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Early Permian ammonoids from the Kaeng Krachan Group of the Phatthalung-Hat Yai area, southern peninsular Thailand

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Abstract

An Early Permian small ammonoid fauna consisting of *Neocrimites* sp., *Agathiceras suessi* Gemmellaro, *A. girtyi* Böse, *Agathiceras*? sp., and *Miklukhoceras* sp. was found in nodules of a fine sandstone bed exposed in the Phatthalung-Hat Yai area of southern peninsular Thailand. The ammonoid-bearing bed belongs stratigraphically to the uppermost part of the Kaeng Krachan Group, which is essentially a clastic-dominant, Late Carboniferous (?) to Early Permian stratigraphic unit, widely distributed in western and peninsular Thailand. This ammonoid fauna is considered to be of Bolorian (Kungurian) age and includes *Agathiceras girtyi* Böse, which is described for the first time from Thailand. The present discovery of Bolorian ammonoids suggests that the uppermost part of the Kaeng Krachan Group is slightly younger than previously considered and around the latest Early Permian. This further implies that the continental margin environment of the Sibumasu Block drastically changed at around Bolorian time from a cool, clastic-dominant shelf condition to a temperate to subtropical, carbonate platform due to rapid northward drift after middle Artinskian rifting.

Keywords: Ammonoidea; Kaeng Krachan Group; Peninsular Thailand; Permian; Ratburi Limestone

1. Introduction

Late Paleozoic ammonoids have been reported from various areas of Southeast Asia since Haniel's (1915) classic work in Timor. In Thailand, their occurrence is mostly restricted to the northern, northeastern, and eastern areas (Pitakpaivan et al., 1969; Glenister et al., 1990; Ishibashi and Chonglakmani, 1990; Ishibashi et al., 1994, 1996, 1997; Fujikawa and Ishibashi, 1999; Zhou and Liengjarern, 2004). In contrast, ammonoid fossils are scarcely known in peninsular Thailand, except for those reported by Reed (1920), despite the widespread distribution of Late Paleozoic strata. In this area basic paleontological data on Late Paleozoic ammonoids are still insufficient.

The Phatthalung-Hat Yai area is situated in the southernmost part of peninsular Thailand. There have been several paleontological studies in the areas surrounding Hat Yai since Reed (1920) described a Carboniferous ammonoid from Kuan Lin Soh in southern peninsular Thailand. In the last two decades, Triassic conodonts (Igo et al., 1988; Ampornmaha, 1995), Triassic radiolarians (Sashida and Igo, 1992), Triassic ichthyopterygian marine reptile (Mazin et al., 1991), Triassic foraminifers and corals (Fontaine et al., 1993; Ueno et al., 2003), Permian shallow-marine fossils (Fontaine et al., 1994), and Permian foraminifers and corals (Ueno et al., 1996) have been reported from this area. However, most of these previous reports are from Phatthalung and nearby areas, located about 80 km

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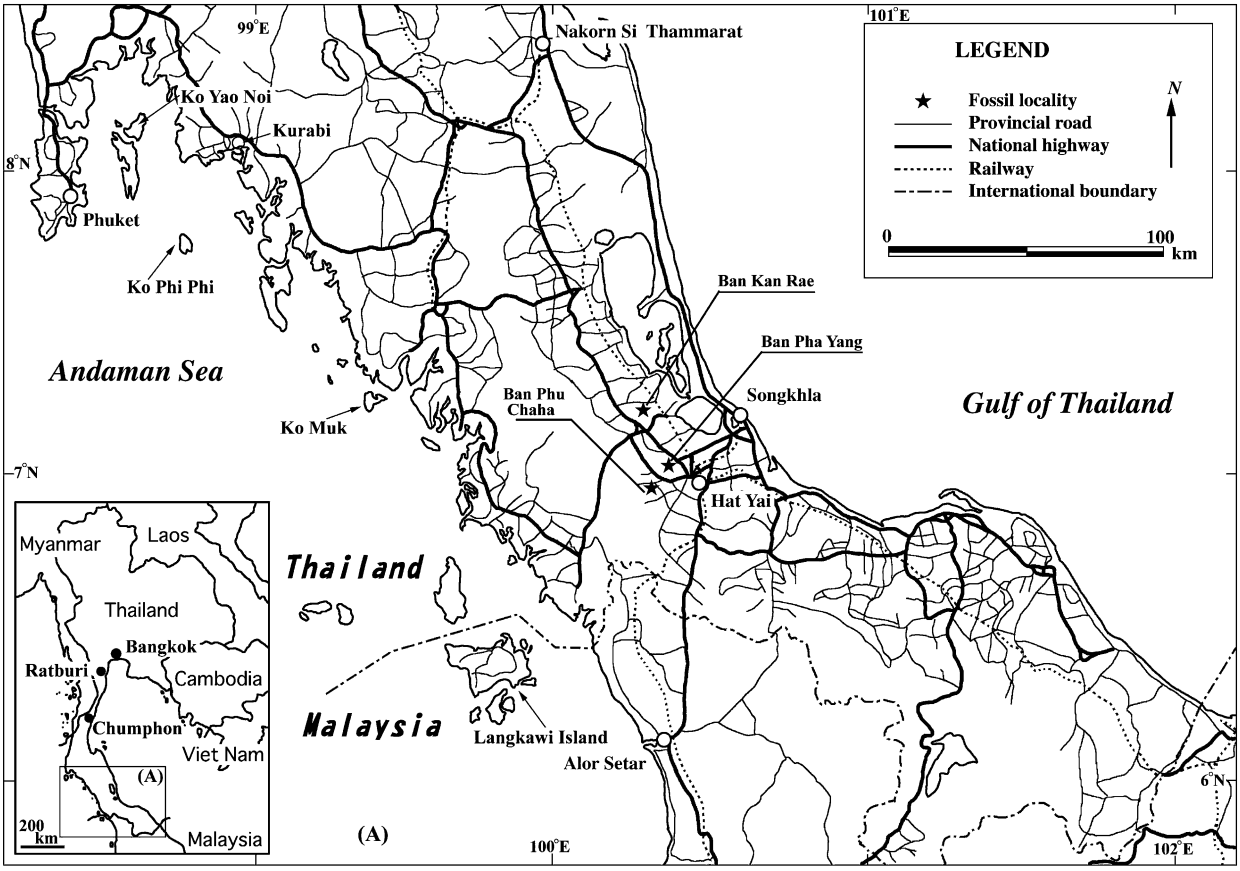

Fig. 1. Index map showing ammonoid localities studied herein and other Permian fossil localities in the Malay Peninsula, referred to in this paper.

northwest of Hat Yai. Paleontological information on the Permian is still poor in the southern peninsular area, compared to other parts of Thailand.

In the course of mapping the 1:50,000 Hat Yai Quadrangle (Sardsud and Saengsrichan, 2001), directed by the Geological Survey Division, Department of Mineral Resources (DMR), Thailand, Permian ammonoids were collected from a fine sandstone bed belonging to the upper part of the Kaeng Krachan Group, exposed at Ban Kan Rae in the southernmost part of Changwat Phatthalung, southern peninsular Thailand (Figs. 1 and 2). The present paper describes these ammonoids and discusses the age of the topmost Kaeng Krachan Group, which has been equivocal for a long time.

All samples described herein are deposited and registered in the paleontological collection of the National Science Museum of Japan with the prefix NSM PM.

2. Geologic setting and ammonoid-bearing locality

The Phatthalung-Hat Yai area in the southern part of peninsular Thailand belongs geologically to the eastern part of the Sibumasu (or Shan-Thai) Block of the eastern Cimmerian Continent. In this block, the Permian is generally represented by two highly contrasted lithologies. The lower part is composed of various kinds of siliciclastics, and is characterized by containing glaciogene diamictite beds at some levels (e.g. Stauffer and Mantajit, 1981). It has been named the Kaeng Krachan Group or Phuket Group in western and peninsular Thailand, the Singa and Kubang Pasu formations in Peninsular Malaysia, and the Mergui Group in peninsular Myanmar. On the other hand, the upper lithologic unit consists mainly of carbonate rocks, and is referred to as the Ratburi Limestone (Group) in peninsular Thailand and the Chuping Limestone (Formation) in Peninsular Malaysia.

The stratigraphy, sedimentology, and paleontology of the Kaeng Krachan Group and its equivalent strata in peninsular Thailand have been studied by many geologists (e.g. Piyasin, 1975; Garson et al., 1975; Waterhouse et al., 1981; Raksaskluwong and Wongwanich, 1993; Shi et al., 2002). Originally, three formations were proposed for the Kaeng Krachan Group (Piyasin, 1975); in ascending order the Huai Phu Noi, Khao Phra, and Khao Chao formations. In recent papers, however, the group has been subdivided into the following four formations; in ascending order the Khao Wang Karadat, Spillway, Ko He, and Khao Phra (or Ko Yao Noi) formations (Raksaskluwong and Wongwanich, 1993).

The Kaeng Krachan Group and similar lithofacies in peninsular Thailand characterized by the presence of diamictites were originally regarded as Devonian to

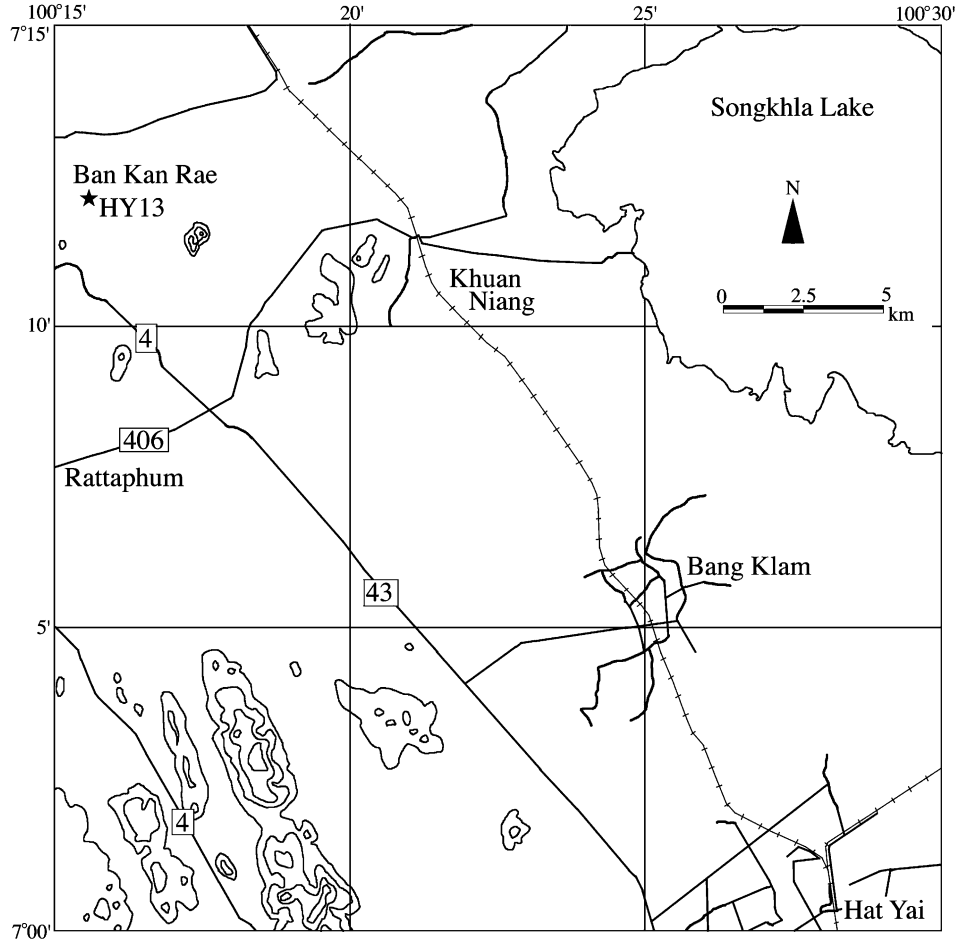

Fig. 2. Location map showing fossil locality at Ban Kan Rae in Phatthalung-Hat Yai area, southern peninsular Thailand.

Permian in age (Ridd, 1971; Piyasin, 1975). However, in recent studies they are generally assigned to the Carboniferous to Permian (e.g. Raksaskulwong, 2002). Fossils (mainly brachiopods and bryozoans) have been documented particularly from the Khao Phra Formation (Mitchell et al., 1970; Sakagami, 1971; Waterhouse et al., 1981; Waterhouse, 1982; Shi et al., 2002) of Raksaskluwong and Wongwanich (1993) and its equivalents above the main diamictite levels in the Ko He Formation. These fossils are exclusively of Early Permian (chiefly Asselian to Artinskian) age. This suggests that part of the great thickness of the lower three formations of the Kaeng Krachan Group could possibly be of Late Carboniferous age, despite the absence of paleontologic evidence.

The Kaeng Krachan Group is overlain conformably by the Ratburi Limestone (Ratburi Group). However, the exact stratigraphic contact between the Kaeng Krachan Group and the Ratburi Limestone has not been documented in continuous outcrop until now. In addition, the precise age of the boundary between these two groups is still controversial, although it would broadly correspond to the Early/Middle Permian boundary.

The ammonoid fossils studied herein were collected from a weakly bedded fine sandstone (partly siltstone) unit exposed at Ban Kan Rae (coordinates N07°12′15″, E100°15′38″) about 34 km northwest of Hat Yai (Fig. 2). The ammonoids occur in nodules contained in a gray fine sandstone (sample HY13), which strikes N12°E and dips 24° southeastward. Similar lithofacies to this ammonoid-bearing siliciclastics bed are scattered throughout the western part of the Hat Yai Quadrangle, forming a NNW–SSE trending low mountain range.

Due to poor exposure around the fossil localities, it is difficult to fix the ammonoid-bearing level in the stratigraphic framework of this area exactly. However, available field data suggest that the ammonoid-bearing fine siliciclastics, at least 50 m thick, are succeeded by a reddish sandstone unit several meters thick and then by a nodular-bedded, chertified rock unit, about 20 m thick (Fig. 3). A thin paleosol layer is locally developed at the top of the reddish sandstone unit.

The chertified rock was probably a shallow-marine limestone (presumably grainstone and/or packstone) in origin, as it shows in thin section plenty of relics of shallow-marine skeletal debris such as bryozoans, crinoids, and foraminifers. This chertified carbonate yields younger Permian-indicating *Codonofusiella* and several smaller foraminiferal genera (such as *Pachyphloia* and

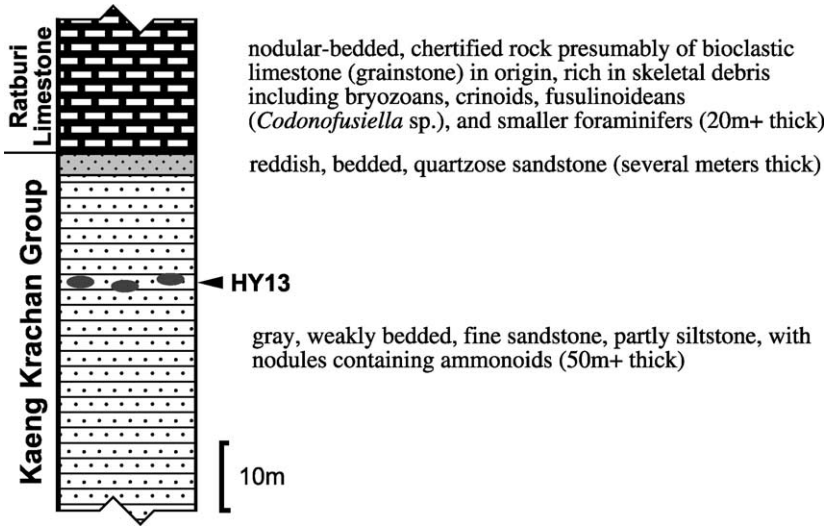

Fig. 3. Simplified columnar section of Permian strata distributed around Ban Kan Rae. HY13 indicates approximate stratigraphic position of ammonoids studied herein.

Globivalvulina), and can be treated as merely a completely silicified part of the Ratburi Limestone, widespread in western and peninsular Thailand. This further suggests that the ammonoid-bearing unit just below the Ratburi Limestone can reasonably be referred to the Kaeng Krachan Group from the viewpoint of both lithology and stratigraphic position. Moreover, it would correspond stratigraphically to the uppermost part of the group, and could be the correlative of the Khao Phra (or Ko Yao Noi) Formation of Raksaskluwong and Wongwanich (1993) or to the Khao Chao Formation of Piyasin (1975). As a *Codonofusiella*-bearing part of the Ratburi Limestone, definitely of post-Kubergandian/post-Roadian age, rests directly on siliciclastic strata of the Kaeng Krachan Group with a thin intervening paleosol layer, it is apparent that the lower (especially basal) part of the Ratburi Limestone, characterized by bedded muddy limestone with rich brachiopod faunas in other areas, is not developed in the Ban Kan Rae area. Thus, the Ratburi Limestone rests unconformably on the Kaeng Krachan Group in this area.

3. Ammonoid fauna and its age

We obtained the following ammonoid fauna from sample HY13 at Ban Kan Rae, comprising five species referable to three genera (numerals in parenthesis indicate numbers of specimens collected): *Neocrimites* sp. (5), *Agathiceras suessi* Gemmellaro (15), *A. girtyi* Böse (1), *A.*? sp. (6), and *Miklukhoceras* sp. (1). Although not described in this paper due to poor preservation, we also found fragments of *Agathiceras* sp. from similar fine sandstone beds exposed at Ban Pa Yang about 19 km SSE of Ban Kan Rae, and in a small abandoned quarry near Ban Phu Chaha (coordinates N06°56′36″, E100°17′44″) about 27 km south of Ban Kan Rae in Changwat Hat Yai, respectively (Fig. 1).

Of the ammonoids from Ban Kan Rae, *Agathiceras*, the most dominant genus in this fauna, is one of the commonest Late Paleozoic genera reported from various areas of the world. According to Zhou et al. (1999), it ranges from the Moscovian up to Murgabian (Wordian). Of the two identified species from Ban Kan Rae, *A. suessi* Gemmellaro is known to be restricted to the Sakmarian to Kubergandian (Roadian) (e.g. Plummer and Scott, 1937; Miller and Furnish, 1940; Ishibashi et al., 1996) and *A. girtyi* Böse is considered to occur from the Asselian to Kubergandian (Böse, 1919; Baker, 1929; Plummer and Scott, 1937; Miller and Furnish, 1940).

The genus *Neocrimites* is also a well-known cosmopolitan taxon in the Early to Middle Permian. Its stratigraphic range is known to be from the Bolorian (Kungurian) to Midian (Capitanian) (Zhou et al., 1999). The other genus in the Ban Kan Rae fauna, *Miklukhoceras*, has been known hitherto only from SE Pamir and Nakorn Ratchasima of northeastern Thailand, and is considered to indicate a Sakmarian to Bolorian age (Zhou et al., 1999).

Fig. 4 summarizes the stratigraphic ranges of ammonoids from Ban Kan Rae. It indicates that the age of the Ban Kan Rae fauna is referable to the Bolorian (Kungurian) of the latest Early Permian. This implies that the upper part of the Kaeng Krachan Group ranges in age over the latest Early Permian.

Until now, Permian ammonoids have been poorly documented in the Malay Peninsula, including peninsular Thailand, except for those sporadically found from western Peninsular Malaysia (e.g. Lee, 1980; Leonova et al., 1999). These autors reported several Early Permian ammonoids. The ammonoid faunas yield *Neocrimites* species and *Agathiceras suessi* Gemmellaro and thus show some

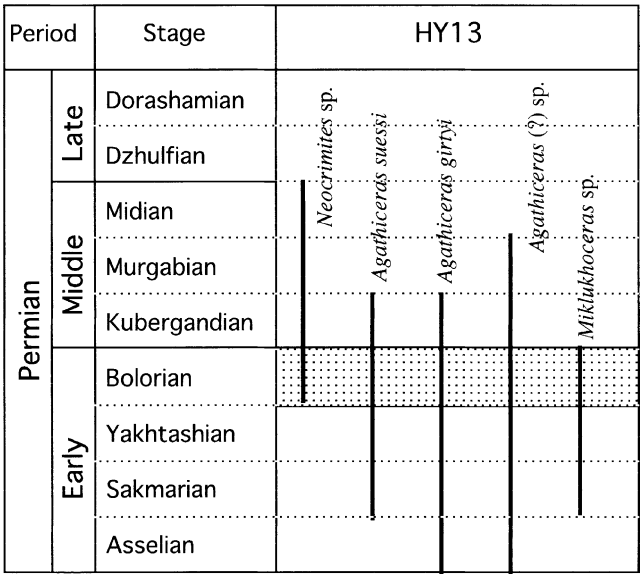

Fig. 4. Range chart showing stratigraphic distributions of ammonoids from Ban Kan Rae.

similarities to the present Bolorian ammonoid fauna from southern peninsular Thailand.

In Southeast Asia outside the peninsula, Permian ammonoids have been reported abundantly from Timor Island since Haniel (1915). Recently, Owen (in Charlton et al., 2002) reassessed the Permian ammonoid faunas of Timor and made a comprehensive list of ammonoid taxa. Some of the Permian ammonoid faunas of Timor, such as those from Lidak and Bitauni, are probably coeval with the Ban Kan Rae fauna. However, critical comparison between the Timor and the present Thailand faunas is difficult because only the genus *Agathiceras*, which is rather cosmopolitan and long-ranging among Early Permian ammonoids, is common to the two faunas. Notwithstanding the small ammonoid fauna from Ban Kan Rae, this is important information as it provides the first description of Permian ammonoids from southern peninsular Thailand and also the first report of the occurrence of *Agathiceras girtyi* Böse in Southeast Asia.

4. Discussion

In western and peninsular Thailand, the Permian siliciclastic-dominated unit is assigned to the Kaeng Krachan Group or Phuket Group, and its upper part is broadly considered to be of Early Permian age (e.g. Waterhouse, 1982), although the unit may extend downwards into the Carboniferous. On the other hand, the upper Permian lithostratigraphic unit, dominated by carbonates, is called the Ratburi Limestone (or Group), and is generally referred to the Middle–Late Permian. The boundary between the two groups has been broadly settled near the Early/Middle Permian boundary, but the precise age of the boundary has been the subject of controversy for a long time, due to insufficient paleontologic data from near the boundary levels.

The brachiopod fauna of the Ratburi Limestone has provided a valuable tool for age determination (Waterhouse and Piyasin, 1970; Yanagida, 1970; Waterhouse, 1973,1981; Grant, 1976; Archbold, 1999) (Fig. 5). Brachiopods have

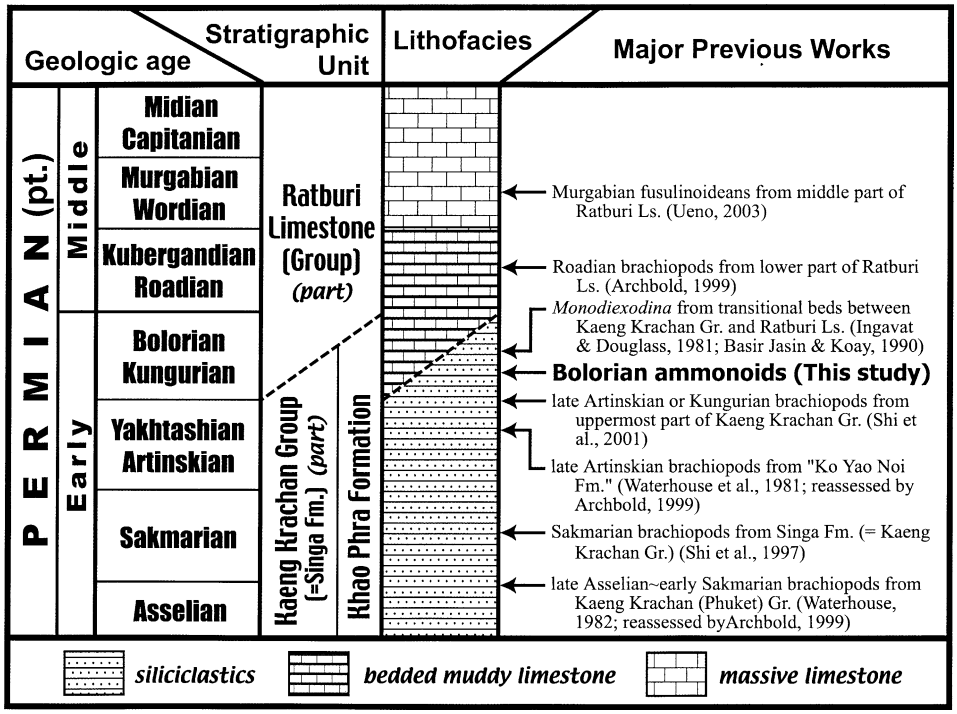

Fig. 5. Schematic Permian stratigraphy of Sibumasu Block and summary of major previous works on biochronology of upper part of Kaeng Krachan Group and lower/middle part of Ratburi Limestone.

been reported from several stratigraphic levels in a number of far distant localities in different areas of peninsular Thailand, so that it is not easy to establish their biostratigraphy and biochronology in a unified stratigraphic scheme. Variable age assignments have been proposed for these brachiopod faunas, although most of them likely occur at rather low stratigraphic positions in the Ratburi Limestone. Recent reassessment of their ages by Archbold (1999), as well as the stratigraphic account of the Ratburi Limestone by Fontaine et al. (1994), suggests, generally, an Ufimian (Kubergandian) age for most brachiopod faunas, and a Bolorian to Late Permian age for the entire chronostratigraphic range of the Ratburi Limestone.

Ueno (2003) has shown that fusulinoideans occur mainly in massive limestone in the middle part of the Ratburi Limestone. The fusulinoideans are represented by *Eopolydiexodina afghanensis* (Thompson), *Rugosochwagerina* sp., *Chusenella* aff. *tumefacta* Chedija, *Yangchienia haydeni* Thompson, and several other species, and indicate a Murgabian age. The lower part of the group is essentially barren in fusulinoidean occurrences, although two *Monodiexodina* species have been reported by Ingavat and Douglass (1981) and Basir and Koay (1990) from calcareous sandstone or sandy limestone in the very basal part of the Ratburi Limestone, or from transitional beds between the Ratburi Limestone and the underlying clastic-dominant Kaeng Krachan Group (and equivalent strata). Ueno (2003) presumed that the *Monodiexodina* fauna, which would occupy a slightly lower stratigraphic position than the main brachiopod levels of the Ratburi Limestone, is of Bolorian age.

Brachiopods also play an important role in the age assignment of the Kaeng Krachan Group and its equivalents in the Malay Peninsula, such as the Phuket Group and the Singa Formation (Fig. 5). Work on brachiopods from the group by Hamada (1960) and Garson et al. (1975) was followed by Waterhouse (in Waterhouse et al., 1981) who described a rich brachiopod fauna from the Ko Yao Noi Formation at Ko Yao Noi and near Krabi, southern peninsular Thailand. This formation is the same as the Khao Phra Formation of Raksaskluwong and Wongwanich (1993) and the correlative of the Khao Chao Formation of Piyasin (1975). The brachiopods occur in the upper part of the Kaeng Krachan Group, just below the Ratburi Limestone, and were considered to be of probable Sakmarian age. Waterhouse (1982) further reported brachiopod faunas from the upper part of the Phuket (namely Kaeng Krachan) Group of Ko Muk and Ko Phi Phi in the same area, and, based on the occurrence of *Cancrinelloides monticulus* Waterhouse, a form close to *Cancrinelloides* from the Early Permian Burnett Formation of the Yarrol Basin, Queensland, he referred the Ko Muk and Ko Phi Phi faunas to the late Asselian.

Later, Shi et al. (1997) reported brachiopods from two localities in the Singa Formation, exposed in Langkawi Island of northwestern Peninsular Malaysia, which is again a correlative of the Kaeng Krachan Group of peninsular Thailand. They drew attention to a strong connection of the Singa brachiopod collections with the *Spinomartinia prolifica* Assemblage of the Ko Yao Noi Formation, and suggested a broad Sakmarian age for the Langkawi fauna.

Recently, Archbold (1999) reassessed the age of brachiopod faunas reported from the Kaeng Krachan Group and its equivalents in the Malay Peninsula. He recognized two distinct brachiopod faunas with different ages. The older one is represented by those described by Hamada (1960) and Waterhouse (1982), which consist of the genera *Arctitreta*, *Komukia*, *Bandoproductus*, *Phynchopora*, *Sulciplica*, *Spirelytha*, *Lamniplica* and *Elasmata*. A late Asselian or more likely, an early Sakmarian (Tastubian) age is preferred for this fauna. On the other hand, the younger fauna, which was described by Waterhouse (in Waterhouse et al., 1981) from the Ko Yao Noi Formation, is characterized by the genera *Demonedys*, *Dyschrestia*, *Retimarginifera*, *Spiriferella*, and *Spirelytha*. Archbold (1999) suggested a late Artinskian (Baigendzhinian) age for this fauna.

Very recently Shi et al. (2001) reported a small but important brachiopod fauna from the upper part of the Khao Phra Formation of the Kaeng Krachan Group exposed near Chumphon, central peninsular Thailand. They conclude that it can be dated to the late Artinskian or possibly as young as the Kungurian. This is the youngest age assignment by brachiopods of the Kaeng Krachan Group and its equivalent strata in the Malay Peninsula, and is in good agreement with the fact that the Shi et al.'s (2001) fauna occurs in the uppermost part of the Kaeng Krachan Group just below the overlying Ratburi Limestone.

Our present results, based on ammonoids, reinforces the dating by Shi et al. (2001) of the topmost Kaeng Krachan Group. Thus, the upper part of the group would be slightly younger than has been previously considered, and could be referable to around the latest Early Permian (Bolorian). This view is also broadly consistent with a Bolorian age assignment by Ueno (2003) for the basal part of the Ratburi Limestone or the transitional beds between the Kaeng Krachan Group and the Ratburi Limestone based on the *Monodiexodina* fauna. The present conclusion further means that the continental margin environment of the Sibumasu Block drastically changed at around Bolorian time, from a cool, clastic-dominant shelf environment to a temperate to subtropical, carbonate platform due to a rapid northward drift after the middle Artinskian rifting of the eastern Cimmerian continent from main Gondwanaland (Ueno et al., 2002). Moreover, global warming in latest Early Permian time (Leven, 1994) could also be substantially responsible for this rapid environmental change.

Fig. 6. 1–6. *Neocrimites* sp., 1, 2: lateral and ventral views, NSM PM16595, 3: lateral view, NSM PM16596, 4: lateral view, NSM PM16597, 5: lateral view, NSM PM16598, 6: lateral view, NSM PM16599. 7–14, 17–20. *Agathiceras suessi* Gemmellaro, 7, 8: lateral and ventral views, NSM PM16600, 9, 10: lateral and ventral views, NSM PM16601, 11, 12: lateral and ventral views, NSM PM16602, 13, 14: lateral and ventral views, NSM PM16603, 17, 18: lateral and ventral views, NSM PM16605, 19, 20: lateral and ventral views, NSM PM16606. 15, 16. *Agathiceras girtyi* Böse, lateral and ventral views, NSM PM16604. All x2.

5. Systematic paleontology

Class CEPHALOPODA Cuvier, 1797
Subclass AMMONOIDEA Zittel, 1884
Order GONIATITIDA Hyatt, 1884
Suborder GONIATITINA Hyatt, 1884
Family ADRIANITIDAE Schindewolf, 1931
Genus *Neocrimites* Ruzhencev, 1940

Neocrimites sp.
Fig. 6: 1–6

Material examined: Five specimens, consisting of a single uncrushed specimen (NSM PM16595), one incomplete fragment (NSM PM16597) and three lateral moulds (NSM PM16596, 16598, 16599).

Description: Conch inflated subdiscoidal to subglobose, umbilicus small, but not closed. Umbilical ratio to diameter about 0.15. Surface of test ornamented by shallow, moderately spaced longitudinal lirae. Umbilical shoulder not angular. Venter gently rounded and obvious ornamentation absent, except shallow longitudinal lirae. Sinuous,

periodic, and deep grooves cross over the ventral, and growth lines not preserved in our specimens. External suture-line absent.

Remarks: The Ban Kan Rae specimens definitely belong to the group of adrianitids, which are characterized by a globular conch, small umbilicus and prominent longitudinal lirae. Because of the presence of a narrow umbilicus and shallow longitudinal lirae in all our specimens, and a globular conch shown in one uncrushed complete specimen (NSM PM16595), they can be referred to the genus *Neocrimites*. The genus was proposed by Ruzhencev (1940), and is now known to exhibit considerable intra-generic morphological variations. It is widespread in the Lower to Middle Permian (Bolorian to Midian) from various areas of the world (Gemmellaro, 1887; Haniel, 1915; Miller and Furnish, 1940; Glenister and Furnish, 1961; Lee, 1980; Leonova, 1988; Zhou and Liengjarern, 2004).

Generally, species identification of *Neocrimites* is based on the configuration of the septal suture-line, and therefore, the proportions of the conch and/or surface ornamentation are considered to be less important in their classification. In our specimens, the suture-line is not sufficiently preserved, so that their exact identification should be postponed until better material is obtained.

One of our specimens (Fig. 6-1 and -2) is somewhat similar to *Adrianites adamsi* Miller and Furnish described by them (Miller and Furnish, 1940) from Texas. This species was assigned to the genus *Neocrimites* by Glenister and Furnish (1961), but our specimen can be distinguished from *Neocrimites adamsi* (Miller and Furnish) in having shallower transverse lirae.

In Southeast Asia, Lee (1980) described *Neocrimites* cf. *guangxiensis* Chao and Liang together with some other Permian cephalopods from the Lee Mine beds, Perak, Malaysia. The Lee Mine specimen resembles ours, but has a smaller umbilicus. Very recently, Zhou and Liengjarern (2004) described *Neocrimites nalivkini* (Toumanskaya) of a Kungurian age from the uppermost Nong Pong Formation distributed in Changwat Nakorn Ratchasima, East Thailand. This species apparently has a smaller conch than *Neocrimites* sp. in this study. Further comparison between these two forms is difficult at the moment because the Nakorn Ratchasima specimen lacks outer ornamentation (sculpture), whereas the present Ban Kan Rae specimens do not show suture-line that is essential for taxonomy.

Glenister and Furnish (1961) noted that *Agathiceras cancellatum discoidalis* and *A. cancellatum globosa*, both described by Haniel (1915) from the Bitauni and Basleo beds of Timor Island (Indonesia), should be referred to the genus *Neocrimites*. *Neocrimites* sp. in this study can be distinguished from the former in having a narrower conch, and from the latter in having wider umbilicus.

Measurement. See Table 1.

Family AGATHICERATIDAE Arthaber, 1911
Genus *Agathiceras* Gemmellaro, 1887
Agathiceras suessi Gemmellaro, 1887
Fig. 6:7–14, 17–20, Fig. 7:1–11, and Fig. 8

Agathiceras suessi Gemmellaro, 1887, p. 79–80, pl. 6, Figs. 1–4, pl. 7, Fig. 36; Gemmellaro, 1888, p. 22–24, pl. C, Fig. 20, pl. D, Fig. 13; Diener, 1927, p. 68, pl. 13, Fig. 2; Toumanskaya, 1931, p. 55–56, pl. 4, Figs. 20–29, pl. 6, Fig. 25; Plummer and Scott, 1937, pl. 29, Figs. 1 and 2; Martynov (in Likharev, 1939), p. 178, pl. 44, Fig. 1; Miller and Furnish, 1940, p. 118, pl. 31, Figs. 8–12; Moore, 1957, p. L51, Fig. 57; Miller and Furnish, 1957, p. 705–712, pl. 83, Figs. 9 and 10; Lee, 1980, p. 68, pl. 3, Figs. 13–15.

Agathiceras cf. *suessi*, Hayasaka, 1965, p. 19–21, pl. 2, Figs. 3 and 4.

Agathiceras aff. *suessi*, Hayasaka, 1963, p. 596–597, text-fig. 5; Pitakpaivan et al., 1969, p. 57–59, pl. 26, Figs. 4–8; Ishibashi et al., 1996, p. 181–184, pl. 11, Figs. 1–10.

Material examined: Fifteen specimens (NSM PM16600–16603, NSM PM16605–16615), most of them fragmentary; seven are lateral moulds.

Description: Shell medium to large in size, inflated discoidal to subdiscoidal, and strongly involute with a small and nearly closed umbilicus. Umbilical ratio to diameter in our specimens smaller than 0.1. Venter gently rounded and not angular. Surface of test marked by longitudinal lirae. In some mould specimens, fine and moderately deep longitudinal lirae observed. Transverse constrictions, sometimes sinuous, present. Growth lines absent. Deformed external suture-line possesses a bifid ventral lobe and four pairs of simple rounded lobes (Fig. 8).

Remarks: *Agathiceras* is one of the most well-known and widespread occurring goniatitid ammonoid genera. It was established by Gemmellaro (1887) based on specimens from the Sosio beds of Sicily. It is an almost cosmopolitan genus, and is known to occur from the Lower Pennsylvanian to the Middle Permian. The genus is characterized by a discoidal inflated conch, small umbilicus, fine longitudinal lirae, and

Table 1
Measurements of *Neocrimites* sp.

Figure	Reg. no.	*D*	*H*	*W*	*U*	*H/D*	*W/H*	*U/D*
6-1, 6-2	NSM PM16595	32.4	13.3	22.0	5.1	0.41	1.65	0.16
6-4	NSM PM16597	29.5			4.0			0.14

Values in mm where applicable. *D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

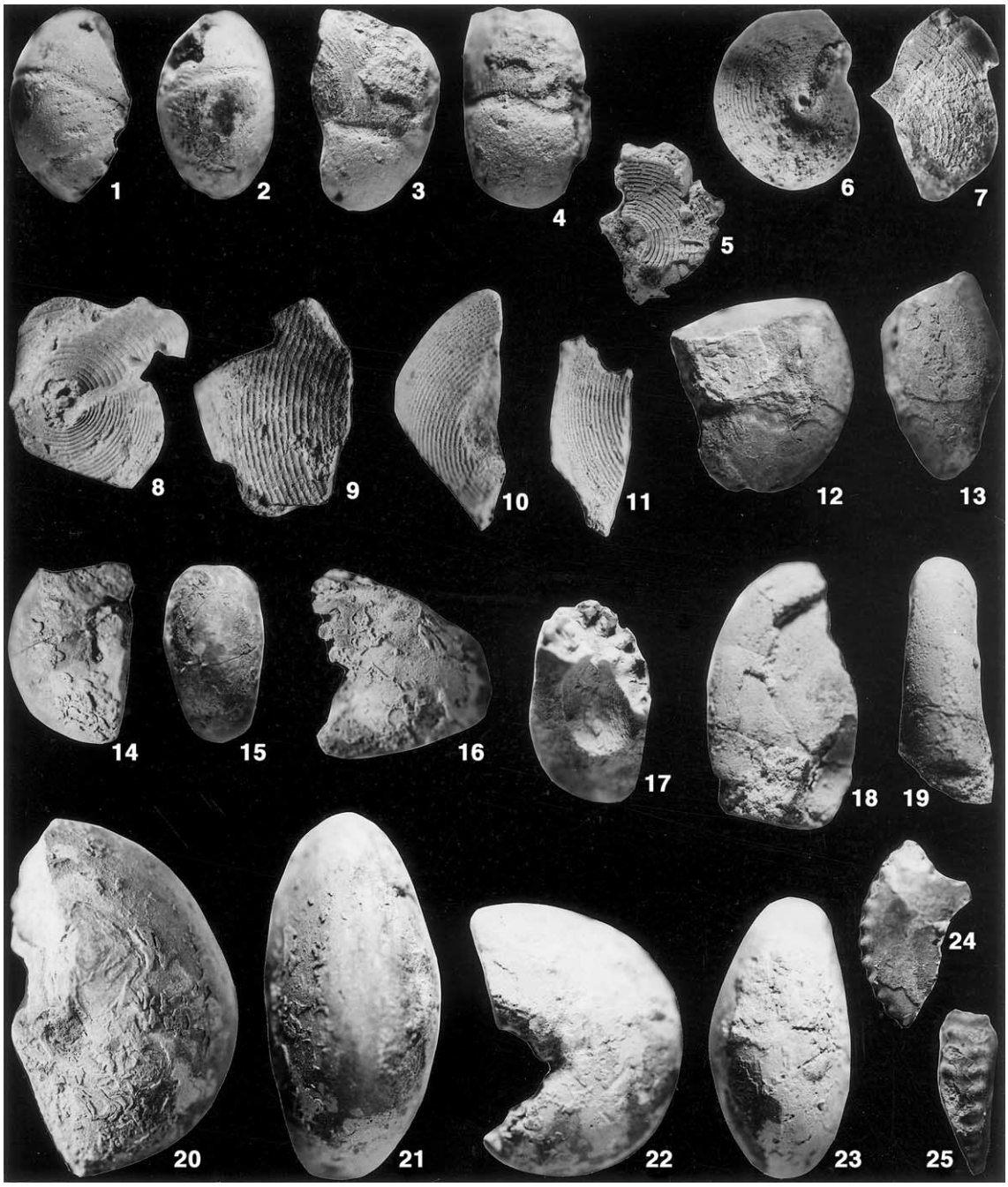

Fig. 7. 1–11. *Agathiceras suessi* Gemmellaro, 1, 2: lateral and ventral views, NSM PM16607, 3, 4: lateral and ventral views, NSM PM16608, 5: lateral view, NSM PM16609, 6: lateral view, NSM PM16610, 7: lateral view, NSM PM16611, 8: lateral view, NSM PM16612, 9: lateral view, NSM PM16613, 10: lateral view, NSM PM16614, 11: lateral view, NSM PM16615. 12–23. *Agathiceras*? sp., 12, 13: lateral and ventral views, NSM PM16616, 14, 15: lateral and ventral views, NSM PM16617, 16, 17: lateral and ventral views, NSM PM16618, 18, 19: lateral and ventral views, NSM PM16619, 20, 21: lateral and ventral views, NSM PM16620, 22, 23: lateral and ventral views, NSM PM16621. 24, 25. *Miklukhoceras* sp., lateral and ventral views, NSM PM16622. All x2.

sinuous transverse constriction in some cases. Generally, species identification of the genus *Agathiceras* is based on the proportions of the conch or on the surface ornamentation. The configuration of the suture-line is seldom treated as an essential feature for classification.

Agathiceras suessi Gemmellaro is close to *A. girtyi* Böse described from the Middle Permian Word Formation of Texas and *A. frechi* Böse described from the Pennsylvanian Gaptank Formation of Texas (Böse, 1919), but the former has a less inflated conch than the latter two. Moreover, it also resembles *A. contractum* Plummer and Scott and *A. applini* Plummer and Scott, both described originally from the Permian Belle Plains and Admiral formations of Texas (Plummer and Scott, 1937), but the latter two species can be distinguished from the former in having flattened lateral sides.

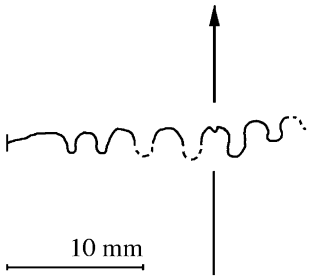

Fig. 8. Diagram showing suture-line of *Agathiceras suessi* Gemmellaro (NSM PM16612 illustrated in Fig. 7-8).

Agathiceras suessi and *A.* aff. *suessi* reported from Southeast Asia (Pitakpaivan et al., 1969; Lee, 1980; Ishibashi et al., 1996) are represented by fragmentary mould specimens. However, they share many common features with the Ban Kan Rae specimens and are regarded as conspecific.

Measurements: See Table 2.

Occurrence: Sosio Limestone of Sicily (Gemmellaro, 1887,1888), Soramnian and Martian-Bournian beds of Crimea (Toumanskaya, 1931), *Bellerophon* limestone of the Djebel Tebaga area, Tunisia (Miller and Furnish, 1957), Sungei Cheroh, Pahang, Malaysia (Lee, 1980); upper part of the Kaeng Krachan Formation of Ban Kan Rae, southern peninsular Thailand (present study), Huai I Loet Formation of Changwat Loei, NE Thailand (Ishibashi et al., 1996), unnamed Permian shale of Changwat Khon Kaen, NE Thailand (Pitakpaivan et al., 1969), Kashiwadaira Formation of Takakura-yama, NE Japan (Hayasaka, 1965), Kanokura Formation of South Kitakami, NE Japan (Hayasaka, 1963). Sakamarian to Kubergandian (Roadian).

Agathiceras girtyi Böse, 1919
Fig. 6:15 and 16

Agathiceras girtyi Böse, 1919, p. 117–121, pl. 6, Figs. 27–46; Plummer and Scott, 1937, p. 123–124, pl. 29, Figs. 7–10; Miller and Furnish, 1940, p. 119–121, pl. 31, Figs. 1–7.

Material examined: One fragmental specimen (NSM PM16604).

Description: Shell moderate in size, thickly subdiscoidal to subglobose, and strongly involute with a very small umbilicus. Umbilical ratio to diameter in our specimen smaller than 0.1. Venter gently rounded and not angular. Fine longitudinal lirae developed on surface of conch. Sinuous transverse constrictions observed throughout whorl. Growth line and suture-line not observed in our specimen.

Remarks: This specimen has some typical characters of the genus *Agathiceras*, such as an inflated conch, small umbilicus, fine longitudinal lirae, and sinuous transverse constrictions. The conch is inflated (W/H = 1.38) and is identified as *Agathiceras girtyi,* reported originally by Böse (1919) from the Word Formation of Texas. *Agathiceras girtyi* Böse is a less commonly occurring species of *Agathiceras*, and this is the first reported occurrence of the species in Southeast Asia. The present specimen particularly resembles those of *A. girtyi* Böse from Texas illustrated by Plummer and Scott (1937), although the Ban Kan Rae specimen seems to have a slightly smaller umbilicus.

Measurement: See Table 3.

Occurrence: Word Formation of the Glass Mountains and the Chinati Mountains, Texas (Böse, 1919; Baker, 1929; Plummer and Scott, 1937; Miller and Furnish, 1940), Word Formation in the Valle de Las Delicias of Coahuila, Texas (Miller and Furnish, 1940), upper part of the Kaeng Krachan Group of Ban Kan Rae, southern peninsular Thailand (present study). Asselian to Kubergandian (Roadian).

Agathiceras? sp.
Fig. 7: 12–23 and Fig. 9

Table 2
Measurements of *Agathiceras suessi* Gemmellaro

Figure	Reg. no.	*D*	*H*	*W*	*U*	*H/D*	*W/H*	*U/D*
6-7, 6-8	NSM PM16600	20.3	11.9	9.2	0.8	0.59	0.77	0.04
6-9, 6-10	NSM PM16601	22.2	12.0	11.1	1.9	0.54	0.93	0.09
6-19, 6-20	NSM PM16606	14.6	8.4	7.75		0.58	0.92	
7-3, 7-4	NSM PM16608	22.2		11.4				
7-6	NSM PM16610	15.4	8.9		1.4	0.58		0.09
7-8	NSM PM16612		12.5	11.1			0.89	

Values in mm where applicable. *D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

Table 3
Measurement of *Agathiceras girtyi* Böse

Figure	Reg. no.	*D*	*H*	*W*	*U*	*H/D*	*W/H*	*U/D*
6-15, 6-16	NSM PM16604	11.9	8.7	12.0	1.1	0.73	1.38	0.09

Values in mm where applicable. *D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

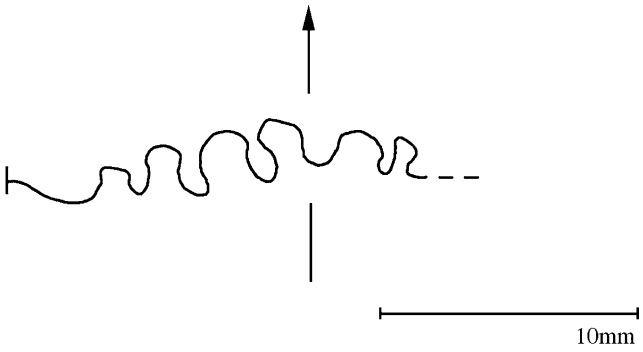

Fig. 9. Diagram showing suture-line of *Agathiceras*? sp. (NSM PM16618 illustrated in Figs. 7-16 and -17).

Material examined: Six incomplete specimens (NSM PM16616-16621).

Description: Shell moderate in size, thickly lenticular to subdiscoidal, and strongly involute with a nearly closed umbilicus. Umbilical ratio to diameter smaller than 0.1. Venter subangular and strongly rounded. Shell nearly smooth without distinct ornamentation. External suture-line deformed and ventral lobe indistinct. Three or four pairs of lateral lobes and saddles observed between ventral and umbilical lobes. Prongs of ventral lobes not pointed but rounded (Fig. 9).

Remarks: Although it has been slightly deformed, the pattern of the suture-line suggests that these specimens can be included in the genus *Agathiceras*. *Agathiceras ciscoense* Smith, originally reported from Texas by Smith (1903), is probably closest to the present unidentified species as they both have lenticular conchs. Our specimens somewhat resemble those described by Miller and Furnish (1940) under the name of *A. girtyi* Böse (Miller and Furnish, 1940, pl. 31, Figs. 1 and 2). However, the Ban Kan Rae specimens can be distinguished from the latter by the lacking of transverse constrictions or surface ornamentation.

The genus *Agathiceras* has been documented from various areas of Southeast Asia, but most of them are more or less crushed or fragmented, so that the comparison with the present material is less easy. It is morphologically noteworthy that the present Ban Kan Rae specimens lack conspicuous surface ornamentation.

Measurements: See Table 4.

Family MEDLICOTTIDAE Karpinsky, 1889
Genus *Miklukhoceras* Pavlov, 1967
Miklukhoceras sp.
Fig. 7: 24 and 25

Material examined: Only one specimen (NSM PM16622) of outer whorl cast is examined.

Description: Conch narrowly discoidal to subdiscoidal, laterally flattened, and 4.8 mm in width. Venter also flattened, and ventral shoulder rounded and squared. Groove hardly discernible along venter. Nodes prominent on ventral-lateral shoulders becoming more pronounced adaptically and transversely elongated, and transversely elongated and extended on lateral zones of the conch. Surface ornamentation and external suture-lines not observed in our specimen.

Remarks: *Miklukhoceras* is rare. Up to the present, it has been reported mainly from SE Pamir (Pavlov, 1967; Leonova, 1984, 1992; Leonova and Dmitriev, 1989). In these studies, only two species, *Miklukhoceras pamiricum* Pavlov and *M. pressulum* Leonova, have been described.

Glenister et al. (1990) reported *Miklukhoceras* cf. *pamiricum* Pavlov from Amphoe Muaglek, Changwat Nakorn Ratchasima, northeastern Thailand. Their *Miklukhoceras*-bearing outcrop is broadly referred to the Saraburi Limestone, a carbonate-dominant Permian lithostratigraphic unit in the Indochina Block, but its precise stratigraphic position has not yet been determined. The Glenister et al. (1990) is the only record of the occurrence of the genus *Miklukhoceras* outside SE Pamir, although it lacks illustration of the specimen.

The genus *Miklukhoceras* is distinguished from other genera belonging to the family Medlicottidae by such characteristics as a largely opened umbilicus and indistinct groove along the center of venter. The Ban Kan Rae specimen typically shows the latter feature although its umbilicus cannot be observed. In this genus, species identification is based largely on the shape of suture-line. It is not preserved in our specimen, so that we should treat this specimen under the open nomenclature.

Table 4
Measurements of *Agathiceras*? sp.

Figure	Reg. no.	*D*	*H*	*W*	*U*	*H/D*	*W/H*	*U/D*
7-14, 7-15	NSM PM16617		10.1	8.8	1.0		0.87	
7-20, 7-21	NSM PM16620	31.7	19.2	15.2	1.0	0.61	0.79	0.03
7-22, 7-23	NSM PM16621	25.0	14.5	12.0		0.58	0.83	

Values in mm where applicable. *D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

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