Geol. Soc. Malaysia, Bulletin 6, July 1973; pp. 177–185.

Geology of the Region Sri Sawat—Thong Pha Phum-Sangkhlaburi (Kanchanaburi Province/Thailand)

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Abstract: The area was mapped on a scale of 1:250 000 by the German Geological Mission from 1968 to 1971, by field mapping and airphoto interpretation.

Strata in the area comprise about 3000 m of mostly marine metasedimentary and sedimentary rocks, whose age ranges from Cambrian to Jurassic, locally covered by fluviatile Cenozoic sediments. The marine sedimentary basin forms part of a geosynclinal tract which extends from Yunnan in the north to Malaysia in the south—the Yunnan—Malaya Geosyncline.

Tectonic activity is indicated by turbidites of Lower Carboniferous age, and a late Carboniferous phase is also indicated. There is also evidence for Triassic and Post-Jurassic orogenies, and late Cenozoic faulting.

Several granites, as yet not positively dated, occur in the area. They are: Khwae Yai granite (Triassic?); Central granite (Paleozoic?); and Pilok granite (Triassic?).

INTRODUCTION

The area of investigation (see Fig. 1) has been mapped by the German Geological Mission (assigned by the Geological Survey of the Federal Republic of Germany, Hannover) in cooperation with the Thai Department of Mineral Resources, during the field seasons 1968 to 1971. A provisional account of results is given here in order to make available the essential outlines of the geology in upper Kanchanaburi Province, prior to final assessment of fossil faunas collected, and future radiometric datings of igneous rocks. Field data have been complemented by airphoto interpretation for the accomplishment of a geological map 1:250 000.

STRATIGRAPHY

The stratigraphical sequence comprises about 3,000 m of mostly marine sediments and metasediments, the age of which ranges from Cambrian to Jurassic, locally covered by fluviatile sediments of Cenozoic age (see Fig. 2). The marine sedimentary basin forms part of a geosynclinical tract, which extends from Yunnan in the North to west Malaysia in the South. It is referred to as Yunnan-Malaya Geosyncline (Burton, 1967, Baum, *et al.*, 1970).

Cambrian

The Cambrian comprises a sequence of fine to coarse sandstone and quartzite, occasionally grading to finer clastic sediments occurring as intercalations towards its top. These rocks are generally metamorphosed, the finer clastic parts being transformed to sericite slate, biotite-muscovite schist and biotite schist with occasional intercalations of calcsilicates. The primary thickness of this series seems to be well over 500 m.

From a corresponding clastic succession in the Pindaya Range, Southern Shan State, Burma, olenellid trilobites of clearly Cambrian age have been reported quite

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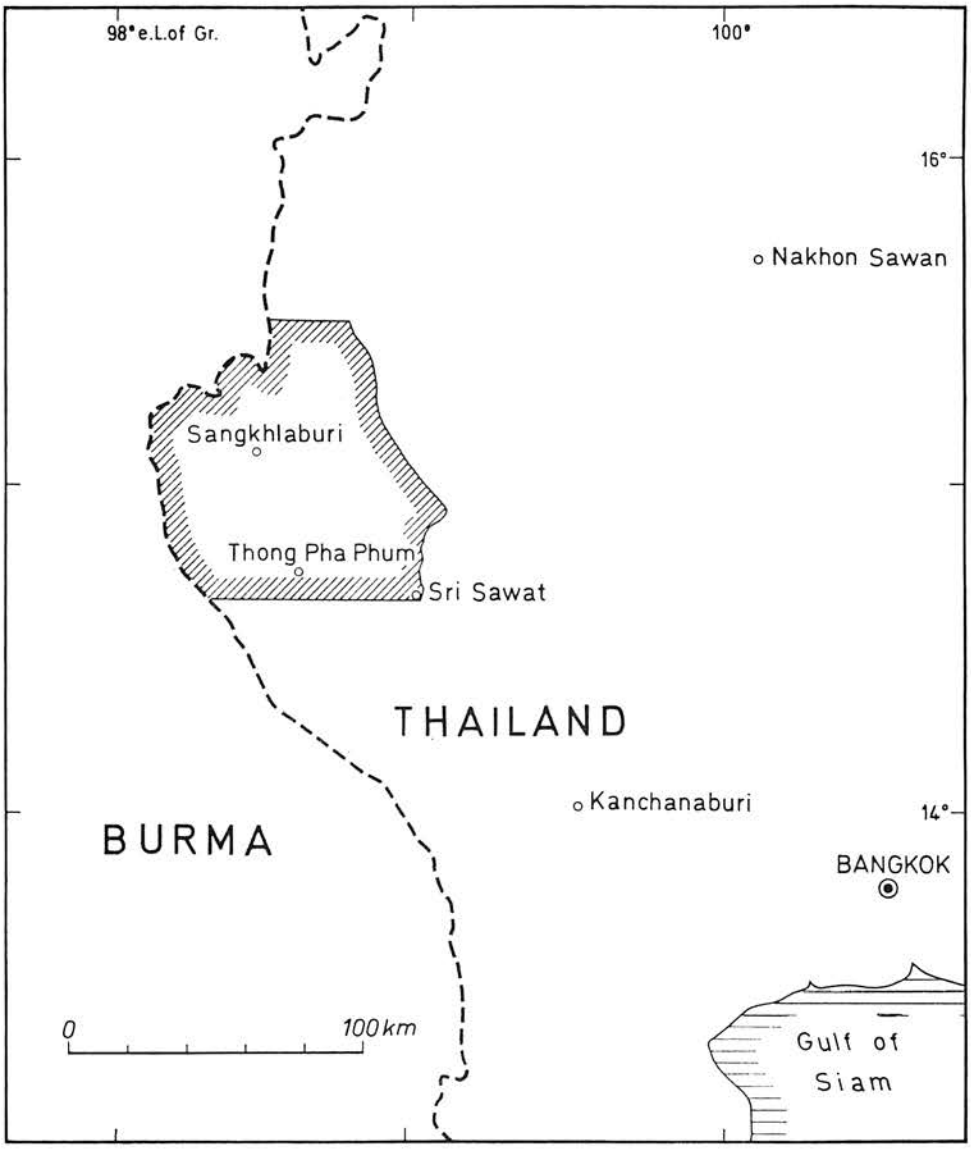

Fig. 1. Location map, Region Sri Sawat—Thong Pha Phum—Sangkhlaburi (Kanchanaburi Province, Thailand).

recently (Myint Lwin Thein, *et al.*, 1971). Further to the South (on Ko Tarutao) upper parts of a corresponding sequence (red sandstone) have been dated as Upper Cambrian by means of trilobites and brachiopods (Kobayashi, 1964), a date which has probably to be corrected to lowermost Ordovician (personal communication, R. Wolfart, Hannover).

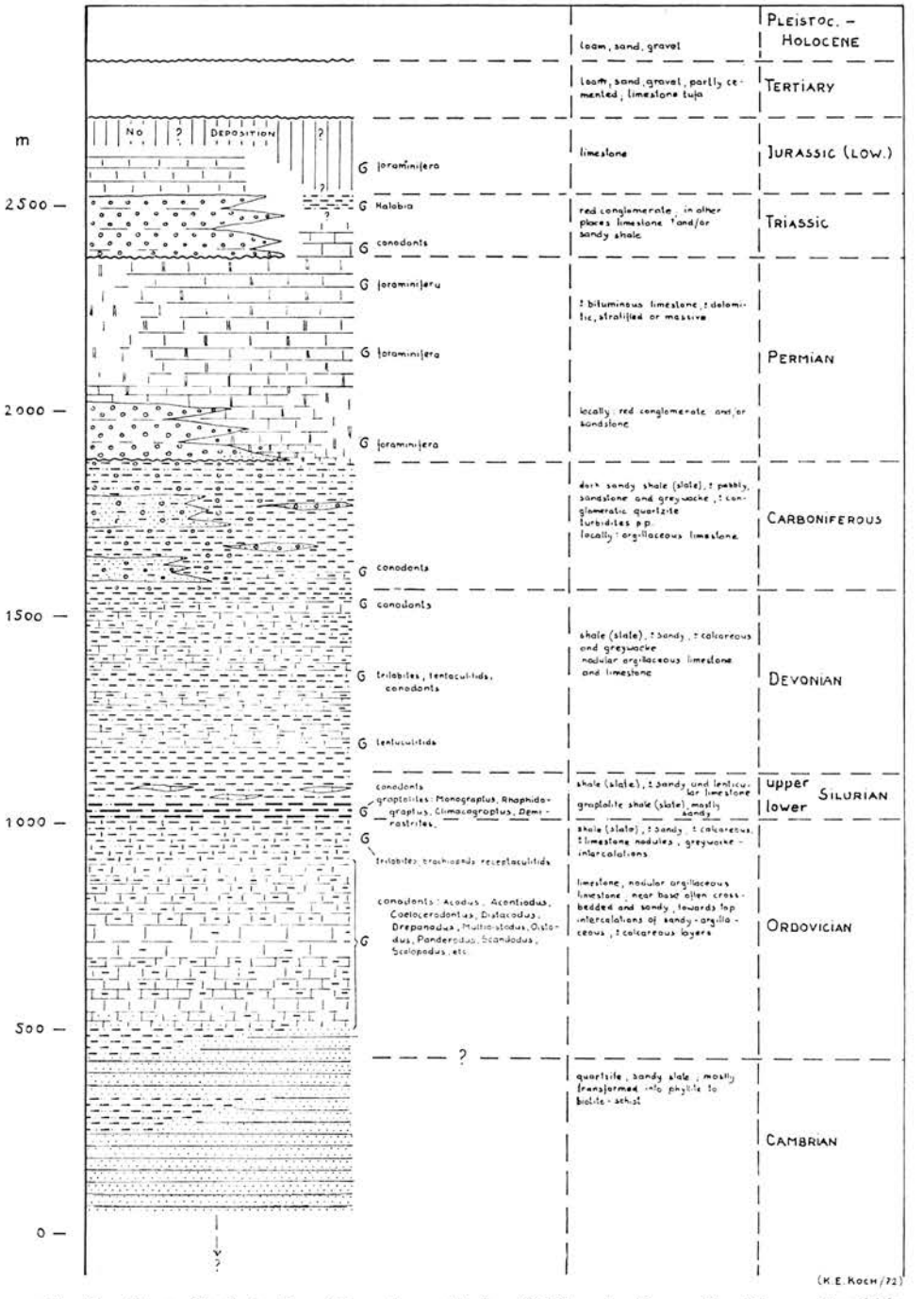

Fig. 2. Generalised stratigraphic column, Region Sri Sawat—Thong Pha Phum—Sangkhlaburi (Kanchanaburi Province).

The unmetamorphosed equivalents of the clastic succession crop out along the Mae Nam Khwae Yai, about 30 km, south of Sri Sawat, and comprises more than 400 m of fine to coarse sandstone, becoming more and more calcareous towards the top, with occasional impure limestone intercalations. These upper parts contain several fossil beds mainly with brachiopods and trilobites. They have not yet been examined in detail, but indicate Lower to Middle Ordovician age (personal communication, R. Wolfart, Hannover).

It may be concluded therefore that sedimentation of this clastic complex started well back in Cambrian time, continuing to a certain degree into the Ordovician. This sequence is by no means to be correlated with the so called "Phuket Series" of peninsular Thailand and corresponding sequences in adjacent Malaysia and Burma, the age of which is Upper Paleozoic (compare: Carboniferous).

Ordovician proper

The Ordovician comprises a limestone sequence, overlying conformably the Cambrian deposits. Basal portions tend to contain fine to coarse sand in cross-bedded limestone. The main part of the limestone is mostly fine grained and grey, often with finely intercalated argillaceous bands or streaks, or even forming nodular limestone. Reef limestone occurs occasionally (e.g. Bo Yai lead mine, east of Thong Pha Phum). Towards the top the limestone content decreases. A series of finely sandy and micaceous shale terminates the Ordovician part of the stratigraphical section.

This sequence is to be compared with the "Thung Son Series" of Southern Thailand, and correspondingly with the Setul Formation on Langkawi Island, Malaysia (Mitchell, *et al.*, 1970) or the "Mawson Series" of Upper Burma (Holland, *et al.*, 1956).

Microfossils (mainly conodonts from the limestone) and megafossils found, (determinations by D. Stoppel and R. Wolfart, Hannover) indicate an age, ranging from Lower or Middle to Upper Ordovician. The original thickness of the limestone may reach about 450 m (near Sangkhlaburi), the overlying clastic series 100 to 150 m. It may be noted here that within the Ordovician limestone a widespread lead-zinc mineralization with accompanying copper, silver and baryte occurs, the origin of which may be sedimentary and/or hydrothermal.

Silurian

Without a major change of facies, sedimentation continued with fine clastic sediments from the Ordovician into the Silurian, the next discernable lithological unit being black, finely stratified and sandy graptolite shales of about 60 m thickness, yielding graptolite faunas of Lower Silurian age, e.g. *Climacograptus* cf. *medius* TOERNQUIST, *Rhaphidograptus toernquisti* (Elles & Wood) *Diplograptus* sp. of Llandoverian age (Bastin *et al.*, 1970). Silurian strata continue with shale and minor intercalations of nodular and/or lenticular limestone to an overall thickness of about 120 m.

Devonian

The Devonian sequence overlies Silurian shale without any noticeable break. Near the base occasionally dark and mostly calcareous shale with tantaculites *and* graptolites occur, representing the lowermost Devonian. This corresponds well to findings in Northern Thailand (Jaeger, *et al.*, 1969; Baum, *et al.*, 1970). The major part of

the Devonian sequence is formed by sandy shale, greywacke, and mostly nodular limestone, alternating with each other in units of 10 to 100 m thickness. The sequence is overlain by soft, greenish shale, which grade into shale of Lower Carboniferous age. Megafossils (trilobites, brachiopods, tentaculites, graptolites) and conodonts have been found frequently, covering practically the complete range of Devonian chronology. A well studied section east of Thong Pha Phum shows the Devonian sequence to be approximately 450 m thick (Hagen, 1970).

Carboniferous

The Carboniferous comprises a preponderably clastic sequence. Generally it may be said that major tectonic movements in the source-area of the Carboniferous sediments led to a rather sudden increase of sandy and/or pebbly components, but no hiatus could be observed against the Upper Devonian shale in the area mapped. The limit Devonian/Carboniferous has tentatively been drawn where hard and dark grey to blackish sandy shale occurs first in the stratigraphic section. In the western and northwestern parts of the area the shales frequently contain mostly well rounded phenoclasts of up to 10 cm. Quartz, sandstone, quartzite, slate, chert, phyllite and granite are the most frequent components observed. The pebbly shale corresponds to a sequence of considerable distribution in peninsular Thailand, extending into Burma ("Mergui series") and Malaysia, formerly called "Phuket Series" in Thailand, and formerly regarded as of Cambrian age. Fossil evidence there has since proved a younger Paleozoic age for this series (Baum & Koch, 1968; Young & Jantaranipa, 1970).

Intercalated into the more shaly sequence are some sandstone, arkosic sandstone and greywacke, which may be conglomeratic to a varying degree. The sequence clearly shows flyschlike characteristics, a considerable part of the sequence apparently being formed by turbidity currents. The thickness of this clastic sequence, regarded as Carboniferous because of sporadic fossil evidence, is estimated to about 200 to 400 m.

Permian

The Carboniferous is overlain by a carbonate sequence, 200 to 400 m thick. Very often it is strongly dolomitic, and bituminous and tends easily to mylonitisation, and thus corresponds well to comparable sequences in Western Burma (e.g. Gramann, 1972). Preliminary fossil determinations (brachiopods, fusulinid foraminifera, etc.) indicate that this carbonate sequence comprises the entire Permian (personal communication E. Kemper & Wolfart, Hannover).

In some areas, e.g. northwest of Thong Pha Phum, an apparently transgressive sequence replaces the lower parts of the carbonate deposits. In its characteristic appearance, a coarse, probably marine conglomerate with a thickness of up to 200 m overlies directly sandy and pebbly shale of Carboniferous age. No hiatus between the two can be observed directly, but one must be postulated. The matrix of the conglomerate is mostly red and marly-sandy. The phenoclasts, up to 30 cm, consists of quartz, sandstone, slate, and predominantly of grey and red limestone. At the top a rather abrupt transition towards the overlying carbonate series can be observed. Laterally the conglomerate tends to pinch out rather fast, or is replaced by red sandstone with intercalations of cellular dolomite.

Triassic

South and southeast of Thong Pha Phum and north of Sri Sawat a probably marine conglomeratic sequence of similar appearance as the one mentioned before

occurs. The very coarse components (mostly limestone) reach 50 cm. Some pebbles contain Lower and Upper Permian fossils respectively (Hagen, 1970). Tentatively, the age of this conglomerate is regarded as Triassic, and would thus correspond to that of comparable formations in Burma and northeastern Thailand. The thickness of the sequence may attain approximately 200 m. This conglomeratic sequence may be replaced laterally by limestone, as indicated by a conodont fauna of Anisian age (personal communication D. Stoppel, Hannover), found north of Sri Sawat. This limestone overlies without hiatus the underlying carbonate series of Permian age, and may not be separated from the latter without fossil evidence. This sequence corresponds well to one described by Gramann, *et al.*, (1972) from the Southern Shan and Kayah States in Burma, where Permian parts of the Upper Plateau Limestone are followed by a Permotriassic carbonate sequence (Thigaungdaung limestone) without a noticeable break.

Triassic sandstones and shales with *Halobia* and/or *Daonella*, comparable to the "normal" facies within West Malaysia and Northern Thailand, as found by geologists of the Department of Mineral Resources in the Khwae Yai valley south of Sri Sawat, could not yet be ascertained to occur in the area of investigation.

Jurassic

Conformably overlying the conglomeratic sequence of presumably Triassic age and not yet ascertained in another stratigraphic position in other parts of the region, is a limestone deposit of up to 300 m thickness, well bedded, and of brownish to grey colour. Preliminary determinations of microforaminifera from thin sections (E. Kemper, Hannover) indicate an age younger than Triassic, most probably Lower Jurassic. This dating allows a comparison with the Upper Jurassic Namyau-Beds of Burma, southeast of Mandalay.

Tertiary to Pleistocene/Holocene

Terrace-fillings of larger valleys occur in different parts of the region, and may exceed a thickness of 200 m. According to their respective local environment they consist of gravel, sand, loam and calcareous tufa, and are practically cut throughout by subrecent and recent erosion, with the exception of the Holocene parts.

STRUCTURAL GEOLOGY

The present structural situation is the result of several orogenic events of varying intensity, as well as of postorogenic fracturing, the latter being active until the very recent past.

Precambrian/early Cambrian Orogeny

No direct indication of this orogeny, observable elsewhere in Northern Thailand and adjacent regions (Baum, *et al.*, 1970) could be found. Nevertheless the clastic sequence underlying the Ordovician limestone indicates an erosional cycle, following such an orogenesis.

Carboniferous Orogeny

As indicated by the turbiditic sediments of Carboniferous age, tectonically unstable conditions developed during that time apparently starting during Upper Devonian as shown by a mixed fauna of conodonts (Upper Devonian IV–VI with reworked Upper Devonian II–D. Stoppel, Hannover). Whereas, within the area of

investigation the basin seems to have persisted at least during the first phase of that orogeny, considerable erosion must have taken place elsewhere, as indicated by the coarse clastic sediments or components in turbiditic sediments. Beside older sedimentary rocks the most striking component of these pebbles is a granite of unknown age and provenience. It remains doubtful, whether this granite may be identified with or related to an older granite in Northern Thailand, the age of which has been dated previously as 344 m.y. (Baum, *et al.*, 1970).

During a late phase of the Carboniferous orogeny at least certain parts of the former basin area were affected too, as indicated by strongly terrestrial influenced sediments, and the coarse lacustrine conglomerate sequence, deposited during Lower Permian time. As there is no hiatus observable directly between sediments of Carboniferous and Permian age, and as in large parts no conglomerate is developed at all, orogenic movements seem to have been rather gentle within the area proper, stronger movements must have taken place outside the area, probably to the west. During Middle and Upper Permian time the basin area seems to have been rather flat and relatively stable.

Triassic Orogeny

With the end of the Permian, conditions in the sedimentary basin seem to have become definitely unstable. Sedimentation may have ceased in some areas completely. Nevertheless, marine transgression apparently took place, as indicated by the littoral conglomerate of post-Permian origin southeast of Thong Pha Phum and north of Sri Sawat, but in other parts sedimentation of carbonate sediments continued from Permian to Triassic.

Post-Jurassic Orogeny

As the limestone of ?Lower Jurassic age, overlying the Triassic conglomerate sequence, is incorporated into the actual structural pattern of orogenic origin, it may be concluded that during Upper Jurassic or Cretaceous time the last and major orogenesis took place, creating the majority of the present-day structures. Intense folding and faulting took place, dominated by disharmonic movements, due to considerable differences in plasticity of the different rock units and overburden. They resulted in steep, striking faults, more or less parallel to the structural axis, cutting the latter occasionally at an acute angle. These "scissor-faults" reach considerable importance, and can be clearly traced morphologically, for instance from the Khwae Noi valley zone to the north-northwest more than 80 km into Burma. The direction of the structural axis varies from N–S to NW–SE, with occasional sigmoidal deviations to E–W.

During this orogeny dynamometamorphism affected those parts of the sequence which were downfolded to sufficient depth and thus projected into zones of sufficiently high pressure-temperature conditions. Consequently, rocks of Cambrian age were the most effected, and rocks of Ordovician to Devonian age to a certain extent only.

Young Fracturing

Young fracturing affected practically the whole area, including Upper Tertiary to Pleistocene sediments. It determines much of the present day morphology. In many cases, especially in zones following the Khwae Yai and Khwae Noi valley zones, the

young fracturing seems to be a rejuvenation of "scissors faults" from the post-Jurassic orogeny.

INTRUSIVE ROCKS

Several granite plutons occur within the area of investigation. Up to now no radiometric age determinations exist for any of these (some are in preparation), and no definite dating by geologic reasoning is possible so far either.

Khwae Yai Granite

A fine to medium grained, finely porphyric biotite granite occurs 20 to 30 km upstream the Mae Nam Khwae Yai from Sri Sawat. It is not stressed as far as observable, and it intrudes rocks of Lower Paleozoic age. Tentatively this granite is regarded as of Triassic age. No accompanying mineralization is known so far.

Central Granite

A biotite granite, fine to medium grained, occasionally porphyric, slightly stressed attains a considerable distribution in the mountains east and southeast of Sangkhlaburi, often covered by metasediments. It intruded metasediments and sediments of Lower Paleozoic age, causing an anatexitic mantle of sometimes considerable thickness. Pegmatitic quartz veins from this granite contain varying amounts of hematite, copper or lead, and baryte veins near the Mae Nam Khwae Noi might also belong to this succession. A scattered stibnite mineralization occurring in the northern part of the region is most probably connected with this granite as well. It is not clear, to what extend a lead-zinc mineralization of the Ordovician limestone is due to or influenced by this intrusive body. The age of the granite is not definite, possibly Paleozoic.

Pilok Granite

A porphyric biotite-muscovite granite, medium to coarse grained, extends roughly NNW–SSE, cropping out in the Thai–Burmese border range. Associated with it are aplitic and pegmatitic dykes, some of which have been altered to greisen. The granite intruded meta-sediments and sediments of Carboniferous and older age which are steeply folded. Generally it may be said that the granite is frequently covered by altered sediments, thus making it impossible to draw a clear limit between the latter and the granite without detailed mapping. An extensive tungsten-tin mineralization, accompanied occasionally by gold, occurs, and is connected with veins injecting the granite as well as its overburden (Brown, *et al.*, 1953). The age of the granite is still unknown, possibly Triassic in parts.

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