In this chapter, marine faunal assemblages (brachiopods, corals, and foraminifers) of three different Permian ages, that is, the early Middle Permian (Roadian to early Wordian), the late Middle Permian (early Capitanian), and the Late Permian, are analysed. Faunal and biogeographic characters of each of these assemblages are outlined and discussed below.

Two early Middle Permian brachiopod faunas from Bera South (lower Bera Formation) and Sermin beds of the East Malaya Terrane reveal possible invasions of Sibumasu or cooler-water elements to East Malayan shallow water. Biogeographically intermediate or mixed faunal affinities of both eastern Cimmeria and the warm-water Tethys are interpreted.

Late Middle Permian faunas are recovered from four areas of the Indochina and East Malaya terranes; that is, three limestone units of the western Indochina Terrane (i.e. the upper Saraburi Limestone of central Thailand, the Khao Taa Ngog Formation of East Thailand, and the Sisophon Limestone of western Cambodia) and the upper Bera Formation of the East Malaya Terrane. The macro- and microfaunas of the Indochina and East Malaya terranes show species-level linkage between each other with strong endemism. They also reveal inclusions of several elements atypical of palaeo-equatorial Cathaysian faunas of the South China Terrane. As will be elaborated, many Middle Permian brachiopod, foraminiferal, and coral taxa are found to be common in Indochinese SE Asia, Cimmeria, and peri-Gondwana of the Tethys but be rare or absent from South China or North China. Thus, their occurrence in the Indochina Terrane and the Sukhothai-Eastem Island-arc terranes suggests bioprovincial affinity out of the Cathaysian Province, and they are called extra-Cathaysian elements hereafter.

Finds of such elements suggest some adjustment in a generally prevailed view (e.g. Metcalfe, 2002; Shi and Archbold, 1998) that the Indochina and East Malaya terranes have strong affinity to the South China Terrane and they all constitute the Cathaysian Province throughout the Permian. A new bioprovine, the Indochinese Province, is proposed based on distinctive faunal characters of the Indochina Terrane and allied micro-terranes of the Early to Middle Permian. It appears that Late Permian marine faunas of the Indochinese Province no longer accommodate extra-Cathaysian elements, and are virtually indistinguishable from those of the Cathaysian Province.
6.1 Early Middle Permian (Roadian to early Wordian) of the East Malaya Terrane: peri-Gondwanan to Cimmerian affinity

6.1.1 Sermin brachiopods (Roadian) of northern Johore

Sone et al. (2003) reported that the Sermin brachiopod fauna of the East Malaya Terrane consists of eight taxa; *Transennatia* sp. cf. *T. insculpta* (Grant, 1976), *Pseudoleptodus* sp., *Caricula* sp. cf. *C. salebrosa* Grant, 1976, *Neochonetes* (*Nongtaia*) aff. *N. arabicus* (Hudson and Sudbury, 1959), *Karavankina* sp., *Hustedia* sp., *Orthothetina* sp., and a martiniid indet. (see Chapter 4 for locality information). The Sermin fauna is interpreted to have close faunal linkage to that of the lower Ratburi Limestone in Ko Muk, southern Thailand (Sibumasu Terrane). The first three Johore forms above are closely comparable to *Pseudoleptodus*? sp. indet., *Caricula salebrosa* Grant, and *Transennatia insculpta* (Grant) of the Ko Muk fauna reported by Grant (1976) (Fig. 6.1). Detailed taxonomic comparisons were already provided by Sone et al. (2003). Some noteworthy biogeographic significance of the Johore species is outlined below.

First, the Johore form of *Transennatia* is close to the Ratburi species *T. insculpta*. Their similarities in both external and internal shell features were discussed in detail by Sone et al. (2003), in conjunction with their differences from the younger Pakistani type species *Transennatia gratiosa* (Waagen, 1884).

Second, the Permian genus *Pseudoleptodus* Stehli, 1956 is a rare constituent of the Tethyan biota. It has been recorded only in Ko Muk of the Sibumasu Terrane (Grant, 1976) and in Johore of the East Malaya Terrane (Sone et al., 2003) within the Tethys, while it is common in the Early to Middle Permian West Texan faunas (e.g. Cooper and Grant, 1974).

Third, the presence of *Caricula* Grant, 1976 in the Johore fauna is most striking in indicating a biotic migratory connection between the East Malaya Terrane and the Sibumasu Terrane across the Palaeo-Tethys seaway in the early Middle Permian. *Caricula* is an unusual productoid brachiopod; it is in the same Paucispiniferini tribal group as *Transennatia*, but it is tinier and has prominent rugae. The type species *C. salebrosa* of the basal Ratburi Limestone in Sibumasu is the only defined species of this genus. A closely comparable form *C. cf. salebrosa* from Johore of the East Malaya Terrane is possibly conspecific. Yet, the specific identification was left open due to the limited number of a specimen from East Malaya. There are only these two records (Ratburi and Johore) available for this extremely rare genus, accordingly.
Figure 6.1 Three brachiopod species from the Sermin beds (Roadian) of Johore, Peninsular Malaysia (East Malaya Terrane), which represent species-level affinity to the Ratburi Limestone brachiopod fauna of southern Thailand (Sibumasu Terrane) (reproduced from Sone et al., 2003, figs 4, 6, 7).
Thus, the above three forms from the Roadian of East Malaya are closely referable in species level to those congeneric counterparts in the Ratburi Limestone of Sibumasu. Moreover, two of the three genera; *Pseudooleptodus* and *Caricula*, are found only in those two terranes within the Tethys. The most significant fact, which can be noted from these finds, is that faunal linkage between the East Malaya and Sibumasu terranes occurs across the Palaeo-Tethys seaway of the Bentong–Raub Suture Zone. The seaway is generally interpreted as the Gondwana-Cathaysia biogeographic divide (e.g. Hutchison, 1993; Metcalfe, 2000; Wu et al., 1995). The present finds suggest that the Palaeo-Tethys in SE Asia was not a biotic migratory barrier for some marine taxa, even benthic animals like brachiopods. This is also evident with some other taxa of the later Middle Permian, as will be discussed later. The Tethyan seaway is thus unlikely to have been such a wide ocean as previously thought by some authors (e.g. Baud et al., 1993; Ricou, 1995; Stampfli, 2000), and as argue by Sone et al. (2003).

In addition, two other Johore forms, *Karavankina* sp. (Fig. 6.2) and *Neochonetes* aff. *N. arabicus* (Hudson and Sudbury, 1959), can also be interpreted as of Cimmerian affinity rather than Cathaysian (see Sone et al., 2003 for discussion). *N. arabicus* is a tiny *Neochonetes* in the Wordian of peri-Gondwanan Oman (Angiolini and Bucher, 1999; Archbold and Burrett, 1990; Hudson and Sudbury, 1959). Permian species of the genus *Karavankina* are rare, and are confined to the southern Tethys, excluding the South China and Indochina terranes of Cathaysian faunal affinity, as outlined below. Three genera, *Pseudooleptodus*, *Caricula*, and *Karavankina*, which are found in Johore, have distribution patterns confined to extra-Cathaysian and southern Tethyan regions, and this is shown in Figure 6.3.

### 6.1.1.1 Brachiopod: *Karavankina* Ramovš, 1966

The echiinoconchid brachiopod *Karavankina* Ramovš is a relatively long-lived genus, ranging from the middle Carboniferous up to the late Middle Permian. It was perhaps most abundant in the Late Carboniferous, and was particularly common in European localities such as the Carnic Alps, the Karavanke Mountains, and the Cantabrian Mountains (e.g. Martínez-Chacón, 1979; Ramovš, 1971). In contrast, the genus declined through the Early to Middle Permian; the Permian occurrences are restricted to the Tethys Sea as outlined below. No Late Permian occurrence is so far known.

The Permian occurrences of *Karavankina* are highly limited. The genus is so far found only in six Tethyan regions; that is, the Early and Middle Permian (up to the Wordian) of the Slovenian Alps region (e.g. Flügel et al., 1984; Ramovš, 1966; 1969; Schellwien, 1900), the
Capitanian of Oman (Yanagida and Pilleuvuit, 1994), the Bamyam limestone (Wordian) of Afghanistan (Reed, 1931; Termier et al., 1974), the Ko Yao Noi Formation (Artinskian) of southern Thailand (Waterhouse et al., 1981), the basal Permian limestone of Laos (Mansuy, 1913, reported as *Productus elegans* M'Coy), and the Sermin beds (Roadian) of Peninsular Malaysia (Sone et al., 2003). Note that the above Oman horizon was initially considered of Early to early Middle Permian age by Yanagida and Pilleuvuit (1994), but was reinterpreted to be of Capitanian (or possibly younger) age by Angiolini and Bucher (1999, p. 674) based on foraminiferal information. The Oman report may therefore represent the youngest occurrence of *Karavankina*. All these Permian localities are confined to the southern part of the Tethys (see Fig. 6.3 for the Middle Permian distribution).

*Echinoconchus mapingensis* Grabau, 1936 from the so-called Maping Limestone of South China is likely a species of *Karavankina* (or its closest relative *Echinoconchella* Lazarev, 1985), and it has been in general believed to be Permian in age. However, the age of the Maping Limestone bed yielding the Grabau echinoconchid is now interpreted most likely to be early Bashkirian (mid-Carboniferous) (see Liao, 1999, p. 319). In addition, there are many reports of *Echinoconchus* from South China and North China (e.g. Fan and He, 1999; Feng and Jiang, 1978; Liu et al., 1982; Zhang et al., 1983), which are probably of *Karavankina*, yet they all are Carboniferous in age.

Consequently, no Permian *Karavankina* is present in the Cathaysian Province. It is curious that *Karavankina* appears common in the Carboniferous of South China and North China but seems to have totally disappeared from those regions in the Permian; a fact previously pointed out by Sone et al. (2003, p. 533). This is probably because of some climatic and tectonic influences, which excluded the genus from the palaeo-equatorial Cathaysian Province in the post-Carboniferous but allowed it to survive in those possible refugia in southern Tethyan localities over the Indochinese Province and the Cimmerian Region until as late as the late Middle Permian.

In summary, Permian *Karavankina* was confined to the southern Tethys Sea, excluding the South China and Indochina terranes, and shows the subtropical to temperate distribution (Fig. 6.3). The Roadian occurrence of *Karavankina* in the Sermin beds presents another piece of evidence for extra-Cathaysian affinity and a subtropical to temperate climatic episode for the early Middle Permian of the East Malaya Terrane.
**Figure 6.2** Brachiopod *Karavankina* sp. from the Sermin beds (Roadian) of northern Johore, Peninsular Malaysia (reproduced from Sone et al., 2003, fig. 9a,c).

**Figure 6.3** Middle Permian occurrences of three brachiopod genera (*Caricula*, *Pseudoleptodus*, and *Karavankina*) found in the Sermin fauna of the East Malaya Terrane and in other regions, plotted on a concurrent palaeogeographic reconstruction map (see text for reports of each occurrence). It shows extra-Cathaysian and southern Tethyan distribution patterns of the three genera. Base map modified after Metcalfe (1998).
6.1.2 Bera South brachiopods of Pahang

The Bera South beds of the lower Bera Formation in central Peninsular Malaysia now indicate a meaningful palaeoclimatic episode for the lower Middle Permian of the East Malaya Terrane (see Chapter 5 for detailed locality information). The Bera South fauna yields brachiopods, cephalopods, and trilobites (see Leman et al., 2000; Sone and Leman, 2005; Sone et al., 2001a). Species of four brachiopod genera are confirmed. Martinia sp. was illustrated in Leman et al. (2000). The linoprodctoid Permudaria perplexa Sone and Leman, 2005 was recently reported. As newly confirmed in Chapter 5, the Bera South brachiopod assemblage includes Retimarginifera aff. R. salebrosa (Grant, 1976) and Magniplicatina sp. The two genera Retimarginifera Waterhouse, 1970 and Magniplicatina Waterhouse, 1983c are generally common in the Early Permian of peri-Gondwana but are quite unusual in warm-water Tethyan regions.

The occurrence of Retimarginifera was previously summarised by Archbold (1984). With later reports, the genus can now be recognised in eastern Cimmeria and Tethyan peri-Gondwana, with the only exception being a Russian Early Permian record (Kalashnikov, 1993). Those occurrences are the Early Permian of the Pamirs (Grunt and Dmitriev, 1973), the early Murghabian of Afghanistan (Termier et al., 1974), the late Early Permian and late Middle Permian of Karakorum (Angiolini, 1995; p. 204; 2001; Gaetani et al., 1995; Merla, 1934), the Juripu Formation (late Middle Permian) of the Yarlung-Zangbo Suture (Shi et al., 2003), the Lopingian of the Himalayas (Shen et al., 2000; Shen et al., 2003b; Waterhouse, 2004; Waterhouse and Shi, 1990), the Ko Yao Noi Formation (Artinskian) and the basal Ratburi Limestone (Roadian) of the Sibumasu Terrane (Grant, 1976; Waterhouse et al., 1981), the Bitauni beds of Timor (Broili, 1916), the Kungurian–Ufimian of Western Australia (Archbold, 1984; 1993; Waterhouse, 1970), and probably in the late Early to Middle Permian of the Lhasa Terrane. The Nepalese occurrence from the Marsyangdi Formation (possible Changhsingian) reported by Waterhouse and Shi (1990) and Waterhouse (2004) with yet unstudied material will represent the latest occurrence of Retimarginifera (J. B. Waterhouse, pers. commun., 2004). Note that Retimarginifera reported from the Early Permian of South China (Feng, 1998) and the Late Permian Leptodus beds of central Malaysia (Leman, 1993) are not considered as congeneric (see Chapter 5 for taxonomic discussions).

The Middle Permian occurrences of Retimarginifera are plotted in Figure 6.4. It is principally endemic to greater Tethyan water, including the Indoralian and Westralian provinces of peri-Gondwana, and is not present in the Austrazean Province. Archbold and Shi

Species of *Magniplicatina* can be found in the Early to early Middle Permian of the Austrazean Province (eastern Australia and New Zealand) (e.g. Briggs, 1998; Campbell, 1953; Parfrey, 1988; Waterhouse, 1964; 1982; 1986), the late Early Permian of Karakorum (Angiolini, 1995; 1996), the Khuff Formation (Wordian) of Oman (Angiolini and Bucher, 1999), the Early Permian of Inner Mongolia (Liu and Waterhouse, 1985), and probably in the Middle Permian of the Lhasa Terrane (see Chapter 5). *Magniplicatina* was also reported recently from the Himalayan Lopingian of the northern India Block (Shen et al., 2003b), which marks the only Late Permian, and the latest, occurrence of the genus. The Mongolian form *Magniplicatina* sp. of Liu and Waterhouse (1985) marks the only occurrence of the genus outside the southern Tethys. Note that those four Karakorum species assigned to *Magniplicatina* by Angiolini (1995; 1996) may belong to a separate genus, as discussed in Chapter 5. Those West Texan forms considered as *Magniplicatina* by Brunton et al. (2000) and Waterhouse (2001) require verification, and are not regarded as congeneric in this study (see Chapter 5). The Middle Permian occurrences of *Magniplicatina* are also plotted in Figure 6.4.

Both *Retimarginifera* and *Magniplicatina* are most common in late Early to early Middle Permian strata, and younger records are much rarer. Their Late Permian occurrence is confined to sediments of the Tibetan and Nepalese Himalayas; that is, the Selong Group, the Qubuerga Formation, and the Marsyangdi Formation of the carbonate platform in the northern India Block. This probably represents the latest refugium for those genera, which was left in the peri-Gondwanan Tethys water before the end-Permian.

Another Bera South brachiopod genus *Permundaria* Nakamura, Kato, and Choi, 1970 is an uncommon rugose linopродuctoid, as reviewed by Sone and Leman (2005). The genus has a relatively short stratigraphic range of the Roadian up to the Wuchiapingian. Species of *Permundaria* are recognised in South China and North China (Jin et al., 1974; Kayser, 1883; Li and Gu, 1980), central Afghanistan (Termier et al., 1974), the northern India Block of southern Tibet (Zhang and Jin, 1976), Japan (Nakamura et al., 1970; Tazawa, 1974), Sisophon Limestone of Cambodia and the Saraburi Limestone of NE Thailand in the Indochina Terrane (Nakamura et al., 1970; Yanagida et al., 1988), the East Malay Terrane (Sone and Leman, 2005), and in the Palepat Formation (equivalent of the Silungkang Formation) of the West Sumatra Terrane (Meyer, 1922). *Permundaria* appears to be confined to the Middle Permian of the eastern Tethys Sea, with the only exception being the
Wuchiapingian species *Permundaria magna* Zhang and Jin, 1976 of peri-Gondwana (northern India Block). Its Middle Permian occurrences are also plotted in Figure 6.4.

![Map of Middle Permian occurrences of three brachiopod genera](map.png)

Figure 6.4 Middle Permian occurrences of three brachiopod genera (*Retimarginifera*, *Magniplicatina*, and *Permundaria*) found in the Bera South fauna of the East Malaya Terrane and in other regions, plotted on a concurrent palaeogeographic reconstruction map (see text for reports of each occurrence, and Sone & Leman, 2005 for *Permundaria*). It shows extra-Cathaysian, southern hemispheric distribution patterns of the first two genera and a broader Tethyan distribution pattern of the last genus. Base map modified after Metcalfe (1998).

As shown in Figure 6.4, the Bera South brachiopod genera consist of mixed elements of cool-water peri-Gondwanan and warm-water Tethyan types in terms of biogeographic affinity. *Retimarginifera* and *Magniplicatina* can be recognised as carrying affinity to peri-Gondwana and/or Sibumasu biota. On the other hand, *Permundaria* is a broad warm-water Tethyan (not necessarily Cathaysian) element. *Martinia* is a cosmopolitan genus, and has little value for biogeography and biostratigraphy.
Inclusion of non-tropical biotic characters is better developed by the Bera South fauna than by the Sermin fauna, as the former includes *Retimarginifera* and *Magniplicatina*, typical of peri-Gondwanan water. Nevertheless, species linkage to the Ratburi Limestone fauna is more definable in the Sermin fauna than the Bera South fauna. This is probably because of a more proximal age relationship between the Ko Muk and Sermin faunas, but the Bera South fauna may be slightly younger than the others. A relationship of the East Malayan brachiopods with those in the Indochina Terrane is not clear, because of a lack of the concurrent fauna in Indochina.

In summary, the Bera South brachiopod fauna has some similar aspects to the Sermin fauna, as both include some taxa indicative of eastern Cimmerian and/or peri-Gondwanan affinity. Nevertheless, the majority of the East Malayan marine biota is dominantly warm-water Tethyan (not only Cathaysian) type. It is interpreted that the marine water condition of the East Malaya Terrane was under some cooler palaeoclimatic (subtropical to warm-temperate) influence during early Middle Permian (Roadian–early Wordian) time. This probably facilitated migration of some cool-water brachiopod taxa from Sibumasu/peri-Gondwanan regions of higher latitudes to East Malaya across the Palaeo-Tethys seaway.

This may have been caused by the periodical cooler climatic condition in the southern Tethys and/or by the tectonic movement of either or both East Malaya and Sibumasu terranes making them more proximal to each other. The Sibumasu Terrane is known to have drifted northwards to lower latitudes. It is also plausible that the East Malaya Terrane moved towards higher latitudes at least some distance to allow the migration of some taxa from the Sibumasu Terrane, as its back-arc opening from the Indochina Terrane proceeded during the Middle Permian. This tectonic interpretation will be combined in a palaeogeographic reconstruction of the next chapter.

In addition to the present study, another occurrence of *Magniplicatina*, with relative abundance, has recently been confirmed by the present author and his Malaysian colleague in the Kepis Formation of Negeri Sembilan, central Peninsular Malaysia (new information). Although it is not yet described, the Kepis form of *Magniplicatina* has elongate ventral spine bases and frequent folded rugae (Fig. 6.5). Therefore, it definitely belongs to a species separate from the Bera South *Magniplicatina* sp. described in Chapter 5, and is possibly a new species. The Kepis form appears more similar to those Gondwanan species of the Austrazean Province (described, for example, by Briggs, 1998; Waterhouse, 1982) than the Bera South form. The Kepis Formation is located close to the Bentong–Raub Suture Zone, and tectonically belongs to sediment of the East Malaya Terrane. The age of the Kepis fossils
is not yet determinable. Nevertheless, a late Early Permian age seems plausible, judging from similarities to eastern Australian forms. This is the second find of Magniplicatina from SE Asia, and is an additional piece of evidence for extra-Cathaysian affinity in the East Malaya Terrane.

![Image](image_url)

Figure 6.5 Unpublished species of Magniplicatina from the Juasseh shale of the Kepis Formation, Negeri Sembilan, Peninsular Malaysia (East Malaya Terrane). A, ventral valve, natural cast of the exterior. B, dorsal valve, external mould.

6.2 Late Middle Permian: faunal linkage between the Indochina Terrane and the East Malaya Terrane, and extra-Cathaysian affinity

6.2.1 Brachiopods of the Sisophon, Tak Fa (Saraburi), and upper Bera formations (early Capitanian)

In this study, three units with early Capitanian brachiopods are investigated; namely, 1) the Tak Fa Formation in the upper Saraburi Limestone Group of central Thailand, 2) Member C of the Sisophon Limestone in western Cambodia, and 3) the upper Bera Formation at the Sungai Bera section of Peninsular Malaysia. The first two are in the carbonate platform of the western Indochina Terrane, and the last is in the East Malaya Terrane. Figure 6.6 shows a comparison chart of brachiopod taxa, which are in common or closely comparable (possible counterparts) among the three units, so far confirmed by Sone et al. (2001b) and in this study. From a list of taxa confirmed in these three assemblages, a relationship among the three faunal stations is tangible, as outlined below.
Sone et al. (2001b) described a brachiopod fauna from the upper Bera Formation, and concluded that three species; *Spyridiophora gubleri* Termier and Termier, *Transennatia termierorum* Sone, and *Urushtenoidea chaoi* (Ching), are in common with the Cambodian Sisophon fauna. As revised in Chapter 5, the Bera *Urushtenoidea* is no longer considered conspecific with *U. chaoi*, and its specific identification is left open. The Bera species of *Urushtenoidea* may alternatively be conspecific to the Sisophon species *Urushtenoidea khmerianus* (Termier and Termier, 1970b). A further investigation is needed to confirm this. Nevertheless, another Sisophon species *Gubleria disjuncta* Termier and Termier is additionally confirmed as being shared with the Bera fauna, with new material from both Malaysia and Cambodia (see Chapter 5). Thus, at least three species, *S. gubleri*, *T. termierorum*, and *G. disjuncta* are in common between the Sisophon and Bera faunas.

The Tak Fa Formation (upper Saraburi Limestone Group) of Thailand and the Sisophon Limestone of Cambodia are laterally correlated in the Wordian–Capitanian upon a stable carbonate platform covering the western margin of the Indochina Terrane. This platform apparently extends to Laos. Two brachiopod species previously known in the Sisophon Limestone are confirmed also present in the Tak Fa Formation (upper Saraburi Limestone); they are *Hustedia indosinica* n. sp. and *Reticulariina cambodgiensis* (Mansuy, 1914) (see Chapter 5). These finds are perhaps reasonable, considering that basins in which these species existed were within the same platform of the western Indochina Terrane. Nevertheless, it is noteworthy that the two faunas also have four other genera, *Tyloplecta*, *Monticulifera*, *Composita*, and *Cleiothyridina* in common, but each species differ slightly from their counterparts in the other, as shown in Figure 6.6 (see Chapter 5 for taxonomic details). Notable examples are *Tyloplecta gobbetti* n. sp. and *Monticulifera cambodgiensis* (Mansuy) in the Sisophon fauna and *Tyloplecta pseudogobbetti* n. sp. and *Monticulifera khaowangensis* n. sp. in the Tak Fa fauna. Their morphological differences are indeed subtle but are definable. This probably reflects regional variations of each genus, and/or is possibly due to a slight age difference between the two faunas. Nevertheless, as a whole, all brachiopod species of the Sungai Bera, Saraburi, and Sisophon beds recognised in this study are endemic to the Indochinese Province.
### Figure 6.6. Comparison chart of brachiopod taxa among the upper Bera Formation, the upper Saraburi Limestone, and the Sisophon Limestone, indicating a taxon of its specified horizon in which raw samples are obtained.

<table>
<thead>
<tr>
<th>EAST MALAYA Terrane</th>
<th>INDOCHINA Terrane</th>
<th>Sisophon Limestone (Cambodia)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>upper Bera Formation (Malaysia)</strong></td>
<td><strong>upper Saraburi Limestone (Thailand)</strong></td>
<td><strong>Sisophon Limestone (Cambodia)</strong></td>
</tr>
<tr>
<td><em>Gubleria disjuncta</em> Termier &amp; Termier, 1960</td>
<td><em>G. disjuncta</em> Termier &amp; Termier, 1960</td>
<td></td>
</tr>
<tr>
<td><em>Transennatia termierorum</em> Sone in Sone et al., 2001b</td>
<td><em>T. termierorum</em> Sone in Sone et al., 2001b</td>
<td></td>
</tr>
<tr>
<td><em>Spyridiophora gubleri</em> Termier &amp; Termier, 1970a</td>
<td><em>S. gubleri</em> Termier &amp; Termier, 1970a</td>
<td></td>
</tr>
<tr>
<td><em>Urushitenoides</em> spp.</td>
<td><em>Urushitenoides khmerianus</em> (Termier &amp; Termier, 1970b)</td>
<td></td>
</tr>
<tr>
<td><em>Linoproduc tus</em> sp.</td>
<td><em>Linoproduc tus cambodiensis</em> Termier &amp; Termier, 1970b</td>
<td></td>
</tr>
<tr>
<td><em>Echinauris</em> sp.</td>
<td>cf. <em>Echinauris khmerianus</em> (Mansuy, 1914)</td>
<td></td>
</tr>
<tr>
<td><em>Hustedia indosinica</em> n. sp.*</td>
<td><em>H. indosinica</em> n. sp.</td>
<td></td>
</tr>
<tr>
<td><em>Reticularina</em> cambodiensis (Mansuy, 1914)*</td>
<td><em>Reticularina</em> cambodiensis (Mansuy, 1914)</td>
<td></td>
</tr>
<tr>
<td><em>Tyloplecta pseudogobetti</em> n. sp.*</td>
<td><em>Tyloplecta gobetti</em> n. sp.*</td>
<td></td>
</tr>
<tr>
<td><em>Monticulifera khaowangensis</em> n. sp.*</td>
<td><em>Monticulifera cambodiensis</em> (Mansuy, 1913)*</td>
<td></td>
</tr>
<tr>
<td><em>Composita permica</em> n. sp.*</td>
<td><em>Composita</em> indosinensis (Mansuy, 1914)*</td>
<td></td>
</tr>
<tr>
<td><em>Cleiothyridina</em> sp.*</td>
<td><em>Cleiothyridina indosinensis</em> (Mansuy, 1914)*</td>
<td></td>
</tr>
<tr>
<td><em>Compressoproduc tus</em> sp.*</td>
<td>cf. <em>C. dijufensis</em> (Stoyanow) sensu Termier &amp; Termier, 1970b</td>
<td></td>
</tr>
<tr>
<td><em>Schuchertella yanagadai</em> n. sp.*</td>
<td>cf. <em>Streptorhynchus</em> in Tran, 1961</td>
<td></td>
</tr>
</tbody>
</table>
On the other hand, no brachiopod species is so far confirmed in common between the East Malayan and Saraburi faunas. Information is still limited to define faunal linkage between the upper Bera Formation and the Tak Fa Formation. Nevertheless, this may be primarily because of a subtle age difference between the two faunal stations. Yet, it is perhaps more likely, due to a difference in lithology and palaeoenvironment, that is, the Bera brachiopod beds are dominantly siliciclastic with abundant tuffaceous inputs (in the East Malaya island arc), whereas the Saraburi beds are limestone (on the stable platform of the Indochina Terrane). Nevertheless, sampling in both areas is not confidently sufficient, and thus it is very likely that more sampling will reveal more affinity between the Bera and Saraburi faunas.

As a whole, these Capitanian brachiopod faunules of the Indochinese Province show affinity to those of South China. This is clearly noticeable when looking at generic members. Of those genera recorded in the present three assemblages, Transennatia, Gubleria, Orthothetina, Monticulifera, Urushtenoidea, Tyloplecta, Spinomarginifera, Hustedia, and Compressoproductus are common in the warm-water Tethys, and are frequently seen in South Chinese sediment. The first seven genera are endemic to the Tethys. Nonetheless, none of them is indicative of absolute Cathaysian linkage, since they also occur in other distant areas of the Tethys, such as Transcaucasia, Iran, and Japan.

Yet, two of them, Monticulifera and Urushtenoidea, may be regarded as carrying stronger affinity with Cathaysian biota in Middle Permian time. This is because they are confined to Asian (or eastern) Tethys, and are particularly common in South China but are rarer outside. Monticulifera is found in the Middle Permian of South China, North China, Inner Mongolia, Cambodia, central Thailand (this study), and eastern Tibet (Qinghai). The genus is also reported from the basal Chuping Limestone (Kungsurian or Roadian) of the Sibumasu Terrane (Ishii et al., 1972) and from the Late Permian of the Himalayas (Waterhouse, 1978), although these two reports require verification. Urushtenoidea is a typical Middle Permian genus. It is found in Japan, South China, North China, Indochina (Laos and Cambodia), and Malaysia (East Malaya).

In addition, Urushtenoidea was recently reported by Shen et al. (2003a) from a Capitanian limestone block in the Indus–Zangbo Suture Zone of the Himalayas. The Himalayan material is not excellent in preservation and better material would be required for confident generic assignment. Nevertheless, assuming that the generic identification is correct, this occurrence extends the distribution of the genus to peri-Gondwanan waters. Note that Shen et al. (2003c)
interpreted the block as a Permian seamount or carbonate built-up originating in the Neo-Tethys, as they supported a theory for the Lhasa Terrane as part of the Cimmerian Superterrane. In this study, the Lhasa Terrane is not considered in that way, but is regarded as a peri-Gondwanan terrane in the Permian; based on palaeomagnetic data (see Chapter 2 for discussion).

Figure 6.7 Early Permian (Artinskian to Kungurian) and Middle Permian (late Wordian and early Capitanian) occurrences of the brachiopod genus *Liraplecta* Jin and Sun, 1981 plotted on a Middle Permian palaeogeographic reconstruction map (see text in Chapters 5 and 6 for reports of each occurrence). Base map modified after Metcalfe (1998).
Thus, well-built endemism of the Indochinese Province is displayed in the species composition of the present three Capitanian assemblages. All brachiopod species of the Indochina and East Malaya terranes confirmed by Sone et al. (2001b) and this study (Chapter 5) are endemic, and are not present in the South China or North China terranes. Similarities with the Cathaysian Province are only up to the generic level.

Furthermore, even in generic members of faunas of the Indochinese Province, some genera appear atypical or unrelated to Cathaysian biota. Kozlowskia Fredericks, 1933 in the upper Bera Formation (see Sone et al., 2001b) and Liraplecta Jin and Sun, 1981 in the Tak Fa Formation (this study) are such examples. The two genera are uncommon constituents of the Middle Permian Tethyan biota, and are rare or absent from South China or North China.

As outlined in Chapter 5, Liraplecta is most common in the Early Permian of the Tarim Basin, and elsewhere it is reported only from the Kungurian of the Qamdo Terrane (Jin and Sun, 1981). Yet, as discussed in Chapter 5, its type species was based on a poorly preserved shell of Chao (1927), and this vaguely stands as the presence of the genus in South China. This requires verification. Middle Permian occurrences of the genus are only those of the present Tak Fa species, Liraplecta khokiensis n. sp., in the Indochina Terrane and Liraplecta sumatrensis (Roemer) in the West Sumatra Terrane, and thus are limited to the Indochinese Province. All occurrences of Liraplecta are plotted in Figure 6.7, which shows a difference in distribution pattern from Early to Middle Permian.

### 6.2.2 Implications from non-brachiopod taxa of extra-Cathaysian affinity

As noted above, Capitanian brachiopods indicate strong species linkage between the Indochina Terrane and the East Malaya Terrane, and many of those species are endemic to the two terranes constituting the Indochinese Province. Apart from brachiopods, some other taxa (foraminifers and corals) of extra-Cathaysian affinity are examined to test the brachiopod result indicating that shallow-water biota of the Indochinese Province bear distinctions from those of the Cathaysian Province. Those non-brachiopod taxa are introduced below. Some of those calcareous taxa are not necessarily endemic to the Indochinese bioprovence. They are common in the southern Tethys through the peri-Gondwanan to Cimmerian regions and up to the Indochinese Province, or are also present in the transitional biotic zone of the northern Tethys, such as the Sino-Mongolian Province (i.e. bitemperate or amphi-tropical distribution). They, however, are absent from the Cathaysian Province, as will be displayed below.
6.2.2.1 Fusulinid: *Lepidolina asiatica* (Ishii, 1966)

The fusulinid species, *Lepidolina asiatica* (Ishii, 1966), is endemic to the Indochinese Province, like those brachiopods mentioned earlier. Ishii (1966, p. 134) originally proposed it as a species of *Yabeina*, and Ozawa (1975) later reclassified it within *Lepidolina*. Those authors regarded the species as an intermediate form between *Colania douvilleii* and *Lepidolina multisepata* [referred to as *Neoschwagerina douvilleii* and *Yabeina multisepata* in Ishii (1966)]. Ozawa (1975, p. 118) considered it the most primitive and oldest form of *Lepidolina*, and thus interpreted it as being indicative of the lowest part of the so-called *Lepidolina* fusulinid zone (early Midian).

*L. asiatica* has been recorded from the Jengka Pass and Kampong Awah limestones of Pahang, central Peninsular Malaysia (the East Malaya Terrane), and from upper Member B and Member C of the Sisophon Limestone in western Cambodia (the Indochina Terrane) (see Fontaine et al., 1994a; Ishii, 1966; Ishii et al., 1969; Ozawa, 1975). Another Malaysian form, reported as *Yabeina cf. tobleri* (Lange, 1925) by Igo (1963) from Sungai Atok of northern Pahang may also belong to *L. asiatica*, according to Ishii (1966, p. 133). *L. asiatica* thus acts as an excellent index for correlating early Capitanian (Midian) horizons between the Indochina and East Malaya terranes. The species can also be regarded as a biotic linkage of late Middle Permian time between the two terranes, in addition to inter-terrane brachiopod affinity presented by Sone et al. (2001b) and this study.

Furthermore, the biostratigraphic occurrence of *L. asiatica* seems meaningful. As seen in the Sisophon Limestone and correlative East Malayan limestones (in Kampong Awah, Jengka Pass, and Sungai Atok), the species occurs together with *Neoschwagerina margaritae* or its allies, *Colania douvilleii, Sumatrina annae*, and more advanced *Lepidolina multisepata* (see Fontaine et al., 1994a; Ishii, 1966; Ishii et al., 1969; Ozawa, 1975). The occurrence of *N. margaritae* and *C. douvilleii* generally indicates the uppermost Murghabian or basal Midian in the fusulinoid biozonation of the Tethyan standard, whereas *L. multisepata* marks a slightly higher level within the Midian (e.g. Leven, 2003). In addition, those species may co-occur at some transitional stratigraphic range. Meantime, the so-called *Yabeina* fusulinid zone (lower Midian) of the Tethyan standard is not known in the Indochina or East Malaya terranes, since true *Yabeina* is possibly absent from SE Asia (see Hada et al., 1997). This fact also marks another dissimilarity to the Cathaysian marine biota of the South China Terrane, where the *Yabeina* zone is commonly well established below the *Lepidolina* or *Metadoliolina* zone within the Lengwan (= upper Maokouan, Capitanian) (see Jin et al., 1997, fig. 2; Leven,