* sp., *Acanthotriletes* sp., *Dictyotriletes castaeniformis* and *?Anapiculatisporites hispidus.*

Importance of the localities. The sediments of this area were originally mapped as Upper Moscovian by Fromaget[3] (map 4) and later interpreted as being possibly equivalent to the Lower Khorat Group by Workman[4] (figure 2 & 3). The diverse palynological floras give an Early Carboniferous (Mississippian: Late Visean – Early Serpukhovian) age, suggesting that either the unit covers a long span of time (at least Serpukhovian to Moscovian) or that the unit is somewhat older than Fromaget had concluded.

2. Serpukhovian (Early Namurian) Nam Thom Formation of Ban Bochan anthracite mine, Vientiane Province.

Location. 1:100,000 Sheet E-48-49 grid reference 049651 (locality 16.4.92 RBS 2).

Geology. A steeply dipping sequence of laminated sandstones, shales and anthracite horizons is exploited in an open cast mine north-west of Ban Bochan. Exposures to the south-west of the main part of the mine include a black, bituminous, argillaceous limestone with pyrite which yielded abundant fossils. These were identified in the field as productid brachiopods with calcitic shells, internal and external mould of the gastropod *Bellerophon* sp., crinoid ossicles and tabulate corals.

Biota. The productid brachiopod was subsequently regarded as distinctive and comparable to the Chinese genus *Kueichoviella* which is of Serpukhovian age. Two samples from this locality proved barren of palynomorphs.

Importance of the Ban Boham fauna. The Serpukhovian age of the brachiopod indicates that the coal-bearing sediments west of the Vientiane Basin, which extend for 80 km from the Mekong to the Nam Lik, are Early Carboniferous deposits. This conflicts with previous datings as Late Carboniferous[5], Late Carboniferous (Stephanian) to Permian age[6], Early Permian[7]. Fontaine & Pouymot[8] recently recorded palynological evidence for a Permian age for anthracites at Na Duang, Loei Province in Thailand. These authors were inclined to consider that the anthracites in Laos and Thailand were probably formed during the same period. There is clearly a need for more detailed work to date these economic deposits.

3. Lower Bashkirian (?Nam Thom Formation) of Nam Ngom, Bolikhamxai Province.

Location. No geographic coordinates are available. A hand-held GPS reading gave a latitude of 18°29'50" North, and a longitude of 104°25'08" East (unknown datum)
Geology. The specimens recorded here were collected by a geologist working on a hydrological project who later donated them to Monument Oil & Gas plc. No details of the outcrop are available.
Biota. The specimens collected here include a number of ammonoids, an orthoconic cephalopod and a brachiopod. The orthocone is either an orthoceratid nautiloid or bactritid, and like the brachiopod, cannot be identified sufficiently to be of stratigraphic value. The ammonoid specimens do not preserve suture lines, however the external ornament is characteristic of the genera *Phillipsoceras, Retites* and *Reticuloceras* of Namurian R_1 age. The specimens could be the same as those identified as (?) *Eumorphoceras cf. reticulatum*" by Fromaget[7] from black fetid limestones at Ban Phit at Km 51.5 on the road from Thakhek to Vinh. One specimen lacks the distinctive ornament indicated in the specimens above and appears to belong to a different group, resembling the genus *Homoceratoides.* Although this is a long-ranging genus, the specimen shows particular similarity to specimens from Europe and the Urals of Namurian R zone age. The fauna is certainly Late Carboniferous, and most probably Late Namurian in age, and probably from the Namurian R_1. This corresponds to the Kinderscoutian in terms of European stages, and in turn corresponds to the lowest part of the Bashkirian Series in the current international classification.
Importance of the locality. The fauna shows a northward extension of the mid-Carboniferous (Late Namurian/ Early Bashkirian) fauna of Ban Phit into Bolikhamxai Province. Fromaget[3] (map 4) had mapped undifferentiated Devonian-Dinantian and undifferentiated Ouralian-Permian units in this area, but it is difficult to discern to which of these units the cephalopod locality belongs.

Permian

4. Early to Late Permian (Sakmarian – Midian) Nalang Formation core samples from exploration well at Gnommelat, Khammouan Province.

Location. 1:100,000 Sheet E-48-91 grid reference 190470. Core fragments in the forest next to a cemented-in well-head and mud-pits. According to a local elder at Ban Gnomelat the well was drilled by a French company in ca. 1938 but there are no known records from this well, nor of its existence. Core fragments are of 300 (top hole), 110 and 80 mm diameters.
Geology. Limestones varying in colour from light grey to black related to argillaceous content. Biomicrite with calcite veins in parts; some reworking visible in parts. Occasional bands of chert nodules.
Biota. Three core fragments gave the following results : 22.11.91-13. Mudstone of late Early Permian (Asselian/ Sakmarian – Yahtashian) age with rare foraminifera : *Robustoschwagerina* sp., *Palaeotextularia* sp. 22.11.91-19. Packstone/boundstone of Middle to early Late Permian (late Murghabian – Midian) age with a faunal assemblage similar to that of NE Thailand. Dominated by *Calcitornella, Tuberitina, Tubiphytes* and *Girvanella* as binding elements. Skeletal elements include *Langella, Pseudovermiporella, Globivalvulina, Nodosarina, Hemigordius, Geinitzina, Baisalina, Climacammina, Cribrogenerina* and ?*Paraglobivalvulina*. 22.11.91-21. Packstone of late Middle to early Late Permian (late Murghabian-Midian) age. The assemblage is similar to that of NE Thailand and includes *Ungdarella, Tubiphytes, Boultonia, Nankinella, Neofusulinella, Schubertella, Codonofusiella* (?), *Globivalvulina, Parafusulina, ?Schwagerina, ?Maklaya/ Cancellina, Rauserella, Neoendothyra, Tubiphytes, Macroporella* and other Dasycladacean algae.
Importance of the locality. The core material proves an earlier, unrecorded, interest in the petroleum potential of the location with known oil seeps, and proves carbonate sedimentation from the Early (Asselian/Sakmarian) to Late (Midian) Permian.

5. Middle Permian (Murgabian) Nalang Formation of Ban Chamngoua, Luang Prabang Province.

Location. 1:100,000 Sheet E-48-1 grid reference 933013 (locality 1.12.92 RBS 6).
Geology. In the left bank of the Nam Khong to

the west of Ban Chamngoua a small old quarry exposes micritic limestone cut by numerous calcite veins yielding abundant silicified fusulinid foraminifera and colonial rugose coral colonies. **Biota.** The foraminifera are readily observed on the weathered rock surface as dark grey disc shapes. They have been identified (by RBS) as *Verbeekina verbeeki* (Geinitz) 1876 and *Pseudodoliolina pseudolepida* (Deprat[9]) 1912. This association is generally taken to indicate a Murgabian (late Middle Permian) age[10], but Andrew Racey (personnel communication, 5 August 2010) stated that *Verbeekina verbeeki* (zonal index of the latest Murgabian) ranges up into the early Midian (Upper Permian), and that *Pseudodoliolina pseudolepida* also ranges into the Midian where is it most commonly found. **Importance of this locality.** It dates the Permian limestones which are overlain by the *Dicynodon*-bearing red-beds. The Permian reptile can be no older than Late Murgabian as deduced by Fontaine (*in* Battail[11]; Battail[12]) on the basis of the derived colonial corals (*Ipciphyllum laosence, Ipcipohyllum subelegans* and *Multimurinus kmerianus*) forming pebbles in the basal conglomerate of the purple beds. The *in-situ* occurrence of Murgabian fusulinds confirms this conclusion, and suggests that the red-beds may be no older than Midian. It may be speculated that the corals identified by Fontaine were silicified and that this enabled them to survive re-working; it can be further suggested that the coral colonies at Ban Chamngoua belong to the same taxa.

6. Late Permian (Dzhulfian – Dorashmian/ Dorasamian/Darashamian) Nalang Formation of Nam Ngum Reservoir, Vientiane Province. Location. 1:100,000 Sheet E-48-50 grid reference 547493 (locality 7.1.92 RBS 4). Poorly exposed, discontinuous outcrops about 2 m above water level (in the dry season) show in-situ micritic limestone at the western end and boulders of limestone conglomerates, to the east. One particle-supported conglomerate composed of mixed lithic fragments in a clayey micro-dolomite matrix, contained fossils in coarse brecciated grainstone clasts. The biota comes from limestone fragments in a conglomerate at or below the base of the Cretaceous Khorat Group sequence of continental red-beds. They are clearly derived from the underlying Nalang Formation. The mixing of fusulinids from both the Murghabian - Midian and the Dzhulfian – Dorashamian results from the limestone clasts being derived from these two different intervals. **Biota.** The limestones contain *Palaeofusulina* cf. *fusiform* Sheng, *Colaniella* sp., *Langella* sp., *Parafusulina* sp. and *Neoschwagerina* sp. plus some milliolids, crinoid and algal fragments. *Parafusulina* and *Neoschwagerina* are Murghabian - Midian markers whilst *Palaeofusulina* and *Colaniella* indicate a younger Dzhulfian – Dorashamian age. **Importance of this locality.** It is a rare outcrop of the youngest marine Permian recorded in Laos. Dzhulfian-Dorashamian limestones are also known from northern Thailand - first recorded from the Chiang Mai- Nan Provinces by Baum[13] (Sheet DD24) as Middle Permian (see Toriyama[14]), and later from Lampang Province[15,16,17]. A *Palaeofusulina* and *Colaniella* fauna indicating a Dzhulfian age (Dongdangian stage of Vietnamese workers) is recorded from northern Vietnam from the upper horizons of the Dong Dang Formation at Lang Son and the upper part of the Bac Son Series at Lang Nac, and in southern Vietnam from the upper part of the Tathiet Formation, at Ta Thiet, in limestones near the Cambodian border[18,19]. In the Nam Ngum reservoir the limestones are exposed in the core of a SE-plunging anticline in an area usually mapped as Mesozoic[5,20]. They show the extension of Permian limestones from the celebrated Vang Vieng region in a south-easterly direction and lead to the prediction that they may provide suitable reservoir rocks at depth even further along this trend.

Acknowledgements

We thank the directors of E.N.I.(who acquired MROL following a series of mergers) and the Department of Geology and Mines, Lao PDR, for permission to publish this paper; colleagues from the Department of Geology and Mines and Geomining Enterprise (Vientiane) for assistance with the field work.

References

1. Pham Van Hung, Bountheung Phengthavongsa. La géologie et les ressources minérales de la région de Vientiane. *Geology of Kampuchea Laos and Vietnam*, 1989; 1: 13-18. General Department of Mines and Geology, Hanoi.
2. Lovatt Smith PF, Stokes RB. Geology and petroleum potential of the Khorat Plateau Basin in the Vientiane area of Lao P.D.R. *Journal of Petroleum Geology* 1997; 20(1): 27-50, 8 figs. Beaconsfield.
3. Fromaget J. Etudes géologiques dans le Nord de l'Indochine centrale. *Bulletin de la Service géologique de l'Indochine* 1927; 16(2): 1-386, 12 pls., 10 maps. Hanoi.
4. Workman, DR. Study of the strata in Southern Laos equivalent to the Khorat Group of Thailand using satellite imagery. *Journal of the Geological Society of Thailand* 1981; 4: 1-12, 1 tab., 6 figs. Bangkok.
5. Workman DR. Lao People's Democratic Republic: Explanatory Brochure. *Atlas of Mineral Resources of the ESCAP Region* 1990; 7: 19 pp., 2 figs., 2 folding maps. UN, New York.
6. Saurin E. Indochine. *Lexique stratigraphique International*, 3 Asia 1956; 6a: 141 pages plus 5 maps. CNRS, Paris.
7. Fromaget J. Note sur le *Daraelites* des calcaires d'age namurien de la province du Cammon (Moyen Laos). *Bulletin de la Société géologique de France* 1931; (5)1**:** 659-661, pl. 36. Paris.
8. Fontaine H, Poumot, C. The age of anthracite in Thailand. *Journal of Southeast Asian Earth Sciences* 1988; 2(1): 41-42, 1 fig. Oxford.
9. Deprat J. Etude géologique du Yunnan oriental. 3. Etude des Fusulinidés de Chine et de l'Indochine et Classification des Calcaires à Fusulines. *Mémoires de la Service géologique de l'Indochine* 1912; 1(3): 76 pp., 9 pl. Hanoi.
10. Fontaine H, Vachaud D. Study of Permian samples collected from Sumatra. *In* Fontaine, H., The Permian of Southeast Asia. *CCOP Technical Bulletin* 1986; 18: 112-116, pl. 1-10. Tokyo.
11. Battail B, Dejax J, Richir P, Taquet P, Véran M. New data on the continental Upper Permian in the area of Luang-Prabang, Laos. *Journal of Geology* (B) 1995**;** 5-6, 11-15. Hanoi.
12. Battail B. Late Permian dicynodont fauna from Laos. *In*: Buffetaut, E., Cuny, G., Le Loeuff, J. & Suteethorn, V. (Eds) *Late Palaeozoic and Mesozoic ecosystems in SE Asia*. Geological Society, London, Special Publications 2009; 315: 33-40, 7 figs.
13. Baum F, von Braun E, Hahn L, Hess A, Koch K-E., Kruse G, Quarch H, Siebenhuner M. On the Geology of Northern Thailand. *Beihefter zum Geologischen Jahrbuch* 1970; 102:23 pp., 1 table, 1 geological map. Hannover.
14. Toriyama R, Hamada T, Igo H, Ingavat R, Kanmera K, Kobayashi T, Koike T, Ozawa T, Pitakpaivan K, Piyasin S, Sakagami S, Yanagida J, Yin EH. The Carboniferous and Permian Systems in Thailand and Malaysia. *Geology and Palaeontology of Southeast Asia* 1975; 15**,** 39-76, 1 map, 4 tables. Tokyo.
15. Sakagami S, Hatta A. On the Upper Permian *Palaeofusulina - Colaniella* fauna from Khao Doi Pha Phlung, north Thailand. *Geology and Palaeontology of Southeast Asia* 1982**;** 24: 1-14, pl. 1-5. Tokyo.
16. Ingavat-Helmcke R. Review on fossils of Thailand. *Proceedings of the International Symposium on Biostratigraphy of mainland Southeast Asia: Facies & Palaeontology, Chiang Mai, Thailand 31 January – 5 February 1993*; 1: 1-22.
17. Ingavat-Helmcke R. Paleozoic paleontological evidence of Thailand. *Proceedings of the International Symposium on Stratigraphic Correlation of Southeast Asia 15-20 November 1994, Bangkok, Thailand* 1994; 43-54. Department of Mineral Resources, Bangkok.
18. Nguyen Van Liem. A Late Permian microfauna from Ta Thiet Limestone southern Viet Nam. *Proceedings of the 4th Regional Conference on the Geology, Mineral and Energy Resources of South East Asia* 1981; 329-340, 1 fig., 1 table, 3 plates. Manila.
19. Phan Cu Tien (Editor). *Geology of Cambodia, Lao and Vietnam (Explanatory note to the geological map of Cambodia, Lao and Vietnam at 1 :1,000,000 scale)* 2nd edition, 1991;158 pages, 2 figs., 12 tables. Geological Survey of Vietnam, Hanoi.

20. British Geological Survey. *Lao P.D.R. Geological and Mineral Occurrence Map 1:1000000.* 1991.

Figure 1 Map of Lao PDR showing province boundaries and the location of the numbered localities described in this paper.

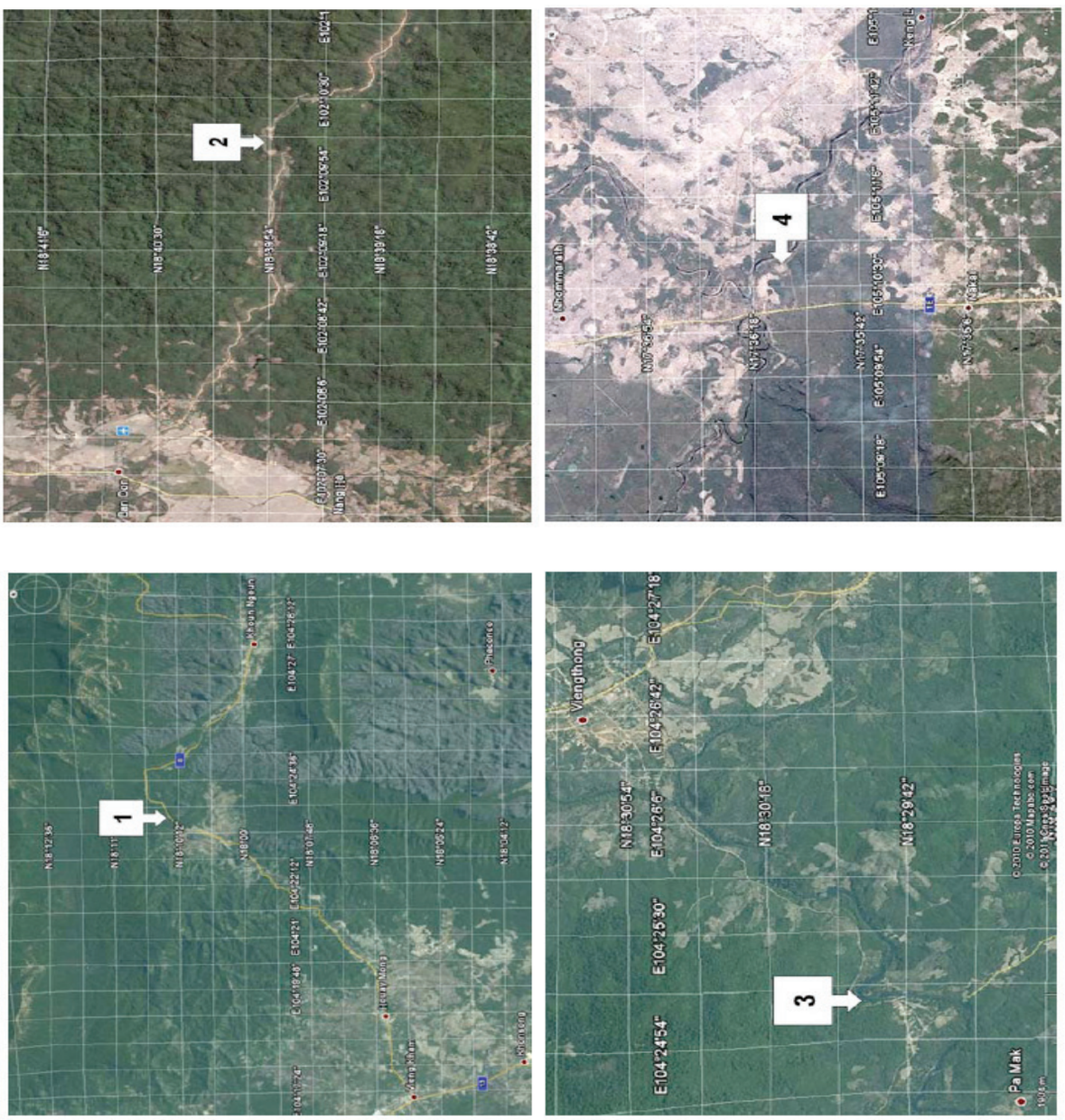


Figure 2-5. Position of localities on maps from Google Earth.Clockwise from top left:

Figure 2 - Early Carbonifererous Phatha Formation on Route 8, Bolikhamxai Province;

Figure 3 - Serpukhovian Nam Thom Formation of Ban Bochan anthracite mine, Vientiane Province;

Figure 4 – Lower Bashkirian (?Nam Thom Formation) of Nam Ngom, Bolikhamxai Province;

Figure 5 – Early to Late Permian (Sakmarian – Midian) Nalang Formation of Gnommelat, Khammouan Province.

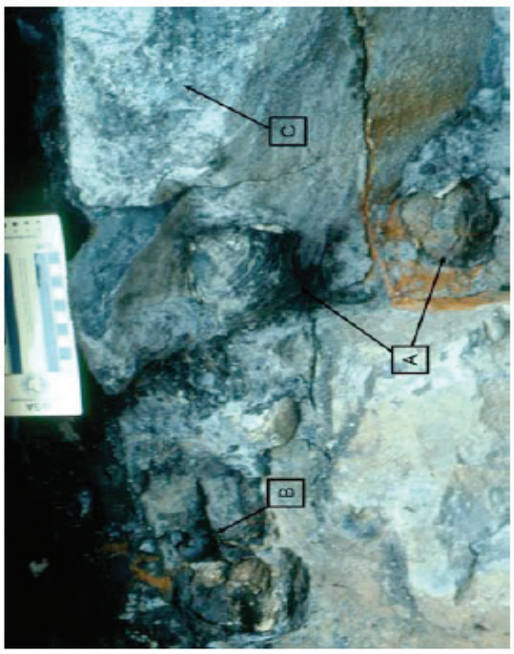


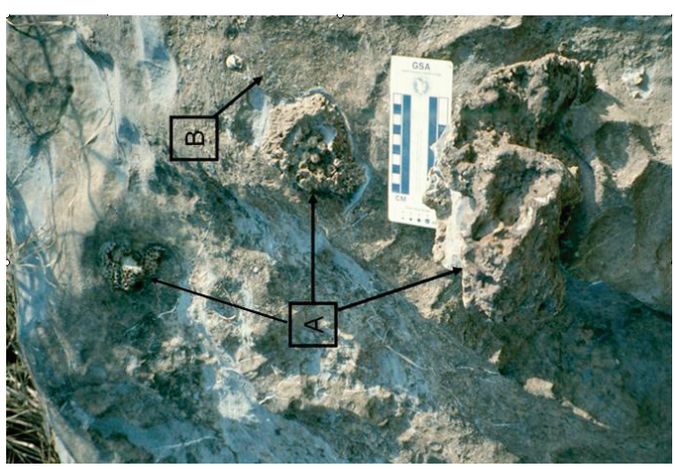
Figure 6-7 Position of localities on maps from Google Earth. Clockwise from top left.

Figure 6 (top left)-Middle Permian (Murgabian) Nalang Formation of Ban Chamngoua, Luang Prabang Province;

Figure 7-Late Permian Nalang Formation of Nam Ngum Reservoir,Vientiane Province.

Figure 8-9 Field photographs. **Figure 8**-PLS at Early Carboniferous Phatha Formation locality on Route 8, Bolikhamxai Province;

Figure 9 – Fossils in the Serpukhovian Nam Thom Formation of Ban Bochan anthracite mine, Vientiane Province, A = produtid brachiopod *Kueichoviella* sp., B = *Bellerophon* sp., C = crinoid ossicles and tabulate corals.



Figures 10-13. Field photographs. Clockwise from top left.

Figure 10 – Discarded core of Early to Late Permian (Sakmarian – Midian) Nalang Formation at exploration well, Gnommelat, Khammouan Province.

Figures 11 & 12 - Middle Permian (Murgabian) Nalang Formation at Ban Chamngoua, Luang Prabang Province.

Figure 11 – general view of exposure;

Figure 12 – close-up showing fossils : A – rugose coral colonies and B – abundant fusulinid foraminifera**.** Figure 13 – pebbles of Late Permian (Dzhulfian – Dorashmian/Dorasamian/Darashamian) Nalang Formation in Mesozoic conglomerate at Nam Ngum Reservoir, Vientiane Province.