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Carbonate Formations and UNESCO Global Geoparks-A Sustainable Development Approach

Xiaochi Jin

Institute of Geology, Chinese Academy of Geological Sciences, 26 Baiwanzhuang Road, Beijing 100037, China.
Email: jinxchi@sina.com; jinxchi@cags.ac.cn

ABSTRACT

Carbonate formations are reliable documents of the past of the earth. Man has made a great effort to study their distribution patterns, sedimentary structures, microfacies, chemical compositions, fossils contained, etc., in order to explore their depositional processes, paleogeographic indications, geomorphological properties, as well as their commercial values.

Meanwhile carbonate terrains are home to a considerable number of human beings, providing the essential ecological substrate. Coexistence of human beings and their surroundings has been maintained by means of adapted living styles, which, however, in many places mean a low and sometimes rather primitive living standard. The desire of quickly improving living conditions but without rational strategies often brought about deforestation, overcultivation, and overgrazing, leading to desertification of carbonate terrains in an alarming state. This in turn exacerbates depopulation, making development even more unsustainable, let along research and education.

The Geopark concept arose in the mid-1990s as a response to the need to conserve and enhance the value of areas of geological significance in Earth history. Now, the UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. This provides an efficient way for communities residing largely on carbonate terrains to improve their living standards without sacrificing the future of next generations.

Successful examples of UNESCO Global Geoparks with their significant geological heritage sites and landscapes developed on carbonate formations are to find in South China and Southeast Asia, where these important carbonate sites are properly conserved, studied and celebrated. These are in turn used as attractions of responsible tourism, dada for science education, ideas of eco-agriculture, and inspirations for local products design. In these territories more job opportunities are created. Some migrant workers came back home from big cities to make their fortunes in the geopark. UNESCO Global Geoparks become label that local people are proud of.

The philosophy of protection/conservation, research/education, and sustainable development is being increasingly understood by local communities. Successful examples have inspired more and more communities in different areas to follow.

Triassic Carbonates of Lampang Group, Northern Thailand

Pol Chaodumrong[1] and Clive Burrett[2]

[1]Geological Expert, Geological Society of Thailand
[2]Palaeontological Research and Education Centre, Mahasarakham University, MahaSarakham 44150, Thailand

ABSTRACT

Triassic Lampang Group consists of 7 formations, in ascending order namely Phra That, Pha Kan, Hong Hoi, Doi Long, Pha Daeng, Kang Pla and Wang Chin Formations. The lower 5 formations occurred in Lampang subbasin that displayed a deepening upward sequence commencing from continental red beds upward to carbonate platform and submarine fan sediments, followed by a shallowing upward sequence, starting from submarine fan sediments upward to carbonate platform and continental red beds. While the upper 3 formations consecutively formed in adjacent Phrae subbasin, to the present east, and contained similar deepening upward sequence. Development of the Phrae subbasin to the east favors westward subduction.

Thirteen microfacies and one lithofacies of the Lampang carbonates are interpreted on the basis of lithology, type of allochems, sedimentary structure, paleontology, facies associations, and analogy to standard microfacies. The carbonates are mainly limestones, with minor of dolomitization, silicification and metamorphism. They formed in three depositional models namely ramp platform represented by the Pha Kan and the Kang Pla, drowned ramp platform by Cave Temple Member and the Kang Pla, and regressive ramp platform by the Doi Long. Although most of them were shallow marine limestones, but deep marine limestones are also interpreted from clastic units of Huai Muang Member of the Hong Hoi, and Huai Chan and Phu Tap Members of the Wang Chin. Interpretation of ramp platforms is based on lack of elongate barrier-reef, fore-reef deposits, lack of shelf slope break, and limited distribution. In addition, the Pha Kan displays high-energy grainstone belt in a landward position as observed from the reference section at Phra That Muang Kham temple. Utilization, Pha Kan limestones in Chae Hom area are using as raw material for cement. Whereas Pha Kan limestones in Mae Moh- Mae Tha areas and Kang Pla limestones in Phayao area have been using for aggregates.

Structural and Sedimentary Characteristics of the Khao Khwang Fold and Thrust Belt, Central Thailand: Implications for Reconstructing the Indosinian Orogeny and Permian Palaeogeography of the Indochina Block

Chris Morley

Woodpecker Cottage, Coffinswell, Devon, UK

ABSTRACT

The E-W trending, predominantly north-verging, Khao Khwang Fold and Thrust belt (KKFTB) developed during the Triassic during the Early to Late Triassic (c. 250-205 Ma) and is dominated by outcrops of deformed Saraburi Group (late Early Permian to early Late Permian), platform carbonates and equivalent deeperwater allodapic limestones, shales, silicified shales, sands, and cherts. In addition, syn-tectonic c. 250-245 Ma Triassic clastic sequences (Pang Asok Formation) are present, as are a few outcrops of Late Triassic, Hua Hin Lat Formation equivalent shales and sandstones. These units are intruded by pre-syn-and post-deformation Late Permian-Late Triassic andesitic sills and dykes that consistently show an island-arc type geochemistry throughout their history. The KKFTB is covered by numerous large (c. 3 km across) and small (100 m across), active and abandoned quarries that provide extensive sections through the different stratigraphic units. They are important in demonstrating the following characteristics of the area: 1) numerous major thrusts that would be difficult to identify from natural exposures only. 2) stratigraphic variations in long sections through the Saraburi Group and Triassic units. 3) Variations in structural style that accompany the stratigraphic variations, including extensive development of detachments within carbonate sequences. 4) Extensive variations in carbonate cement type (and their preservation) in the limestones, and degree of recrystallization in limestones related to burial, diagenesis and structural deformation. 5) The three key carbonate formations (Khao Khwang, Khao Khad, and Phu Phe formations) do not represent one, or 3 platforms, but actually represent numerous minor platforms that were separated by deeper water basins, probably in a broadly rifted setting (similar to the Khorat Plateau area). 6) The formations can be described as: Khao Khwang Formation = northern platform or platforms, Khao Khad Formation = central platforms (numerous), Phu Phe Formation = southern platforms and intervening basinal clastics with significant igneous influence. The intervening basinal areas for the Khao Khwang and Khao Khad formations is represented by the Nong Pong Formation. 7) The carbonate platforms can reach thicknesses of c. 1 km, the Nong Pong Formation is > 3 km thick in places. 8) The presence of numerous thrusts has juxtaposed once geographically widely separated platforms and basins, the palaeogeographic restorations cannot be made in detail at present, but may well involve shortening of hundreds of kilometers. 9) Shelfal to deepwater sandstones are present in the Nong Pong, Khao Khad and Sap Bon Formation indicating the presence of some emergent land to be incorporated into the restorations. Much work remains to be done in refining the stratigraphy and

sedimentology of the KKFTB and documenting its structural development from the Permian to the Cenozoic. U-Pb dating of carbonates is difficult, but offers considerable potential for unravelling the complex history of deformation via carbonate vein development. The KKFTB is important for demonstrating the potential stratigraphic and structural complexity of carbonates on the Indochina Block. The anomalous orientation of the KKFTB with respect to the main N-S trends of blocks associated with the Indosinian Orogeny together with the large amount of shortening in the belt, and multiple phases of deformation, suggests considerable complexity regarding how the Palaeo-Tethys Ocean closed in Thailand, including that the Indochina Terrane actually comprised separate northern and southern blocks that were closed along the KKFTB.

New Kungurian Brachiopods from Khao Khok, Central Thailand (Indochina Block): A Revised Early–Middle Permian Problem in the Tak Fa Limestone Revisited

Masatoshi Sone[1] and Anisong Chitnarin[2]

[1]Department of Geology, University of Malaya, 50603 Kuala Lumpur, Malaysia.
Email: masatoshi.sone@gmail.com

[2]School of Geotechnology, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima 30000, Thailand.
Email: anisong@sut.ac.th

ABSTRACT

Khao Khok is located about 50 km north of Khok Samrong and represents the largest limestone massif in the area. It consists of a well-bedded, fine-grained calcareous sequence, mapped as part of the Tak Fa Limestone which is in general considered to be dominantly a Middle Permian unit. It belongs to the Khao Khwang Platform of the western Indochina Block. Nevertheless, the earlier 2008 find of conodonts from Khao Khok showed an unexpected occurrence of older, Kungurian strata. The said conodont species, *Sweetognathus subsymmetricus* and *Pseudosweetognathus costatus*, were originally thought to be early Kungurian in age, but today this is better referred to as a later Kungurian. This find brought questions about whether 1) the basal Tak Fa Limestone extends down to the late Early Permian, or 2) there is a separate Early Permian unit beneath the area (recalling the Khao Kad Formation near Saraburi). Here, we report a new brachiopod suite from the same Khao Khok fossil beds, together with rare fusulines. The three brachiopod species, *Liraplecta* n. sp., *Schuchertella* n. sp., and *Acosarina* cf. *kanmerai* Yanagida & Nakornsri, are present. *Liraplecta* is found in SE Asia for the first time: it is a rare, large dictyoclostine productoid genus known mostly from the Kungurian of Tarim and eastern Tibet, and now from the Indochina Block. *Schuchertella* n. sp. is distinct from another Thai representative, *Schuchertella cooperi* Grant from the basal Ratburi Limestone, in having a wider hinge outline. The Khao Khok brachiopods appear to be of warm-water Tethys in affinity. The co-occurring fusulines *Minojapanella*, *Pseudodoliolina*, and *Codonofusiella* are common members in the Kubergandian–Murgabian (that is, Middle Permian in the Tethys standard) limestones: this is now correlated to the late Kungurian of the international standard. Thus, there is a concordance to find both Kubergandian–Murgabian fusulinoids and late Kungurian conodonts/brachiopods together. On balance, a late Kungurian age is suggested for the Khao Khok fossil beds. The Ratburi 'mammoth' brachiopod fauna of the West Malaya Block (not Sibumasu) is also coeval, late Kungurian in age, but no affinity is tangible. Note that the fusuline-based Tethyan stratigraphic standard that we have traditionally used for the Early–Middle Permian carbonates of SE Asia now needs to be closely correlated (converted) to the up-to-date international standard.

Revision of Saraburi Group and Its Related Stratigraphic Units

Thasinee Charoentitirat

Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330 Thailand
Email: thasineec@gmail.com

ABSTRACT

The name Saraburi Group was originally proposed for Upper Paleozoic (recently more restricted sense for latest Pennsylvanian to Permian) mixed carbonate-siliciclastic strata widely distributed on the east side of lower Chao Phraya Central Plain in central Thailand. Six formations of this group: Phu Phe, Khao Khwang, Nong Pong, Pang Asok, Khao Khad, and Sap Bon formations were proposed (Hinthong, 1981, 1985 and Hinthong et al. 1985). Originally, stratigraphic relationship of these formations is a simple upward superposition. The large overlap of ages, particularly of two main carbonate formations (Khao Khad and Khao Khwang formations) and mixed carbonate-siliciclastic formation (Nong Pong Formation) in the Saraburi area can make it difficult to distinguish them. Many attempts have been made in order to clarify the stratigraphic relationship and paleoenvironment of these formations. Based on paleontological and sedimentological data, they suggest that the Khao Khad and Khao Khwang formations represent shallow marine carbonate platform-facies whereas the Nong Pong Formation could be a slightly deeper area with time-equivalent of carbonate platforms. Besides Upper Paleozoic carbonate-dominant formations of Saraburi Group, central Thailand, there are several lithostratigraphic names representing Upper Paleozoic carbonate-dominant distributed along the western margin of the Khorat Plateau of Thailand. The Nam Mahoran Formation has been used for the sequence distributed in the Loei area, whereas the Pha Nok Khao Formation has been mainly adopted for strata exposed in the area south of Loei and Khon San area and Tak Fa Formation in Phetchabun and Lopburi provinces. These formations are mainly composed of Upper Paleozoic thin to thick-bedded or massive limestones with the intercalations of thin-bedded clastic rocks. They are also shallow-marine carbonate platform formations and have a deposition time equivalent to the Khao Khad and Khao Khwang formations of the Saraburi Group.

Key words: Saraburi Group, Upper Paleozoic carbonates, Thailand

Permian Ostracods from Limestones Associated with A Coal Deposit, Tak Fa Formation, Phetchabun Province

Anisong Chitnarin and Prachya Tepnarong

School of Geotechnology, Institute of Engineering, Suranaree University of Technology, 111 University Avenue, Mueang District, Nakhon Ratchasima Province 30000, Thailand.

ABSTRACT

Ostracods are small crustaceans which can live in variety of habitats ranging from freshwater to marine environments and are accepted as the most important arthropods for paleoenvironmental interpretation. Permian ostracods found from carbonate rocks of the Pha Nok Khao and Khao Khwang Platforms are represented by shallow marine habitants (Chitnarin *et al*., 2008; 2012; 2017; Chitnarin and Ketwetsuriya, 2021) and an assemblage of mixed fauna found in deeper-water slope deposit (Burrett *et al*., 2015). In this research, the ostracods recovered from limestones of the Tak Fa Formation in Nong Phai area reveal evidence of transitional environment. Core samples mostly argillaceous limestones were obtained in course of subsurface prospecting. There were two coal seams found at 45- and 82-meters depth. Under microscope, limestones can be classified to bioclastic wackestone and packstone containing fragments of brachiopods, ostracods, gastropods, dasyclad green algae, calcispheres and smaller foraminifers. Carbonate microfacies suggests the inner part of homoclinal ramp, from shallow marine to shoal and restricted lagoon. Thirty-three samples were processed and yielded 34 species belonged to 16 genera. The assemblage is dominated by Bairdioidea, minored by Hollinoidea, Kirkbyoidea and Kloedenelloidea. Surprisingly, genera *Paleodarwinula* and *Carbonita?* were recognized at 13 meters depth. These genera are known to be early freshwater invaders that suggest the influence of freshwater during deposition. These limestones and coals at Nong Phai District seem to have accumulated in shallow to transitional marine waters. These observations may relate to the regional sea level drop during late Middle Permian (Wordian-Capitanian) when the coals being deposited in lagoons along the regressive shoreline.

Keywords: Khao Khwang Platform, Argillaceous limestone, Indochina Block, Capitanian

References:

Burrett, B., Udchachon, M., Thassanapak, H. and Chitnarin, A. (2015). Conodonts, radiolarians and ostracodes in the Permian E-Lert Formation, Loei Fold Belt, Indochina Terrane, Thailand. Geological Magazine, 152(1): 106-142.

Chitnarin, A., Ketwetsuriya, C. (2021). Middle Permian ostracod fauna from the Khao Khad Formation (Indochina Terrane), Central Thailand. Annales de Paléontologie 107(4):102521.

Chitnarin, A., Crasquin, S., Chonglakmani, C., Broutin, J., Grote., J. and Thanee, N. (2008). Middle Permian ostracods from Tak Fa Limestone, Phetchabun Province, Central Thailand. Geobios, 41(3):341-353.

Chitnarin, A., Crasquin, S., Charoentitirat, T., Tepnarong, C. Thanee, N. (2012). Ostracods (Crustacea) of the Early - Middle Permian from Central Thailand (Indochina Block). Part 1.: Order Palaeocopida. Geodiversitas, 34(4). 801–835.

Chitnarin, A., Crasquin, S., Forel, M.-B., Tepnarong, P. (2017). Ostracods (Crustacea) of the Early-Middle Permian (Cisarulian-Guadalupian) from Central Thailand (Indochina Block): part II, Orders Podocopida, Platycopida and Myodocopida. Geodiversitas, 39(4): 651-690.

The Carboniferous Wang Saphung Formation: New Information from Field Work I and Ii Courses

Pitaksit Ditbanjong[1]*, Natthawiroj Silaratana[1] and Kiattisak Sonpirom[1]

[1]Department of Geotechnology, Faculty of Technology, Khon Kaen University, Khon Kaen 40002, Thailand
*Corresponding author: pitadi@kku.ac.th

ABSTRACT

Wang Saphung Formation (Wsp Fm) is established in 1976 from Loei province which mainly composed of shale, siltstone, sandstone, pebbly conglomerate, and limestone. Fossils including brachiopod, trilobite, fusuline and plant debris indicate Carboniferous in age. It is exposed in Loei-Phetchabun Fold Belt (equivalent to Huai Som Formation (C3) in Udon Thani, Khon Kaen and Phetchabun 1:250,000 Map). This study, remapping in a scale of 1:20,000, focuses on Wang Saphung and Ban Sup area, Loei Province where Field Work I and II courses were taken place during April and July 2022 respectively.

The result of remapping of Wsp Fm shows that it can be subdivided into 3 members. From older to younger, Member 1 starts with polymictic orthocomglomerate and greenish gray, thick to massive sandstone. Locally, reddish- and greenish-mudstone, limestone and tuff are observed in this member. Member 2, composing of siltstone, mudstone, shale and very thin to medium bedded sandstone, is poorly expose and it forms undulatory topography. They are rich in fossil such as brachiopod, bryozoa, trilobite and crinoid stem. Thin to medium bedded limestone with planar bedding, HCS, ripple is also present in this member. Ooid and oncoid are present within limestone bed. Solitary and colony rugosa, chaetetid obviously notice. Shallow marine such as tidal, lagoon, reef or nearshore depositional environment is proposed for member 2. In Member 3, proportion of mudstone is decreasing upward and medium to thick bedded limestone becomes dominated. Irregular shape of chert nodules and Tricites sp. is found within limestone bed. Locally, stromatolite layer present at the top of this member. It possibly limits the top of Wsp Fm before very thick to massive Permian limestone are taken place. Due to very well preserved and rich of fossil in Wsp Fm, biostratigraphy with precise age is recommended for future work.

Keywords: Upper Carboniferous, Wang Saphung Formation, nearshore deposit, Loei-Phetchabun Fold Belt

Geological, Mineralogical and Invisible Gold Distribution in Mesozoic Bau Limestone, Kuching, East Malaysia

Carolyn Nicole Marjon, Vijay Anand Sundarrajan*

Department of Applied Sciences, Curtin University, CDT 250, 98009, Miri, Sarawak, Malaysia
Email: vijay.anand@curtin.edu.my

ABSTRACT

In east Malaysia, the Sarawak continental margin is a part of the Sunda Shelf, which structurally connects with Borneo and other parts of SE Asia. In east Malaysia, Sarawak can be subdivided into three tectono-stratigraphic zones: Kuching Zone, Sibu Zone, and Miri Zone.Approximately 86 tons of Au (3million ounces) is associated with Mesozoic Bau limestone and they are the main ore producer, in the Kuching zone, Sarawak in the early 1990s. The Bau limestone hosted Goldfield is situated within the Bau district of Kuching, Sarawak, east Malaysia. The limestone formation is exposed in the main gold prospects of Jugan hill, Tai Parit and Pejiru hill and consists of Late Jurassic to Early Cretaceous dominated marine carbonate deposition. The Bau Limestone Formation is intruded by several episodes of porphyritic dykes (diabase) and sills.. Carbonate-replacement gold occurs at the Bau Formation (limestone)-Pedawan Formation (shale) contact, adjacent to high-angled faults. These deposits can also be found along the brecciated fault zone within the host of a massive bed of limestone and shale (Timothy et al., 1990; Kirwin and Royle, 2018). Gold occurrences in Bau is dominantly related to visible and invisibleform in different stages of sulfides (e.g., arsenopyrite and pyrite), and is structurally controlled.

Besides article research, two limestone quarries managed by Marup and Sin Seng Ann Quarry located SW of Kuching city in the Gunung Panga region were assessed. Earlier studies proposed two lithofacies in Marup Quarry and five in Sin Seng Ann Quarry, which includes bioclastic wacke-packstone, bafflestone, conchoidal packstone, peloidal packstone, bioclastic packstone, bindstone, and frame-bafflestone. This paper demonstrates the mineralogical and geochemical characteristics of the Bau Limestone Formation, gold occurrences in limestone, and invisible gold distribution in different stages of sulfides are well studied.Further collected samples were analysed for scanning electron microscope (SEM-EDS), XPS to observe the mineral assemblages of each sample and the presence of invisible gold on different stages of sulphides in limestone. The trace element concentration of Ni and Co identified in different stages of sulphides and the increasing or decreasing concentration mainly controlled gold precipitation. The paramagnetic impurities of Li, Ge, Mn in sulphides are the characteristic features observed in the Bau gold prospect.

Petrography and X-Ray Mineralogy of Cretaceous of Ariyalur Group of Carbonate Fossils of Tiruchirappalli Succession, Tamil Nadu, India

Babu Nallusamy[1*], Rajeev Shesha Joshi[2], Vijay Anand S[3], C. Perumalsamy[4] and Kocherla Muralidhar[5]

[1]Department of Geology, School of Earth Sciences, Central University of Karnataka, Karnataka, India.
[2]Department of Physics, School of Physical Sciences, Central University of Karnataka, Kadaganchi, Karnataka, India
[3] Department of Applied Sciences (Applied Geology), Faculty of Engineering and Science, Curtin University, CDT 250, Miri, Sarawak-98009, Malaysia
[4] Petrology and Geochemistry Group, Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand 248001
[5]CSIR-National Institute of Oceanography, Dona Paula,Goa-403004, India
[*]Presenting and Corresponding Author: Dr. Babu Nallusamy, Email: babun@cuk.ac.in

ABSTRACT

Cretaceous of Ariyalur group in Tamil Nadu, India is famous for its best developed sedimentary sequences and it is also very well known for its fossiliferous limestone deposits. A diverse set of work has been carried out on stratigraphy, paleontology, and geochronology of these fossils, but there is a limited work carried out from the petrography and mineralogy point of view. The detailed petrography and mineralogical studies will allow us to understand the fossil formation process, the climatic change, time line and habitat of the life form which underwent mineralization. In the present study we have used microscopy and X-ray diffraction to profile the petrography pattern and minerals embedded in the Cretaceous fossils to interpret the geochronology of the samples.

Petrography studies were carried on fossils using Optical microscope. Biosparite and biomicrite has been observed. Snake scale skin, ray scale skin, distinct layers, wavy and ripple mark pattern were recorded. In addition, microfossils were embedded within the fossil were also found. X-rays, the electromagnetic radiation with wavelengths between about 0.02 Å and 100 Å (1Å = 10-10 meters) can be used to study the structure of crystals. Hence, for the present study, fossil such as Petrified Wood, Rhizome fossil, Echinoids, Turritella, Buccinum, Gryphaea, Osteria, Belemnite, Phosphatic Nodule, Coraline Fossil, Coral, Arca, Fossiliferous Limestone, Dinosaur Bone, Brachiopod Terebratula, and Bivalvia Alectronia were subjected to microscopic study and X-Ray Diffractometer studies as well and the textural pattern and X-Ray diffraction peaks obtained were de-convoluted to identify the morphological and its minerals patterns. The intensity ratios were used to understand the proportion of the minerals in the fossil content. Further, the Debye-Scherrer analysis allowed us to estimate the graining ratios, which allows us to interpret the effect of geochronological environment / primordial environment on mineralization. It has been observed from the analysis that basic mineral compositions of most of the samples confirmed the presence of calcite, quartz, aragonite, fluorapatite, pyrite, muscovite, and goethite. Interestingly, replacement and/or permineralization processes were found to be the reasons for the mineral incorporation through the fossilization. It is understood that most fossilizations

of fossils are fillings (Permineralized). Permineralization structures (casts) were disturbed by recrystallization. Silicification of wood, indicates the presence of marine environment during the process of crystallizations, but mainly an event of terrestrial, influenced by Eh and pH conditions exclusively.

Keywords: Petrography, biosparite, biomicrite, snake scale skin, Ray scale pattern, X-Ray Mineralogy, Fossils, Calcite, Quartz, Aragonite, Fluorapatite, Pyrite, Muscovite and geothite.

Early Permian (Kungurian) Molluscs of Gondwanan Affinity from The Kubang Pasu Formation–Chuping Limestone Passage Beds of Perlis, Peninsular Malaysia (West Malaya Block)

Yasuhisa Igarashi[1,2] and Masatoshi Sone[1]

[1]Department of Geology, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Present address: Isuzu Motors, Yokohama, Japan
Emails: yasuhisa0514.kametu@gmail.com; masatoshi.sone@gmail.com

ABSTRACT

Early Permian molluscs (bivalves and gastropods) were recovered from the transitional strata between the uppermost Kubang Pasu Formation and basal Chuping Limestone in Perlis, northwestern Peninsular Malaysia. This fauna consists of four bivalve taxa, *Promytilus* n. sp., *Praeundulomya* n. sp., *Streblopteria* sp., and Heteropectinidae sp., and one gastropod, *Peruvispira* n. sp. These identified genera are typically anti-tropical, bi-polar/bi-temperate in distributions, and reveal intimate linkages to Early Permian marine faunas of Gondwana, for example, in Australia, New Zealand, Irian Jaya, the Himalayas, central India, Oman, and Argentina. The Perlis fossil beds are laterally equivalent to the coeval lithostratigraphic boundary between the Kaeng Krachang Group and Ratburi Limestone in southern Thailand, correlated over the West Malaya Block (not Sibumasu) or eastern Cimmeria of peri-Gondwana in origin. This major lithostratigraphic boundary in SE Asia is now known to be late Kungurian (late Early Permian/Cisuralian) in age, suggested by fossil ages of radiolarians, fusulinoids, and brachiopods. *Praeundulomya*, *Streblopteria*, and *Peruvispira* are found in Malaysia for the first time.

Review of Carbonate Rocks Onshore and Offshore Sarawak, Malaysia

Patricia Henry* and Dominique Dodge-Wan*

Department of Applied Geology, Faculty of Engineering and Science, Curtin University Malaysia, CDT 250, 98009, Miri, Sarawak, Malaysia
Email: 700024310@student.curtin.edu.my, dominique@curtin.edu.my

ABSTRACT

This research, conducted during the Covid pandemic lockdown, consists of a comprehensive literature review of about 60 publications describing onshore and offshore carbonates in Sarawak, Malaysia. The characteristics of all onshore and offshore carbonate deposits in Sarawak are presented, with references, in stratigraphic order from the oldest to the youngest zones: (Kuching, Sibu and Miri zones) across the state. Among the 30 carbonate units reported, four are very significant carbonate deposits: onshore Bau (Bau Limestone), Mulu (Melinau Limestone), Niah (Subis Limestone) and offshore Bintulu (Luconia Province). Stratigraphic charts of the three zones have been constructed for each of the three zones, based on review of all the available data. The range of carbonate microfacies present in Luconia Province, Melinau Limestone and Subis Limestone is discussed and related to their respective paleoenvironments. Limited fieldwork was conducted post-pandemic at one outcrop, near Bekenu (Miri, Sarawak). The rocks are wackestones with benthic and planktonic foraminifera of Early to Mid-Miocene age deposited in shallow marine environment. Karstification process is also discussed briefly, with reference to paleokarst and the spectacular karst topographies noted in Bau Limestone, Melinau Limestone and Subis Limestone. Bau Limestone also has gold mineralisation occurring in the karstified beds of limestone. Central Luconia Province, a well-known offshore reserve hosts several gas-bearing karst reservoirs.

Keywords: Sarawak, carbonate rocks, limestone, onshore, offshore, karstification.

Review of the Permian platform, slope and basin in the Indochina Terrane, Central Thailand

Mongkol Udchachon, Clive Burrett and Hathaithip Thassanapak

[1] Excellence Center in Basin Studies and Applied Palaeontology, Palaeontological Research and Education Centre, Mahasarakham University, Maha Sarakham 44150, Thailand
[2] Applied Palaeontology and Biostratigraphy Research Unit, Department of Biology, Faculty of Science, Mahasarakham University, Maha Sarakham 44150, Thailand

ABSTRACT

The area studied was originally mapped by Chonglakmani and Sattayarak (1979, 1984) and further south by Nakonsri (1976), is close to the western edge of the unconformably overlying Mesozoic siliciclastics of the Khorat Plateau and consists of Carboniferous to Permian sedimentary and volcanic rocks. The recently re-opened Chatree gold mine is nearby (Diemar et al., 2020; Salam et al., 2014) where episodic igneous activity has been well dated using zircons. The Carboniferous to Permian limestones and associated siliciclastics and volcaniclastics of the Khao Kwang Platform were separated to the east from the Pha Nok Khao Platform by deeper water basins such as the Nam Duk Basin (Wielchowsky & Young, 1985). However, this palaeogeographic scenario is probably in need of revision as it is likely that these long elongate carbonate platforms consist of many, sometimes structurally superimposed, smaller carbonate platforms separated by sometimes wide, deep-water basins (Burrett et al., 2016; Morley & Jitmahantakul, 2020; Vattanasak et al., 2020).

The oldest sedimentary-volcanic sequence known so far in the Khao Kwang Platform area is gently dipping to 75° 'early' Carboniferous probably early Visean in age (Chonglakmani et al., 1983; Chonglakmani, & Fontaine, 1992). These oldest rocks consist of unfossiliferous (so far), thinly bedded, chert and volcaniclastics and, although outcrops are scattered, appear to be overlain by a succession of limestones from early Visean to middle Permian containing dateable foraminiferans and corals (Chonglakmani & Fontaine, 1992: Ueno & Charoentitirat, 2011; Udchachon et al., 2014).

Some of this Visean limestone appears to be deposited as mud mounds. Potentially economically important deposits of 45 m of gypsum/anhydrite is probably interbedded in the Carboniferous sequence, appears to be coeval with reddish siliciclastics and, on the basis of seawater isotope composition and overlying fusuline-bearing carbonates, was deposited by "hypersaline seawater on a shallow lagoon or shelf on the Khao Khwang Platform during the Serpukhovian" (or late Mississippian) (Kuroda et a., 2017).

Early to middle Permian carbonate sequences are well exposed in the central part of the Phetchabun-Lamnarai to Saraburi area. Biostromes and coral reefs are well exposed in some intervals with obvious massive and fasciculate rugose corals and other associated faunas. Allodapic limestone sequences -the evidence of slope facies - are often observed between this platform facies and the basin deposits which is

mainly characterised by successions of shale-chert. Conodonts are observed in the turbidite successions and indicate a late early Permian (Kungurian) age for at least parts of the slope deposits. Late middle Permian carbonates were eroded and unconformably overlain by carbonate breccias and polymictic conglomerates. These breccias and conglomerates are pronounced at the Khao Somphot and Khao Paeng Ma sections in Lopburi. This rock assemblage is also observed at Khao Amon Rat and Phu Nam Yot as well as the sequences in the Phra Phutthabat and other areas along the Loei-Phetchabun terrane. This might be correlative to a major subaerial exposure event and the consequent demise of the Upper Palaeozoic platform in this region related to an early phase of the Indosinian Orogeny (Udchachon et al., 2014; Burrett et al., 2021).