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# Geologic significance of land organisms that crossed over the Eastern Tethys "Barrier" during the Permo-Triassic

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During the Permo-Triassic (P-T), some terrestrial organisms had distributions that spanned the eastern Tethys Sea between Gondwanaland and Asia while avoiding a Northwest African-Southwest European connection. These data strongly suggest that a broad paleotethys ocean-barrier did not exist, while transport across it on displaced terranes leads to further difficulties. Earth expansion overcomes these problems by joining eastern Gondwanaland and southern Asia throughout P-T times. The apparent failure of various plate tectonic models in this region stems from their requirement that the earth's diameter has remained constant through time, thus creating an unnecessarily wide Tethys ocean. Instead, if Paleotethys were a shallow epicontinental seabarrier, it would allow some terrestrial organisms to cross at narrow passage ways during regressions. The data also require India to be connected with Asia in P-T times, whereas plate tectonic models have them separated by a wide ocean barrier then and not rejoined until Eocene times.

**Key-words**—Plate tectonics, Earth expansion, Paleobiogeography, Tethys, Permo-Triassic.

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## सारांश

परमी-त्रिसंधी कल्प में पूर्वी टेथीज "उपरोध" को पार करने वाले स्थली जीवों का महत्व

ऑक्ले शील्ड्स

परमी-त्रिसंधी कल्प में कुछ स्थली जीवों का एशिया एवं गोंडवानाभूमि के मध्य पूर्वी टेथीज समुद्र तक वितरण पाया जाता है तथा इन पर उत्तर-पूर्व अफ्रीकी एवं दक्षिण-पश्चिम यूरोपीय संयोजन का कोई प्रभाव नहीं पड़ा। इन आँकड़ों से प्रदर्शित होता है कि उस समय एक बहुत चौड़ा पुराटेथीय समुद्री "उपरोध" नहीं था तथा दूरस्थ स्थलीय भागों तक इन जीवों का पहुँच पाना तो और भी कठिन था। भू भाग के विस्तार के कारण पूरे परमी-त्रिसंधी कल्प में गोंडवानाभूमि और दक्षिणी एशिया के परस्पर जुड़ने के कारण ये समस्यायें स्वतः समाप्त हो जाती हैं। इस क्षेत्र में विभिन्न प्लेट विवर्तनिक माडलों की असफलता के कारण यह स्पष्ट हुआ है कि प्रारम्भ से ही पृथ्वी का व्यास स्थिर रहा है। इसके बजाय यदि पुराटेथीज एक छिछला उपमहाद्वीपीय समुद्री "उपरोध" होता तो यह संकुचित मार्ग के संकुचन के समय कुछ स्थली जीवों को पार होने देता। आँकड़ों से यह भी प्रदर्शित होता है कि परमी-त्रिसंधी कल्प में भारत एशिया से जुड़ा हुआ था जबकि प्लेट विवर्तनिक मॉडल इन्हें एक बृहत समुद्र के कारण अलग-अलग प्रस्तावित करते हैं तथा आदिनूतन कल्प तक ये आपस में जुड़ नहीं पाये थे।

PALEOBIOGEOGRAPHIC data are often used now to test various plate tectonic reconstructions. Terrestrial paleobiogeography during P-T times provides an effective, independent test of whether the Tethys was a wide ocean with northward-drifting terranes (plate tectonics) or a relatively shallow epicontinental seaway without ocean crust flooring between sutured Laurasia and Gondwanaland (earth expansion).

Attention is drawn here to certain terrestrial biotic links between Asia and Gondwanaland, i.e., those exhibiting a trans-Tethyan distribution during specific time intervals within the P-T. Distributions that include Northwest Africa and Southwest Europe, however, were excluded from the analysis since some plate tectonic Tethys reconstructions incorporate a relatively broad land-connection there.

A geological reconstruction, to be valid, should agree with the distributional patterns of terrestrial fossil organisms for the appropriate time-interval since these patterns indicate where former land connections must have existed between continents, with dispersal tracks acting as a control that can in turn improve global reconstructions (cf. Tasch, 1981; Colbert, 1982; Buffetaut, 1989). Formerly continuous ranges of Pangaeian organisms often have since become isolated on various continents due to continental rifting and seafloor spreading.

### TRANS-TETHYAN DISTRIBUTIONS

#### Permian

During the Lower Permian, the plant order Vojnovskyales had an extended range from South Africa and the Congo to the Karharbari Basin of India; Victoria, New South Wales, and Tasmania in Australia; then northward to the Angaran floristic realm (Pechora, Tunguska, and Kuznetsk basins, western Mongolia, Siberia, South Maritime Territory, Primorye, Dunay Peninsula, and Russia Island), to Texas and Kansas (cf. Plumstead, 1963; Zimina, 1967b; le Roux, 1970; Mamay, 1976; Krassilov & Burago, 1981).

In the Permian, the highly speciose form-genus *Glossopteris* (Glossopteridae) was widespread in Gondwanaland, occupying Antarctica, Tasmania, Australia, southwest New Guinea, India, and south of the present equator in Africa and South America. During Lower Permian times, some *Glossopteris* species invaded Asia in the Mamal Formation (Kashmir) and southern Xizang (southernmost Tibet) (cf. Hsu, 1976; Li & Wu, 1994), and in the Upper Permian in the Tunguska and Kuznetsk basins, southern Mongolia, and South Primorye (Zimina, 1967a). The Russian and Mongolian *Glossopteris* species have very similar venation to *G. tortuosa* and *G. divergens* from the Late Permian of Raniganj, extreme eastern India (Zimina, 1967a); *G. divergens* was endemic to India, while *G. tortuosa* was also found in Queensland and South Africa. These and the *Glossopteris* species, from Kashmir and Xizang had ranges that overlapped only in India. The Kashmir and Xizang *Glossopteris* co-occurred with other elements of the *Glossopteris* flora, and South Primorye *Glossopteris* were found in as-

sociation with several *Gangamopteris* species. Upper Permian "*Glossopteris*" from Turkey, Thailand, Yunnan, and Guizhou, however, are generally considered too fragmentary to be properly identified or to be misidentified.

The first glossopterids, the Protoglossopteridae, originated in the Middle or Upper Carboniferous glacial deposits of the Transvaal, South Africa, and the first Vojnovskyales (*Plumsteadia*, *Vannus*) arose from *Gangamopteris* in the Early Permian of the Transvaal (cf. Plumstead, 1963, 1966, 1967; le Roux, 1966).

The Permian flora of western New Guinea is most closely related to the early Upper Permian Cathaysian flora of Southeast Asia and is only secondarily related to northeast Australia via *Glossopteris* (cf. Kon'no, 1963; Chaloner & Lacey, 1973; Lele, 1974; Li & Yao, 1982; Li, 1986; Kimura, 1987; Maheshwari & Bajpai, 1987; Li & Wu, 1994). The localities in western New Guinea occur on either side of the so-called Tertiary collision zone of plate tectonics between the Australian block and the Indonesian arcs, so late collision would not explain how these floras became mixed (Lacey, 1975) though expanding earth reconstructions could explain this (Li, 1986).

#### Triassic

The reptile *Lystrosaurus* (dicynodont), confined to a narrow time zone (Gangetian) at the base of the Triassic, has a widespread distribution in South Africa, Antarctica, India, the Shansi and Sinkiang provinces of North China, and the Vetluga River of European Russia. *L. murrayi* ranged in South Africa, Antarctica, India, Sinkiang, and Shansi, and *L. curvatus* was found in South Africa, Antarctica, India, and Sinkiang (cf. Colbert, 1973, 1982; Chatterjee & Roy-Chowdhury, 1974; Cosgriff, 1984). *Lystrosaurus* probably originated in South Africa since the three most primitive species overlap in distribution only there (cf. Colbert, 1982; Cosgriff *et al.*, 1982). Though *Lystrosaurus* is sometimes considered a semi-aquatic herbivore, its morphology indicates a fully terrestrial herbivore that excavated burrows (King, 1991; King & Cluver, 1991). It is often associated with dry-land reptiles and must have spread via land connections, being incapable of crossing ocean barriers (Colbert, 1970). Another reptile, *Chasmatosaurus*

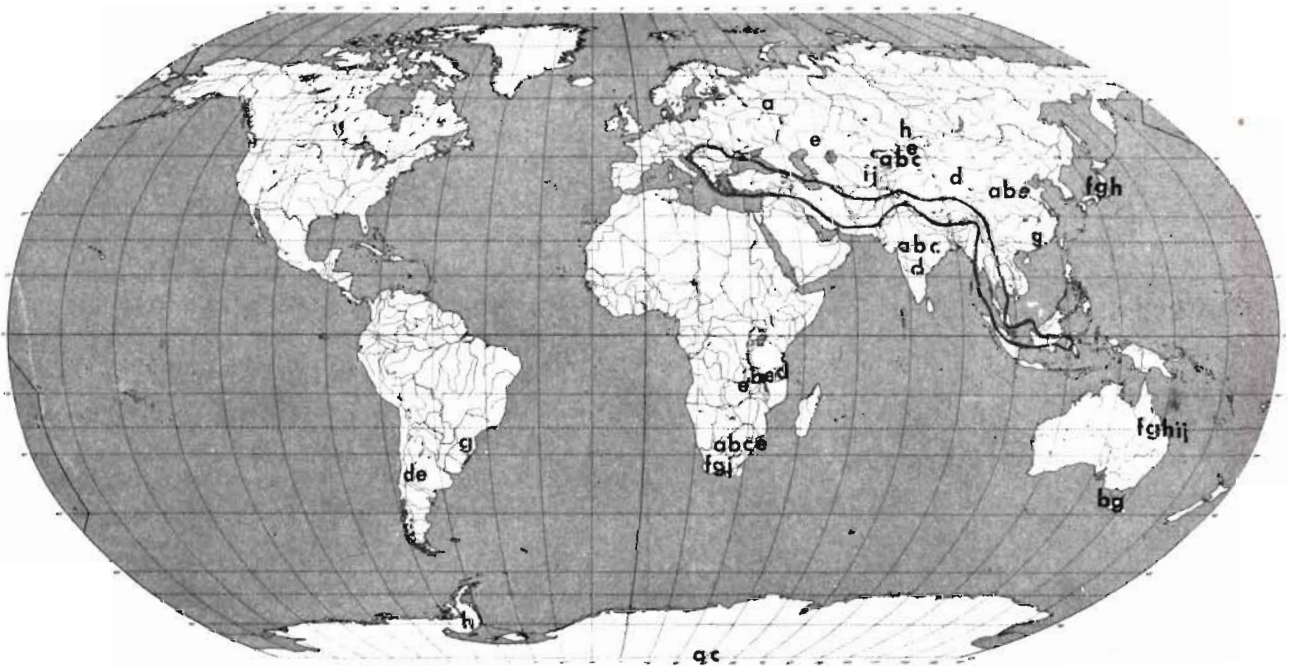
(Proterosuchia), a semi-aquatic crocodile-like predator, occurred in the *Lystrosaurus* and/or *Cynognathus* zones of South Africa, northeastern Zambia, Tasmania, India, and Shansi and Sinkiang in the Lower Triassic (Thulborn, 1979).

The labyrinthodont amphibian *Lydekkerinidae* (five genera) was restricted to South Africa, Antarctica, Tasmania, Queensland, India, Sinkiang, European Russia, and Greenland in the Lower Triassic (cf. Colbert, 1982; Cosgriff, 1984; Rage, 1988). Though aquatic, their small size, weak limbs, and amphibian nature would rule out transoceanic dispersal. *Lydekkerina* is known from Antarctica, South Africa, India and Sinkiang.

During Late Spathian-Early Anisian times (Lower/Middle Triassic boundary region), the terrestrial dicynodont tribe *Kannemeyeriini* was confined to Argentina, southern Africa, Tanzania, India, Shansi and Sinkiang, Mongolia, and Russia (cf. Romer, 1975; Kemp, 1982; Thulborn, 1983; King, 1990). The Early to Middle Triassic genus *Kannemeyeria* was distributed in Argentina, southern Africa, Tanzania, India, North China, and Mongolia

(cf. Thulborn, 1983; King, 1990). Some *Kannemeyeria* are now regarded as a separate genus (*Rechnisaurus*), i.e., species from Argentina, Tanzania, India, North China, and Inner Mongolia from the Early Anisian (lower Middle Triassic) biochron (cf. Cox, 1991; De Fauw, 1993). Both *Kannemeyeria* and *Rechnisaurus* overlapped in Argentina and Tanzania but occupied slightly different-aged deposits. *Shansiodon* of the tribe *Shansiodontini* occurred in the Early Anisian of Argentina, South Africa, Zambia, Tanzania, the southern Urals of European Russia, Shansi (Lucas, 1993), and the North Xinjiang-Beishan region.

In insects, the blattid genus *Samaroblatta* was restricted to South Africa, Queensland, and Japan during the Carnian, and *Triassoblatta* ranged in extreme southern Brazil, South Africa, Tasmania, Queensland, Canton (Kuantung province, China,) and Japan in the Carnian (cf. Fujiyama, 1973; Riek, 1974, 1976; Martins-Neto, 1987; Lin & Mou, 1989; Kukalova-Peck, 1991). *Ademosynoides* of Coleoptera was confined to the Antarctic Peninsula, Queensland, Japan and Central Asia then (Fujiyama, 1973;



**Text-figure 1**—Spatial distribution of some Triassic nonmarine animals as outlined in the text: **a**, *Lystrosaurus*; **b**, *Chasmatosaurus*; **c**, *Lydekkerina*; **d**, *Rechnisaurus*; **e**, *Shansiodon*; **f**, *Samaroblatta*; **g**, *Triassoblatta*; **h**, *Ademosynoides*; **i**, *Prorhynchophila*; and **j**, *Proparagryllacrididae*. The Cimmeride orogenic system (bold outline) cuts across the distribution pattern. According to plate tectonics, its north boundary was the site of Paleotethys closure, while its south boundary was the site of Neotethys closure (cf. Sengor, 1985, 1987; Nakazawa, 1985).

Schluter, 1990). *Prorhyacophila* of Trichoptera was confined to the Carnian in Queensland and the upper Upper Triassic of Fergana (cf. Riek, 1955; Sukatsheva, 1973; Ponomarenko & Rasnitsyn, 1974), a pattern repeated in Cladochoristidae and Xyelidae (see Text-figure 1). Similarly *Aeroplana* of Phasmida from the latest Carnian of Queensland is closely related to *Paraplana* from the upper Upper Triassic of Fergana (cf. Sharov, 1971; Ponomarenko & Rasnitsyn, 1974). Proparagryllacrididae of Orthoptera ranged from the Carnian of South Africa and Queensland to the upper Upper Triassic of Fergana (Riek, 1976). Also in the Upper Triassic the plant spore *Tuberculatosporites aberdarensis* was found in the Central Transantarctic Mountains, Queensland, and northern Afghanistan (Farabee *et al.*, 1989).

The results of this analysis clearly indicate that at various time intervals during the P-T (Lower Permian-Norian, *ca.* 290-210 Ma), some north-south terrestrial biotic exchanges did indeed occur across the Tethys "barrier," thus favouring earth expansion reconstructions over plate tectonic models since the data contradict a wide Tethys ocean, though displaced terranes must also be considered (see below). Only direct land connections rather than island hopping would explain the Triassic distributions of the herbivorous dicynodonts *Lystrosaurus*, *Shansiodon*, and *Rechnisaurus*. Chance oversea dispersal for the plant seeds and the insets (on rafts) appears unlikely given a Tethys ocean 5000-6000 km wide and the fact that equatorial ocean current gyres were oriented east-west, not north-south, in the Tethys (see Tollmann & Tollman, 1985a, 1985b). From Lower Permian to Middle Triassic times, these trans-Tethyan exchanges were mostly by way of India, while during the Upper Triassic these were via Queensland. Both tracks (dispersion routes) are located in northeastern Gondwanaland where Tethys was the widest on plate tectonic models, though much narrower as depicted on paleogeographic maps (cf. Termier & Termier, 1960; Kimura, 1984; Dobruskina, 1987). The Morocco-Spain land connection can be ruled out as a track for these organisms since Northwest Africa and Southwest Europe were devoid of their fossils. Regressions are recorded for the Scythian to Early Anisian, the mid-Carnian, and latest Carnian (cf. Haq

*et al.*, 1987; Stanley, 1988; Simms & Ruffell, 1989), coinciding with the Triassic exchanges.

#### PLATE TECTONICS AND DISPLACED TERRANES

If the plate tectonics theory is correct, a triangular Tethys Sea 5000-6000 km wide in its eastern sector separated Eurasia from eastern Gondwanaland during P-T times. On this model, portions of southern Eurasia and Southeast Asia represent an amalgamation of various displaced terranes that rifted from the northern margin of Gondwanaland in the Permian, travelled northward (anticlockwise) across Paleotethys, and collided with Russia in Late Triassic-Early Jurassic, followed by a Neotethys which closed in the Cretaceous-Paleogene due to the formation of the present Indian Ocean. Many different scenarios have been proposed for these events, including some that precede and follow P-T times, so only those rifting and collision events that are reasonably well-constrained by geologic, paleomagnetic, and/or paleontologic evidence will be considered here.

Early Permian glacial-marine deposits were extensive along Cimmeria in Iran, Afghanistan, the Lhasa and Changtang blocks of Tibet, and Sibumasu (in central Burma, southwestern Thailand, northern Malaya, and western Sumatra) Stauffer, 1985; Metcalfe, 1988). The great extent of these tilloids and their exotic cratonic megaclasts indicate that Cimmeria was still joined then to the northern margin of Gondwanaland where the Early Permian glaciations extended northernmost in India and Australia (see Crowell & Frakes, 1970, fig. 4). Cimmeria supposedly rifted from the northeast Gondwanaland margin in late Early to mid-Permian, while western Cimmeria rifted from the northern African margin in the Late Permian (cf. Metcalfe, 1988, 1990; Wilson *et al.*, 1989). The late Early Permian articulate brachiopod faunas of western New Guinea and peninsular (Sibumasu) Thailand were extremely similar at the generic and species levels, suggesting these terranes were still in close proximity then (Archbold *et al.*, 1982) but the Sibumasu Middle Permian brachiopods were similarly related to those in Indo-China and South China as well (Metcalfe, 1988). Late Permian displaced terrane models frequently separate Cathaysia from Cimmeria by a wide Paleotethys ocean (e.g., Sengor, 1985; Metcalfe, 1988; Burrent *et al.*, 1991; Kazmin, 1991),

yet early Upper Permian Cathaysian floras intermixed with Gondwana floras along Cimmeria in Kashmir, western and southern Xizang, northwest Thailand, and peninsular Thailand and even within the Indo-Australian plate itself in northeastern India and western New Guinea (cf. Kon'no, 1965; Li & Wu, 1994) indicating instead that Cathaysia was attached to northeastern Gondwanaland via Cimmeria at that time. Late Paleozoic rugose coral genera indicate that North and South China plus Tarim were joined during Carboniferous and Early Permian times and thus could not have rifted until the Late Permian (Smith, 1988).

Based on paleomagnetic data, initial collision of the North and South China blocks occurred in the Early Triassic with their fusion completed by the Late Triassic-Early Jurassic Indosinian orogeny when North China-Mongolia-Northeast China collided with Siberia, closing off the Paleotethys remnant (cf. Zhao & Coe, 1989; Lin & Fuller, 1990). This is incompatible with the fossil floras which exhibit great similarity between China, Siberia, and western Europe in the Early Triassic (Dobruskina, 1987). The Qiantang block (Central Tibet) collided with the Jinsha foldbelt south of the Tarim craton in the Late Triassic (Kazmin, 1991), and the Lhasa block (South Tibet) is a continuation of Sibumasu that collided with Central Tibet in the Late Triassic (Mitchell, 1981). The initial collision of Sibumasu with South China and East Malaya-Indo-China was in the Early Triassic, with their fusion in the Late Triassic, and Late Triassic and Jurassic paleomagnetic data show that these blocks were united then (cf. Klimetz, 1983; Metcalfe, 1988, 1990; Hutchinson, 1989). Improved paleomagnetic data, however, suggest the major blocks of China and Mongolia were in contact throughout the Upper Permian and Triassic (Enkin *et al.*, 1992). Japan was near Sino-Korea and widely separated from Gondwanaland in the Middle Triassic (Wilson *et al.*, 1989). Western Cimmeria collided with southwestern Eurasia during Late Triassic-Early Jurassic times (Sengor, 1979). Later, India initially collided with Tibet in lower Middle Eocene times based on paleomagnetic data. However, there is nearly a total lack of endemism in the Mesozoic-Early Cenozoic fossil vertebrates of India, suggesting instead that India was not an island continent before colliding

with Asia (cf. Chatterjee, 1984; Sahni, 1984; Prasad & Sahni, 1988; Briggs, 1989; Patterson & Owen, 1991; Sahni & Bajpai, 1991; Rage & Jaeger, 1995). Furthermore, a recently discovered Lower Cretaceous flora from Tingri (Xizang), just to the north of the Indian plate, displays rather strong affinities with various Lower Cretaceous floras from Rajmahal, Kutch, etc. within the Indian continent (cf. Wu & Hong, 1989; Drinnan & Crane, 1990). Australia-New Guinea initially collided with eastern Indonesia during Early Miocene times (cf. Patriat & Achache, 1984; Charlton, 1986; Burrett *et al.*, 1991). This date is questionable, however, since the floras and microfloras of Siberia and China exhibit a definite connection with those of Australia in the Early Cretaceous (Burger, 1981, 1990) and thus Indonesia and Australia were unlikely to have been widely separated then. Also the first fleas known only from the Early Cretaceous of Mongolia, Transbaikalia, and Victoria (Kukalova-Peck, 1991).

These plate tectonic models are largely incongruent with the paleobiogeographical data for the Tethys region. A number of Indian-eastern Asian terrestrial exchanges across the Tethys occurred throughout Early Permian to early Middle Triassic times for plants and vertebrates (this paper), yet plate tectonics requires that India and Southeast Asia were separated during this 50 m.y. time-span by a wide and deep ocean barrier. Some Late Triassic insects exhibit links between Queensland, Japan, and Fergana, while plate tectonics again requires a wide ocean barrier between them. Some of these models also have China widely separated from Eurasia in the Late Permian and colliding with it in the Triassic, yet Late Permian floras show widespread mixing of Cathaysian and Angaran elements from Turkey to Kamchatka, Mongolia, and North China, as well as strong floristic similarities between North China and western Europe in the Late Permian (cf. Li & Yao, 1982; Wang, 1985; Zhang *et al.*, 1985; Dobruskina, 1987). These models usually show North and South China as separate blocks during their Late Permian or even Early Permian journey across the Paleotethys (e.g. Klimetz, 1983; Parker & Gealey, 1985; Sengor, 1987; Metcalfe, 1988, 1990; Maruyama *et al.*, 1989; Burrett *et al.*, 1991). However, Early Permian corals suggest North and South China were joined then, and

there were floral similarities between North and South China during the late Early and Late Permian (cf. Li & Yao, 1982; Wang, 1985). The presence of *Lystrosaurus murrayi* and *L. curvatus* in China suggests eastern Asia was attached to Gondwanaland (via India) in the Lower Triassic (Colbert, 1974). *Lystrosaurus bedini* and *L. youngi* (= *L. curvatus*) were discovered in the Fukang area north of Tianshan in Sinkiang within the Tarim-Sino-Korean microplate, yet the geological evidence indicates this microplate was already accreted to the Siberian craton in the Upper Permian and would imply that Lower Triassic Paleotethys could only have been a narrow epicontinental sea in this region (Zhang *et al.*, 1984). Clearly the P-T paleobiogeography is primarily at odds with various displaced terrane models developed from geology and paleomagnetism for the Tethys region, continental ophiolites, suture zones, radiolarian cherts, granites and paleomagnetism for this region are subject to alternative interpretations (cf. Coney, 1973; Carey, 1976, pp. 181-222; Brookfield, 1977; Sonnenfeld, 1978; Sugisaki *et al.*, 1982; Stocklin, 1984b; Helmcke, 1985; Petford, 1991). The P-T paleobiogeography also appears counter to the concepts of Tethys being floored by oceanic crust, Cimmeria and China as displaced terranes that travelled across the Tethys, and Triassic collision of these terranes with southern Asia. The Paleotethys subduction rate of at least 17 cm/yr (5000 km in 30 m.y.), though not impossible, would certainly be unusually high by today's standards.

#### EARTH EXPANSION

Rapid earth expansion models would completely close Panthalassa and the oceanic part of the Tethys sea during P-T times (cf. Carey, 1976, 1987; Shields, 1979), and an 80 per cent diameter globe would also close the Tethys ocean (Owen, 1983). Trans-Tethyan paleobiogeographic links for the P-T would then be brought into much closer geographic proximity than in plate tectonic models. India, Tibet, and Sinkiang-Mongolia would become joined throughout the P-T; Queensland, Japan, and Fergana, though not joined, would be in closer proximity in the Upper Triassic; China and Russia would be joined in the Late Permian; and North and South China would be joined in the Late Permian, thus overcoming the various incon-

sistencies encountered between paleobiogeography and plate tectonic models which have these regions widely separated by ocean barriers during these time-intervals.

Panthalassa and pre-Jurassic Tethys ocean may simply be artifacts produced when reconstructing Pangaea on a present-sized earth and create more problems than they solve (Crawford, 1979, 1982). For example, a double paleoequator separated by *ca.* 30° of latitude is produced in non-Tethys areas when Triassic paleomagnetic data are plotted on the present-sized earth (Carey, 1976, p. 209). The wide P-T Tethys ocean is required only if the paleomagnetic data are plotted on an earth of present size (Stocklin, 1984a) such that northern continents are positioned in reference to the north paleopole and southern continents in reference to the south paleopole. Yet in eastern most Pangaea, Triassic paleomagnetic poles on the present-size earth were *ca.* 50° closer together than are the present poles (cf. Schmidt, 1976, fig. 6; Besse & Courtillot, 1991, fig. 1b-c) and thus would close the *ca.* 50° Tethys paleomagnetic gap. When the paleomagnetic positions of Sumatra (Triassic) and Sumba (Early Jurassic) are calculated with respect to the north and south paleopoles on a present-sized earth, they were clearly below; not above, the paleoequator and near the northwest margin of Australia (cf. Sasajima *et al.*, 1989; Otofuiji *et al.*, 1979).

Though there are some serious objections to earth expansion that still need to be answered (Hallam, 1984), and neither theory is necessarily air-tight, earth expansion does pass the explanation test of how some P-T land organisms were able to readily cross the eastern Tethys, while plate tectonics fails this test.

#### EASTERN GONDWANA-SOUTHEAST ASIA REASSEMBLY

None of the existing plate tectonic or earth expansion P-T reassemblies of continents surrounding the Indian Ocean appears to completely satisfy all of the constraints imposed by paleobiogeography. Here a new reassembly is synthesized that appears compatible with the paleobiogeography requirements.

The Sibumasu-Indochina-Indonesia morphological fit of Carey (1976, fig. 179) agrees with the

paleomagnetic orientation for the Lower Jurassic of Besse and Courtillot (1988, fig. 2) and Enkin *et al.* (1992, fig. 25). This involves an anticlockwise rotation of Sibumasu which then is positioned alongside the northwest margin of clockwise-rotated Australia, as indicated by peninsular (Sibumasu) Thailand shallow marine invertebrate links to the Canning Basin in the Ordovician and to the Carnarvon Basin in the Early Permian (cf. Waterhouse, 1982; Burrett & Stait, 1985; Laurie & Burrett, 1992), as well as Lower Carboniferous foraminifera links between Sibumasu Sumatra and the Bonaparte Basin (Metcalf, 1988). The reassembly also brings the Carnian *Triassoblatta* distribution in Queensland, Canton, and Japan into north-south alignment and is in accord with Permian-Jurassic paleogeography for the region (see Lloyd, 1978).

The Gondwanaland reconstructions that best agrees with the data from paleomagnetism, seafloor spreading patterns, hotspot tracks, and continental geology is diagrammed by Parish (1990), Lawver *et al.* (1991), and Eliot (1991, fig. 6). Supporting data from paleomagnetic poles appear in Kloothwijk (1979, fig. 9), seafloor spreading patterns in Johnson *et al.* (1976), Veevers *et al.* (1980), and Lawver *et al.* (1992), and hotspot tracks in Duncan and Storey (1992) Storey (1995). The geologic matching between Australia/Antarctica for pre-Jurassic time is given by Veevers (1976) and Veevers *et al.* (1994), and between India/Antarctica by Grew and Manton (1986), Yoshida *et al.* (1992), and Brandon and Meen (1995). Continental dispersal in Gondwanaland was away from a stable Africa (cf. Norton & Sclater, 1979; Fairhead & Binks, 1991, fig. 2).

Some paleobiogeographic data support this separation, rather than juxtaposition, of India and Australia. Thus in the Middle and Late Triassic, the Onslow microflora was confined to Tanzania, Madagascar, northeastern India, the Prince Charles Mountains of East Antarctica, and western, northwestern, and northeastern Australia (Foster *et al.*, 1994); and during the Early Cretaceous, Pentoxylales was confined to the Rajmahal Hills of northeastern India and to Victoria (Drinnan & Chambers, 1985).

The Gondwanaland reconstruction adopted here creates a Sinus Australis between northern India and

western Australia. Early plate tectonic models first proposed that this missing landmass was Tibet (e.g., Veever *et al.*, 1975). However, because of suture zone alignments, southern Tibet is considered a continuation of Sibumasu and Central Tibet a continuation of Indo-China (e.g., Mitchell, 1981, fig. 1), such that Tibet must be folded at a right angle along western Australia to preserve this continuity (e.g., Gorur & Sengor, 1992, fig. 5). Some of the latest reconstructions now favour a missing Greater India landmass that occupied Sinus Australis between the Indian Plate and the Himalayas which subsequently underwent subduction beneath Tibet (cf. Kloothwijk *et al.*, 1985; Brookfield, 1993; Ogg & von Rad, 1994), in better accord with the paleomagnetic data, perhaps resulting from an 800 km diameter Amirante-Shiva impact crater at the K/T boundary (Chatterjee, 1992). The double crusted thickness of Tibet and its uppermost mantle seismic velocity similarity to the Indian shield's uppermost mantle suggest shield-like material is present beneath Tibet (cf. Barazangi & Ni, 1982; Chun & McEvilly, 1986). The Early Permian reconstruction of Audley-Charles (1991, fig. 7) has Tibet against Greater India and Sibumasu against northwest Australia such that southern Tibet and Sibumasu remain contiguous and aligned latitudinally. Inserting Paleotethys into any terrane suture zone between the Himalayas and Tien Shan is not supported by the marine faunal relationships there in the Early Permian (cf. Smith, 1988; Smith & Xu, 1988).

#### GENERAL CONCLUSIONS

During the Permo-Triassic, some terrestrial plants, vertebrates and insects were able to cross over the Paleotethys ocean between northeastern Gondwanaland and southeastern Asia without dispersing by way of Northwest Africa/Southwest Europe or the Americas. Chance oversea dispersal for the plant seeds and insects appears unlikely, and the Triassic vertebrate distributions are best explained by direct land connections. Other paleobiogeographical data (plants, shallow marine invertebrates) suggest China and Southeast Asia were already in contact with each other and with Russia in the P-T.

Plate tectonic models call upon displaced terranes that these organisms could have boarded for transport across the Paleotethys during a Late Per-

mian to Middle Triassic journey, but the timing of the proposed rifting, terrane transport, and collision events is incompatible with their dispersal tracks. Thus the Permian plants reached Russia well ahead of the docking of most displaced terranes, while Triassic vertebrates and insects were in Gondwanaland and Asia simultaneously when the wide Tethys barrier was still in effect. Earth expansion models, however, are compatible with these dispersal tracks throughout the P-T, providing these organisms crossed at narrow passage ways (land bridges) during regressions. Paleomagnetic data applied to an earth of the present-size create a P-T Paleotethys that was 5000-6000 km wide in its eastern sector but would close this ocean on an expanding earth so that it was a narrow epicontinental shallow seaway, thus joining northern Gondwanaland and southern Asia. India played a central role in these dispersal patterns, and its lack of endemism in Mesozoic-Cenozoic fossil vertebrates suggests it was not an island continent before colliding with Asia.

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