

# CAMBRIAN BIOGEOGRAPHY OF THE PERIGONDWANA FAUNAL REALM

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## ABSTRACT

The Cambrian Perigondwana Faunal Realm includes the Mediterranean region (Morocco, Spain, South France, Sardinia and Jordan) and Central Europe (Doberlug and Görlitz, both in Germany) during the Early and Late Cambrian time; and the Near East, Central, South and Southeast Asia, China, Korea, Australia and Antarctica from Early to Late Cambrian time. In Altai-Sayan and western Mongolia there is faunal overlap of Redlichioid and Olenelloid Faunal Provinces as in Morocco and Spain. The areas of overlap are widely separated by areas of no known overlap and the time duration is small.

Lower Cambrian genera of the Superfamily Redlichioidea, Middle Cambrian genera of Families Proasaphiscidae, Dorypygidae, Dolichometopidae and Oryctocephalidae, late Middle and early Late Cambrian genera of the Superfamily Dameselloidea and late Late Cambrian genera of the Superfamilies Leiostegioidea and Ptychaspidoidea are the bases for defining the Perigondwana Faunal Realm. Some open-shelf agnostid and polymerid genera are also used. At the same time, the boundaries between the Mediterranean and the Acado-Baltic Faunal Provinces and the palaeogeography of the Near East and South Asia are discussed. The appearance of *Paradoxides*-fauna in North Africa and the Mediterranean region is explained.

**Key words:** Cambrian, trilobites, biogeography, Perigondwana Faunal Realm.

## RESUMEN

El Reino Faunístico de Perigondwana en el Cámbrico incluye el área mediterránea (Marruecos, España, sur de Francia, Cerdeña y Jordania) y la Europa central (Doberlug y Görlitz, en Alemania) durante el Cámbrico Temprano y Cámbrico Tardío; así como Oriente Próximo, Asia central, meridional y suroriental, China, Corea, Australia y la Antártida durante todo el Cámbrico. En la región de Altai-Sayan y en Mongolia occidental se da el solapamiento de las provincias faunísticas de los redlichioideos y de los olenelioideos, al igual que en Marruecos y España. Estas áreas de solapamiento están separadas por amplias áreas sin solapamiento conocido y son de una duración corta.

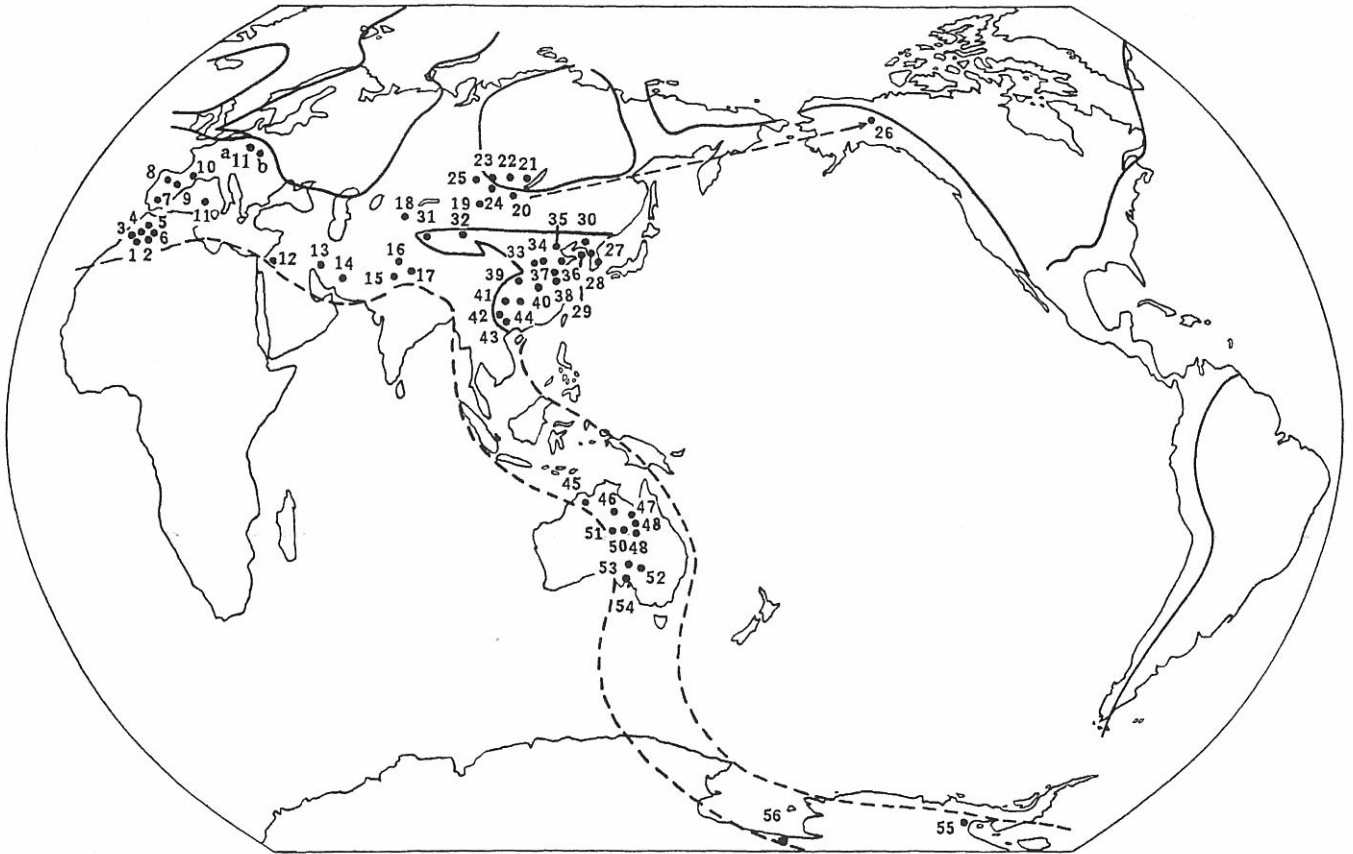
Las bases paleontológicas que sirven para definir el Reino Faunístico de Perigondwana son géneros de trilobites del Cámbrico Inferior de la Superfamilia Redlichioidea, géneros del Cámbrico Medio de las familias Proasaphiscidae, Dorypygidae, Dolichometopidae y Oryctocephalidae, géneros del Cámbrico Medio tardío y Cámbrico Tardío temprano de la Superfamilia Dameselloidea, y géneros del Cámbrico Tardío tardío de las superfamilias Leiostegioidea y Ptychaspidoidea. También se emplean para ello algunos géneros de agnóstidos y polímeros de plataforma abierta. Al mismo tiempo, se discuten los límites entre las provincias faunísticas Mediterránea y Acado-Báltica y la paleogeografía de Oriente Próximo y Asia meridional. También se explica la aparición de la fauna de *Paradoxides* en el área mediterránea.

**Palabras clave:** Cámbrico, trilobites, biogeografía, Reino faunístico de Perigondwana.

## INTRODUCTION

Based on present-day geography, the distribution of the Cambrian trilobites around the world suggests two large first-level faunal realms from Early to Late Cambrian time (Cowie, 1971; Chang, 1989). Study of the

distribution of Cambrian trilobite genera suggests that the Perigondwana Realm (Kobayashi, 1976; Palmer and Repina, 1993), or the western Pacific Realm (Chang, 1989), has rather precise boundaries and can be recognized on the basis of several endemic families or superfamilies of trilobites.



**Figure 1.** Biogeography of Redlichioidea (Early Cambrian) trilobites. 1. Oujjane, southern Morocco. *Resserops*, *Richterops*, *Abadiella* (Hupé, 1953). 2. Timghit, southern Morocco. *Pareops*, *Gigantopygus*, *Perrector*, *Clariondia*, *Longianda*, *Peudosaukianda* (Hupé, 1953). 3. Amouslek, southern Morocco. *Richterops*, *Resserops*, *Neoredlichia*, *Marsaisia* (Hupé, 1953). 4. Tazemmourt, southern Morocco. *Pararedlichia* (= *Eoredlichia*) (Hupé, 1953). 5. Lemdad, Ounein, southern Morocco. *Lemdadella* (Sdzuy, 1978). 6. Tiout, southern Morocco. *Resserops* (Hupé, 1953). 7. Alanís (province of Sevilla), south-western Spain. *Lemdadella*, *Saukianda*, *Perrector* (Richter and Richter, 1941a; Henningsmoen, 1958; Liñán and Sdzuy, 1978). 8. a) Los Barrios de Luna (province of León), northern Spain. *Dolerolenus*, *Lunolenus*, *Metadoxides*. b) Concha de Artedo (province of Oviedo), northern Spain (Atlantic coast). *Dolerolenus*, *Pararedlichia*. c. Hermida (province of Lugo), northern Spain. *Dolerolenus*, *Pararedlichia* (= *Eoredlichia*). (Liñán and Sdzuy, 1978; Sdzuy, 1961). 9. Huérmeda, near Calatayud (province of Zaragoza), northeastern Spain. *Redlichia* (Sdzuy, 1961). 10. Montagne Noire, southern France. *Galloredlichia* (= *Eoredlichia*) (Courtessole and Jago, 1980). 11. Sardinia, Italy. *Sardoredlichia*, *Nebidella*, *Eoredlichia*, *Sardaspis*, *Metadoxides*, *Enantiaspis*, *Dolerolenus*, *Iglesiaella*, *Yiliangella* (Pillola, 1991). 11. a) Doberlug; southeastern Germany. *Dolerolenus*, *Ferralsia* (Sdzuy, 1962; Geyer and Elicki, 1995). 12. Chirbet et-Burdsh, Sö, Ghor es-Safi, Jordan. *Redlichops* (Richter and Richter, 1941b). 13. Zagros Mountains, Western Isfahan, Iran. *Redlichia* (King, 1937; Wolfart, 1983). 14. Darreh Sangi, Rizu and Chabdjerh, Kuhbana, NW Kerman, Iran. *Redlichia* (Wolfart, 1974a). 15. Salt Range, Pakistan. *Redlichia* (Schindewolf and Seilacher, 1955). 16. Kashmir, *Redlichia* (Kobayashi, 1967). 17. Spiti. *Redlichia* (Reed, 1910). 18. Malayj Karatau, southern Kazakhstan. *Redlichia*, *Ushbaspis* (= *Metaredlichioides*) (Keller and Pokrovskaya, 1965). 19. Akbashi, 40 km NE Khobdo, western Mongolia. *Redlichia*, *Sajanaspis*, *Judomia* (olenelloid) (Korobov, 1989). 20. South Khubsugul region, Mongolia. *Bulaiaspis*, *Redlichia*, *Elganellus*, *Chengkouaspids* (Korobov, 1989). 21. Irkutsk, Russia. *Tungusella*, *Bulaiaspis*, (Repina, 1960). 22. East Sayan, Russia. *Irgitkhemia*, *Olgaspis*, *Tungusella*, *Terechtaspis*, *Kolbaspis*, *Sajanaspis* (Repina, 1960; 1979). 23. West Sayan, Russia. *Sajanaspis*, *Inella*, *Terechtaspis*, *Redlichina* (Repina, 1960, 1966; Repina *et al.*, 1964). 24. Tuva, Russia. *Irgitkhemia*, *Menneraspis*, *Sajanaspis*, *Terechtaspis* (Tschernysheva, 1977; Pokrovskaya, 1959; Repina, 1960, 1966). 25. Altai, Russia. *Redlichina*, *Inella*, *Belliceptis*, *Elganellus* (Lermontova, 1940; Repina *et al.*, 1964; Repina, 1966). 26. Yukon River (Water Level) area, Alaska, U.S.A. *Churkinia* (Palmer, 1968). 27. Chuwa, North Korea. *Redlichia* (Chang, 1988). 28. Bunkei, South Korea. *Redlichia* (Chang, 1988). 29. Liaodong Peninsula, Liaoning, China. *Redlichia* (Chang, 1988). 30. Taizihe Valley, Liaoning, China. *Redlichia* (Chang, 1988). 31. Keping, Xinjiang, western China. *Redlichia* (Chang, 1988). 32. Qurug Tagh, Xinjiang, western China. *Ushbaspis* (= *Metaredlichioides*), *Parazhenbaspis* (Zhu and Lin, 1983). 33. Zhongtiaoshan and Hejin district, southern Shanxi, China. *Redlichia* (Chang, 1988). 34. Jixian, northern Henan, China. *Redlichia* (Chang, 1988). 35. Kaiping Basin, eastern Hebei, China. *Redlichia* (Chang, 1988). 36. Central Shandong and northern Jiangsu, China. *Neoredlichia*,

At the beginning of the Cambrian, the seas of the world were already populated by a diverse biota that included representatives of most of the major invertebrate phyla, as shown by the Chengjiang fauna of eastern Yunnan. The Arthropoda of the Cambrian include, first and foremost, the Trilobita. This was the largest and most diverse group of Cambrian organisms and apparently occupied most normal marine environments. It included open-ocean planktonic representatives, as well as restricted vagile benthos. Trilobites are the most commonly encountered Cambrian fossils and are the group from which almost all biogeographic data have been derived. Other Arthropoda are relatively rare. Some important superfamilies, such as, Redlichioidea, Dameselloidea, and some genera of the Leiostegioidea and Ptychaspidoidea, as well as genera of other families mentioned below, define the Perigondwana Faunal Realm.

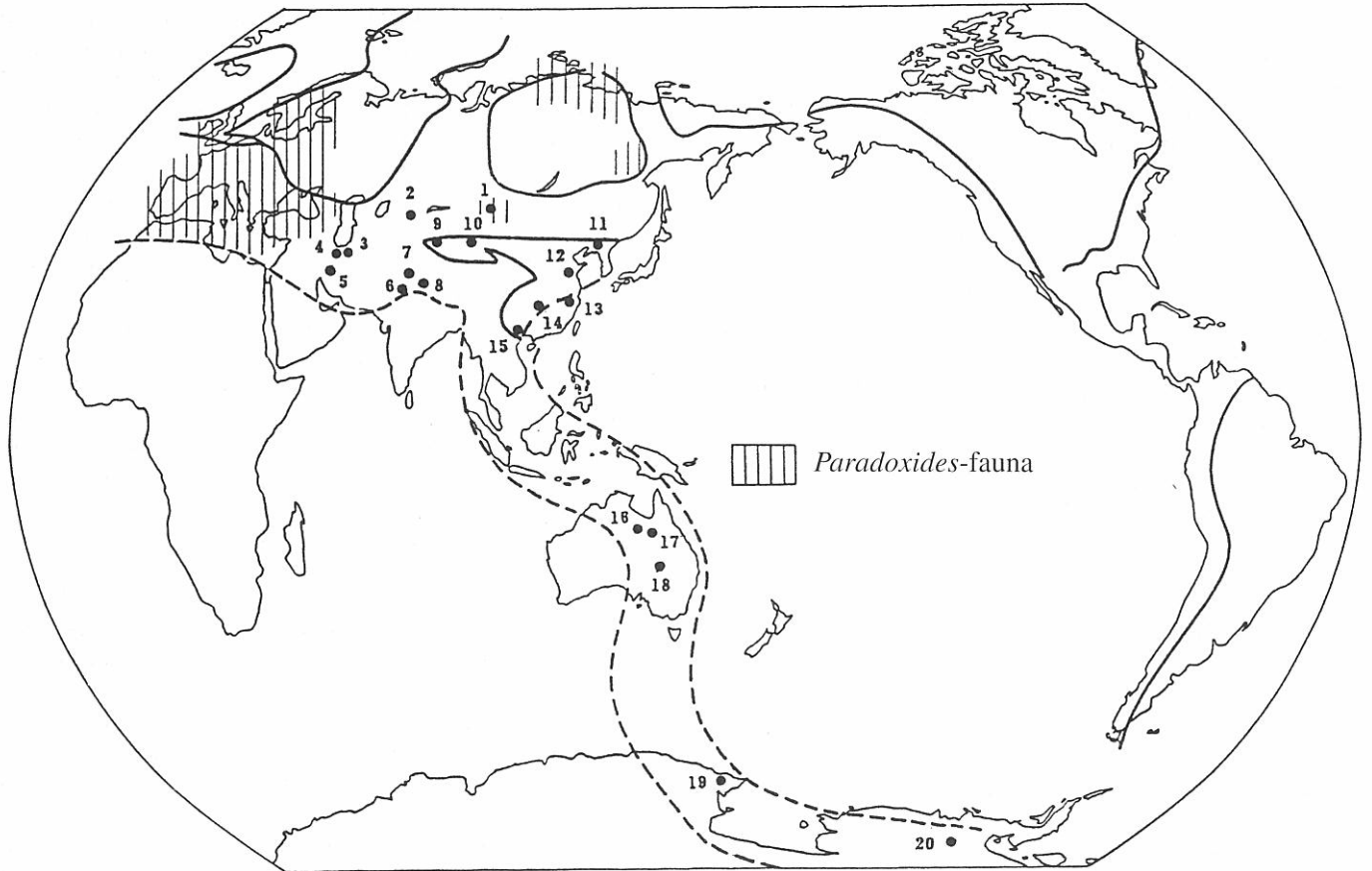
## BIOGEOGRAPHY AND PHYLOGENY OF THE REDLICHIOIDEA

### Biogeography

(Fig. 1). This superfamily contains 136 genera and is confined to the Early Cambrian. More than half the genera occurred on the China Platform, especially in the Yangtze platformal area. Most genera of this group of trilobites were confined in China to the western Subprovince of the Yangtze, or Southwest China Platform (Chang *et al.*, 1980). Most genera of the Metaredlichiiinae and *Yinites*, *Parayinites*, *Qingkouia*, *Paokannia*, *Parapaokannia* and *Meitanella* of the Yinitidae which are always associated with protolenids and eodiscoids, occur in the Central Subprovince. In the eastern Subprovince or in the northern, or northwestern marginal part of the Chiangnan Belt, more or less equivalent to the upper part of the slope biofacies, very

rare specimens of *Redlichia* may be found but they are always with a small cranidium and relatively thin exoskeleton, while in the southeastern parts of the Chiangnan belt which may represent the lower part of the continental slope, redlichiid trilobites disappeared entirely. Based on ecological studies, the Archaeocyatha which flourished best in the Early Cambrian sediments of the Central subprovince lived in marine, benthic, warm and shallow-water (20-50 m; Hill, 1972). If this data is reliable, the depth of sea-water in the western subprovince may be from zero to 20 m where most genera of the Wutingaspininae, Pararedlichinae, Redlichinae, Yiliangellinae, and of the Mayiellidae, Dolerolenidae, as well as some pedomorphic Yinitidae (*Drepanopyge*, *Drepanuroides*, *Yunnanaspidella* and *Yunnanaspis*) and the Chengjiang biota occurred. The depth of sea-water in the Eastern subprovince, or along the eastern Yangtze platformal margin may be 50-100 m, and the upper part of the continental slope is estimated to be 100 to 150 m. In North and Southwest China, Cambrian rocks including oolitic limestones, varicolored suite of brick-red to violet argillaceous dolomitic limestones, red sandy shales, pseudomorphic crystals of salt as well as thick rock salt deposits of late Early and early Middle Cambrian age suggest a warm climate during the Cambrian. Thus distribution of redlichiid trilobites in Southwest China is mainly controlled by depth of sea water and temperature. Most species of redlichiiids were found in sandstone, yellow or green shales and limestones which represent the normal deposits within the continental shallow shelf; only a few species of, for instance, *Metaredlichia*, *Wutingaspis*, *Parabadiella* in Southwest China, and species of *Redlichia* associated with *Hsuaspis* in Kangaroo Island of Australia, may occur in both the black and yellow or green shales, near the marginal part of, or within, the platform.

*Redlichia* (Chang, 1988). 37. Huainan, northern Anhui, China. *Redlichia*, *Leptoredlichia* (Chang, 1988). 38. Nanjing, Jiangsu and Chuxian, northern Anhui, China. *Redlichia*, *Paokannia* (Chang, 1988). 39. Southern Shaanxi and northern Sichuan, China. *Redlichia*, *Paokannia*, *Mayiella*, *Drepanopyge*, *Paramalungia*, *Shatania*, *Yiliangella*, *Malungia*, *Eoredlichia*, *Wutingaspis*, *Parabadiella* (Chang, 1988). 40. Yichang, Hubei, China. *Redlichia*, *Metaredlichia* (Chang, 1988). 41. Emei, Sichuan, China. *Redlichia*, *Ushbaspis*, *Yiliangella*, *Changshanaspis*, *Chaoaspis*, *Wutingaspis* (Chang, 1988). 42. Eastern Yunnan and southwestern Sichuan, China. *Redlichia*, *Conoredlichia*, *Mayliella*, *Drepanuroides*, *Drepanopyge*, *Yunnanaspidella*, *Yunnanaspis*, *Yiliangella*, *Paramalungia*, *Malungia*, *Eoredlichia*, *Wutingaspis*, *Kuanyangia*, *Supushania*, *Chengjiangaspis*, *Parabadiella* (Chang, 1966, Chang *et al.*, 1980). 43. Southeast Yunnan, China. *Redlichia*, *Metaredlichia*, *Yinites* (Luo, 1984; Chang, 1966). 44. Northern Guizhou and Southeastern Sichuan, China. *Redlichia*, *Drepanuroides* (Chang, 1988). 45. Mount Panton, Northern Territory, Australia. *Redlichia* (Öpik, 1970). 46. Gum Ridge at Tenant Creek, Northern Territory, Australia. *Redlichia* (Öpik, 1970). 47. Yelvertoft Bed Locality M426, northwestern Queensland, Australia. *Redlichia* (Öpik, 1970). 48. Cornford Bore Locality M262, west of Mt. Isa, northwestern Queensland, Australia. *Redlichia* (Öpik, 1970). 49. Localities D41 and D131, Urandangi Area, western Queensland, Australia. *Redlichia* (Öpik, 1970). 50. Dinner Creek, Tobermory Area, SE Northern Territory, Australia. *Redlichia* (Öpik, 1970). 51. Locality AS 59, Phillipson Pound, Alice Springs Area, S Northern Territory, Australia. *Redlichia* (Öpik, 1970). 52. Mount Wright, White Cliffs Area, New South Wales, Australia. *Redlichia* (Öpik, 1970). 53. Wirrealpa Limestone, Flinders Ranges, South Australia, Australia. *Redlichia*, *Xelà*, *Emuella*, *Balcoracannia*, *Parabadiella huoi*, *Pararaia* (Öpik, 1970; Jell *in Bengtson et al.*, 1990). 54. Yorke Peninsula and Kangaroo Island, South Australia, Australia. *Redlichia*, *Dolerolenus* sp. *Parabadiella*, *Emuella*, *Balcoracannia*, *Eoredlichia*, *Pararaia*, *Yorkella*, (Öpik, 1970; Jell *in Bengtson et al.*, 1990). 55. Boulder from Mount Spann, Antarctica. *Redlichia*, *Australaspis* (Palmer and Gatehouse, 1972). 56. Mt. Bowers, Antarctica. *Lemdadella* (Palmer and Rowell, 1995).



**Figure 2.** Middle Cambrian biogeography of the Perigondwana Realm. 1. Khobdo, western Mongolia; *Paradoxides*, *Eccaparadoxides*, *Hydrocephalus*, and *Solenopleura* (Dumicz *et al.*, 1970; Chang, 1980; 1988). 2. Malyj Karatau, southern Kazakhstan. Agnostid trilobites are the same as in western hunan and western Zhejiang, South China; polymerid trilobites are also the same as in China. Genera are listed as follows: *Wanshan* (= *Peichiashania*, Ergaliev, 1980), *Blackweldera*, *Palaeadotes*, *Ajrikina* (= *Jiangnan*), *Fuchouia*, *Lisania*, *Lisaniella*, *Prodamesella*, *Meringaspis karatauensis* Ergaliev, 1980 (= *Paradamesops karatauensis* Ergaliev, 1980), *Prohedinia*, *Platylisania*, *Dorypyge*, *Solenoparia*, *Maotunia*, *Tonkinella*, *Manchuriella*, *Honanaspis*, *Proasaphiscus* (Ergaliev, 1980; Abdulin and Chakabaev, 1984; Abdulin *et al.*, 1990). 3. Mila-Kuh, Shahmirzad; Hasanakdar; northern Iran. *Dorypyge*, *Iranoleesia* (Kushan, 1973). 4. Abhar; Sanghabad and Qanli-Chapoghlu; northern Iran. *Dorypyge*, *Iranoleesia*, (Kushan, 1973). 5. Ma'dan, 290 km northwest of Shiraz, Iran. *Iranoleesia*, *Anomocarella*. (Fortey and Rushton, 1976). 6. Salt Range, Pakistan. *Chittidilla* (Schindewolf and Seilacher, 1955). 7. Kashmir. *Hundwarella*, *Tonkinella* (Kobayashi, 1967). 8. Spiti. *Oryctocephalus*, *Prychoparia* (Reed, 1910). 9. Keping, Xinjiang, western China. *Kunmingaspis*, *Chittidilla* (Lin *et al.*, 1990). 10. Qurug Tagh, Xinjiang, western China. *Dorypyge*, *Fuchouia*, *Amphoton*, *Lisania*, *Paradamesops*, *Paradamesella*, *Prodamesella*, and *Eoshengia* (Lin *et al.*, 1990). 11. Taitzuhe, northeastern China. *Damesella*, *Lisania*, *Dorypyge*, *Amphoton*, *Fuchouia*, *Crepicephalina*, *Bailiella*, *Manchuriella*, *Proasaphiscus*, and *Shantungaspis* (Chang, 1988). 12. Central Shantung, eastern China. *Damesella*, *Leiopeshania*, *Fuchouia*, *Amphoton*, *Dorypyge*, *Taitzuia*, *Anomocarella*, *Crepicephalina*, *Lioparia*, *Proasaphiscus*, *Poriagraulos*, *Hsuchuangia*, *Shantungaspis*, and *Yaojiayuella* (Chang, 1988). 13. Western Zhejiang, eastern China. *Fuchouia*, *Prohedinia*, *Buttsia*, *Paradamesella* (Lu and Lin, 1989). 14. Western Hunan, South China. Agnostid trilobite genera are mentioned in the text; polymerid trilobite genera are listed as follows: *Prohedinia*, *Fuchouia*, *Wanshan*, *Palaeadotes*, *Dorypyge*, *Lisania*, and *Eoshengia* (Song, 1989). 15. Southeast Yunnan. *Solenoparops*, *Taitzuia*, *Amphoton*, *Damesella*, *Inouyella*, *Kaotai*, *Oryctocephalus*, *Tonkinella*, *Bailiella*, *Lioparia*, *Wuania*, *Kunmingaspis*, *Mengzia*, and *Plesiagraulos* (Luo, 1984). 16. Eastern part of Northern Territory, Australia. *Oryctocephalus*, *Xystridura* (Öpik, 1975; Shergold, 1969). 17. Western Queensland, Australia. *Oryctocephalites*, *Xystridura*, *Pagetia*, *Amphoton*, *Fuchouia*, *Dorypyge*, *Mapania*, *Prohedinia* (Öpik, 1961, 1975, 1982; Shergold, 1969). 18. Western New South Wales, Australia. *Xystridura* (Öpik, 1975). For agnostid trilobite genera in Australia, see Öpik (1979). 19. North Victoria Land, Antarctica. *Dorypyge*, *Fuchouia*, *Solenoparia* (Cooper and Shergold, 1991). 20. Ellsworth Mountains, Antarctica. *Damesellidae*, *Fuchouia*, *Pagetia* (Jago and Webers, 1992).

### Phylogeny

Genera of the Pararedlichiinae, Wutingaspiinae and Metadoxididae occur in the Chiungchussuan and genera of the Yinitidae, Mayiellidae, Metaredlichiinae, Kueichowiidae and Yiliangellinae in the early Tsanglangpuan age. *Mianxianella*, *Kepingaspis* and *Wengangaspis* of the Wutingaspiinae are of early Tsanglangpuan age, while *Metaredlichia* and *Zhenbaspis* in China and *Iglesiaella* in Sardinia, of the Metaredlichiinae, may be late Chiungchussuan. Redlichiinae and Neoredlichiinae occur in the Upper Tsanglangpuan and Lungwangmiaoan. The Wutingaspiinae, (*Wutingaspis*), Pararedlichiinae (*Eoredlichia*) and Redlichiinae [*Redlichia* (*Redlichia*) and *R. (Pteroredlichia)*] represent a peramorphic evolutionary trend of the Redlichiidae from early to late Early Cambrian in Southwest China. Peramorphosis involves the eye lobe moving toward the glabella, anterior branches of the facial sutures becoming increasingly divergent, frontal glabellar lobe increasing in size as later species reach the protraction stage, genal angle moving anteriorly, pleural spines becoming increasingly longer, pygidial axial lobe becoming smaller and shorter, and two pairs of hypostomal spines becoming shorter or disappearing. These genera of the Yinitidae were derived from earlier *Wutingaspis*-like trilobites of the Chiungchussuan. The paedomorphic reduction in number of thoracic segments in these genera of the family Yinitidae is accompanied by a progressive increase in size of pygidium, by increase in pygidial spinosity and by increase in dorsal exoskeletal size. The Yinitidae is regarded as a miomeric off-shoot of the stem-form Redlichiidae by paedomorphosis. Because *Neoredlichia* and *Leptoredlichia* are very rare, the evolutionary relationship of Neoredlichiinae within the Redlichiidae is not known. Neoredlichiinae is almost exclusively a North China and Northern Korea subfamily and is one of the two phylogenetically terminal groups of the Redlichiidae.

The Gondwana and Perigondwana Realm for Redlichioid trilobites includes present-day eastern Asia, western Mongolia, parts of the south Siberian foldbelt, Kazakhstan, Middle South Asia (Kashmir, Pakistan, Iran, Afghanistan), the Near East, the Mediterranean region, Central Europe, North Africa, Australia and Antarctica. Kobayashi (1972) proposed the term Intermediate Faunal Province for the relatively small areas where there is faunal overlap of the Redlichian and Olenellian Provinces in Morocco, Spain, southern Siberia and western Mongolia (Korobov, 1989). Kobayashi (1987a) and the author (Chang, 1989) do not agree with the term Intermediate Faunal Province because definition of its boundaries will always be uncertain and the areas of overlap are widely separated by areas of no known overlap, and because the time duration of overlap is small.

### BIOGEOGRAPHY OF EARLY CAMBRIAN ARCHAEOCYATHIDS

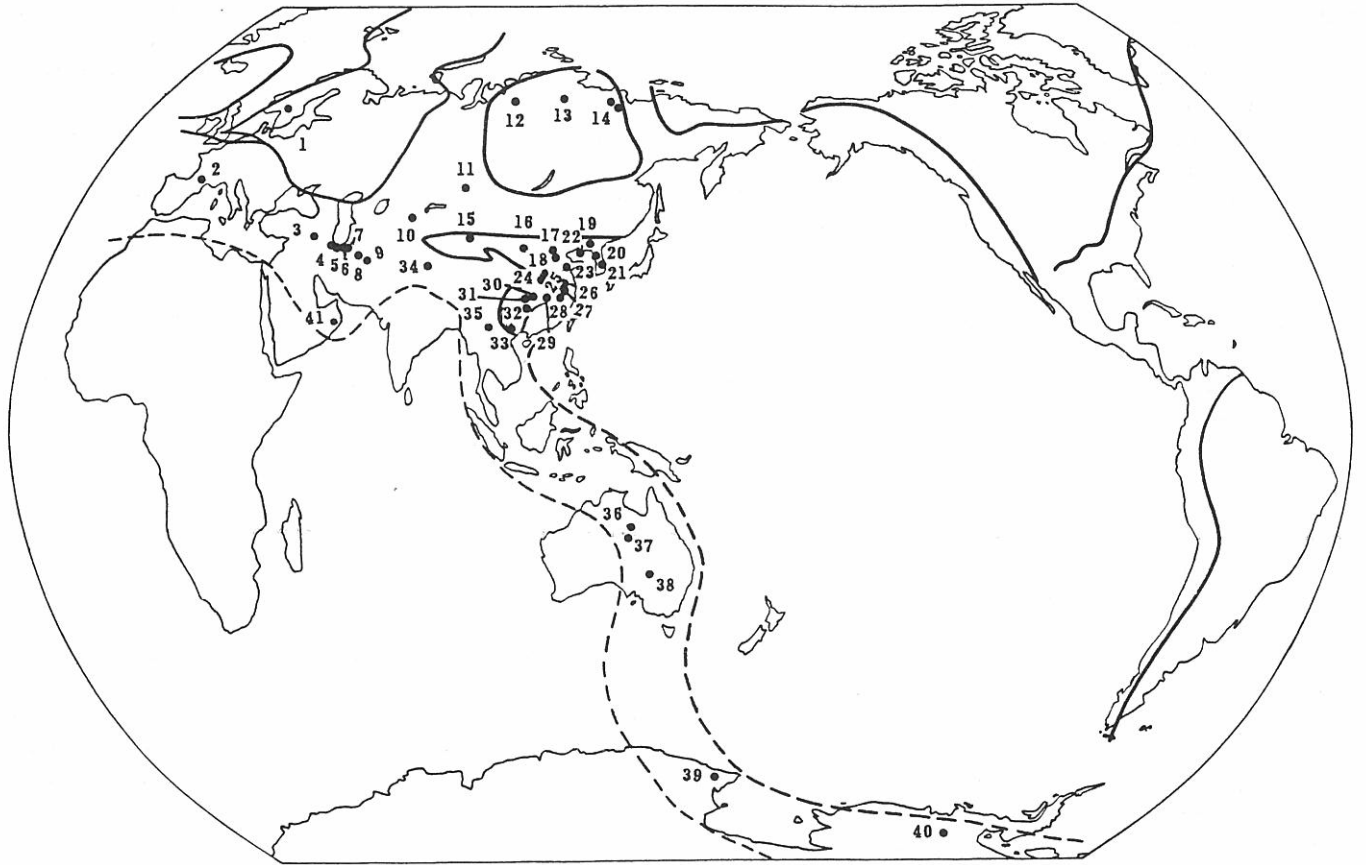
Based on Chinese Early Cambrian Archaeocyathids, Yuan and Zhang (1983) suggested that the Tianshan-

Altai-Great Khingan Geocline (Chang, 1988: fig. 1, Unit VII) should be referred to the Siberian Faunal Province where the Ethmophyllidae flourished. However, the Coscinocyathidae, which dominated the China platform, especially the Southwest China platformal area, are intimately related to the Mediterranean region. Yuan and Zhang (1983) also mentioned that, during the Cambrian, China may have been situated near the equator, and that Siberia and Australia were located within the subtropical zones on both sides of the equatorial region, because of the presence of the Ethmophyllidae also in Australia. Debrenne (1992) suggested three Archaeocyathid faunal provinces, as follows: 1) the Afro-European Province, which may extend to China and Kazakhstan, characterized by Anthomorphaeidae; 2) the Australo-Antarctica Province, with Flindersicyathidae, Metacyathidae and Syringocnemididae; and 3) the Siberian Province, where all these families are represented.

### MIDDLE CAMBRIAN BIOGEOGRAPHY OF THE PERIGONDWANA REALM

(Fig. 2). Although olenelloid trilobites have been found in Morocco, Spain and Germany, Early Cambrian redlichioid trilobites seem to dominate in the Mediterranean region and Central Europe, as mentioned above. During the Middle Cambrian, the Mediterranean region and Central Europe were dominated by Paradoxidoidea, such as *Paradoxides* (*Eccaparadoxides*), *P. (Acadoparadoxides)*, *Luhops* and *Hydrocephalus*, and by European endemic Ptychoparioidea, for instance, *Ptychoparia*, *Sao*, *Jincella*, *Badulesia*, *Conocoryphe*, *Ctenocephalus*, *Solenopleura* and *Solenopleurina*. At the beginning of the Middle Cambrian, genera of eastern Asiatic affinities were entirely absent in the Mediterranean region and Central Europe, except *Dorypyge* which occurred in eastern Turkey, Sweden, Spain and probably South France (Thoral, 1935; Sdzuy, 1961; Dean, 1982). To the east of Turkey and south of the Alpine-Himalayan foldbelt, so far, there are no typical paradoxidoid trilobites in the Middle Cambrian. A Paradoxidoid trilobites fauna including *Eccaparadoxides oelandicus*, *E. insularis*, *E. mongolicus*, *Hydrocephalus carens* and *Solenopleura* sp. has been described and illustrated by Wojcik (*in Dumicz et al.*, 1970), from the Middle Cambrian rocks of the Khobdo region, western Mongolia. Thus I am convinced that an open marine connection existed between western Mongolia and the Paradoxidoid Province, possibly by two routes, one across the Siberian Platform in the north, and the other to the Mediterranean region in the west through Central Asia, the Alborz Mountains in northern Iran, the Caucasus and Turkey, where a deep sea-way existed just north of the margin of Gondwanaland.

Middle Cambrian trilobites of Baltic aspect were evidently indigenous to the deep outermost shelf or upper basin slope, whereas those of western United States, western Queensland, southern Kazakhstan, western parts of the Chiangnan Belt, south China as well as northern



**Figure 3.** Biogeography of *Dameselloidea* trilobites (late Middle to early Late Cambrian). 1. Djupadalen, Västergötland, Sweden. *Palaeadotes*, *Paradamesella* (Westergård, 1947; Daily and Jago, 1975). 2. Montagne Noire, South France. *Palaeadotes* (Feist and Courtessole, 1984). 3. Southeastern Turkey. *Palaeadotes* (Dean, Monod and Perincek, 1981). 4. Qanli Chapoghlu, northern Iran. *Palaeadotes* (Kushan, 1973). 5. Abhar, northern Iran. *Palaeadotes* (Kushan, 1973). 6. Shahmirzad, northern Iran. *Palaeadotes* (Kushan, 1973). 7. Mila Kuh, northern Iran. *Palaeadotes* (Kushan, 1973). 8. Taraka, West Herat, Afghanistan. *Damesella*, *Palaeadotes* (Wolfart, 1983). 9. Surkh Bum, Afghanistan. *Airaspis*, *Blackwelderia* (Wolfart, 1974b). 10. Malyj Karatau, southern Kazakhstan. *Prodamesella*, *Palaeadotes*, *Paradamesops*, *Blackwelderia*, *Paradamesella* (Ergaliev, 1980). 11. Salair, Altai-Sayan, Russia. *Damesella*, *Palaeadotes*, *Paradamesella* (Poletaeva, 1960; Peng, 1987). 12. Norilsk, northern Siberia. *Palaeadotes* (Astashkin *et al.*, 1991). 13. Khatanga, northern Siberia. *Palaeadotes* (Astashkin *et al.*, 1991). 14. Khara-Ulakh, northern Siberia. *Palaeadotes* (Astashkin *et al.*, 1991). 15. Qurug Tagh, Xinjiang, western China. *Damesella*, *Paradamesops*, *Palaeadotes* (Zhang, 1981). 16. Alashan-Zuoqi, Inner Mongolia. *Blackwelderia*, *Drepanura*, *Dorypygella* (Zhou and Zheng, 1980). 17. Northern Shansi, China. *Taitzehoia*, *Stephanocare*, *Damesella* (Zhang and Wang, 1985). 18. Taihang Mountains, North China. *Drepanura*, *Damesops* (Zhang and Wang, 1985). 19. Taizihe, Northeast China. *Drepanura*, *Damesella*, *Blackwelderia*, *Stephanocare*, *Taitzehoia*, *Teinistion*, *Shantungia* (Chang, 1988). 20. North Korea. *Blackwelderia*, *Damesella* (Chang, 1988). 21. South Korea. *Stephanocare*, *Damesella*, *Blackwelderia*, *Drepanura*, *Bergeronites* (Chang, 1988). 22. Liaodong Peninsula, China. *Drepanura*, *Bergeronites*, *Damesella*, *Blackwelderia*, *Dorypygella*, *Teinistion*, *Shantungia*, *Parashantungia*, *Taitzehoia*, *Chiawangella*, *Paramenomonia* (Chang, 1988). 23. Shandong, China. *Drepanura*, *Bergeronites*, *Stephanocare*, *Damesella*, *Blackwelderia*, *Dorypygella*, *Teinistion*, *Shantungia*, *Metashantungia* (Chang, 1988). 24. Western Henan, China. *Drepanura*, *Teinistion*, *Blackwelderia* (Chang *et al.*, 1995). 25. Xichuan, Southwest Henan, China. *Palaeadotes*, *Paradamesops* (Yang *et al.*, 1991). 26. Chuxian, Anhui, China. *Palaeadotes* (Lu and Zhu, 1980). 27. Guichi, Southern Anhui, China. *Paradamesella*, *Palaeadotes*, *Paradamesops* (Qiu *et al.*, 1983). 28. Jiangshan, Zhejiang, China. *Palaeadotes*, *Paradamesella* (Lu and Lin, 1989). 29. Xianfeng, Hubei, China. *Fengduia* (Lu *et al.*, 1974; Chang *et al.*, 1980). 30. Taoyuan, Hunan, China. *Palaeadotes* (Peng, 1987). 31. Western Hunan, China. *Paradamesops*, *Palaeadotes*, *Dorypygella*, *Teinistion*, *Paradamesella*, *Protaitzehoia* (Peng, 1987). 32. Borderland between Hunan and Guizhou, China. *Palaeadotes*, *Protaitzehoia*, *Paradamesella* (Yang, 1978). 33. Southeast Yunnan, China. *Damesella*, *Blackwelderia*, *Drepanura*, *Stephanocare* (Luo, 1984). 34. Zanskar, Ladakh, northern India. *Blackwelderia* (Whittington, 1986; Jell, 1986). 35. Baoshan, western Yunnan, China. *Blackwelderia*, *Palaeadotes*, *Blackwelderoides* (Luo, 1984, 1985). 36. Mungerebar-Mindyalla Area, northwestern Queensland, Australia. *Meringaspis*, *Damesella*, *Palaeadotes*, *Dipentaspis*, *Blackwelderia*, *Stephanocare* (Öpik, 1967). 37. Glenormiston-

and southern parts of Tianshan, Xinjiang (western China) inhabited open-shelf or upper part of the open-shelf facies. Typical paradoxidoid trilobites lived in deep, cool water (Babcock, 1994). Sea level rise resulted in increasing depth of sea-water in the Mediterranean region and Central Europe during the Middle Cambrian time. Paradoxidoidea trilobites were certain to flourish. This was the reason why the warm shallow shelf trilobite faunas of eastern Asiatic affinities entirely disappeared in the Mediterranean region and Central Europe during the Middle Cambrian. This biological event took place perhaps in the late Early Cambrian.

On the North China Platform the warm shallow shelf benthic Middle Cambrian trilobite faunas, including Ptychopariidae, Proasaphiscidae, Sunaspidae, Inouyiidae, Crepicephalidae, Anomocarellidae, Dolichometopidae, Dorypygidae, Lisaniidae and Damesellidae, occurred in limestones, oolitic limestones and shales. A few species of *Peronopsis*, *Hypagnostus*, *Baltagnostus* and *Iniospheniscus* and *Ptychagnostus sinicus* occurred in association with those Middle Cambrian trilobites in the eastern Subprovince of the North China Platform (Chang and Jell, 1987). It deserves to be mentioned that a few eurytopic genera of those polymerid trilobites from North China occurred in the slope biofacies with cosmopolitan agnostid genera in South and western China as well as Australia. They are, primarily *Fuchouia*, *Amphoton*, *Dorypyge*, *Lisania*, *Damesella*, *Blackwelderia* and *Stephanocare*.

In South China, within the slope biofacies the early Middle Cambrian clastics and the late Middle Cambrian carbonate rocks contain many genera and species of Oryctocephalidae and agnostids, such as *Oryctocephalus*, *Ptychagnostus gibbus*, *Ptychagnostus atavus*, *Hypagnostus pavifrons*, *Ptychagnostus punctuosus*, *Goniagnostus nathorsti* and *Lejopyge laevigata* Zones by which the Middle Cambrian zonal standard has been established in Australia, China and Kazakhstan. Some important polymerid genera in the slope biofacies are *Kaotia*, *Oryctocephalus*, *Xystridura*, *Prohedinia*, *Centropleura*, *Fuchouia*, *Wanshan* and early pandemic damesellids. These trilobites both in shallow shelf or slope biofacies are the chief component parts of the Middle Cambrian of the Perigondwana Realm. It should be mentioned that rich agnostid and polymerid trilobites associations in the slope biofacies of the Perigondwana Faunal Realm of Asia may be regarded as the equivalent to the upper part of the open-shelf area, or the carbonate slope apron, whereas the Perigondwanan Mediterranean region represents the lower part of the open-shelf, or the deep outermost shelf during the Middle Cambrian. The absence of Ptychagnostidae and the scarcity of agnostids in general around the Mediterranean region and Central Europe indicates ecological and environmental difference from that of the upper part of the open-shelf area.

*Condylopyge* and *Pleuroctenium* which occurred in the Mediterranean region, Central and Northern Europe, England, Newfoundland and northern and southeastern Siberia probably represent the deep water agnostid trilobites; they have not been found in China. Distribution of agnostid trilobites in China, as with polymerid trilobites, was controlled by depth and temperature; and three different ecologic environments (shallow-shelf, slope biofacies and deep water) can be recognized.

Only 9 genera of agnostids (*Peronopsis*, *Hypagnostus*, *Pseudoperonopsis*, *Ptychagnostus*, *Iniospheniscus*, *Diplagnostus*, *Kormagnostus*, *Formosagnostus* and *Baltagnostus*) have been described and illustrated from the North China Platform (Sun, 1989), but only *Peronopsis* and *Hypagnostus* are abundant in both limestones and shales. The others are few in species and rare.

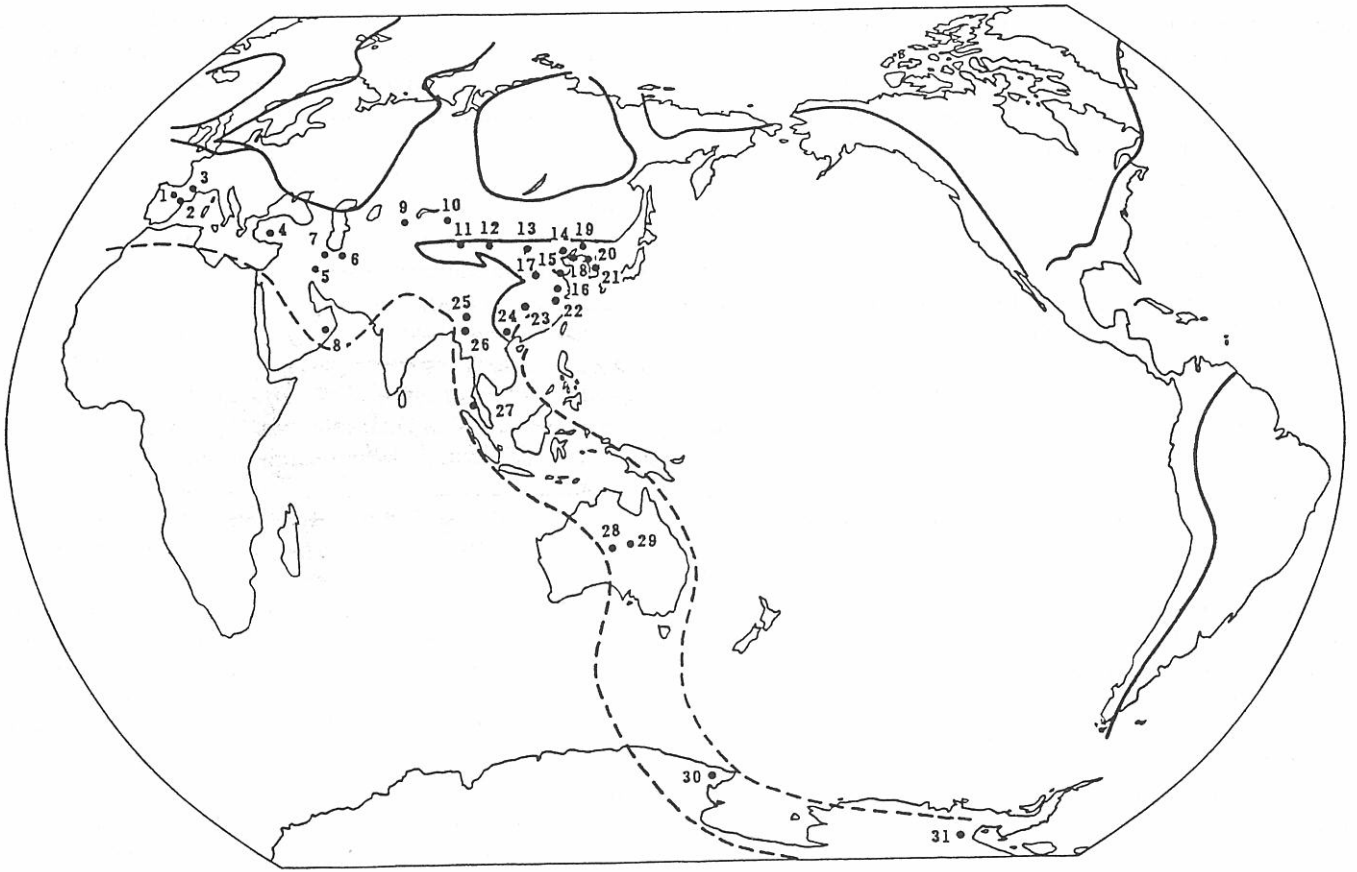
In the Huaqiao Formation at Paibi, Huayuan County, western Hunan, late Middle Cambrian agnostid trilobites of the slope biofacies in the marginal part of the Yangtze Platform (Song, 1989) include 14 genera (*Connagnostus*, *Diplagnostus*, *Linguagnostus*, *Oidalagnostus*, *Proagnostus*, *Clavagnostus*, *Hypagnostus*, *Peratagnostus*, *Valenagnostus*, *Acmahachis*, *Goniagnostus*, *Lejopyge*, *Ptychagnostus* and *Toragnostus*) and 23 species, ranging from the *Ptychagnostus atavus* to *Lejopyge laevigata* Zones. They are quite different from the agnostid trilobites in the shallow-shelf on the North China Platform. It is evident that the controlling factor for the faunal difference is the depth and temperature of sea water.

At Taizimiao, Xinshao County, 240 km southeast of Paibi village, Huayuan County, western Hunan, *Centropleura rotundata* Liu and Zhang, 1979 and *Centropleura angustata* Westergård, 1950 have been discovered in late Middle Cambrian shale beds (Liu and Zhang, 1979; Liu, 1982). Perhaps the two agnostid genera mentioned above will be discovered in the Middle Cambrian shales in this area. A second occurrence of *Centropleura* in China is in northern Tianshan, Xinjiang (Xiang and Zhang, 1985); about 1,260 km east of this site, *Centropleura* also appears in the Beishan area of northern Gansu (Liu and Zhang, 1979). The Perigondwana Realm during the Middle Cambrian includes present-day eastern, central, southern and southeastern Asia, Australia and Antarctica; the Mediterranean region and Central Europe may be affiliated with the Acado-Baltic Faunal Realm.

### BIOGEOGRAPHY OF DAMESELLIDAE (LATE CHANGHIAN AND KUSHANIAN STAGES) TRILOBITES

(Fig. 3). The Damesellidae includes 43 genera belonging to 5 subfamilies. Genera of this superfamily have a narrow to broad-based glabella, preglabellar field

Sylvester Creek Area, northwestern Queensland, Australia. *Cyrtoprora*, *Teinistion*, *Palaeadotes*, *Dipyrgotes* (Öpik, 1967). 38. Western New South Wales, Australia. *Blackwelderia*, *Palaeadotes* (Wang *et al.*, 1989). 39. North Victoria Land, Antarctica. *Palaeadotes* (Cooper *et al.*, 1982). 40. Ellsworth Mountains, Antarctica. *Palaeadotes*, *Damesella* (Jago and Webers, 1992). 41. Qarn Mahatta Humaid, Oman. *Fengduia* (= *Dipyrgotes*, Fortey, 1994).



**Figure 4.** Biogeography of Changshanian and Fengshanian Stages (middle and late Late Cambrian). 1. Logroño and Burgos provinces, northeastern Spain. *Maladioidella*, *Langyashania*, *Lajishanaspis*, *Pagodia* (Shergold, Liñán and Palacios, 1983). 2. Zaragoza province, northeastern Spain. *Parachangshania*, *Pagodia* (Shergold and Sdzuy, 1991). 3. Montagne Noire, South France. *Prochuangia* (Feist and Courtessole, 1984). 4. Sultan Dag, southwestern Turkey. *Maladioidella* (Shergold and Sdzuy, 1984). 5. Bakhtiari Geb., southwestern Iran. *Saukia*, *Chuangia*, *Maladioidella* (King, 1937). 6. Eastern part of the Alborz gebirge, North Iran. *Chuangia*, *Prochuangia*, *Paracoosia*, *Eokaolishania*, *Chuangiella*, *Pagodia*, *Saukia*, *Alborsella*, *Koldiniella*, *Wuhuia*, *Stigmatoa*, *Torifera* (Kushan, 1973; Wittke, 1984). 7. Qanli-Chapoglu, Alborz Mountains, west of Tehran, Iran. *Prochuangia*, *Eokaolishania*, *Luyanhaolia*, *Koldiniella*, *Paracoosia* (Wittke, 1984). 8. Qarn Mahatta Humaid, Oman. *Eosaukia*, *Yokusenia*, *Prochuangia*, *Afghanocare*, *Maladioidella* (Fortey, 1994). 9. Malyj Karatau, southern Kazakhstan. Most genera of the Changshanian and Fengshanian ages are the same as the eastern Tianshan within the Chinese Territory, or as the western Hunan (Ergaliev, 1980; Lin *et al.*, 1990; Peng, 1992). 10. Huocheng, northwestern Xinjiang, western China. *Bulbolenus*, *Lotagnostus punctatus*, *Agnostotes*, *Glyptagnostus reticulatus* (Xiang and Zhang, 1985). 11. Qurug Tagh, central Xinjiang, western China. *Lotagnostus hedini*, *Lotagnostus asiaticus*, *Hedinaspis*, *Prochuangia* (Lin *et al.*, 1990). 12. Beishan, Gansu, western China. *Lotagnostus hedini*, *Charchaqla*, *Hedinaspis*, *Glyptagnostus reticulatus* (Lin *et al.*, 1990). 13. Hangula, western Inner Mongolia, China. *Charchaqla*, *Hedinaspis*, *Diceratopyge*, *Glyptagnostus reticulatus* (Lu *et al.*, 1981). 14. Tangshan, northeastern Hebei, China. *Saukia*, *Ptychaspis*, *Kaolishania*, *Maladioidella*, *Changshania*, *Chuangia* (Zhu and Wittke, 1989). 15. Central Shandong, eastern China. genera of Saukiidae and Ptychaspidae, *Kaolishania*, *Maladioidella*, *Changshania*, *Chuangia* (Chang, 1988). 16. Huainan, Anhui, China. with rocks of Changshanian and Fengshanian ages (Chang, 1988). 17. Dengfeng, central Henan, China. *Changia*, *Changshania*, *Chuangia* (Chang, 1988). 18. Liaodong Peninsula, Liaoning, northeastern China. genera of Saukiidae, Ptychaspidae and Kaolishaniidae, *Changshania*, *Chuangia* (Chang, 1988). 19. Taizihe Valley, Liaoning, northeastern China. genera of Saukiidae, Ptychaspidae and Kaolishaniidae, *Changshania*, *Chuangia* (Chang, 1988; Qian, 1994). 20. Chosan area, North Korea. *Ptychaspis*, *Kaolishania*, *Changshania*, *Chuangia* (Chang, 1988). 21. Southern Korea. genera of Saukiidae, Ptychaspidae and Kaolishaniidae, *Changshania*, *Chuangia* (Chang, 1988). 22. Western Zhejiang, eastern China. *Lotagnostus punctatus*, *L. asiaticus*, *Hedinaspis*, *Charchaqla*, *Lophosaukia*, *Agnostotes* (*Pseudoglyptagnostus*), *Glyptagnostus reticulatus*, *Erinxanium* (Lu and Lin, 1989). 23. Western Hunan, South China. *Lotagnostus*, *Glyptagnostus*, *Agnostotes*, *Stigmatoa*, *Lorrettina*, *Wuhuia*, *Maladioidella*, *Saukia*, *Mictosaukia*, *Lophosaukia*, *Eugonocare*, *Chuangia*, *Pagodia*, *Prochuangia*, *Peichiashania*, *Yuepingia*, *Charchaqla*, *Hedinaspis* (Peng, 1992). 24. Southeastern Yunnan, China. *Chuangia*, *Irvingella*, *Kaolishania*, *Saukia*, *Prosaukia*, *Ptychaspis*, *Pagodia*, (Luo, 1984; Chang, 1988). 25. Batang, western Sichuan,



usually narrow or absent, genal spines of variable length or absent, thorax with 12 segments, pygidium with 2 to 11 pairs of pygidial spines of variable length and smooth or granulose exoskeleton. The origin of this group of trilobites is not known, but it may have evolved from an older ptychoparioid trilobite. This family first appeared in the late Middle Cambrian, approximately in the *Hypagnostus parvifrons*, or *Ptychagnostus punctuosus* Zone (Chang, 1957; Song, 1989), flourished from the *Damesella* Zone to the *Drepanura* Zone, and disappeared entirely at the end of the Kushanian, or Mindyallan. In early 1940s, palaeontologists considered this family confined to eastern and southeastern Asia (Kobayashi, 1941, 1942). In recent years more information has come from many parts of the world (Poletaeva, 1960; Öpik, 1967; Kushan, 1973; Wolfart, 1974b; Daily and Jago, 1975; Ergaliev, 1980; Dean *et al.*, 1981; Feist and Courtessole, 1984; Jell, 1986; Whittington, 1986; Kobayashi, 1987b; Astashkin *et al.*, 1991; Jago and Webers, 1992; Fortey, 1994). Therefore, a wide geographical distribution is known. It includes not only eastern and southeastern Asia but also central and south Asia, (Kazakhstan, Himalaya, Afghanistan, Iran, Oman), Salair (southwestern Siberia), northern Siberia, Turkey, Sweden, South France, Australia and Antarctica. Except Sweden and northern Siberia, all areas fitted in with the Perigondwana Realm during the late Middle to early Late Cambrian.

Most genera of the Damesellidae lived on the warm shallow-shelf of the North China Carbonate Platform, whereas those within the Chiangnan Belt inhabited the open-shelf biofacies. The former include *Damesella*, *Blackwelderia*, *Stephanocare*, *Fengduia*, *Parablackwelderia*, *Prodamesella*, *Taitzuheia*, *Liuheaspis*, *Pingquania*, *Pionaspis*, *Xintaia*, *Taihangshania*, *Guancenshania*, *Drepanura*, *Bergeronites*, *Teinistion*, *Dorypygella*, *Shantungia*, *Metashantungia*, *Parashantungia*, *Chia-wangella*, *Paramenomonia*, *Jiawangaspis*, *Haibowania*, *Eodamesella*, *Blackwelderiella* and *Neoblackwelderia* (65% of this family); the latter comprise *Dipyrgotes*, *Dipentaspis*, *Meringaspis*, *Paradamesops*, *Paradamesella*, *Protaitzuheia*, *Cyrtoprura*, *Palaeadotes*, *Pseudobergeronites* and *Histiomona* (about 35% of the Family Damesellidae), which are entirely absent in the shallow-shelf area of the North China Platform. Some platform eurytopic genera, i.e., *Damesella*, *Blackwelderia*, *Prodamesella*, *Stephanocare*, *Teinistion* and *Dorypygella*, may also occur in the slope biofacies. *Palaeadotes* has a wide geographic distribution in the slope biofacies, or

open-shelf area of China (Chiangnan Belt, western Yunnan and Qurugtagh of Xinjiang), Australia, Antarctica (North Victoria Land, Ellesworth Mountains), Kazakhstan, Salair (southwestern Siberia), northern Siberia, northern Iran, eastern Turkey, southern France and southern Sweden. A similar case is *Paradamesella* which has been found in western Hunan, southern Anhui, Salair, southwestern Siberia and Southern Sweden (Chang, 1996). *Drepanura* and *Bergeronites* are endemic genera confined to the warm shallow-shelf area of the North China and Yangtze Platforms. No genus of this superfamily immigrated into the Mediterranean region, or Central Europe, during the late Middle Cambrian.

### LATE CAMBRIAN (CHANGSHANIAN AND FENGSHANIAN) BIOGEOGRAPHY OF THE PERIGONDWANA REALM

(Fig. 4). Cambrian biogeography of the Perigondwana Realm for the middle and late Upper Cambrian should be defined on the Leiostegeoidea (*Chuangia*, *Prochuangia*, *Kaolishania*, *Paichiashania*, *Pagodia*), Ptychaspidoidea (*Ptychaspis*, *Changia*, *Saukia*, *Prosaukia*, *Mictosaukia* and other saukiid genera) and *Yokusenian*, *Paracoosia*, *Changshanocephalus*, *Parachangshania*, *Maladioidella*, *Wuhuia* and *Lorrettina*. These genera mentioned above inhabited the shallow-shelf area of the North China Platform. *Chuangia*, *Prochuangia*, *Yokusenian*, *Paracoosia*, *Changshanocephalus*, *Kaolishania* and *Maladioidella* are Changshanian, while other genera are of the Fengshanian. *Pagodia*, *Wuhuia* and *Lorrettina* have a stratigraphic range from Changshanian to Fengshanian.

Trilobites faunas which lived in the open-shelf area are *Stigmatoa*, *Erixanium*, *Paraacidaspis*, *Archikainella*, *Hedinaspis*, *Charchaquia*, *Irvingella*, *Lophosaukia*, *Olenaspella*, *Eugonocare*, *Pseudeugonocare*, *Euloma* (*Archaeuloma*), *Shergoldia*, *Glyptagnostus*, *Rhaptagnostus*, *Agnostotes*, *A. (Pseudoglyptagnostus)* and *Lotagnostus punctatus*. Genera in the open-shelf area of Gondwana and Perigondwana were distributed in China, Australia, southeast Asia, Iran and Oman. A few Changshanian genera of eastern Asiatic affinities, for instance, *Maladioidella*, *Prochuangia*, *Pagodia*, *Lajishanaspis*, *Langyashania*, *Parachangshania* and *Olentella*, may occur in Turkey, South France, Spain or Morocco. So far, there is no record of Fengshanian trilobites in the Mediterranean region or Central Europe. Late Cambrian (Kushanian to Fengshanian) trilobites of eastern Asiatic affinities have

China. *Mictosaukia*, *Haniwa* (Chang, 1988). 26. Paoshan, western Yunnan, China. *Chuangia*, *Kaolishania*, *Mansuyia*, *Changia*, *Lophosaukia*, *Mictosaukia* (Luo, 1985; Chang, 1988). 27. Tarutao Island, Thailand. *Prosaukia*, *Lichengia*, *Eosaukia*, *Lophosaukia*, *Changia*, *Parakoldinioidia*, *Shergoldia* (Shergold *et al.*, 1988). 28. Amadeus Basin, Northern Territory, Australia. *Eosaukia*, *Mictosaukia*, *Sinosaukia*, *Platysaukia*, *Lichengia*, *Thailandium*, *Changia*, *Shergoldia*, *Mansuyia* (Shergold, 1991). 29. Bouliia and Duchess, western Queensland, Australia. *Lophosaukia*, *Kaolishania*, *Mansuyia*, *Kaolishaniella*, *Wuhuia*, *Lorrettina*, *Maladioidella*, *Taishania*, *Prosaukia*, *Wentsuia*, *Eugonocare*, *Stigmatoa*, *Erixanium*, *Agnostotes*, *Prochuangia*, *Peichiashania* (Öpik, 1963; Shergold, 1971, 1980). 30. North Victoria Land, Antarctica. *Prochuangia*, *Stigmatoa*, *Olentella*, (Shergold *et al.*, 1976; Shergold and Cooper, 1985; Cooper *et al.*, 1982). 31. Ellsworth Mountains, West Antarctica. *Stigmatoa*, *Erixanium*, *Eugonocare*, *Changshanocephalus*, *Prochuangia*, (Shergold and Webers, 1992).

been recorded from Iran and Oman, both to the east of the Mediterranean region (King, 1937; Kushan, 1973; Wolfart, 1974b; Wittke, 1984; Fortey, 1994).

Judging from the distribution of eastern Asiatic trilobite genera in the Mediterranean region during the Late Cambrian, gradually lowering of sea level took place at the end of the late Middle Cambrian, and trilobites of eastern Asiatic affinities withdrew completely from southern Europe at the beginning of the Fengshanian.

### THE BOUNDARY BETWEEN THE PERIGONDWANA AND THE ACADO-BALTIC FAUNAL REALMS DURING THE EARLY AND LATE CAMBRIAN IN WESTERN EUROPE

As mentioned above, Early Cambrian redlichoid trilobites have been found in Morocco, Spain, South France, Sardinia and Germany (Doberlug and Görlitz). About 200 km south of Doberlug is Central Bohemia where neither redlichoid nor olenelloid trilobites have been found; ca. 620 km east of Doberlug are the Holy Cross Mountains of Poland where the Cambrian rocks are situated on the southern marginal part of the East European Platform and trilobite faunas including Early to Late Cambrian are of typical Acado-Baltic type; about 400 km north of Doberlug is the southern marginal parts of Scandinavia which is the nominate site for the typical Cambrian Acado-Baltic faunas. As mentioned earlier, Doberlug is the northernmost locality for the redlichoid *Dolerolichia* in Europe, and Görlitz for the Early Cambrian trilobite *Ferralsia* which is probably a junior synonym of the Chinese *Palaeolenus*.

From the tectonic map of western Europe (Naylor and Mounteney, 1975), the western and southwestern margins of the Eastern European Platform were surrounded by Caledonides. To the south, the margin of the Caledonian chain is abruptly terminated by the cross-cutting folds of the west-east younger Hercynian chain. Doberlug and Görlitz are situated just south of the boundary between the Caledonian and the Hercynian Belts. This boundary may represent the northern margin of the Mediterranean region, or Perigondwana Realm, during the Early and Late Cambrian in western Europe, because on both sides of this boundary there are different Early and Late Cambrian trilobite faunas, as well as Ordovician trilobites and acritarchs (Li, 1987; Zhou and Dean, 1989). This boundary may be regarded as equivalent to the "Torquist Sea" in western Europe already mentioned by Cocks and Fortey (1982) and Fortey and Cocks (1988).

### CAMBRIAN PALAEOGEOGRAPHY OF THE NEAR AND MIDDLE EAST

Fortey (1994) described the Late Cambrian trilobites of Oman and provided a simplified Cambrian palaeogeographic map of the Near and Middle East. It shows a continuous depositional pattern of continental or

littoral shallow-shelf limestone, sandstone and dolomite; open-shelf limestone and marl, and deep water shale and sandstone areas within a distance of 1,650 km in the west and 2,500 km in the east from the Arabian Peninsula northward to Turkey, or northeastward to the northern border between Iran and Afghanistan. Trilobite faunas of Oman, southwest Iran, northern Iran and Turkey represent to each of the depositional environments mentioned above. For example, *Torifera*, *Fengduia* (= *Dipyrgotes*), *Paracoosia*, *Prochuangia*, *Maladioidella*, *Yokusenia* and *Eosaukia* from Oman, and *Redlichia* and ptychopariid trilobites from southwest Iran, are all of the shallow-shelf biofacies of the Perigondwana Realm, whereas *Palaeadotes*, *Dorypyge* and *Cheildonocephalus* from the Alborz Mountains of northern Iran are of slope or open-shelf biofacies. *Protolenus*, *Paradoxides* and *Badulesia* in Turkey are of deep water biofacies. This continuous distribution of the Cambrian litho- and biofacies in the Near and Middle East convinces me that a wide Tethyan Ocean did not exist in the Early Palaeozoic as I have argued repeatedly (Chang, 1980, 1987, 1989). From faunal evidence, a relatively narrow and deep geoclinal belt existed which extended from southern Europe, eastward through Turkey, northern Iran or the Caucasus, and northern Afghanistan to the Himalayan region (Jell, 1986; Whittington, 1986; Reed, 1910). This belt may be connected with the eastern Australian geoclinal belt and the transitional belt between eastern and western Antarctica, via southeast Asia. Judging by the thick sequences of Cambrian sandstone and evaporites on the margins of Gondwana in the Middle East, it is possible that West Yunnan and Malay Peninsula, Iran, Afghanistan, Pakistan and Burma may be also parts of Gondwanaland.

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