Available online at www.sciencedirect.com

Gondwana Research 9 (2006) 24 – 46

www.elsevier.com/locate/gr

Palaeozoic and Mesozoic tectonic evolution and palaeogeography of East Asian crustal fragments: The Korean Peninsula in context

I. Metcalfe

Asia Centre, University of New England, Armidale, NSW 2351, Australia

Received 1 February 2005; accepted 12 April 2005
Available online 9 January 2006

Abstract

East and Southeast Asia comprises a complex assembly of allochthonous continental lithospheric crustal fragments (terranes) together with volcanic arcs, and other terranes of oceanic and accretionary complex origins located at the zone of convergence between the Eurasian, Indo-Australian and Pacific Plates. The former wide separation of Asian terranes is indicated by contrasting faunas and floras developed on adjacent terranes due to their prior geographic separation, different palaeoclimates, and biogeographic isolation. The boundaries between Asian terranes are marked by major geological discontinuities (suture zones) that represent former ocean basins that once separated them. In some cases, the ocean basins have been completely destroyed, and terrane boundaries are marked by major fault zones. In other cases, remnants of the ocean basins and of subduction/accretion complexes remain and provide valuable information on the tectonic history of the terranes, the oceans that once separated them, and timings of amalgamation and accretion. The various allochthonous crustal fragments of East Asia have been brought into close juxtaposition by geological convergent plate tectonic processes. The Gondwana-derived East Asia crustal fragments successively rifted and separated from the margin of eastern Gondwana as three elongate continental slivers in the Devonian, Early Permian and Late Triassic–Late Jurassic. As these three continental slivers separated from Gondwana, three successive ocean basins, the Palaeo-Tethys,. Meso-Tethys and Ceno-Tethys, opened between these and Gondwana. Asian terranes progressively sutured to one another during the Palaeozoic to Cenozoic. South China and Indochina probably amalgamated in the Early Carboniferous but alternative scenarios with collision in the Permo–Triassic have been suggested. The Tarim terrane accreted to Eurasia in the Early Permian. The Sibumasu and Qiangtang terranes collided and sutured with Simao/Indochina/East Malaya in the Early–Middle Triassic and the West Sumatra terrane was transported westwards to a position outboard of Sibumasu during this collisional process. The Permo–Triassic also saw the progressive collision between South and North China (with possible extension of this collision being recognised in the Korean Peninsula) culminating in the Late Triassic. North China did not finally weld to Asia until the Late Jurassic. The Lhasa and West Burma terranes accreted to Eurasia in the Late Jurassic–Early Cretaceous and proto East and Southeast Asia had formed. Palaeogeographic reconstructions illustrating the evolution and assembly of Asian crustal fragments during the Phanerozoic are presented.

Keywords: East Asia; Palaeozoic–Mesozoic; Crustal fragments; Tectonic evolution; Palaeogeography; Korean Peninsula

1. Introduction

East and Southeast Asia comprises a complex assembly of allochthonous continental lithospheric crustal fragments (terranes, blocks, massifs) together with volcanic arcs, and other terranes of oceanic and accretionary complex origins (Fig. 1). These crustal fragments are located at the zone of convergence between the Eurasian, Indo-Australian and Pacific Plates. The boundaries between Asian terranes are marked by major geological discontinuities (suture zones) that represent the sites of former ocean basins that once separated them. In some cases, remnants of the ocean basins have been completely destroyed and lost, and terrane boundaries are marked by major fault zones. In other cases, remnants of the ocean basins and of subduction/accretion complexes remain and provide valuable information on the tectonic history of the terranes and the oceans that once separated them. The various allochthonous crustal fragments of East Asia have been brought into close juxtapopsition by geological convergent plate tectonic processes. The former wide separation of terranes of the region are indicated by contrasting faunas and floras developed on adjacent terranes due to their prior geographic separation, different palaeoclimates, and biogeographic isolation. Two remarkable biogeographic boundaries are recognised, a Late

---

E-mail address: imetcal2@une.edu.au.

1342-937X/$ - see front matter © 2005 International Association for Gondwana Research. Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.gr.2005.04.002

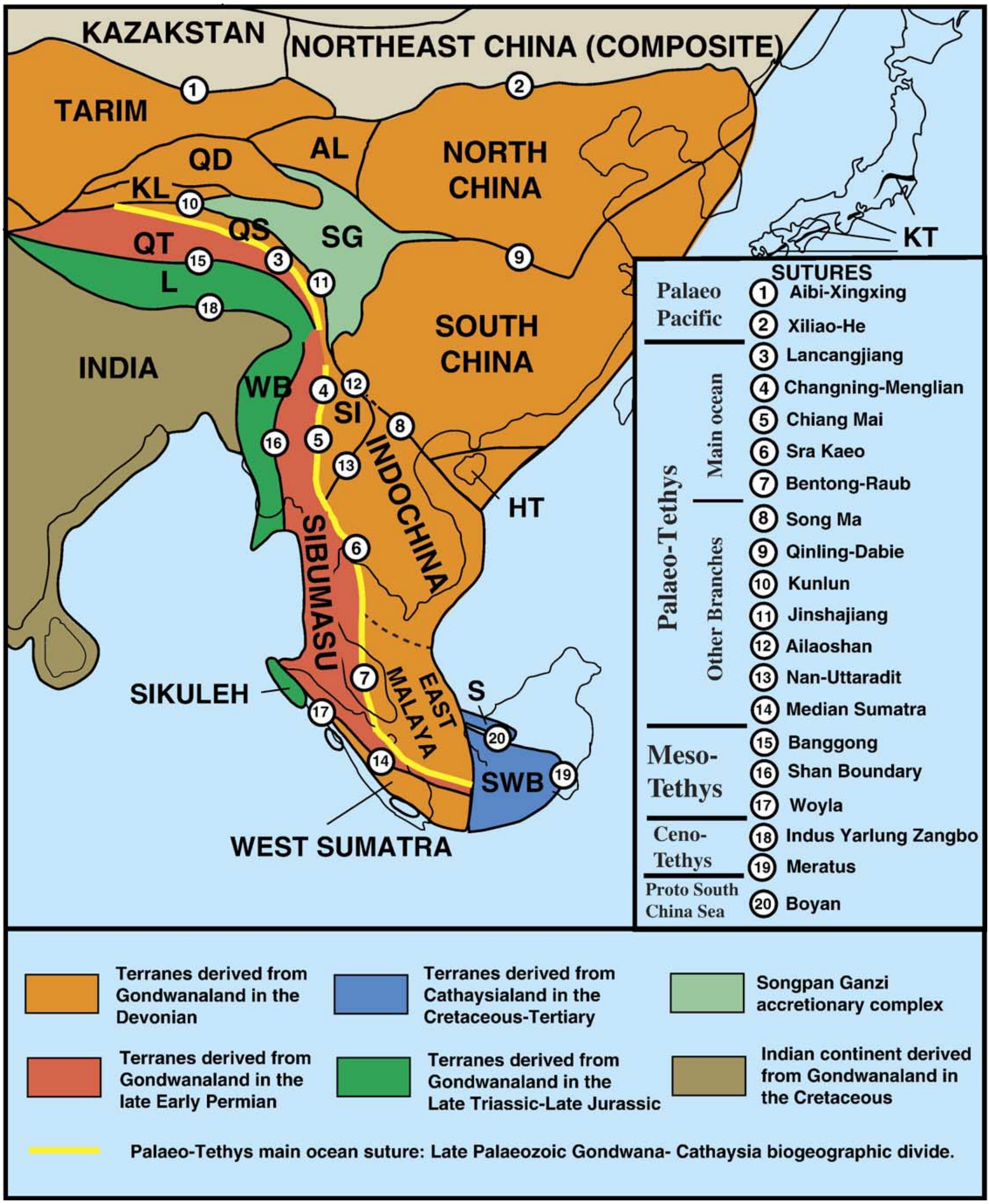

Fig. 1. Distribution of principal continental terranes and sutures of East and Southeast Asia. WB = West Burma; SWB = Southwest Borneo; S = Semitau Terrane; HT = Hainan Island terranes; L = Lhasa Terrane; QT = Qiangtang Terrane; QS = Qamdo–Simao Terrane; SI = Simao Terrane; SG = Songpan Ganzi accretionary complex; KL = Kunlun Terrane; QD = Qaidam Terrane; AL = Ala Shan Terrane; KT = Kurosegawa Terrane.

Palaeozoic Gondwana–Cathaysia Divide (see Figs. 1 and 2) and the extant Wallace's Line. The Late Palaeozoic Gondwana–Cathaysia Divide forms the boundary between high-latitude, cold climate, southern hemisphere Gondwanaland faunas and floras, and equatorial and northern hemisphere, warm climate, sub-tropical and tropical Cathaysian faunas and floras. The ancient Wallace's Line separates Eurasian faunas and floras to the northwest from Australasian faunas and floras to the southeast and was recognised by and named for Alfred Russel Wallace, now regarded as the Father of Biogeography. The regional geology of East and Southeast Asia is fundamentally underpinned by the kinematic history and framework of the allochthonous lithospheric crustal fragments of the region, and the evolution of the various ocean basins that once separated them. All of the East Asian continental crustal fragments are here interpreted to have had their origin on the Indo-Australian Early Palaeozoic margin of eastern Gondwana. They rifted and separated from Gondwana as three successive collages of terranes (as three elongate continental strips) in the Devonian, late Early Permian, and Late Triassic–Late Jurassic. In this paper, I provide an overview review of the tectonic evolution of these terranes in the Palaeozoic and Mesozoic and some snapshot palaeogeographic reconstructions, including the specific context of the Korean Peninsular in this evolution.

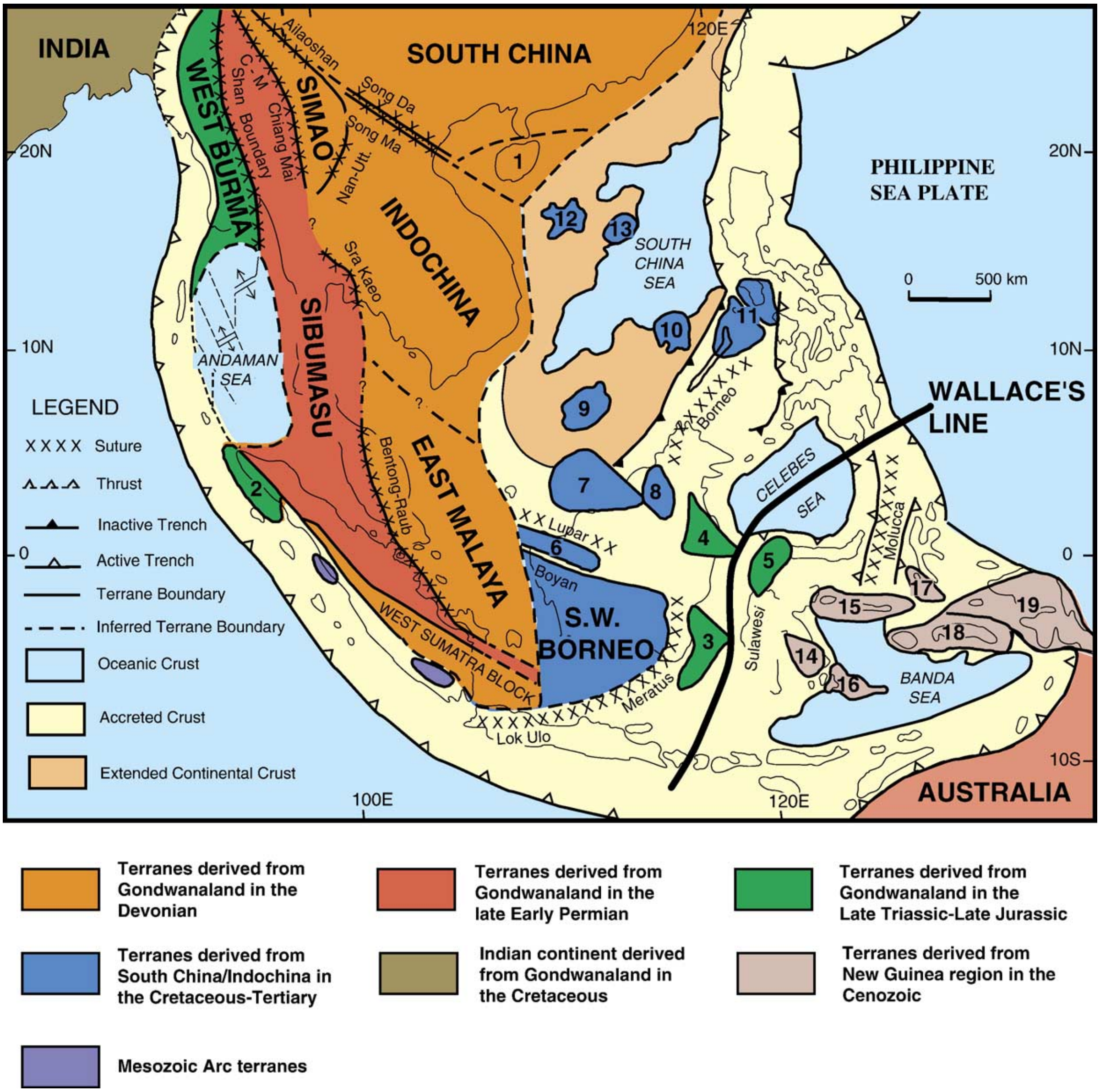

Fig. 2. Distribution of continental blocks, fragments and terranes, and principal sutures of Southeast Asia. Numbered microcontinental blocks: 1. Hainan Island terranes, 2. Sikuleh, 3. Paternoster, 4. Mangkalihat, 5. West Sulawesi, 6. Semitau, 7. Luconia, 8. Kelabit–Longbowan, 9. Spratley Islands–Dangerous Ground, 10. Reed Bank, 11. North Palawan, 12. Paracel Islands, 13. Macclesfield Bank, 14. East Sulawesi, 15. Bangai–Sula, 16. Buton, 17. Obi–Bacan, 18. Buru–Seram, 19. West Irian Jaya. C–M = Changning–Menglian Suture.

In order to work out the tectonic evolution of the east Asian terranes, evidence for their origin and original continental attachment, for the timing of rifting and separation from parent continents, evidence for timing, direction and rates of drift, and evidence for timing and nature of suturing (collisions–amalgamation/accretion) must be assembled. Table 1 shows the principal types of evidence and constraining data for the origins and the rift/drift/suturing of terranes.

2. Principal East Asian crustal fragments and their boundaries

The principal East Asian crustal fragments are shown in Figs. 1 and 2 and are discussed individually below.

2.1. South China Block

The South China Block is a composite terrane. Some authors (e.g., Hsu et al., 1988, Hsu et al., 1989) recognise two component terranes, the Yangtze and Huanan Blocks separated by the "Xiangganzhe" Mesozoic suture. Alternatively, Li et al. (1995) recognise two terranes, the Yangtze and Cathaysia terranes, separated by a Neoproterozoic (Grenville) age suture. A more complex four terrane model has been proposed by Chen et al. (1993) who recognise four component blocks for South China, from NW to SE, the Yangtze, Xianggui, Cathaysia and Dongnanya blocks, separated by Palaeozoic to Jurassic mélange zones. Hoe and Rangin (1999) proposed a three terrane model with the Yangtze, "N. Indochina–SE China" (extending into N. Vietnam, Laos and Yunnan) and

Table 1
Multidisciplinary constraining data for the origins and the rift/drift/suturing of terranes (after Metcalfe, 1998)

Origin of terranes	Age of rifting and separation	Drifting (palaeopositions of terranes)	Age of suturing (amalgamation/accretion)
Indicated by:	Indicated by:	Indicated by:	Indicated by:
* Palaeobiogeographic constraints (fossil affinities with proposed parent craton)	* Ocean floor ages and magnetic stripe data	* Palaeomagnetism (palaeolatitude, orientation)	* Ages of ophiolite and ophiolite obduction ages (pre-suturing)
* Tectonostratigraphic constraints (similarity of gross stratigraphy with parent craton, presence of distinctive lithologies characteristic of parent craton, e.g., glacials)	* Divergence of Apparent Polar Wander Paths (APWPs) indicates separation	* Palaeobiogeography (shifting from one biogeographic province to another due to drift)	* Melange ages (pre-suturing)
* Palaeolatitude and orientation from palaeomagnetism consistent with proposed origin	* Divergence of palaeolatitudes (indicates separation)	* Palaeoclimatology (indicates palaeolatitudinal zone)	* Age of ‘stitching’ plutons (post suturing)
* Provenance studies, e.g., ages of detrital zircons in sedimentary units.	* Age of associated rift volcanism and intrusives		* Age of collisional or post-collisional plutons (syn to post suturing)
* Mantle signatures, e.g., lead isotopes.	* Regional unconformities (formed during pre-rift uplift and during block faulting)		* Age of volcanic arc (pre-suturing)
	* Major block-faulting episodes and slumping		* Major changes in arc chemistry (syn-collisional)
	* Palaeobiogeography (development of separate biogeographic provinces after separation)		* Convergence of Apparent Polar Wander Paths (APWPs)
	* Stratigraphy — rift sequences in grabens/half grabens		* Loops or disruptions in APWPs (indicates rapid rotations during collisions)
			* Convergence of palaeolatitudes (may indicate suturing but no control on longitudinal separation)
			* Age of blanketing strata (post suturing)
			* Palaeobiogeography (migration of continental animals/plants from one terrane to another indicates terranes have sutured)
			* Stratigraphy/ sedimentology (e.g., provenence of sedimentary detritus from one terrane on to another)
			* Structural geology (age of deformation associated with collision)

“Indocathaysia” blocks. Formation of South China in the Mesozoic by amalgamation of the Yangtze and Huanan blocks (Hsu et al., 1988, Hsu et al., 1989) has been challenged by Rogers (1989), Rowley et al. (1989), and Li et al. (1995), and geochronological data from Anhui and Jiangxi Provinces suggest that the suture recognised by Hsu et al. (1989) is in fact of Proterozoic age (Chen et al., 1991). Structural and geochronological work (Charvet et al., 1999) indicate that the Yangtze and Cathaysia blocks amalgamated along the Jiangnan suture around 950–900 Ma. A nucleus of Late Archaean (2800 Ma) basement is known to be present in the Yangtze Block of the South China terrane but most other basement ages are Proterozoic, ranging from 1800 to 800 Ma. South China (excluding Hainan Island) is here regarded as a single tectonic unit since the Palaeozoic following the arguments of Rogers (1989), Rowley et al. (1989), Chen et al. (1991), Li et al. (1995) and Charvet et al. (1999). Its boundaries with North China and the Indochina Block are the Qin Lin–Dabie and either the Song Ma or Danang–Zhejiang Suture in South China/Vietnam, respectively. Early Palaeozoic shallow marine faunas of South China have affinities with those of northeast Gondwanaland and belong to the Asia–Australian and Austral realms in the Cambrian and Ordovician, respectively (Yang, 1994; Li, Zhiming, 1994). These faunal affinities, together with stratigraphic comparisons suggest that South China may have had its origin on the Himalaya–Iran region of the Gondwanaland margin (Burrett et al., 1990; Nie et al., 1990; Nie, 1991; Metcalfe, 1996a,b). The Early Palaeozoic placement of South China adjacent to the Himalaya–Iran region is consistent with the palaeomagnetic evidence which places South China in mid-southern palaeolatitudes in the Ordovician (Lin et al., 1985; Burrett et al., 1990; Metcalfe, 1990; Zhao et al., 1996). Another alternative and cogently argued hypothesis places South China as the “missing link” between Eastern Australia and Laurentia in the Neoproterozoic (Li et al., 1995; Li et al., 1996). If one accepts this placement, South China must have separated from Rodinia by Early Cambrian times and this would probably preclude it forming part of Early Palaeozoic Gondwanaland.

The recent proposition that the main suture between Indochina and South China is the Danang–Zhejiang Suture of Early Devonian age and that the Song Ma suture represents short-lived subduction of a back-arc basin in the Devonian (Hoe and Rangin, 1999) may support this view. However, the Early Palaeozoic stratigraphy of South China is unlike that of Eastern Australia but seems to show similarities to that of the India–Himalaya region of Gondwanaland suggesting proximity to that region. The Early Palaeozoic faunal affinities of South China also seem to suggest such a connection which is preferred here pending further studies of critical areas of Vietnam, Laos and Yunnan.

2.2. North China Block (Sino–Korean Craton)

The North China Block (or Sino–Korean Craton) is bounded to the north by the Xiliao–He suture (Sengör, 1987) and to the south by the Qin Lin–Dabei suture and the Tan Lu Fault. A probable suture now recognised as the western Ordos thrust belt forms the western boundary of the North China Block and its boundary with the Ala Shan terrane. The North China Block has a basement comprising several Late Archaean (2800 Ma) nuclei, with some metamorphic basement rocks being as old as >3.8 Ga (Liu et al., 1992) surrounded by Palaeoproterozoic orogenic belts of about 1800 Ma which are overlain by Mesoproterozoic and Late Proterozoic shallow-marine siliciclastics and carbonates. The Late Proterozoic sequences of North China have been interpreted as rift-related and a possible consequence of rifting from the supercontinent Rodinia. Sinian rocks are rare on North China except around its margins and the Proterozoic rocks are succeeded by Lower Palaeozoic sedimentary sequences.

Early Palaeozoic fossils of this block (particularly trilobites and brachiopods) strongly suggest proximity, and probable continental connection to Australian Gondwanaland during the Early Palaeozoic (Burrett et al., 1990). The Palaeozoic sequence shows marked constrast to that of South China, and contains a massive stratigraphic break with Late Ordovician–Lower Carboniferous rocks being essentially absent. Gross stratigraphical comparisons between North China and the Arafura Basin of North Australia, suggests that North China may have been attached to North Australia, adjacent to the Arafura Basin, during the Early Palaeozoic (Nicoll and Totterdell, 1990). This placement is also supported by palaeomagnetic data (Klootwijk, 1996a,b,c). Carboniferous and younger faunas and floras of North China show no affinities to Gondwanaland.

2.3. Tarim Block

The northern boundary of the Tarim Block is formed by the Tien Shan Range and the Late Palaeozoic Aibi–Xingxing (or Southern Tien Shan) suture (Windley et al., 1990; Allen et al., 1991; Chen and Rong, 1992), and its southern boundary is formed by the Kun Lun suture which separates this block from the Qaidam, Kunlun and Ala Shan blocks to the south and east. Amphibolite and gneiss along the northeast margin of the block have yielded the oldest basement ages with Archaean Sm–Nd ages of 3263 and 3046 Ma and U–Pb zircon ages from granitoids in the same region have yielded Palaeoproterozoic (2300–1800 Ma) ages (Wang, 1994; Li et al., 1996). Palaeoproterozoic rocks are also found around the other margins of the block. Early Palaeozoic shelly faunas and conodonts of the Tarim Block are similar to those of the South China and North China block and suggest an origin on the northeast margin of Gondwanaland, proximal to both North and South China (Chen and Rong, 1992). Silurian brachiopods of the western Tarim Block belong to the marginal Gondwanaland Sino–Australian Province (Rong et al., 1995). The central part of the Tarim Block is covered by Cenozoic sediments but an east–west trending magnetic high in the central part of Tarim and other magnetic highs in the southern part have led to speculation of an Archaean nucleus to the block. The Archaean and Palaeoproterozoic rocks of the block are overlain unconformably by Mid-Proterozoic low-grade metamorphosed shallow-marine clastics and carbonates that are in turn overlain unconformably by a Neoproterozoic littoral to shallow-marine clastic and carbonate succession. Sinian deposits are known along the northern and western margins of the block. A dominantly carbonate Cambrian–Ordovician sequence disconformably overlies the Sinian. Interestingly, the Middle–Late Cambrian of the Tarim Block contains phosphates and evaporites at similar stratigraphic levels to those of the North and South China blocks and Australia. There is a major stratigraphic break in the Palaeozoic sequence of the Tarim Block from Upper Silurian through to Lower Carboniferous and this is believed to be related to the rifting and separation of the block from Gondwanaland. Marine sedimentation in the Carboniferous, gives way to largely continental deposition in the Permian following the collision of Tarim with the Tien Shan/Kazakhstan.

2.4. Ala Shan (Alxa) Block

This small block is bounded by the Tian Shan–Ying Shan suture to the north, and the Qilian suture to the south, which converge westwards, and the western Ordos thrust belt in the east which forms the boundary between the Ala Shan Block and the North China Block. Some authors regard the Ala Shan Block to be an extension of North China and contiguous with the Tarim Block (e.g., Golonka et al., 1994; Yin and Nie, 1996). Further work is required to determine if the Ala Shan Block originally formed part of the North China Block, the Tarim Block, or is a separate small terrane now juxtaposed between North China and Tarim.

2.5. Qaidam Block

This small continental block is bounded by the Altun Tagh Fault zone to the north west, the Qilian suture to the north east, and the Kun Lun suture and Songpan Ganzi accretionary complex to the south. The basement of the block is formed by Early Proterozoic metamorphic rocks with a Late Proterozoic–Palaeozoic sedimentary cover which is similar that of the Tarim

Block. It seems most probable that the Qaidam Block originally formed part of the Tarim terrane and reached its current relative position to the Tarim Block by strike slip displacement along the Altun Tagh fault zone during the latest Cretaceous to Early Cenozoic (Allen et al., 1994).

2.6. Kun Lun Block

The small Kun Lun Block is sandwiched between the Tarim, Qaidam and Qiangtang Blocks and is bounded by the Altyn Tagh Fault zone to the north and the Jinshjiang suture to the south (Fig. 1). The metamorphic rocks and Early–Middle Proterozoic basement of the block correlate well with similar basement rocks of the Qaidam Block (Wu, 1999). This small terrane may well represent an accretionary wedge constructed on the southern margin of the Tarim–Qaidam terrane.

2.7. Indochina Block

This block is bounded to the northeast by the Song Ma suture zone and to the west by the Uttaradit–Nan–Sra Kaeo sutures in Thailand and Malaysia, respectively. Its eastern and southern boundaries are poorly defined and constrained. The basement of the block comprises a Precambrian core (Kontum massif) of granulite facies rocks exposed in Vietnam, and it has been suggested that this may have originally formed part of the Gondwanaland granulite belt (Katz, 1993). Nd depleted mantle model ages of 1.2 to 2.4 Ga indicate crustal formation in the Palaeoproterozoic and Mesoproterozoic (Lan et al., 2003) and subsequent Permo–Triassic Indosinian (~254 Ma) granulite facies metamorphism is indicated by U–Pb SHRRIMP zircon dating studies (Nam et al., 2001). Early to Middle Palaeozoic rocks are rare and restricted to the marginal areas of the block. Silurian brachiopods from Central Vietnam belong to the Sino–Australian Province (Rong et al., 1995) indicating Gondwanaland connections in the Silurian. Devonian fish, including a yunnanolepiform antiarch previously known only from the South China Block, recently reported from central Vietnam (Thanh et al., 1996) indicate close proximity/continental connection with South China in the Early to Middle Devonian. The Late Palaeozoic and Mesozoic faunas and floras of Indochina are Cathaysian/Tethyan types, have affinities to those of South and North China, and show no relationship to Gondwanaland (Metcalfe, 1986, 1988). Recent field structural data and Ar–Ar isotopic dating have led to the proposition that the Indochina–East Malaya region was an archipelagic zone comprising microcontinents and marginal basins, much akin to modern day SE Asia (Lepvrier et al., 2004). An Early Triassic tectono-thermal event seen in Ar–Ar ages of 250–240 Ma is also interpreted by these authors to represent Early Triassic Indosinian collision between these micro-blocks and with South China and Sibumasu.

2.8. East Malaya Block

The East Malaya Block of Stauffer (1974, 1983) and Metcalfe (1988) is bounded to the west by the Bentong–Raub Suture Zone (Metcalfe, 2000) and to the south by the Median Sumatra Suture. The eastern and northern boundaries are difficult to place precisely. The tectonostratigraphy, and the Tethyan faunas and Cathaysian floras of this block are extremely similar to Indochina (see Metcalfe, 1988, 1996a,b, 2005 for details) and this similarity led me to include this block as part of the Indochina terrane in a number of recent papers (e.g., Metcalfe, 1998, 1999, 2000, 2002). However, more recent studies of macrofossil biogeography (Sone et al., 2003) and a reassessment of the tectonic framework of SE Asia have indicated that East Malaya may well have been an independent Cathaysian terrane at times in the Late Palaeozoic. Indochina, East Malaya and West Sumatra, may be disrupted blocks of a single large Late Palaeozoic Cathaysian terrane. Further work is required to resolve this issue.

2.9. West Sumatra Block

The narrow elongate West Sumatra Block (Barber and Crow, 2003) is bounded to the northeast by the Medial Sumatra Tectonic Zone (Median Sumatra Suture) and to the southeast by the Woyla Suture and Nappe. Its eastern termination against the Southwest Borneo Block is obscure. The block is characterised by low-latitude Visean faunas in the Kuantan limestones, Early Permian volcanics and Early Permian Cathaysian floras (Jambi Flora) and Tethyan (Cathaysian) faunas (Barber and Crow, 2003; Metcalfe, 2005, Fig. 10). These characteristics indicate that this block has strong affinities to the Cathaysian Indochina and East Malaya blocks and it may well have formed part of a larger Late Palaeozoic terrane. However, the current position of the West Sumatra Block, outboard of the Sibumasu Block, requires that it has been translated to its present position by westwards transport, probably during Permo–Triassic collision between Sibumasu and Indochina/East Malaya.

2.10. West Burma Block

Formerly known as the “Mount Victoria Land” Block (Mitchell, 1989). Mitchell (1993) has reinterpreted Western Burma (together with the Woyla Group of Sumatra and the Meratus ophiolite of Borneo as an Early Cretaceous mafic arc, produced by southwest directed subduction, which was then thrust on to the Asian margin in the Late Lower Cretaceous. Following Metcalfe (1990), I prefer to regard Western Burma as a probable continental fragment now largely obscured by younger sediments and volcanic rocks. This block has a pre-Mesozoic schist basement overlain by Triassic turbidites and Cretaceous ammonite-bearing shales and limestones in the Indoburman Ranges and by a Late Mesozoic–Cenozoic arc association in the Central Lowlands of Burma. There is as yet no direct evidence for the origin of this block but it sutured to Sibumasu in Cretaceous times. The West Burma Block is considered (Metcalfe, 1990) a good candidate for part of the continental sliver that provided a source for sediments derived from the northwest in Timor during the Triassic, and which must have rifted from Gondwanaland in the Late Jurassic. This interpretation however remains speculative.

2.11. Qiangtang terrane

The Qiangtang terrane is bounded to the south by the Banggong Suture and to the north by the Lancangjiang suture. The basement of the block is largely buried beneath Palaeozoic and Mesozoic sediments but exposures do occur in fault bounded blocks where the rocks include schists, marbles and meta-andesites of possible Precambrian age. The basement rocks are unconformably overlain by Silurian and Devonian sediments. The Upper Palaeozoic sequence includes Upper Carboniferous and Lower Permian glacial–marine and glacial deposits and Lower Permian cold-water faunas and Gondwanaland floras and faunas. These pass up into Upper Permian shallow-marine deposits with Cathaysian faunas and floras. Lower Triassic marls unconformably overly the Upper Permian and these are in turn unconformably overlain by Middle Jurassic clastics and carbonates. The northern boundary of the Qiangtang Block has previously been regarded as the Jinshajiang suture (eg. Chang et al., 1986; Dewey et al., 1988). However, although the Qiangtang Block also exhibits Late Palaeozoic glacial-marine sediments and cold-water faunas with Gondwanaland affinities, these occurrences are restricted to the region southwest of the Lancangjiang Suture (Wang and Mu, 1983; Metcalfe, 1988; Chen and Xie, 1994). In the region between the Lancangjiang and Jinshajiang sutures, Cathaysian faunas and floras have been reported, and there are no glacial–marine deposits or cold-water faunal indicators. This region is now recognised as a separate block forming part of the Simao terrane (see below). The Qiangtang terrane is here regarded as being contiguous with the Sibumasu terrane to the south and as having formed part of the Cimmerian continental strip that separated from northeast Gondwanaland in the late Early Permian.

2.12. Simao Terrane

This terrane includes what has previously been variously referred to as the "Lanpin–Simao", and "Qamdo–Simao" blocks of Tibet and which some authors have termed the "North Qiangtang Block" (eg., Jin, 2002, Bian et al., 2004) or "Eastern Qiangtang" Block (Zhang et al., 2002) and the Simao Block of SW China first proposed by Wu et al. (1995). I previously regarded this terrane as a probable extension of the Indochina Block, and some authors still hold this view (e.g., Jin, 2002), but new information on the Ailaoshan and Nan–Uttaradit suture zones in SW China and Thailand, respectively, indicating that these sutures probably represent a marginal back-arc basin (Wang et al., 2000; Ueno and Hisada, 1999), and identification of the main Tethys ocean suture in the Chiang Mai–Chiang Dao area of NW Thailand (Metcalfe, 2002), suggests that the Simao Block is a separate terrane derived from South China by back-arc spreading in the Early Carboniferous. The terrane is bounded to the west by the Chiang Mai, Changning–Menglian and Lancangjiang suture zones and to the east and south by the Jinshajiang, Ailaoshan and Nan–Uttaradit suture zones (Figs. 1 and 2).

The basement rocks of this terrane are buried beneath thick Palaeozoic–Mesozoic sequences. High grade metamorphic rocks sporadically outcropping in Qinhai may represent a Precambrian crystalline basement (Chang et al., 1989). The oldest sedimentary rocks that crop out are Lower Ordovician low grade metasedimentary rocks including slates, phyllites, quartzites and meta-limestones. The Ordovician is unconformably overlain by Middle Devonian basal conglomerates and shallow-marine sediments followed by Carboniferous to Permian shallow-marine, paralic and continental sediments with coal measures in places, and Lower and Middle Triassic shallow-marine clastics and carbonates. Permian faunas and floras of this terrane are Tethyan and Cathaysian, respectively and there are no known Lower Permian glacial–marine deposits on this terrane. Disconformities are common in the Late Permian and Triassic. Upper Triassic red continental clastics overly these sediments. Recently, Ueno and Hisada (1999) and Ueno (1999, 2000, 2003) have equated the Changning–Menglian "Belt" with the "Inthanon Zone" of Thailand (Barr and Macdonald, 1991) which equates with part of the "Sukhothai Fold Belt" and suggested that these represent the Palaeo-Tethys. I agree with this interpretation and have suggested (Metcalfe, 2002) that the main Palaeo-Tethys ocean is represented by the oceanic rock-association distributed in the Chiang Dao–Chiang Mai area of west Thailand and that this association should be termed the "Chiang Mai Suture" as introduced in figures, but not discussed in the text, by Cooper et al. (1989, Figs. 1 and 6) and Charusiri et al. (1997) in an extended abstract. There is no firm evidence for a separate "Chiang Mai–Malacca Microplate" as advocated by Chonglakmani (1999) who mistakenly interpreted the sea mount carbonates NW of Chiang Mai as continental platform facies. Charusiri et al. (1997) did recognise the Simao Block in their tectonic reconstruction but called this the "Lampang–Chiang Rai" Block which they considered to have separated from the Sibumasu Terrane by back-arc spreading during Carboniferous–Permian times. This interpretation is not tenable in view of the unequivocal Lower Permian Tethyan/Cathaysian biogeographic affinities of the block, and lack of typical Gondwanaland stratigraphy in the Lower Permian.

2.13. Lhasa Block

The Lhasa Block is bounded by the Indus–Yarlung–Tsangpo suture to the south, and the Bangong suture to the north. An Early Proterozoic basement is indicated by inherited zircon ages of about 2000 Ma from the Yangbajain granite. The oldest sedimentary rocks are Ordovician limestones and shales which pass upwards into Silurian, and Devonian dolomitic and oolitic limestones and shales. The Carboniferous strata are mainly shallow-marine sandstones, siltstones and minor limestone with glacial-marine diamictites (with dropstones) and glacial deposits (with striated pebbles) in the Upper Carboniferous. The Permian rocks comprises mainly shallow-marine limestones and shales and these are overlain by coarse terrigenous Triassic sediments with abundant basic and intermediate volcanics, followed by Jurassic and Cretaceous shallow-marine clastics and limestones with calc-alkaline volcanics in the south and coal measures in the north. The Upper Carboniferous sediments contain a low-diversity Gondwanaland fauna (Chang et al., 1986; Chang et al., 1989). The Lower Permian rocks continue to contain Gondwanaland faunas and floras and cold-water faunal elements.

2.14. Songpan–Ganzi accretionary complex

This terrane represents a giant "suture knot" and comprises huge thicknesses of accretionary complex rocks and volcanic arc rocks constructed over trapped remnant Palaeo-Tethyan oceanic lithosphere and underthrust continental lithosphere of the surrounding crustal blocks. The rocks filling the ancient basin comprise some Permian deep-sea sedimentary rocks but are largely Triassic ophiolitic mélange, flysch and molasse. The Permo–Triassic sequence represents a basin filling and shallowing sequence culminating in latest Triassic paralic deposits (Görür and Sengör, 1992). It has been suggested (Nie et al., 1995) that exhumation of the Qinlin–Dabei orogenic zone contributed huge amounts of Triassic sediment to the Songpan–Ganzi basin.

2.15. Southwest Borneo and Semitau blocks

These two blocks are bounded to the north by the Lupar suture, to the southeast by the Meratus and Luk Ulo sutures of SE Borneo and Java, and to the southwest by the Woyla suture and are separated from each other by the Boyan mélange belt, which I have interpreted as a separate suture zone. Other workers regard these two blocks as forming a single SW Borneo terrane. The boundary of these blocks with the Indochina terrane is cryptic. Poorly exposed schists and hornstones may represent the crystalline basement of these blocks but further work is required to provide age constraints and confirmation of this. The origins of these two blocks, separated by the Boyan suture, are poorly constrained. The oldest dated rocks are Devonian limestones with corals of the "Old Slates Formation" that appears to form part of a mélange unit accreted to the NE margin of SW Borneo. The oldest dated autochthonous rocks are Upper Carboniferous and Lower Permian limestones with fusulinids and conodonts. The Lower Permian microfossils are similar to South and North China and do not have affinities with those of west Malaya or Thailand (Vachard, 1990). Middle and Upper Permian and Early Triassic sedimentary rocks appear to be absent. The Middle and Upper Triassic is represented by basal conglomerates overlain by marine volcaniclastics with *Daonella* and *Halobia* bivalves. The latest Triassic and Early and Mid-Jurassic appear to be absent. Upper Jurassic and Lower to Middle Cretaceous sediments are represented by shallow-marine limestones, clastics and volcaniclastics (Metcalfe, 1988). Latest Cretaceous and Tertiary continental sandstones overly the earlier rocks. Jurassic floras and faunas have affinities with South China, Indochina, Japan and the Philippines (Kimura, 1984; Kobayashi and Tamura, 1984; Hayami, 1984). There does not appear to be any Gondwanaland connections in the faunas and floras of these two blocks. A South China/Indochina origin seems likely as proposed by Rammlmair (1993) but reconciliation between substantial progressive counter-clockwise rotation of southwest Borneo during the Cenozoic with the various tectonic models is required. The only Cenozoic plate tectonic model for Southeast Asia which takes into account both the clockwise rotation of the Philippine Sea Plate and the counter clockwise rotation of Borneo is that of Hall (1996, 2002).

2.16. Japanese Islands terranes

The Japanese Islands are composed of a rifted Asian basement (e.g., Hida Block) and a huge accretionary complex, produced by long-lived westwards subduction of the Pacific and Philippine Sea plates beneath Asia, over which the volcanic arc has migrated eastwards. A number of accreted terranes have been recognised within the accretionary complex including oceanic (seamount) terranes (e.g., Akiyoshi Limestone terrane) and continental allochthonous terranes. The Kurosegawa continental terrane is a highly attenuated and disrupted composite terrane of predominantly Palaeozoic age now sandwiched between two Mesozoic terranes in the Chichibu Belt of SW Japan. It comprises an Early Palaeozoic basement of igneous and high-grade metamorphic rocks, Silurian–Devonian volcaniclastic sediments with carbonate blocks, serpentinite, a Late Palaeozoic–Mesozoic chaotic complex and well-bedded Upper Palaeozoic-Lower Mesozoic cover sediments (Aitchison et al., 1991). Early and Middle Palaeozoic faunas and floras have affinities with Australia and suggest a north Australian Gondwanaland margin origin for this exotic terrane (Yoshikura et al., 1990; Aitchison, 1993). Studies of chromium spinels from serpentinites of the terrane (Hisada et al., 1994) suggest that the serpentinites were emplaced in a forearc setting during the Devonian. The precise location of the terrane in Silurian–Devonian times is at best speculative but a position adjacent to eastern South China, on the Gondwanaland margin, has been suggested (Saito, 1992; Hisada et al., 1994). The precise site of original attachment to Gondwanaland and the drift history of this terrane, however, remains largely unknown. The South Kitakami terrane (Yoshida and Machiyama, 2004) in northeast Japan is a stratigraphic terrane with Silurian to Lower Cretaceous sedimentary rocks resting on a pre-Silurian basement. Permian deposits are particularly well developed and rest on Carboniferous strata unconformably. It is interpreted to have had its origin along the margin of the North China Block.

3. Origins of the E and SE Asian terranes

By utilising multidisciplinary data, all the E and SE Asian continental terranes are interpreted to have had their origin on the margin of Gondwanaland, and probably on the India–N/NW Australian margin. It has long been known that Cambrian and Ordovician shallow-marine faunas of the North China, South China and Sibumasu terranes have close affinities with those of eastern Gondwanaland, and especially Australian Gondwanaland (Burrett, 1973; Burrett and Stait, 1985; Metcalfe, 1988; Burrett et al., 1990). This is observed in trilobites (Shergold et al., 1988), brachiopods (Laurie and Burrett, 1992), corals and stromatoporoids (Webby et al., 1985; Lin and Webby, 1989), nautiloids (Stait and Burrett, 1982, 1984; Stait et al., 1987), gastropods (Jell et al., 1984), and conodonts (Burrett et al., 1990; Nicoll and Totterdell, 1990; Nicoll and Metcalfe, 1994). Some of the fossils that provide Early Palaeozoic links between these terranes and Australian Gondwanaland are shown in Fig. 6 below. In addition, the Gondwanaland acritarch *Dicrodiacroium ancoriforme* Burmann has been reported from the Lower Ordovician of South China (Servais et al., 1996). Little is known of Cambrian–Ordovician faunas of Indochina but Silurian brachiopods, along with those of South China, North China, Eastern Australia and the Tarim terrane belong to the Sino–Australian province characterised by the *Retziella* fauna (Rong et al., 1995). Early Palaeozoic sequences and faunas of the Qaidam, Kunlun and Ala Shan blocks are similar to those of the Tarim Block and also to South and North China (Chen and Rong, 1992) and these blocks are regarded as disrupted fragments of a larger Tarim terrane by Ge et al. (1991). These data suggest that North China, South China, Tarim (here taken to include the Qaidam, Kunlun and Ala Shan blocks), Sibumasu (with the contiguous Lhasa and Qiangtang blocks) and Indochina formed the outer margin of northern Gondwanaland in the Early Palaeozoic. The close faunal affinites, at both lower and higher taxonomic levels, suggest continental contiguity of these blocks with each other and with Gondwanaland at this time rather than mere close proximity. Early Palaeozoic palaeomagnetic data for the various E and SE Asian terranes is variable in both quantity and quality and is often equivocal. This makes reconstructions based purely on palaeomagnetic data both difficult and suspect. However, a sufficient body of data exists to be able in some cases to reasonably constrain palaeolatitudes (but not always the hemisphere) and in some cases the actual position of attachment to Gondwanaland. North China data (Zhao et al., 1996) provide a Cambrian to Late Devonian pole path segment, which, when rotated about a Euler pole to a position of fit with the Australian Cambrian to Late Devonian pole path, produces a good fit with North China positioned adjacent to North Australia (Klootwijk, 1996b). This position is consistent with that proposed in reconstructions by Metcalfe (1993, 1996a,b) and in this paper. Comparisons of the gross stratigraphies of North China and the Arafura Basin (Metcalfe, 1996b) show a remarkable similarity in the Early Palaeozoic, also supporting the proposed position for North China. Positions for South China, Tarim and Indochina are more equivocal but latitudes of between 1° and 15° are indicated for the Late Cambrian–Early Ordovician for the South China Block (Zhao et al., 1996). Palaeolatitudes of between 6° and 20° south are indicated for the Tarim Block for the same time period that is broadly consistent with a position on the Gondwanaland margin between the North and South China bocks. Comparisons of the Precambrian sequence on the northeast margin of the Tarim Block with Australia led Li et al. (1996) to propose that this block had its origin outboard of the Kimberley region of Australia. Similar comparisons of the Precambrian of South China however led Li et al. (1995, 1996) to propose that South China was positioned between eastern Australia and Laurentia in the Late Proterozoic. This is rather different to the Early Palaeozoic position suggested here. Cambrian to Early Permian faunas of the Sibumasu terrane have strong Gondwanaland affinities, and in particular show close relationships with western Australian faunas (Metcalfe, 1988, 1996a,b; Burrett et al., 1990). In addition, Gondwanaland plants and spores are also reported from this terrane (Wang and Tan, 1994; Yang and Liu, 1996). Glacial–marine diamictites with dropstones and associated cold-water faunas and sediments, of Late Carboniferous to Early Permian age are also found distributed along the entire length of Sibumasu and indicate attachment to the margin of Gondwanaland where substantial ice reached the marine environment. The most likely region for attachment of this terrane is NW Australia. Palaeomagnetic data for the Late Carboniferous suggests a palaeolatitude of 42° south (Huang and Opdyke, 1991) which is consistent with such a placement. Comparison of the gross stratigraphy of Sibumasu with the Canning Basin of NW Australia also reveals striking similarities in the Cambrian to Early Permian, and Sibumasu could easily have been positioned outboard of the Canning Basin of western Australia during this time. Both the Qiangtang and Lhasa blocks of Tibet exhibit Gondwanaland faunas and floras up to the Early Permian, and also have glacial-marine diamictites, tilloids, and associated cold-water faunas and sediments in the Late Carboniferous to Early Permian. Thus, all the major E and SE Asian continental terranes appear to have had their origins on the margin of Gondwanaland (Table 2).

Carboniferous and younger faunas and floras of the North China, South China, Tarim, and Indochina terranes are typically Cathaysian in nature and they show no relationship

Table 2
Suggested origins for the E and SE Asian continental terranes

Terrane	Origin
North China	N. Australia
South China	Himalaya–Iran Region of Gondwana
Indochina	Eastern Gondwana
East Malaya	Eastern Gondwana
West Sumatra	Eastern Gondwana
Sibumasu	N.W. Australia
West Burma	N.W. Australia
Lhasa	Himalayan Gondwana
Qiangtang	Himalayan Gondwana
Simao	Eastern Gondwana: South China
Kunlun	N.E. Gondwana? Originally part of Tarim?
Qaidam	N.E. Gondwana? Originally part of Tarim?
Ala Shan	N.E. Gondwana? Originally part of Tarim?
Tarim	Australian Gondwana?
S.W. Borneo	Cathaysialand (South China/Indochina margin)
Semitau	Cathaysialand (South China/Indochina margin)
Hainan	N.E. Gondwana?
Kurosegawa (Japan)	Australian Gondwana?
South Kitakami	North China margin
Sikuleh	Australian Gondwana?

with Gondwanaland (Metcalfe, 1988). These terranes were also situated at palaeolatitudes that indicate they were no longer attached to the margin of Gondwanaland from the Carboniferous onwards (Zhao et al., 1996). This indicates that these terranes rifted and separated from Gondwanaland in the Devonian as previously suggested by Metcalfe (1994, 1996a,b). Sibumasu, Qiangtang and the Lhasa terranes, continued to remain on the margin of Gondwanaland until the Permian, with the Lhasa terrane remaining attached to Gondwanaland possibly until the Late Triassic but Sibumasu and Qiangtang separating in the late Early Permian. The Lower Palaeozoic stratigraphy and fossils (in particular Cambrian trilobites and Ordovician conodonts) of Hainan Island suggest that the small terranes that make up the Island were originally located on the Gondwanaland margin. Reports of Lower Permian glacial–marine diamictites and Upper Palaeozoic fossils with Gondwanaland affinities are now, following field investigations of these rocks, regarded as erroneous by the author. Lower Permian bivalves of the Island have also been shown to have South China Cathaysian affinities. Hainan Island therefore probably rifted away from Gondwanaland together with North and South China, Tarim and Indochina in the Devonian.

The continental sliver which was located immediately outboard of NW Australia in the Triassic, and which must have rifted and separated in the Late Triassic–Jurassic is here considered to have comprised West Burma, and perhaps the small Sikuleh Block, together with small continental fragments (West Sulawesi, Mangkalihat) that now form parts of Borneo, and eastern Indonesia. There is however little direct evidence to support this, apart from stratigraphic similarities between the Sikuleh Block and the NW Australian shelf and limited palaeomagnetic data showing this block to be derived from the south in the Mesozoic (Haile, 1979; Görür and Sengör, 1992). The Kurosegawa disrupted, composite terrane of Japan is believed derived from Gondwanaland and a position adjacent to eastern South China in the Silurian/Devonian has been speculated (Saito, 1992, Hisada et al., 1994).

Carboniferous and Permian faunas of the Southwest Borneo and Semitau blocks do not appear to have any affinities with those of Sibumasu, but are very similar to those of South and North China (Vachard, 1990). Triassic and Jurassic floras and faunas have affinities with South China, Indochina and Japan and a South China/Indochina origin seems likely.

4. Structural and tectonic framework of the Korean Peninsula

The Korean Peninsula can be divided into five tectono–structural units or terranes (Fig. 3), from south to north, the Yeongnam massif, Okcheon (Ogcheon) Belt, Gyeonggi (Kyonggi) massif, Imjingang Belt, and Nangrim massif/Pyeongnam basin. A brief description of these follows:

4.1. Nangrim massif and Pyeongnam basin

This terrane includes the basement Nangrim massif comprising Late Archaean–Early Proterozoic high grade gneisses

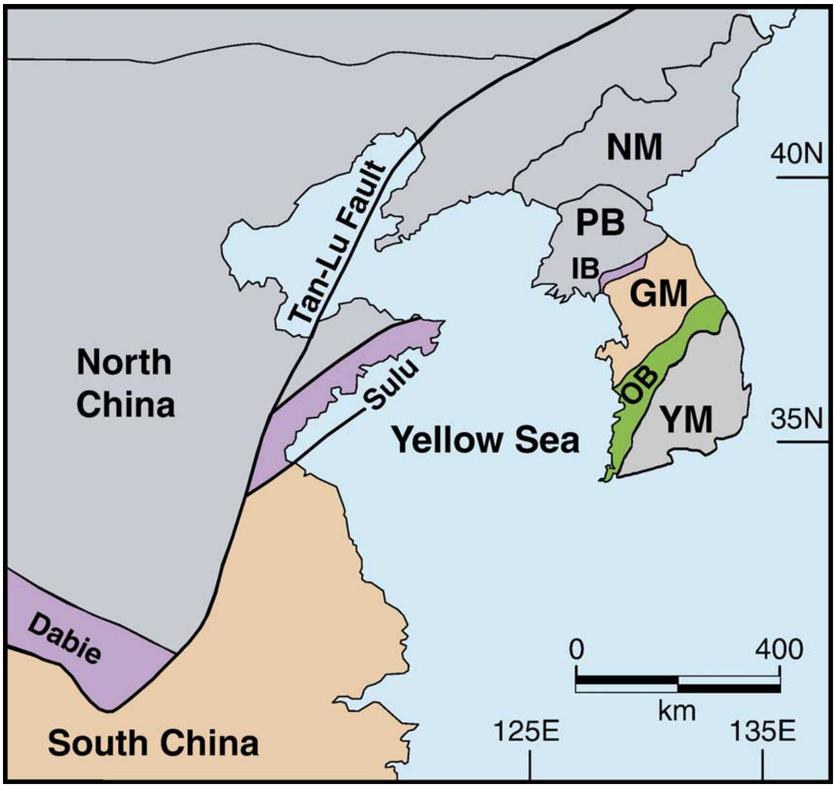

Fig. 3. Crustal blocks and massifs of the Korean Peninsula and adjacent northeast Asia. NM: Nangrim massif; PB: Pyeongnam basin; IB: Imjingang Belt; GM: Gyeonggi massif; OB: Okcheon Belt; YM: Yeongnam massif. After Jeong and Lee (2000).

and schists, and supracrustal sequences of Proterozoic metasedimentary schists, quartzites, marbles, calc-silicates and amphibolites of the Pyeongnam basin. This terrane is regarded to have formed an integral part of the North China Block since the Proterozoic.

4.2. Imjingang Belt

This belt forms the boundary between the Nangrim massif to the north and the Gyeonggi massif to the south. The belt is an east-trending fold and thrust belt comprising Archaean–Proterozoic basement rocks overlain by Silurian, Devonian and Carboniferous siliciclastic and carbonate metasedimentary sequences. It has been suggested, on the basis of structural, petrological and geochronological data, that this belt is the eastwards extension of the Qinling–Dabei–Sulu collisional belt between South and North China (Ree et al., 1996; Chough et al., 2000) and that exhumation of underthrusted basement rocks occurred in the Permo–Triassic (Lee et al., 2000) indicating temporal coincidence with exhumation along the Qinling–Dabei–Sulu Belt.

4.3. Gyeonggi (Kyonggi) massif

The Gyeonggi (or Kyonggi) massif is a metamorphic terrane comprising predominantly Proterozoic gneisses and schists which have experienced at least three phases of folding (Kim et al., 2000). The boundary with the Imjingang Belt is marked by an E–W trending ductile shear zone, the Kyonggi Shear Zone that is unconformably overlain by Late Triassic–Jurassic sediments and which has Late Triassic mylonite ages. Kim et al. (2000) suggest that at least part of the Gyeonggi massif was involved in the Permo–Triassic collision between South and North China and Lee et al. (2000) have suggested that the Gyeonggi massif is correlative with the Yangtze craton of the South China Block.

4.4. Okcheon (Ogcheon) Belt

The Okchon (Ogcheon) Belt is a NE trending fold-and-thrust belt sandwiched between the Kyonggi massif to the north west and the Yeongnam massif to the south east. The belt has been divided into two zones, a southern Okchon basin (zone) and a northern Taebaeksan basin (zone). The Okchon zone comprises generally unfossiliferous low- to medium-grade metasedimentary and metavolcanic rocks. Rare, poorly preserved fossils (Archaeocyathids, conodonts and trilobites, indicate Cambrian–Ordovician ages). Isotopic ages of metamorphic rocks range from Late Proterozoic to Cretaceous with the majority being of Jurassic age but with Pb–Pb metamorphic ages suggesting Late Permian–Early Triassic (Chough et al., 2000) or Early Permian (Cheong et al., 2003) ages of peak metamorphism. The metasedimentary rocks of this zone include slightly sheared diamictite that was originally interpreted as Precambrian tillites, but more recently suggested to be Permian tillites. These diamictites (Fig. 4) comprise mud/silt supported limestone, mudstone and granite clasts. Limestone clasts yield Lower Ordovician conodonts, granite clasts have yielded Permian ages, and micas from the matrix have been isotopically dated as Triassic. All clasts in the diamictite are locally derived and since this part of Korea almost certainly belonged to either North or South China in the Late Palaeozoic, a glacial origin for these diamictites seems unlikely and they probably represent a mass flow deposit.

The Taebaeksan zone comprises fossiliferous Palaeozoic and Early Mesozoic weakly metamorphosed sedimentary rocks which unconformably rest on Precambrian gneiss and metasedimentary rocks of the Yulli Group of the Yongnam massif

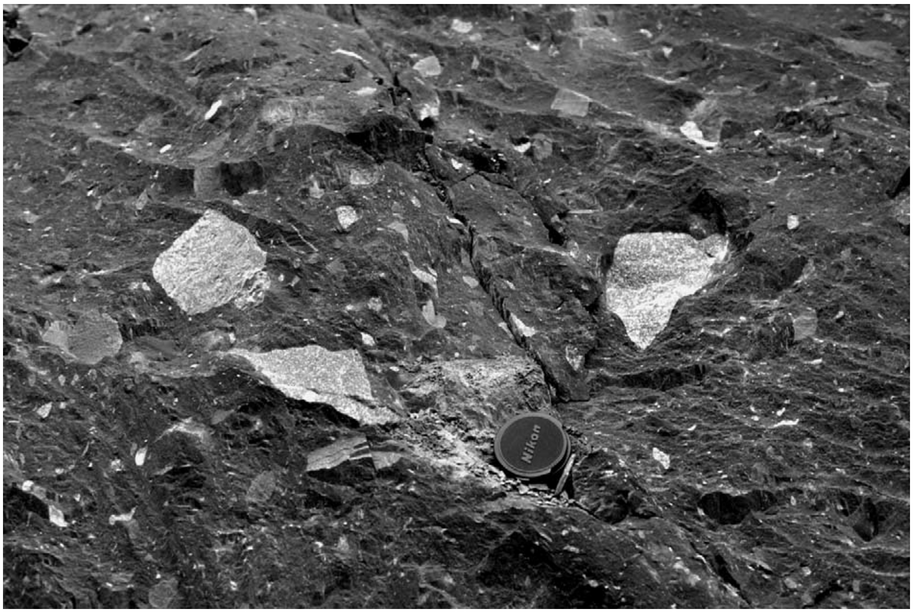

Fig. 4. Sheared diamictite in the Okchon Belt recently suggested to be Permian tillites but here regarded as a mass flow deposit.

(Chough et al., 2000). The sediments overlying the metamorphic basement comprise Cambrian–Silurian shallow-marine sediments, followed by Carboniferous–? Triassic marginal-marine to non-marine sediments with important coal measures. Cambrian–Ordovician trilobite faunas are closely comparable to those of China (in particular North China) and Australia (Chough et al., 2000; Choi et al., 2003) and clearly formed part of the Sino–Australian eastern Gondwana faunal province at that time. Quantitative analysis of Cambrian conodont faunas either side of the Honam Shear zone in the Okchon Belt by Jeong and Lee (2000) suggested that these faunas display higher bioprovincial affinities with North China rather than South China and that differences in the faunas represent differences in depositional setting (shallow vs. deep marine) rather than being of biogeographic significance. These authors go on to suggested that the entire Korean Peninsular formed part of the North China (or Sino–Korean) Block in the Early Palaeozoic. Ordovician conodont faunas include the distinctive Lower Ordovician conodont *Serratognathus*, first described from Korea, which again is biogeographically restricted to eastern Gondwana. Carboniferous and Permian faunas and floras are clearly Tethyan/Cathaysian (with fusulinids) and show no relation to Gondwana.

4.5. Yeongnam massif

The Yeongnam massif is a metamorphic terrane to the southeast of the Okchon Belt and is divided into a southern Jirisan complex and a northern Sobaeksan complex. It is partly overlain by the Cretaceous Kyongsang successor basin. The terrane comprises predominantly gneisses with minor schists, amphibolites, and metasedimentary rocks (mica-schists, quartzites and calc-silicate rocks). Rb–Sr and Pb–Pb whole rock ages for the orthogneisses of the terrane range between 1.6 and 2.2 Ga (Chough et al., 2000). U–Pb zircon ages for granite gneisses range from 1.9 to 2.1 Ga. Sm–Nd and Pb–Pb ages of garnets and garnet–biotite schists indicate that metamorphism in the Yeongnam massif occurred slightly younger than the main felsic magmatism.

4.6. Discussion

The suture between the South China and North China crustal blocks is marked by the Qinling–Dabei–Sulu Belt. Ultra-high-pressure rocks, with generally Late Triassic exhumation ages along this belt indicate that the collision between these two blocks occurred in Permo–Triassic times. Various models for the North–South China collision (e.g., Yin and Nie, 1993; Li, 1994a,b) promoted suggestions that the North China–South China collision zone extends into the Korean Peninsula, and in particular, it has been suggested that the Qinling–Dabei–Sulu Belt extends into Korea along the Imjingang Belt (Ree et al., 1996) and possibly extends to the Sangun Belt of Japan (Ernst and Liu, 1995). Isotopic data from the Imjingang Belt (Lee et al., 2000) appear to support this view. If this scenario is correct, then the Gyeonggi Block should be correlative with the South China Block. Biogeographic studies (Jeong and Lee, 2000; Choi et al., 2003) however, seem to indicate that the entire Korean Peninsula should be included in the North China Block (or Sino–Korean Block) during the Early Palaeozoic. There is clear controversy here regarding the continental affinities of the various crustal

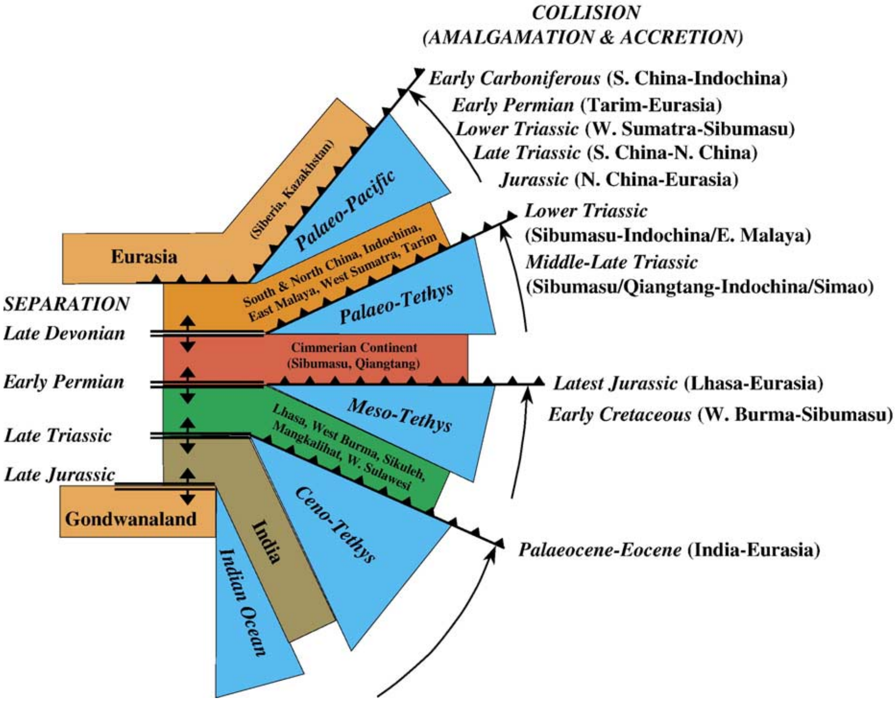

Fig. 5. Schematic diagram showing times of separation and subsequent collision of the three continental slivers/collages of terranes that rifted from Gondwanaland and translated northwards by the opening and closing of three successive oceans, the Palaeo-Tethys, Meso-Tethys and Ceno-Tethys.

Table 3
E and SE Asian sutures and their interpreted ages and age constraints

No. on Fig. 1	Suture name	Colliding lithosperic blocks	Suture age	Age constraints
1	Aibi–Xingxing	Tarim, Kazakhstan	Permian	Lower Carboniferous ophiolites. Major arc magmatism ceased in the Late Carboniferous. Late Permian post-orogenic subsidence and continental sedimentation in Junggar Basin. Palaeomagnetic data indicate convergence of Tarim and Kazakhstan by the Permian. Upper Permian continental clastics blanket the suture.
2	Xiliao–He	North China, Altaid terranes	Jurassic	Late Jurassic–Early Cretaceous deformation and thrust faulting. Widespread Jurassic–Cretaceous granites. Triassic–Middle Jurassic deep–marine cherts and clastics. Upper Jurassic–Lower Cretaceous continental deposits blanket suture.
3	Lancangjiang Suture	Qiangtang, Qamdo–Simao	Early Triassic	Suture zone rocks include Devonian and Carboniferous turbiditic “flysch”. Ocean-floor basic extrusives of Permian age and Carbo–Permian mélange. Carboniferous–Permian island arc rocks are developed along the west side of the suture. Upper Triassic collisional granitoids are associated with the suture. Suture zone rocks are blanketed by Middle Triassic continental clastics.
4	Changning–Menglian Suture	Sibumasu, Simao	Late Permian–Late Triassic	Oceanic ribbon-bedded chert–shale sequences have yielded graptolites, conodonts and radiolarians indicating ages ranging from Lower Devonian to Middle Triassic. Limestone blocks and lenses dominantly found within the basalt sequence of the suture and interpreted as seamount caps, have yielded fusulinids indicative of Lower Carboniferous to Upper Permian ages.
5	Chiang Mai Suture	Sibumasu, Simao	Middle Triassic	Basic volcanics (including pillow basalts) are dated as Carboniferous and Permian. Ages of oceanic deep-marine bedded cherts within the suture zone range from Devonian to Middle Triassic. Seamount limestone caps are dated as Lower Carboniferous (Visean) to Upper Permian (Changhsingian) in age.
6	Sra Kaeo Suture	Sibumasu, Indochina	Late Triassic	Suture zone rocks include melange and chert–clastic sequences which include ultrabasics, serpentinites, Carboniferous pillow basalts, and Early Permian to Late Triassic oceanic sediments and associated pillow basalts. Limestone blocks in the mélange range from upper Lower Permian to Middle Permian and a granitic lens has yielded a zircon U–Pb age of 486+/−5 Ma. Imbricate thrust slices dated as Middle Triassic by radiolarians. Jurassic continental sandstones blanket the suture zone.
7	Bentong–Raub Suture	Sibumasu, East Malaya	Early Triassic	Upper Devonian to Upper Permian oceanic ribbon-bedded cherts. Mélange includes chert and limestone clasts with Lower Carboniferous to Upper Permian ages. The Main Range ‘collisional’ ‘S’ Type granites of Peninsular Malaysia range from Late Triassic (230±9 Ma) to earliest Jurassic (207±14 Ma) in age, with a peak of around 210 Ma. Suture zone is covered by latest Triassic, Jurassic and Cretaceous, mainly continental, overlap sequence.
8	Song Ma	Indochina, South China	Late Devonian–Early Carboniferous	Large-scale folding and thrusting and nappe formation in the Early to Middle Carboniferous. Middle Carboniferous shallow marine carbonates are reported to blanket the Song Ma suture in North Vietnam. Pre-Middle Carboniferous faunas on each side of the Song Ma zone are different whilst the Middle Carboniferous faunas are essentially similar. Carboniferous floras on the Indochina Block in Northeast Thailand indicate continental connection between Indochina and South China in the Carboniferous
9	Qinling–Dabie	South China, North China	Triassic–Jurassic	Late Triassic subduction-related granite. Late Triassic U–Pb dates of zircons from ultra-high pressure eclogites. Late Triassic–Early Jurassic convergence of APWPs and palaeolatitudes of South China and North China. Initial contact between South and North China is indicated by isotopic data in Shandong and sedimentological records along the suture. Widespread Triassic to Early Jurassic deformation in the North China Block north of the suture.
10	Kunlun	Qamdo–Simao Kunlun	Triassic	Permo–Triassic ophiolites and subduction zone mélange. Upper Permian calc-alkaline volcanics, strongly deformed Triassic flysch and Late Triassic granitoids.

Table 3 (*continued*)

No. on Fig. 1	Suture name	Colliding lithosperic blocks	Suture age	Age constraints
11	Jinshajiang	Simao, South China	Late Permian–Late Triassic	Ophiolites are regarded as Upper Permian to Lower Triassic in age. Mélange comprises Devonian, Carboniferous and Permian exotics in a Triassic matrix. Upper Permian to Jurassic sediments unconformably overly Lower Permian ophiolites in the Hoh Xil Range.
12	Ailaoshan Suture	Simao, South China	Middle Triassic	Plagiogranite U–Pb ages of 340±3 Ma and 294±3 Ma indicate that the oceanic lithosphere formed in the latest Devonian to earliest Carboniferous. Ophiolitic rocks are associated with deep-marine sedimentary rocks including ribbon-bedded cherts that have yielded some Lower Carboniferous and Lower Permian radiolarians. Upper Triassic sediments (Carnian conglomerates and sandstones, Norian limestones and Rhaetian sandstones) blanket the suture.
13	Nan–Uttaradit Suture	Simao, Indochina	Middle Triassic	Pre-Permian ophiolitic mafic and ultramafic rocks with associated blueschists. Mafic and ultramafic blocks in the mélange comprise ocean-island basalts, back-arc basin basalts and andesites, island-arc basalts and andesites and supra-subduction cumulates generated in Carboniferous to Permo–Triassic times. Permo–Triassic dacites and rhyolites associated with relatively unmetamorphosed Lower Triassic sandstone–shale turbidite sequence. Suture zone rocks are overlain unconformably by Jurassic redbeds and post-Triassic intraplate continental basalts.
14	Median Sumatra	West Burma, Sibumasu	?Early Triassic?	No remnants of the ocean basin that once separated West Sumatra and Sibumasu so far known. It is likely that West Sumatra was slid into juxtaposition with Sibumasu from east to west along a major strike-slip fault associated with oblique subduction.
15	Banggong Suture	Lhasa, Qiangtang	Late Jurassic–Early Cretaceous	Suture is blanketed in Tibet by Cretaceous and Palaeogene rocks. Structural data indicate that collision around the Jurassic/Cretaceous boundary.
16	Shan Boundary Suture	West Burma, Sibumasu	Early Cretaceous	Cretaceous thrusts in the back-arc belt. Late Cretaceous age for the Western Belt tin-bearing granites.
17	Woyla Suture	Sikuleh, Sibumasu/W Sumatra	Late Cretaceous	Cretaceous ophiolites and accretionary complex material.
18	Indus–Yarlung–Zangbo Suture	India, Eurasia	Late Cretaceous–Eocene	Jurassic–Cretaceous ophiolites and ophiolitic mélange with Jurassic–Lower Cretaceous radiolarian cherts. Late Cretaceous blueschists. Eocene collision-related plutons. Palaeomagnetic data indicates initial collision around 60 Ma. Palaeogene strata blanket the suture.
19	Lok Ulo–Meratus Suture	Paternoster, SW Borneo	Late Cretaceous	Subduction mélange of middle-Late Cretaceous age. Ophiolite with Jurassic ultramafic rocks. Pillow basalts of Jurassic and Early Cretaceous ages. Oceanic cherts of Late Jurassic to Late Cretaceous ages. Turbiditic flysche of early-Late Cretaceous age. Ophiolite obducted in Cenomanian. Suture overlain by Eocene strata.
20	Boyan Suture	Semitau, SW Borneo	Late Cretaceous	Upper Cretaceous mélange.

For location of sutures see Figs. 1 and 2.

fragments of the Korean Peninsula and ongoing differing opinions and interpretations on the possible extension of the Qinling–Dabei–Sulu Belt eastwards into the Korean Peninsula. The significance of the Okchon Belt, separating the Gyeonggi and Yeongnam crustal fragments is also an ongoing problem. Is the Gyeonggi massif correlative with South China? Was the Yeongnam massif also originally part of South China or part of North China, or an independent crustal block? It seems clear from palaeobiogepographic studies that the crustal blocks of the Korean Peninsula formed part of the Sino–Australian province in the Early Palaeozoic and that they were probably attached to either North or South China along the margin of eastern Gondwana. Carboniferous and Permian faunas and floras of the Korean crustal blocks are Tethyan and Cathaysian and indicate that these crustal fragments, along with North China, South China, Tarim, Indochina, East Malaya and West Sumatra, had separated from Gondwana probably in the Devonian. There seems to be emerging evidence that supports an extension of the North–South China collision zone into the Korean peninsula and other papers in this volume will throw new light on this ongoing debate.

5. Rifting and separation of east Asian crustal blocks from Gondwanaland

The Gondwana-derived east Asia crustal fragments successively rifted and separated from the margin of eastern Gondwana as three elongate continental slivers or collages of terranes in the Devonian, Early Permian and Late Triassic–

Late Jurassic (Fig. 5). As these three continental slivers separated from Gondwana, three successive ocean basins, the Palaeo-Tethys, Meso-Tethys and Ceno-Tethys, opened between these and Gondwana.

5.1. Devonian rifting and separation

South China, North China, Tarim, Indochina, East Malaya and West Sumatra were attached to Gondwanaland in the Cambrian to Silurian, but by Carboniferous times were separated from the parent craton, suggesting a Devonian rifting and separation of these blocks. This timing is also supported by the presence of a conspicuous Devonian unconformity in South China, and a subsequent Devonian–Triassic passive margin sequence along its southern margin. Devonian basin formation in South China has also been shown to be related to rifting. The splitting of the Silurian Sino–Australian brachiopod province into two sub-provinces and the apparent loss of links between Asian terranes and Australia in the Early Devonian may be the result of the northwards movement and separation of these terranes from Gondwanaland. A counter-clockwise rotation of Gondwana in the Devonian about an Euler pole in Australia is also consistent with clockwise rotation of the separating Asian terranes and spreading of the Palaeo-Tethys at this time.

5.2. Carboniferous–Permian rifting and Early Permian separation

There is now substantial evidence for rifting along the northern margin of Gondwanaland in the Carboniferous to Permian accompanied by rift-related magmatism. This rifting episode led to the late Early Permian separation of the Sibumasu and Qiangtang terranes, as part of the Cimmerian continent, from the Indo–Australian margin of Gondwanaland in the Late Sakmarian. The late Early Permian separation and Middle–Upper Permian rapid northwards drift of the Sibumasu terrane is indicated by palaeolatitude data which indicates a change of latitude from 42° south in the Late Carboniferous to low northern latitudes by the Early Triassic. In addition, the Sibumasu terrane faunas show a progressive change in marine provinciality from peri-Gondwanan Indoralian Province faunas in the Early Permian (Asselian–Early Sakmarian), to representing an endemic Sibumasu province in the Middle Permian and then being absorbed into the equatorial Cathaysian province in the Late Permian.

5.3. Late Triassic to Late Jurassic rifting and separation

The separation of the Lhasa Block from Gondwanaland has been proposed by different authors as occurring either in the Permian or Triassic. A Permian separation is advocated, either as a part of the Cimmerian continent or as a “Mega-Lhasa” block that included Iran and Afghanistan. Permian rifting on the North Indian margin and in Tibet is here regarded as being related to separation of the Cimmerian continental strip that included Iran, Afghanistan and the Qiangtang Block of Tibet, but not the Lhasa Block. Sedimentological and stratigraphical studies in the Tibetan Himalayas and Nepal have documented the Triassic rifting and Late Triassic (Norian) separation of the Lhasa Block from northern Gondwanaland. This Late Triassic episode of rifting is also recognised along the North West Shelf of Australia where it continued into the Late Jurassic, resulting in the separation of West Burma.

Table 4
Palaeozoic and Mesozoic events and their ages in Southeast Asia

Palaeozoic evolution

Process	Age
Rifting of South China, North China, Indochina, East Malaya, West Sumatra, Tarim and Qaidam from Gondwanaland.	Early Devonian
Initial spreading of the Palaeo-Tethys ocean.	Middle/Late Devonian
Amalgamation of South China, Indochina and East Malaya to form Cathaysialand	Late Devonian to Early Carboniferous
Development of the Ailaoshan–Nan–Uttaradit back-arc basin and separation of the Simao Terrane by back-arc spreading.	Late Early Carboniferous
Rifting of Sibumasu and Qiangtang from Gondwanaland as part of the Cimmerian continent	Late Early Permian (Sakmarian)
Initial spreading of Meso-Tethys ocean	Middle Permian
Collision and suturing of Sibumasu to Indochina and East Malaya	Latest Permian to Early Triassic
Initial collision of South and North China and development of Tanlu Fault	Late Permian to Triassic

Mesozoic evolution

Process	Age
Suturing of South China with North China and final consolidation of Sundaland	Late Triassic to Early Jurassic
Rifting of Lhasa, West Burma and other small terranes	Late Triassic to Late Jurassic
Initial spreading of Ceno-Tethys ocean	Late Triassic (Norian) in west (North India) and Late Jurassic in east (NW Australia)
Northward drift of Lhasa, West Burma and small terranes	Jurassic to Cretaceous
Collision of the Lhasa Block with Eurasia	Late Jurassic–earliest Cretaceous
Accretion of West Burma and Sikuleh? terranes to Sibumasu	Late Early Cretaceous
Suturing of Semitau to S.W. Borneo	Late Cretaceous

6. Amalgamation and accretion of Asian crustal blocks

The continental terranes of E and SE Asia have progressively sutured to one another during the Palaeozoic to Cenozoic. Most of the major terranes had coalesced by the end of the Cretaceous and proto Southeast Asia had formed. The age of welding of one terrane to another can be determined using the various criteria given in Table 1. When these criteria are applied to the various sutures and terranes of East and Southeast Asia the interpreted ages of suturing (amalgamation/accretion) are determined. Table 3 Lists East and Southeast Asian suture zones, colliding lithospheric blocks, interpreted ages of suturing, and constraints on the ages of suturing. The tectonostratigraphic record of each continental terrane in the region documents the geological history of that terrane, including variations in sedimentary environment, climate, faunal and floral affinities (changes in biogeographic regime), latitudinal shift, rifting events, episodes of deformation and plutono–volcanic igneous activity.

7. Palaeozoic–Mesozoic tectonic evolution of East Asia

Table 4 provides a summary of the principal geological events, and their timings, that have affected the East Asian region during the Palaeozoic and Mesozoic Eras. Continental collisions (amalgamation or accretion) are dated by the various

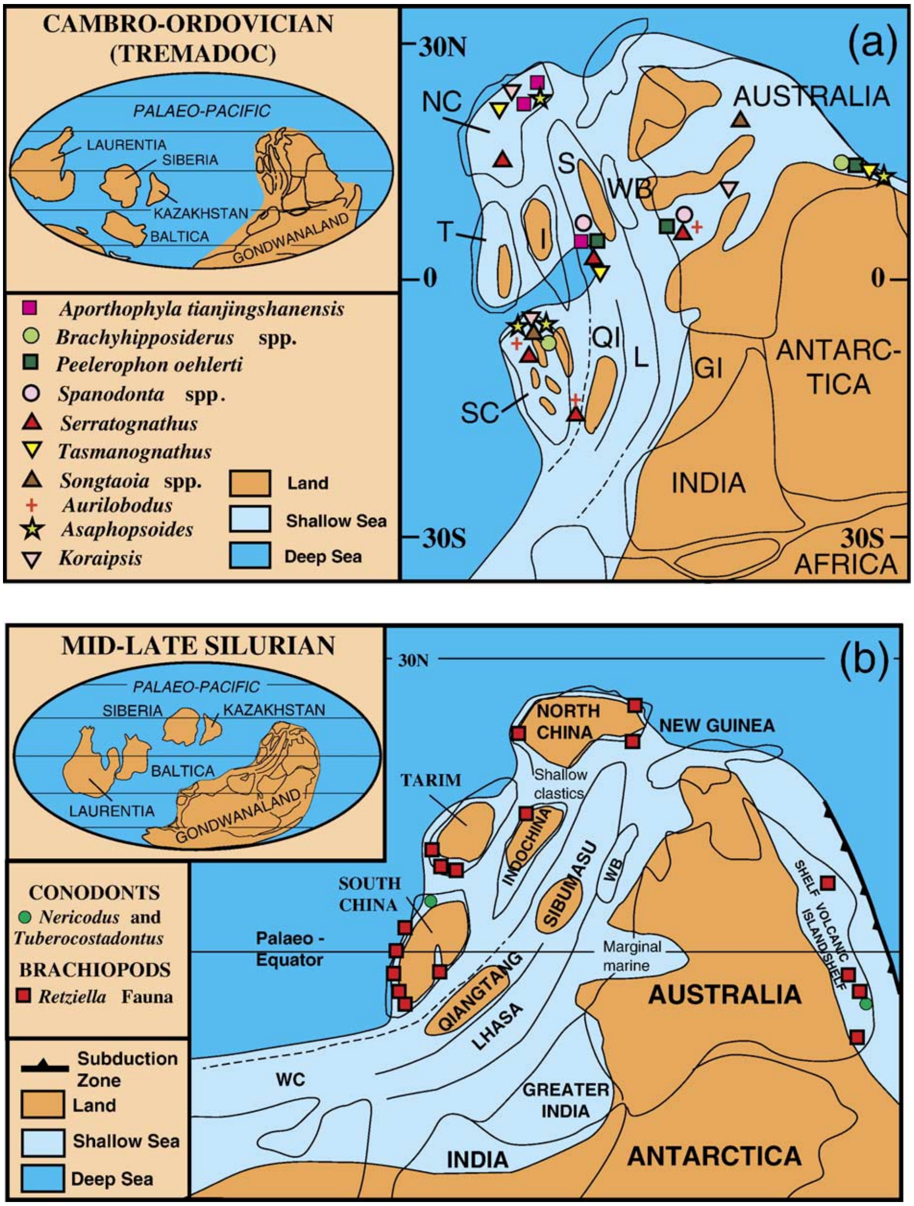

Fig. 6. Reconstructions of eastern Gondwanaland for (a) Cambro–Ordovician (Tremadoc) and (b) Mid–Late Silurian showing the postulated positions of the East and Southeast Asian terranes, distribution of land and sea, and shallow-marine fossils that illustrate Asia–Australia connections at these times. NC = North China; SC = South China; T = Tarim; I = Indochina/East Malaya/West Sumatra; QI = Qiangtang; L = Lhasa; S = Sibumasu; WB = West Burma; WC = Western Cimmerian Continent; GI = Greater India.

suture zones (Table 2). The principal events that have affected the Southeast Asian region during the Phanerozoic are outlined below chronologically.

7.1. Cambrian–Ordovician–Silurian (545–410 Ma)

The East and SE Asian crustal fragments formed part of Indian–Australian "Greater Gondwanaland" in the Cambrian, Ordovician and Silurian (Fig. 6). Faunas of this age on the Asian blocks and Australasia define Asian–Australian palaeo-equatorial warm-climate "provinces", for example the Sino–Australian brachiopod province in the Silurian.

7.2. Devonian (410–354 Ma)

Australian eastern Gondwana continued to reside in low southern latitudes during the Devonian but rotates counter clockwise. This counter clockwise rotation mirrors a clockwise rotation of the North and South China, Tarim, Indochina, East Malaya and West Sumatra terranes as they separate from Gondwanaland as an elongate continental sliver. Separation of this sliver from Gondwanaland opened the Palaeo-Tethys ocean (Fig. 7). Devonian faunas on the Chinese terranes still have some Australian connections. Early Devonian endemic faunas of South China, including some fish faunas and the distinctive *Chuiella* brachiopod fauna (Fig. 7), are interpreted to be a result of the rifting process and isolation of South China on the rifting continental promontory, and do not necessarily imply continental separation of South China from the other Chinese blocks and Australia at this time.

7.3. Carboniferous (354–298 Ma)

During the Carboniferous, Gondwanaland rotates clockwise and collides with Laurentia in the west to form Pangea. Australia, Sibumasu, Qianghtang, Lhasa and West Burma are still attached to northeast Gondwanaland, and drift from low southern latitudes in Tournaisian–Visean times to high southern latitudes in Middle–Late Namurian times. The major Gondwanan glaciation commenced in the Namurian and extended through into the Early Permian. There were major global shifts in both plate configurations and climate during this time and a change from warm to cold conditions in Australasia. This is reflected in the change from high to low diversity of faunas in Australasia and especially eastern Australia where low diversity, endemic faunas developed in the Upper Carboniferous. North and South China, Indochina, East Malaya, West Sumatra and Tarim faunas and floras are tropical/sub-tropical Cathaysian/Tethyan types during the Carboniferous and show no Gondwanaland affinities. These terranes had already separated from Gondwanaland and were located in low latitude/equatorial positions during the Carboniferous (Fig. 8). Indochina and South China collided and amalgamated within the Tethys during the Early Carboniferous along the Song Ma suture zone now located in Laos and Vietnam. Ice sheets and glaciers extended across much of eastern Gondwanaland during the Late Carboniferous and ice reached the marine environment of India–Australian continental shelf of Gondwanaland and glacial–marine sediments (diamictites; pebbly mudstones interbedded with normal marine shales and sands) were deposited on the continental shelf of eastern Gondwanaland. Subduction beneath South

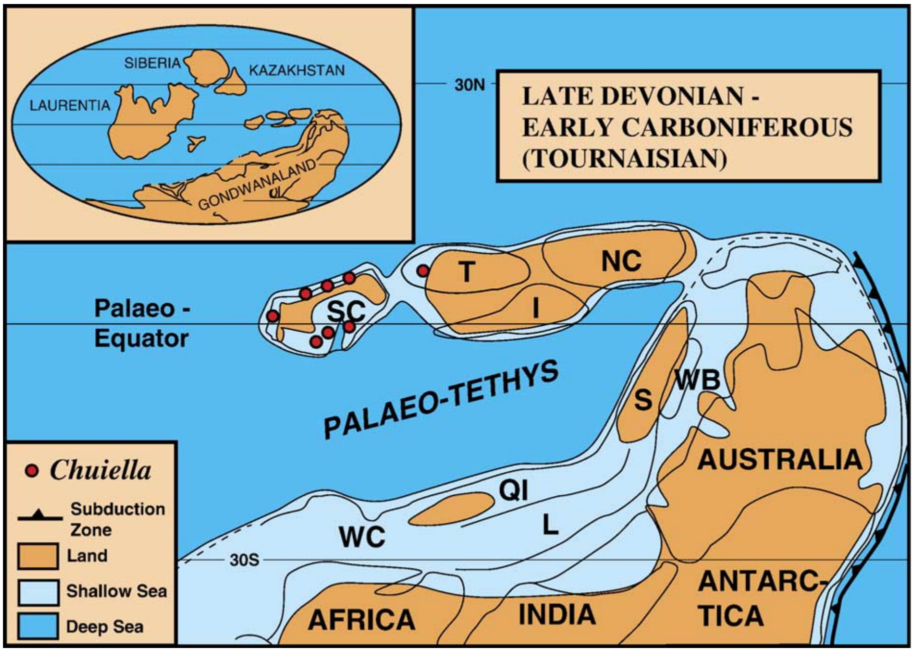

Fig. 7. Reconstruction of eastern Gondwanaland for the Late Devonian to Lower Carboniferous (Tournaisian) showing the postulated positions of the East and Southeast Asian terranes, distribution of land and sea, and opening of the Palaeo-Tethys ocean at this time. Also shown is the distribution of the endemic Tournaisian brachiopod genus Chuiella. NC = North China; SC = South China; T = Tarim; I = Indochina/East Malaya/West Sumatra; QI = Qiangtang; L = Lhasa; S = Sibumasu; WB = West Burma; WC = Western Cimmerian Continent.

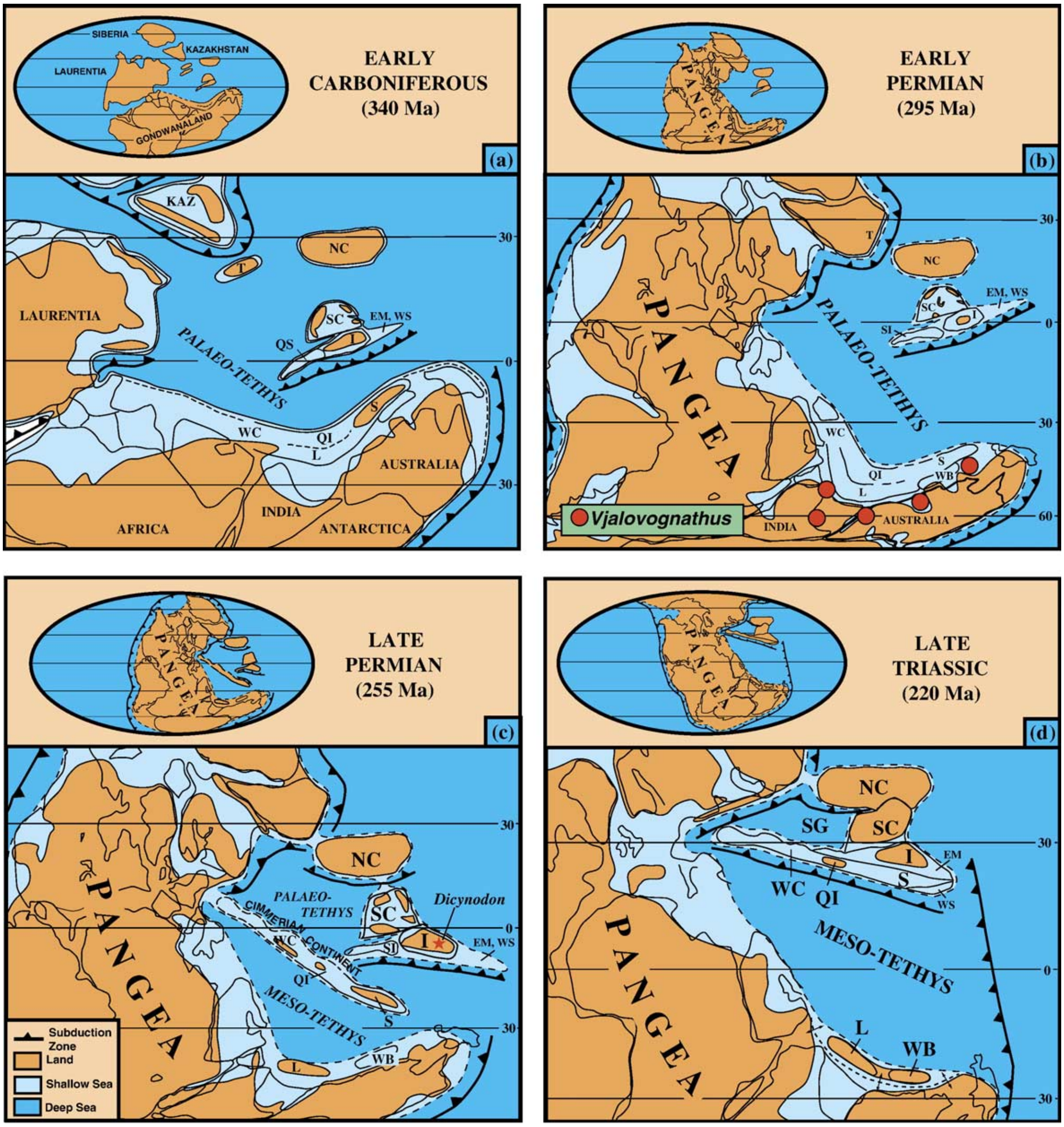

Fig. 8. Palaeogeographic reconstructions of the Tethyan region for (a) Early Carboniferous, (b) Early Permian, (c) Late Permian and (d) Late Triassic showing relative positions of the East and Southeast Asian terranes and distribution of land and sea. Also shown is the distribution of the Early Permian cold-water tolerant conodont Vjalovognathus, and the Late Permian Dicynodon locality on Indochina in the Late Permian. SC = South China; T = Tarim; I = Indochina; Em = East Malaya; WS = West Sumatra; NC = North China; SI = Simao; S = Sibumasu; WB = West Burma; QI = Qiangtang; L = Lhasa; WC = Western Cimmerian Continent.

China/Indochina in the Carboniferous led to the development of the Ailaoshan–Nan–Uttaradit back-arc basin (now represented by the Ailaoshan and Nan–Uttaradit Suture Zones) and separation of the Simao Terrane by back-arc spreading.

7.4. Early Permian (298–270 Ma)

During the Permian, Australia remained in high southern latitudes. Glacial ice continued to reach the marine environment of the northeast Gondwanaland margin and glacial–marine sediments continued to be deposited on the Sibumasu, Qiangtang and Lhasa terranes. Gondwanaland cold-climate faunas and floras characterised the Sibumasu, Qiangtang and Lhasa terranes at this time. In addition, the distinctive cool-water tolerant conodont genus *Vjalovognathus* defines an eastern peri-Gondwanaland cold-water province at this time (Fig. 8). Floral provinces are particularly marked at this time and the distinctive Cathaysian (*Gigantopteris*) flora developed on North China, South China, Indochina, East Malaya and West Sumatra which were isolated within the Tethys and located equatorially (Fig. 8b). During the late Early Permian (end Sakmarian), the Cimmerian continental sliver separated from the northeastern margin of Gondwana and the Meso-Tethys Ocean opened by sea floor spreading between it and mainland Gondwana (Fig. 8c).

7.5. Late Permian (270–252 Ma)

By early Late Permian times the Sibumasu and Qiangtang terranes had separated from Gondwanaland and the Meso-

Tethys opened between this continental sliver and Gondwanaland (Fig. 8c). The Palaeo-Tethys continued to be destroyed by northwards subduction beneath Laurasia, North China and the amalgamated South China/Indochina/East Malaya terranes. Following separation, and during their northwards drift, the Sibumasu and Qiangtang terranes developed initially a Cimmerian Province fauna and were then absorbed into the Cathaysian Province. North and South China begin to collide during the Late Permian and a connection between mainland Pangea and Indochina, via South and North China or via the western Cimmerian continent, is indicated by the occurrence of the genus *Dicynodon* in the Upper Permian of Indochina (Fig. 8c). Sibumasu began to collide with Indochina and east Malaya in the Late Permian and collision continued into the Early Triassic. Deformation associated with this event, and with the

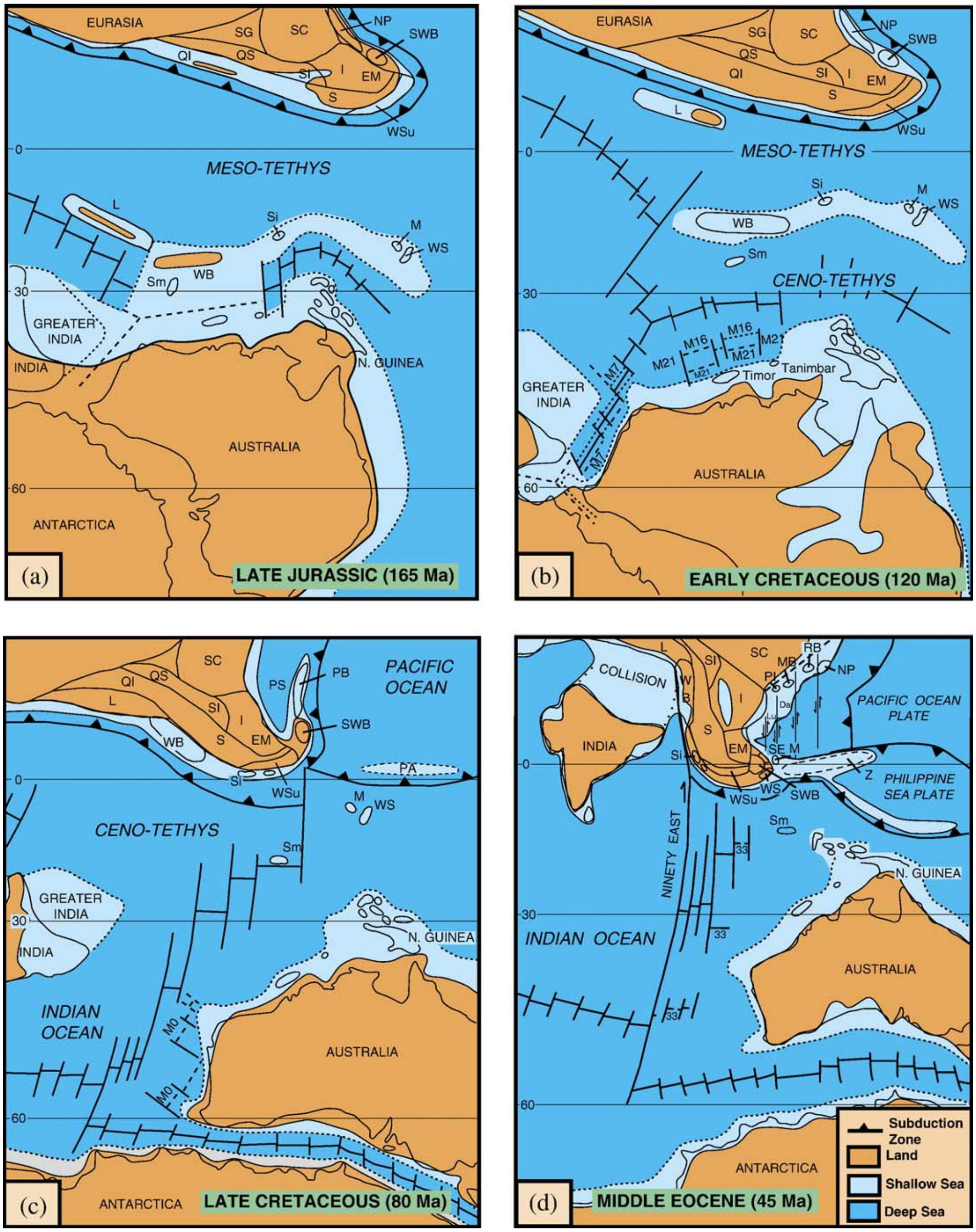

Fig. 9. Palaeogeographic reconstructions for Eastern Tethys in (a) Late Jurassic, (b) Early Cretaceous, (c) Late Cretaceous and (d) Middle Eocene showing distribution of continental blocks and fragments of Southeast Asia–Australasia and land and sea. SG = Songpan Ganzi accretionary complex; SC = South China; QS = Qando–Simao; SI = Simao; QI = Qiangtang; S = Sibumasu; I = Indochina; EM = East Malaya; WSu = West Sumatra; L = Lhasa; WB = West Burma; SWB = Southwest Borneo; SE = Semitau; NP = North Palawan and other small continental fragments now forming part of the Philippines basement; Si = Sikuleh; M = Mangkalihat; WS = West Sulawesi; PB = Philippine Basement; PA = Incipient East Philippine arc; PS = Proto-South China Sea; Z = Zambales Ophiolite; Rb = Reed Bank; MB = Macclesfield Bank; PI = Paracel Islands; Da = Dangerous Ground; Lu = Luconia; Sm = Sumba. M numbers represent Indian Ocean magnetic anomalies.

collision of North and south China is known as the Indosinian orogeny in Southeast Asia and China.

7.6. Triassic (253–205 Ma)

Australia was in low to moderate southern latitudes during the Triassic. The Sibumasu and Qiangtang terranes collided and sutured to the Indochina/South China amalgamated terrane. The West Sumatra Block is pushed westwards by interaction of the westwards subducting Palaeopacific plate and northwards subducting Palaeo-Tethys during the Sibumasu–Indochina/east Malaya collisional process and was translated along major strike-slip faults to a position outboard of Sibumasu in the Early Triassic. The North and South China collision was nearly complete with exhumation of ultra-high pressure metamorphism along the Qinling–Dabie suture zone. Also, sediment derived from the North–South China collisional orogen poured into the Songpan Ganzi accretionary complex basin producing huge thicknesses of flysch turbidites. The Ailaoshan–Nan–Uttaradit back-arc basin was closed when the Simao terrane collided back with South China/Indochina in the Middle to early Late Triassic. By Late Triassic (Norian) times, the North China, South China, Sibumasu, Indochina, East Malaya, West Sumatra and Simao terranes had coalesced to form proto-East and Southeast Asia (Fig. 8d). During this final collisional consolidation of these terranes, the major economically important Late Triassic–Early Jurassic collisional tin-bearing Main Range granitoids were formed in Southeast Asia.

7.7. Jurassic (205–141 Ma)

Australia remained in low to moderate southern latitudes in the Jurassic. Rifting and separation of the Lhasa, West Burma, Sikuleh, Mangkalihat and West Sulawesi terranes from NW Australia occurred progressively from west to east during the Late Triassic to Late Jurassic. The Ceno-Tethys ocean basin opened behind these terranes as they separated from Gondwanaland (Fig. 9). Final welding of North China to Eurasia also took place in the Jurassic (with Yanshanian deformational orogeny) with closure of the Mongol–Okhotsk Ocean. Initial pre-breakup rifting of the main Gondwanaland supercontinent also began in the Jurassic.

7.8. Cretaceous (141–65 Ma)

The Lhasa Block collided and sutured to Eurasia in latest Jurassic–earliest Cretaceous times. Gondwanaland broke up and India drifted north, making initial contact with Eurasia at the end of the Cretaceous (Fig. 9). This early contact between India and Eurasia is indicated by palaeomagnetic data from the Ninetyeast Ridge and also by Late Cretaceous biogeographic links, including frogs and other vertebrates. The small West Burma and Sikuleh terranes also accreted to Sibumasu during the Cretaceous. Australia began to separate from Antarctica and drift northwards but a connection with Antarctica via Tasmania still remained.

Acknowledgements

I thank Dr. Koji Wakita for his constructive review of the paper and Prof. M. Santosh for helpful comments and support. The Australian Research Council is gratefully acknowledged for financial support for my research on the tectonics and palaeogeography of East and Southeast Asia.

References

Aitchison, J.C., 1993. Allochthonous Silurian volcaniclastic rocks of the Kurosegawa terrane: long-dispersed early Gondwana fragments. Third International Symposium of IGCP 321 Gondwana Dispersion and Asian Accretion, Abst., pp. 15–17.

Aitchison, J.C., Hada, S., Yoshikura, S., 1991. Kurosegawa terrane: disrupted remnants of a low latitude Paleozoic terrane accreted to SW Japan. J. Southeast Asian Earth Sci. 6, 83–92.

Allen, M.B., Windley, B.F., Zhang, Chi, Zhao, Zhong-Yan, Wang, Guang-Rei, 1991. Basin evolution within and adjacent to the Tien Shan range, NW China. J. Geol. Soc. (Lond.) 148, 369–378.

Allen, M.B., Windley, B.F., Zhang, C., 1994. Cenozoic tectonics in the Urumqi–Korla region of the Chinese Tien Shan. Geol. Rundsch. 83, 406–416.

Barber, A.J., Crow, M.J., 2003. An evaluation of plate tectonic models for the development of Sumatra. Gondwana Res. 6, 1–28.

Barr, S.M., Macdonald, A.S., 1991. Toward a Late Paleozoic–Early Mesozoic tectonic model for Thailand. J. Thai Geosci. 1, 11–22.

Bian, Q.-T., Li, D.-H., Pospelov, I., Yin, L.-M., Li, H.S., Zhao, D.-S., Chang, C.-F., Luo, S.-L., Gao, S.L., Astrakhantsev, O., Chamov, N., 2004. Age, geochemistry and tectonic setting of Buqingshan ophiolites, North Qinghai–Tibet Plateau, China. J. Asian Earth Sci. 23, 577–596.

Burrett, C., 1973. Ordovician biogeography and continental drift. Palaeogeogr. Palaeoclimatol. Palaeoecol. 13, 161–201.

Burrett, C., Stait, B., 1985. South-east Asia as part of an Ordovician Gondwanaland. Earth Planet. Sci. Lett. 75, 184–190.

Burrett, C., Long, J., Stait, B., 1990. Early–Middle Palaeozoic biogeography of Asian terranes derived from Gondwana. In: McKerrow, W.S., Scotese, C.R. (Eds.), Palaeozoic Palaeogeography and Biogeography, Geol. Soc. Mem., vol. 12, pp. 163–174.

Chang, Chengfa, et al., 1986. Preliminary conclusions of the Royal Society and Academia Sinica 1985 Geotraverse of Tibet. Nature 323, 501–507.

Chang, Chen-fa, Pan, Yu-Sheng, Sun, Yi-Ying, 1989. The tectonic evolution of Qinghai–Tibet Plateau: a review. In: Sengor, A.M.C. (Ed.), Tectonic Evolution of the Tethyan Region. Kluwer Academic Publishers, pp. 415–476.

Charusiri, P., Kosuwan, S., Imsamut, S., 1997. Tectonic evolution of Thailand, from Bunopas (1981) to a new scenario. Proceedings, GOTHAI '97, Department of Mineral Resources, Thailand, vol. 1. Department of Mineral Resources, Thailand, pp. 414–420.

Charvet, J., Cluzel, D., Faure, M., Caridroit, M., Shu, L., Lu, H., 1999. Some tectonic aspects of the pre-Jurassic accretionary evolution of East Asia. In: Metcalfe, I. (Ed.), Gondwana Dispersion and Asian Accretion. IGCP 321 Final Results Volume. A.A. Balkema, Rotterdam, pp. 37–65.

Chen, X., Rong, J., 1992. Ordovician plate tectonics of China and its neighbouring regions. In: Webby, B.D., Laurie, J.R. (Eds.), Global Perspectives on Ordovician Geology. A.A. Balkema, Rotterdam, pp. 277–291.

Chen, Bingwei, Xie, Guanglian, 1994. Evolution of the Tethys in Yunnan and Tibet. J. Southeast Asian Earth Sci. 9, 349–354.

Chen, J., Foland, K.A., Xing, F., Xu, X., Zhou, T., 1991. Magmatism along the southeast margin of the Yangtze block: Precambrian collision of the Yangtze and Cathaysia blocks of China. Geology 19, 815–818.

Chen, Z., Li, Z.X., Powell, C.McA., Balme, B.E., 1993. Palaeomagnetism of the Brewer Conglomerate in central Austral, and fast movement of Gondwanaland during the Late Devonian. Geophys. J. Int. 115, 564–574.

Cheong, C.S., Jeong, G.Y., Kim, H., Choi, M.-S., Lee, S.-H., Cho, M., 2003. Early Permian peak metamorphism recorded in U–Pb system of black slates from the Ogcheon metamorphic belt, South Korea, and its tectonic implication. Chem. Geol. 193, 81–92.

Choi, D.K., Kim, D.H., Sohn, J.W., Lee, S.-B., 2003. Trilobite faunal successions across the Cambrian–Ordovician boundary intervals in Korea and their correlation with China and Australia. J. Asian Earth Sci. 21, 781–793.

Chonglakmani, C., 1999. The Triassic System of Thailand: implications for the palaeogeography of Southeast Asia. In: Ratanasthein, B., Rieb, S.L. (Eds.), Proceedings of the International Symposium on Shallow Tethys (ST) 5,Chiang Mai, Thailand, February, 1999, Faculty of Science, Chiang Mai Univ., pp. 486–495.

Chough, S.K., Kwon, S.-T., Ree, J.-H., Choi, D.K., 2000. Tectonic and sedimentary evolution of the Korean peninsula: a review and new view. Earth-Sci. Rev. 52, 175–235.

Cooper, M.A., Herbert, R., Hill, G.S., 1989. The structural evolution of Triassic Intermontane Basins in Northeastern Thailand. In: Thanasuthipitak, T., Ounchanum, P. (Eds.), Proceedings of International Symposium on Intermontane Basins: Geology and Resources. Chiang Mai Univ., Thailand, pp. 231–242.

Dewey, J.F., Shackleton, R.M., Chang, Chengfa, Sun, Yiyin, 1988. The tectonic evolution of the Tibetan Plateau. Philos. Trans. R. Soc. Lond., A 327, 379–413.

Ernst, W.G., Liu, J.G., 1995. Contrasting plate-tectonic styles of the Qinling–Dabei–Sulu and Franciscan metamorphic belts. Geology 23, 353–356.

Ge, Xiaohong, Duan, Jiye, Li, Cai, Yang, Huixin, Tian, Yushan, 1991. A new recognition of the Altun Fault Zone and geotectonic pattern of North-west China. In: Ren, Jishun, Xie, Guanglian (Eds.), Proceedings First International Symposium on Gondwana Dispersion and Asian Accretion — Geological Evolution of Eastern Tethys, Kunming, China. China Univ. Geosci., Beijing, pp. 125–128.

Golonka, J., Ross, M.I., Scotese, C.R., 1994. Phanerozoic paleogeographic and paleoclimatic modeling maps. In: Embry, A.F., Beauchamp, B., Glass, D.J. (Eds.), Pangea: Global Environments and Resources, Canadian Soc. Petrol. Geol., Mem., vol. 17, pp. 1–47.

Görür, N., Sengör, A.M.C., 1992. Palaeogeography and tectonic evolution of the eastern Tethysides: implications for the northwest Australian margin breakup history. In: von Rad, U., Haq, B.U., et al. (Eds.), Proc. Ocean Drill. Prog., Sci. Res., vol. 122, pp. 83–106.

Haile, N.S., 1979. Palaeomagnetic evidence for rotation and northward drift of Sumatra. J. Geol. Soc. Lond. 136, 541–545.

Hall, R., 1996. Reconstructing Cenozoic SE Asia. In: Hall, R., Blundell, D. (Eds.), Tectonic Evolution of Southeast Asia, Geol. Soc. Spec. Pub., vol. 106, pp. 153–184.

Hall, R., 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions, model and animations. J. Asian Earth Sci. 20, 353–431.

Hayami, I., 1984. Jurassic marine bivalve faunas and biogeography in Southeast Asia. Geol. Palaeontol. Southeast Asia 25, 229–237.

Hisada, K., Arai, S., Negoro, A., 1994. Devonian serpentinite protrusion confirmed by detrital chromian spinels in outer zone of SW Japan. In: Angsuwathana, P., Wongwanich, T., Tansathian, W., Wongsomsak, S., Tulyatid, J. (Eds.), Proceedings of the International Symposium on Stratigraphic Correlation of Southeast Asia, Dept. Min. Res. Bangkok, Thailand, pp. 76–80.

Hoe, N.D., Rangin, C., 1999. The Early Palaeozoic paleogeography and tectonics of Vietnam/South China as markers for the Cenozoic tectonic offset along the Red River fault zone. In: Metcalfe, I. (Ed.), Gondwana Dispersion and Asian accretion. IGCP 321 Final Results Volume. A.A. Balkema, Rotterdam, pp. 297–314.

Hsu, K.J., Sun, S., Li, J., Chen, H., Pen, H., Sengor, A.M.C., 1988. Mesozoic overthrust tectonics in South China. Geology 16, 418–421.

Hsu, K.J., Sun, S., Li, J., 1989. Mesozoic suturing in the Huanan Alps and the tectonic assembly of South China. In: Sengor, A.M.C. (Ed.), Tectonic Evolution of the Tethyan Region. Kluwer Academic Publishers, pp. 551–565.

Huang, K., Opdyke, N.D., 1991. Paleomagnetic results from the Upper Carboniferous of the Shan–Thai–Malay block of western Yunnan, China. Tectonophysics 192, 333–344.

Jell, P.A., Burrett, C.F., Stait, B., Yochelson, E.L., 1984. The Early Ordovician bellerophontoid *Peelerophon oehlerti* (Bergeron) from Argentina, Australia and Thailand. Alcheringa 8, 169–176.

Jeong, H., Lee, Y.I., 2000. Late Cambrian biogeography: conodont bioprovinces from Korea. Palaeogeogr. Palaeoclimatol. Palaeoecol. 162, 119–136.

Jin, X., 2002. Permo–Carboniferous sequences of Gondwana affinity in southwest China and their paleogeographic implications. J. Asian Earth Sci. 6, 633–646.

Katz, M.B., 1993. The Kannack complex of the Vietnam Kontum massif of the Indochina Block — an exotic fragment of Precambrian Gondwanaland? In: Findlay, R.H., Unrug, R., Banks, M.R., Veevers, J.J. (Eds.), Gondwana 8 — Assembly, Evolution, and Dispersal (Proceedings Eighth Gondwana Symposium, Hobart, 1991). A.A. Balkema, Rotterdam, pp. 161–164.

Kim, J.N., Ree, J.H., Kwon, S.T., Park, Y., Choi, S.J., Cheong, C.S., 2000. The Kyonggi shear zone of the central Korean peninsula: late orogenic imprint of the North and South China collision. J. Geol. 108, 469–478.

Kimura, T., 1984. Mesozoic floras of East and Southeast Asia, with a short note on the Cenozoic floras of Southeast Asia and China. Geol. Palaeontol. Southeast Asia 25, 325–350.

Klootwijk, C., 1996a. Phanerozoic configurations of Greater Australia: evolution of the North West Shelf. Part one: review of reconstruction models. AGSO Record 1996/51. 106 pp.

Klootwijk, C., 1996b. Phanerozoic configurations of Greater Australia: evolution of the North West Shelf: Part two. Palaeomagnetic and geologic constraints on reconstructions. AGSO Record 1996/52. 85 pp.

Klootwijk, C., 1996c. Phanerozoic configurations of Greater Australia: evolution of the North West Shelf: Part three. Palaeomagnetic data base. AGSO Record 1996/53. 148 pp.

Kobayashi, T., Tamura, M., 1984. The Triassic Bivalvia of Malaysia, Thailand and adjacent areas. Geol. Palaeontol. Southeast Asia 25, 201–228.

Lan, C.-Y., Chung, S.-L., Long, T.V., Lo, C.-H., Lee, T.-Y., Mertzman, S.A., Shen, J.J.-S., 2003. Geochemical and Sr–Nd isotopic constraints from the Kontum massif, central Vietnam on the crustal evolution of the Indochina block. Precambrian Res. 122, 7–27.

Laurie, J.R., Burrett, C., 1992. Biogeographic significance of Ordovician brachiopods from Thailand and Malaysia. J. Paleontol. 66, 16–23.

Lee, S.R., Cho, M., Yi, K., Stern, R.A., 2000. Early Proterozoic granulites in central Korea: tectonic correlation with Chinese cratons. J. Geol. 108, 729–738.

Lepvrier, C., Maluski, H., Vu Van Tich, Leyreloup, A., Phan Ttuong Thi, Nguyen Van Vuong, 2004. The Early Triassic Indosinian orogeny in Vietnam (Truang Son Belt and Kontum massif); implications for the geodynamic evolution of Indochina. Tectonophysics 393, 87–118.

Li, Zhiming, 1994a. Ordovician. In: Yin Hongfu (Ed.), The Palaeobiogeography of China. Clarendon Press, Oxford, pp. 64–87.

Li, Z.X., 1994b. Collision between the North and South China blocks: a crustal-detachment model for suturing in the region of the Tanlu Fault. Geology 22, 739–742.

Li, Z.X., Zhang, L., Powell, C.McA., 1995. South China in Rodinia: part of the missing link between Australia–East Antarctica and Laurentia? Geology 23, 407–410.

Li, Z.X., Zhang, L., Powell, C.McA., 1996. Positions of the East Asian cratons in the Neoproterozoic supercontinent Rodinia. Aust. J. Earth Sci. 43, 593–604.

Lin, Baoyu, Webby, B.D., 1989. Biogeographic relationships of Australian and Chinese Ordovician corals and stromatoporoids. Mem. Assoc. Australas. Palaeontol. 8, 207–217.

Lin, J., Fuller, M., Zhang, W., 1985. Preliminary Phanerozoic polar wander paths for the North and South China Blocks. Nature 313, 444–449.

Liu, D.Y., Nutman, A.P., Compton, W., Wu, J.s., Shen, Q.H., 1992. Remnants of >3800 Ma crust in the Chinese part of the Sino–Korean craton. Geology 20, 339–342.

Metcalfe, I., 1986. Late Palaeozoic palaeogeography of Southeast Asia: some stratigraphical, palaeontological and palaeomagnetic constraints. Bull. Geol. Soc. Malays. 19, 153–164.

Metcalfe, I., 1988. Origin and assembly of Southeast Asian continental terranes. In: Audley-Charles, M.G., Hallam, A. (Eds.), Gondwana and Tethys, Geol. Soc. Lond. Spec. Pub., vol. 37, pp. 101–118.

Metcalfe, I., 1990. Allochthonous terrane processes in Southeast Asia. Philos. Trans. R. Soc. Lond. A331, 625–640.

Metcalfe, I., 1993. Southeast Asian terranes: Gondwanaland origins and evolution. In: Findlay, R.H., Unrug, R., Banks, M.R., Veevers, J.J. (Eds.), Gondwana 8 — Assembly, Evolution, and Dispersal (Proceedings Eighth Gondwana Symposium, Hobart, 1991). A.A. Balkema, Rotterdam, pp. 181–200.

Metcalfe, I., 1994. Gondwanaland origin, dispersion, and accretion of East and Southeast Asian continental terranes. J. South Am. Earth Sci. 7, 333–347.

Metcalfe, I., 1996a. Pre-Cretaceous evolution of SE Asian terranes. In: Hall, R., Blundell, D. (Eds.), Tectonic Evolution of Southeast Asia, Geol. Soc. Spec. Pub. 106, pp. 97–122.

Metcalfe, I., 1996b. Gondwanaland dispersion, Asian accretion and evolution of Eastern Tethys. Aust. J. Earth Sci. 43, 605–623.

Metcalfe, I., 1998. Palaeozoic and Mesozoic geological evolution of the SE Asian region: multidisciplinary constraints and implications for biogeography. In: Hall, R., Holloway, J.D. (Eds.), Biogeography and Geological Evolution of SE Asia. Backhuys Publishers, Amsterdam, The Netherlands, pp. 25–41.

Metcalfe, I., 1999. Gondwana dispersion and Asian accretion: an overview. In: Metcalfe, I. (Ed.), Gondwana Dispersion and Asian Accretion, Final Results Volume for IGCP Project 321. A.A. Balkema, Rotterdam, pp. 9–28.

Metcalfe, I., 2000. The Bentong–Raub Suture Zone. J. Asian Earth Sci. 18, 691–712.

Metcalfe, I., 2002. Permian tectonic framework and palaeogeography of SE Asia. J. Asian Earth Sci. 20, 551–566.

Metcalfe, I., 2005. Asia: South-east. In: Selley, R.C., Cocks, L.R.M., Plimer, I.R. (Eds.), Encyclopedia of Geology, vol. 1. Elsevier, Oxford, pp. 169–198.

Mitchell, A.H.G., 1989. The Shan Plateau and Western Burma: Mesozoic–Cenozoic plate boundaries and correlation with Tibet. In: Sengör, A.M.C. (Ed.), Tectonic Evolution of the Tethyan Region. Kluwer Academic Publishers, pp. 567–583.

Mitchell, A.H.G., 1993. Cretaceous–Cenozoic tectonic events in the western Myanmar (Burma)—Assam Region. J. Geol. Soc. (Lond.) 150, 1089–1102.

Nam, T.N., Sano, Y., Terada, K., Toriumi, M., Quynh, P.V., Dung, L.T., 2001. First SHRIMP U–Pb zircon dating of granulites from the Kontum massif (Vietnam) and tectonothermal implications. J. Asian Earth Sci. 19, 77–84.

Nicoll, R.S., Metcalfe, I., 1994. Late Cambrian to Early Silurian conodont endemism of the Sinian–Australian margin of Gondwanaland. In: Wang, Zhi-hao, Xu, Fang-ming (Eds.), First Asian Conodont Symposium, Nanjing, China, Abst., p. 7.

Nicoll, R.S., Totterdell, J.M., 1990. Conodonts and the distribution in time and space of Ordovician sediments in Australia and adjacent areas. Tenth Australian Geological Convention, Geol. Soc. Australia Abst. 25, p. 46.

Nie, Y.S., 1991. Paleoclimatic and paleomagnetic constraints on the Paleozoic reconstructions of South China, North China and Tarim. Tectonophysics 196, 279–308.

Nie, Y.S., Rowley, D.B., Ziegler, A.M., 1990. Constraints on the locations of Asian microcontinents in Palaeo-Tethys during the Late Palaeozoic. In: McKerrow, W.S., Scotese, C.R. (Eds.), Palaeozoic Palaeogeography and Biogeography, Geol. Soc. Mem. 12, pp. 397–408.

Nie, Y.S., Yin, A., Rowley, D.B., Jin, Y., 1995. Exhumation of the Dabie Shan ultra-high pressure rocks and accumulation of the Songpan–Ganzi flysch sequence, Central China. Geology 22, 999–1002.

Rammlmair, D., 1993. The evolution of the Philippine Archipelago in time and space: a plate-tectonic model. Geol. Jahrb. 81, 1–48.

Ree, J.H., Cho, M., Kwon, S.T., Nakamura, E., 1996. Possible eastward extension of Chinese collision belt in South Korea: the Imjingang Belt. Geology 24, 1071–1074.

Rogers, J., 1989. Comment on “Mesozoic overthrust tectonics in South China”. Geology 17, 671–672.

Rong, Jia-Yu, Boucot, A.J., Su, Yang-Zheng, Strusz, D.L., 1995. Biogeographical analysis of Late Silurian brachiopod faunas, chiefly from Asia and Australia. Lethaia 28, 39–60.

Rowley, D.B., Ziegler, A.M., Gyou, N., 1989. Comment on “Mesozoic overthrust tectonics in South China”. Geology 17, 384–386.

Saito, Y., 1992. Reading Geologic History of Japanese Islands. Iwanami-shoten, Tokyo. 147 pp. (in Japanese with English abst.).

Sengör, A.M.C., 1987. Tectonic subdivisions and evolution of Asia. Bull. Tech. Univ. Istanb. 40, 355–435.

Servais, T., Brocke, R., Fatka, O., 1996. Variability in the Ordovician acritarch *Dicrodiacrodium*. Palaeontology 39, 389–405.

Shergold, J., Burrett, C., Akerman, T., Stait, B., 1988. Late Cambrian trilobites from Tarutao Island, Thailand. Mem.-N.M. Bur. Mines Miner. Resour. 44, 303–320.

Sone, M., Metcalfe, I., Leman, M.S., 2003. Palaeobiogeographic implications of Middle Permian brachiopods from Johore (Peninsular Malaysia). Geol. Mag. 140, 523–538.

Stait, B., Burrett, C.F., 1982. *Wutinoceras* (Nautiloidea) from the Setul Limestone (Ordovician) of Malaysia. Alcheringa 6, 193–196.

Stait, B., Burrett, C.F., 1984. Ordovician nautiloid faunas of Central and Southern Thailand. Geol. Mag. 121, 115–124.

Stait, B., Wyatt, D., Burrett, C.F., 1987. Ordovician nautiloid faunas of Langkawi Islands, Malaysia and Tarutao Island, Thailand. N. Jb. Geol. Palaont. Abh. 174, 373–391.

Stauffer, P.H., 1974. Malaya and Southeast Asia in the pattern of continental drift. Bull. Geol. Soc. Malays. 7, 89–138.

Stauffer, P.H., 1983. Unravelling the mosaic of Palaeozoic crustal blocks in Southeast Asia. Geol. Rundsch. 72, 1061–1080.

Thanh, Tong-Dzuy, Janvier, P., Phuong, Ta Hoa, 1996. Fish suggests continental connection between the Indochina and South China blocks in Middle Devonian time. Geology 24, 571–574.

Ueno, K., 1999. Gondwana/Tethys divide in East Asia, solution from Late Paleozoic foraminiferal paleobiogeography. In: Ratanasthien, B., Rieb, S.L. (Eds.), Proceedings of the International Symposium on Shallow Tetrhys, vol. 5. Department of Geological Science, Faculty of Science, Chiang Mai University, Chiang Mai, pp. 45–54.

Ueno, K., 2000. Permian fusulinacean faunas of the Sibumasu and Baoshan blocks, implications for the paleogeographic reconstruction of the Cimmerian continent. Geosci. J. 4, 160–163.

Ueno, K., 2003. The Permian fusulinoidean faunas of the Sibumasu and Baoshan blocks, their implications for the paleogeographic and paleoclimatologic reconstruction of the Cimmerian continent. Palaeogeogr. Palaeoclimatol. Palaeoecol. 193, 1–24.

Ueno, K., Hisada, K., 1999. Closure of the Paleo-Tethys caused by the collision of Indochina and Sibumasu. Chikyu Monthly 21, 832–839 (in Japanese).

Vachard, D., 1990. A new biozonation of the limestones from Terbat area, Sarawak, Malaysia. CCOP Tech. Bull. 20, 183–208.

Wang, G., 1994. Tarim Region. In: Cheng, Y. (Ed.), An Outline of the Regional geology of China. Geological Publishing House, Beijing, pp. 104–109 (in Chinese).

Wang, Yu-Jing, Mu, Xi-Nan, 1983. Upper Carboniferous and Lower Permian strata in the Gondwana–Tethys province of Xizang (Tibet). Palaeontol. Cathayana 1, 411–419.

Wang, Z., Tan, X., 1994. Palaeozoic structural evolution of Yunnan. J. Southeast Asian Earth Sci. 9, 345–348.

Wang, Xiaofeng, Metcalfe, I., Jian, Ping, He, Longqing, Wang, Chuanshan, 2000. The Jinshajiang–Ailaoshan suture zone, tectono-stratigraphy, age and evolution. J. Asian Earth Sci. 18, 675–690.

Webby, B.D., Wyatt, D., Burrett, C., 1985. Ordovician stromatoporoids from the Langkawi Islands, Malaysia. Alcheringa 9, 159–166.

Windley, B.F., Allen, M.B., Zhang, C., Zhao, Z.-Y., Wang, G.-R., 1990. Paleozoic accretion and Cenozoic redeformation of the Chinese Tien Shan Range, Central Asia. Geology 18, 128–131.

Wu, Genyao, 1999. Main tectonic units and geological evolution in South China and its environs: in the light of Gondwana dispersion and Asian accretion. In: Metcalfe, I. (Ed.), Gondwana Dispersion and Asian Accretion. A.A. Balkema, Rotterdam, pp. 315–340.

Wu, Haoruo, Boulter, C.A., Ke, Baojia, Stow, D.A.V., Wang, Zhongcheng, 1995. The Changning–Menglian suture zone; a segment of the major Cathaysian–Gondwana divide in Southeast Asia. Tectonophysics 242, 267–280.

Yang, Jialu, 1994. Cambrian. In: Yin, Hongfu (Ed.), The Palaeobiogeography of China. Clarendon Press, Oxford, pp. 35–63.

Yang, W., Liu, B., 1996. The finding of Lower Permian Gondwana-type spores and pollen in Western Yunnan. In: Fang, N., Feng, Q. (Eds.), Devonian to Triassic Tethys in Western Yunnan, China. China Univ. Geosci. Press, pp. 128–135.

Yin, A., Nie, S.Y., 1993. An indentation model for the North and South China collision and the development of the Tan–Lu and Honam fault systems, Eastern Asia. Tectonics 12, 801–813.

Yin, A., Nie, S., 1996. A Phanerozoic palinspastic reconstruction of China and its neighboring regions. In: Yin, A., Harrison, T.M. (Eds.), Tectonic Evolution of Asia. Cambridge Univ. Press, pp. 442–485.

Yoshida, K., Machiyama, H., 2004. Provenance of Permian sandstones, South Kitakami terrane, northeast Japan: implications for Permian arc evolution. Sediment. Geol. 166, 185–207.

Yoshikura, S., Hada, S., Isozaki, Y., 1990. Kurosegawa terrane. In: Ichikawa, K., Mizutani, S., Hara, I., Hada, S., Yao, A. (Eds.), Pre-Cretaceous Terranes in Japan, IGCP Project No. 224 Publication, Osaka, pp. 185–201.

Zhao, X., Coe, R.S., Gilder, S.A., Frost, G.M., 1996. Palaeomagnetic constraints on the palaeogeography of China: implications for Gondwanaland. Aust. J. Earth Sci. 43, 643–672.

Zhang, K.-J., Xia, B., Liang, X., 2002. Mesozoic–Paleogene sedimentary facies and paleogeography of Tibet, Western China: tectonic implications. Geol. J. 37, 217–246.