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PHANEROZOIC PALEOENVIRONMENT AND PALEOLITHOFACIES MAPS. EARLY PALEOZOIC

Mapy paleośrodowiska i paleolitofacji fanerozoiku. Wczesny paleozoik

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Abstracts: The paper presents the detailed plate tectonic, paleogeographic, paleoenvironment and plaeolithofacies maps for eight Early Paleozoic time intervals. Forty maps, generated using PLATES and PALEOMAP programs, contain information about plate tectonics, paleoenvironment, and plaeolithofacies during Cambrian, Ordovician and Silurian. Disintegration of supercontinent Pannotia and origin of Gondwana, Laurentia and Baltica occur during Early Cambrian. Oceans spreading continued during Late Cambrian and Early Ordovician; vast platform flooded by shallow seas existed on the continents. The plate tectonic reorganization happened during Middle Ordovician. Silurian was a time of Caledonian orogeny, closing of Early Paleozoic oceans and origin of supercontinent Laurussia as a result of Laurentia and Baltica collision. Information contained within global and regional papers were posted on the maps and the detailed paleoenvironment and plaeolithofacies zones were distinguished within the platforms, basins and ridges.

Keywords: Cambrian, Ordovician, Silurian, plate tectonics, paleogeography

Treść: Artykuł przedstawia szczegółowe mapy paleogeograficzne dla ośmiu przedziałów czasowych w obrębie wczesnego paleozoiku. Czterdzieści map, skonstruowanych przy użyciu programów PLATES i PALEOMAP, zawiera informacje dotyczące tektoniki płyt, paleośrodowiska i paleolitofacji w czasie kambru, ordowiku i syluru. We wczesnym kambrze nastąpił rozpad superkontynentu Pannotia i utworzyły się kontynenty: Gondwana, Laurencja, Bałtyka i Syberia. W późnym kambrze i wczesnym ordowiku w dalszym ciągu ma miejsce spreding oceanów, istnieją też w tym czasie rozległe platformy zalane przez płytkie morza na kontynentach. Reorganizacja płyt litosfery nastąpiła w środkowym ordowiku. Sylur był okresem orogenezy kaledońskiej, zamknięciem wczesnopaleozoicznych oceanów i powstania superkontynentu Laurosji z połączenia Laurencji i Bałtyki. Informacje zawarte w szeregu globalnych i regionalnych prac zostały naniesione na mapy, a w obrębie platform, basenów i grzbietów wydzielono poszczególne strefy paleośrodowiskowe i paleolitofacjalne.

Słowa kluczowe: kambr, ordowik, sylur, tektonika płyt litosfery, paleogeografia

INTRODUCTION

The aim of this paper is the presentation of Early Paleozoic paleographic maps of the world, containing paleoenvironment and paleolithofacies details. In the previous papers (Golonka 2007a, b, c), the author presented global paleogeographic maps for Late Paleozoic and Mesozoic. Now, the author attempts to cover the entire Phanerozoic in four papers. This paper is dealing with the Cambrian (three time slices), Ordovician (three time slices), and Silurian (two time slices). The maps were constructed using a plate tectonic model, which describes the relative motions between approximately 300 plates and terranes. The detailed reconstruction methodology was described previously in Golonka *et al*. (2003) paper. The rotation file was presented in Golonka's (2007a) paper, online version, the appendix. The facies were assembled according to rules established during the production of Phanerozoic reefs map (Kiessling *et al*. 1999 2003) and also presented by Golonka *et al*. (2006b, c) and Golonka (2007a, b, c).

MAP DISCUSSION

Early Cambrian

The Proterozoic paleogeographic history is defined by two major orogenies (Pisarevsky *et al*. 2008). The Grenvillian orogeny around 1100 Ma is related to the formation of supercontinent Rodinia (Dalziel 1991, Hoffman 1991). The Cadomian/Pan-African orogeny is related to the assembly of the supercontinent Pannotia (Dalziel *et al*. 1994, Dalziel 1997, Golonka 2000, Golonka *et al*. 2006a, b) around the Precambrian-Cambrian boundary. More than 500 hundred million years between these two events allows assuming two full Wilson orogenic cycles during this time. It allows also many different, speculative paleogeographic approaches, causing lively discussion. Pannotia supercontinent is not so badly constrained, however it was short lived. Its history resembled somewhat the history of Pangea. Both Gondwana and Baltica were included in the Pannotia supercontinent (Golonka *et al*. 2006b). The continents forming the core of Gondwana include South America, Africa, Madagascar, India, Antarctica and Australia. The location of numerous smaller continental blocks that bordered Gondwana is less certain. The following were adjacent to Gondwana at some time during the Paleozoic: Yucatan, Florida, Avalonia, central European (Cadomian) terranes between the Armorica and Bohemian Massif, Moesia, Iberia, Apulia and the smaller, southern European terranes, central Asian terranes (Karakum and others), China (several separate blocks), and the Cimmerian terranes of Turkey, Iran, Afghanistan, Tibet and Southeast Asia (Fig. 1). Outside Gondwana three continental plates: Laurentia, Baltica and Siberia were already distinguished during the Earliest Paleozoic (Scotese & McKerrow 1990, van der Voo 1993, Golonka *et al*. 1994 2006b, Lewandowski 2003, Cocks & Torsvik 2005 2007, McCausland *et al*. 2007) (Fig. 1).

The Laurentian continent included major parts of North America, northwest Ireland, Scotland, Greenland, and Chukotka peninsula (Golonka 2000, 2002, Ford & Golonka 2003, Golonka *et al*. 2003) (Figs 1, 2 on the interleaf).

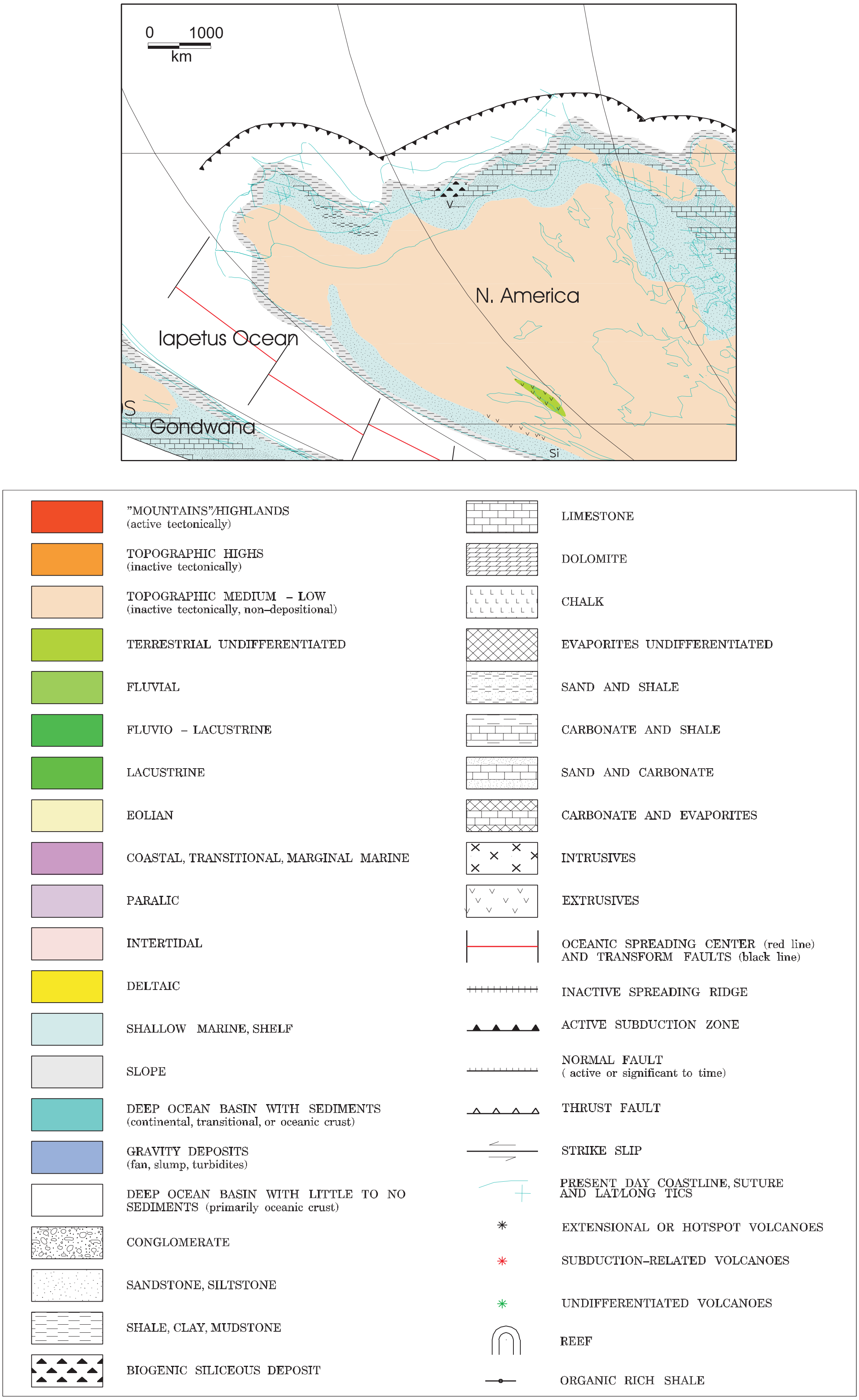

Fig. 2. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Early Cambrian time. Explanations to figures: 2–5, 7–10, 12–15,17–20, 22–25, 27–30, 32–35, 37–40. Qualifiers: B – bauxites/laterites, C – coals, E – evaporites, F – flysh, Fe – iron, G – glauconite, M – marls, O – oolites, P – phosphates, R – red beds, Si – silica, T – tillites, V – volcanics

Fig. 2. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji i i przyległego oceanu Iapetus we wczesnym kambrze. Objaśnienia do figur: 2–5, 7–10, 12–15, 17–20, 22–25, 27–30, 32–35, 37–40. Oznaczenia literowe: B – boksyty/lateryty, C – węgle, E – ewaporyty, F – flisz, Fe – żelazo, G – glaukonit, M – margle, O – oolity, P – fosfaty, R – utwory czerwone, Si – krzemionka, T – tillity, V – utwory wulkaniczne

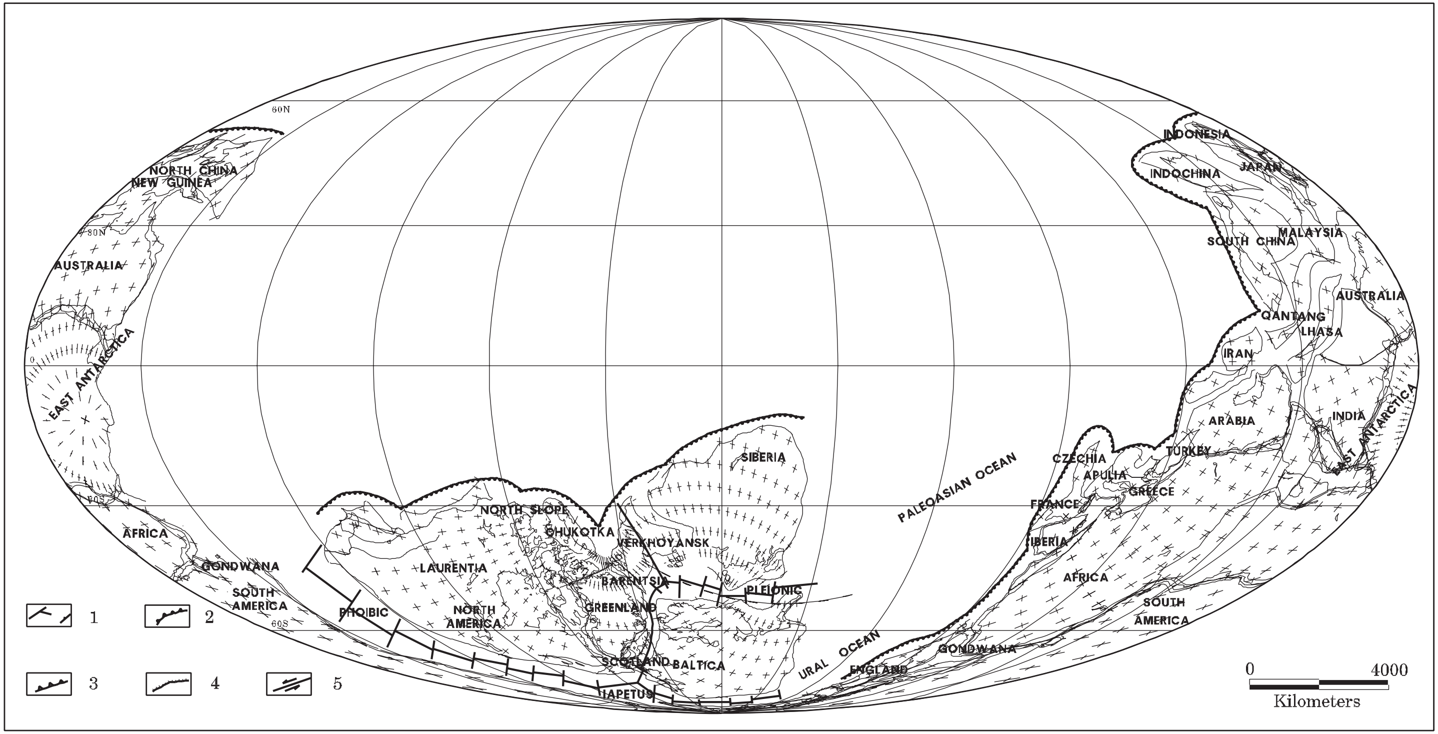

Fig. 1. Plate tectonic map of Early Cambrian (plates position as of 544 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 1. Mapa tektoniki płyt wczesnego kambru (pozycja płyt 544 milionów lat temu. Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

Laurentia rifted away from Pannotia along future Iapetus Ocean during Vendian time and along the Ouachita Ocean during Cambrian time (van der Voo 1993, Golonka *et al*. 2006c, Toelle & Sitchler 2008). At that time uplifts developed on the Laurentian craton and low-land conditions dominated there. Sedimentary basins were located only in the marginal zones (Ronov *et al*. 1984, Garzione *et al*. 1997, Dumoulin *et al*. 2000, Ford & Golonka 2003, Geldon 2003, Golonka *et al*. 2003). The largest one was in the north, in the Peri-Innuitian zone, where low-thick sandy deposits were formed at shallow conditions. Northwards they changed to carbonate deposits of larger thickness 2000 m and more (Trettin & Balkwill 1979, Trettin 1987, 1989, 1994, 1998, Trettin *et al*. 1987, Long 1989, Estrada *et al*. 2003). In the eastern regions of Greenland shelf carbonate deposits were accumulated (Harland 1979, Henriksen & Higgins 2000, Golonka *et al*. 2003, Smith *et al*. 2004). A large amount of coarse-fragmented rocks is present in the Lower Cambrian rocks of the Peri-Cordilleran zone (Stewart & Poole 1974, Mellen 1977, Chafetz 1980, Garzione *et al*. 1997, Golonka *et al*. 2003). However, besides terrigeneous rocks thick layers of shelf carbonates are also known there. The total thickness of deposits is usually large and exceeds 2–3 km. Lithological data indicate that this marginal zone has undergone tectonic differentiation and relatively high tectonic activity (Kluth & Coney 1981, Kluth 1986). Data on plateau basalts which erupted in Utah and Nevada also support this idea (Larson *et al*. 1985, Harper & Link 1986, Keiner 1998, Geldon 2003). The thickness of amygdaloid basalts is tens to hundreds meters. These data indicate that conditions of marginal-continental orogenesis existed there. Subsidence as well as mafic and persilic volcanism were typical for the Peri-Appalachian zone in the Early Cambrian (Brett *et al*. 1990, Feiss *et al*. 1993, Keppie *et al*. 1997, Murphy & Keppie 2005, Murphy *et al*. 2008, Schulz *et al*. 2008). Sedimentary complex in the southern part of the zone is formed by coarse-fragmented rocks of marginal marine and continental facies, while in the northern part it includes marine sandstones and schists; basalts and rhyolites of Macdonalds-Brook are also known there, it is likely that their formation was associated with rifting at the early stage of the Iapetus paleoocean (Murphy *et al*. 1985, Cawood *et al*. 2001, Golonka 2002, Ford & Golonka 2003, Golonka *et al*. 2003 2006c, McCausland *et al*. 2007, Murphy & Nance 2008).

The paleocontinent of Siberia (Figs 1, 3) was bounded on the west by the Urals and the Irtysh foldbelts, in the south by the Amurian (Mongolian) terranes and ophiolitic belts, and on the northeast by the Verkhoyansk fold belt. The relative positions of Laurentia, Baltica and Siberia are somewhat uncertain. Numerous small plates existed between Baltica, Siberia and Gondwana in the Paleoasian Ocean (Zonenshain *et al*. 1990, Pechersky & Didenko 1995, Dobretsov *et al*. 2003, Safonova 2008). These plates were later accreted to different continents. Drifting between Siberia and East Gondwana took place after 725 Ma. The Baikalian and Cadomian-Timanian orogenies took place at the end of the previous Vendian stage (Zonenshain *et al*. 1990, Dobretsov & Buslov 2004). The craton of Siberia (Fig. 3) was almost entirely covered by sea and was the largest sedimentary basin of the Early Cambrian, where carbonate sedimentation dominated (Ronov *et al*. 1984, Kobayashi 1987, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Mel'nikov & Konstantinova 2005, Peryt *et al*. 2005, Kouchinsky *et al*. 2007, Khomentovsky 2008). Maximal thickness of the Lower Cambrian was formed in depressions which appeared at continuations of the neighboring mobile belts (Khantay, Irkineyevo and Urin troughs), in zones of subsidence at the craton margins (Peri-Yenisei, Peri-Sayan, Peri-Baikal, Berezova, Yudoma, Lena Troughs), as well as in the inner troughs (Central and Sukhana). Thickness of the Lower Cambrian rocks in these depressions is as large as hundreds of meters. The southern, south-western and central parts of the craton formed a giant, semi-closed salt--bearing basin with the maximal thickness of deposits up to 2 km. Potash salt was deposited in the Irkutsk basin, which was bordered from the east by a band of barrier reefs oriented north-north-westwards and cutting the middle coarse of the Lena River. Eastwards, low-thick bituminiferous calcareo-argillaceous formations were deposited under the conditions of non-compensated subsidence in relatively deep Sukhana and Yudoma troughs and in the Taimyr peninsula (Bogdanov *et al*. 1998, Sekretov 1999, Metelkin *et al*. 2005, Gee *et al*. 2006).

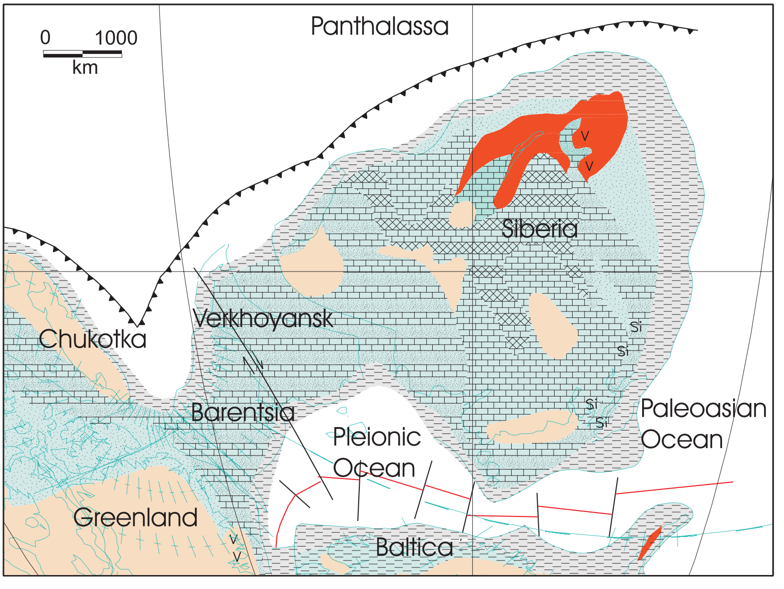

Fig. 3. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Early Cambrian time

Fig. 3. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich we wczesnym kambrze

The Baltica consisted of a major part of northern Europe; it was bounded on the west by the Iapetus suture, on the east by the Ural suture, on the south by the Variscan/Hercynian suture, and on the southwest by a suture located close, but not quite along the Teisseyre–Tornquist line (Golonka 2000, 2002). The Cadomian orogeny in Europe caused the deformation and magmatic events of terranes from Iberia through Armorica. The Baltica (Eastern Europe) might have collided with the Cadomian part of Gondwana during the Vendian time causing deformation in the Timan area and proto-Uralian area. The Pechora--Timan belt and fragments of Ural, Novaya Zemlya and Taimyr (Olovyanishnikov *et al.* 1997, Puchkov 1997, Roberts *et al*. 1997, Vernikhovsky 1997, Roberts & Siedlecka 2002, Gee *et al*. 2006) are equivalent of the Cadomian belt (Golonka 2000, 2002, Golonka *et al*. 2003). The connection between Siberia, the Verhoyansk (Kolyma-Okhotsk-Chersky or Kolyma-Omolon) terranes (northeastern Russia) and Barentsia (Svalbard and adjacent part of the Barents Sea) remain very speculative. At the same time, rifting occurred along the other Baltica border related perhaps to the opening of the Iapetus Ocean (Poprawa *et al*. 1999, Poprawa 2006). In the Lower Cambrian time sedimentary basins often changed their shapes (Ronov *et al*. 1984, Nikishin *et al*. 1996, Ford & Golonka 2003, Golonka *et al*. 2003). Vast territories were occupied by the Baltic-Moscow basin in the central part of the craton and the Scandinavian basin in the north-western part of it; the map (Fig. 4) shows the maximal size of their flooding by the sea. Argillaceous deposits with the total thickness of first tens of meters, in rare cases up to 150–200 m, dominated in the first basin. It is likely that at the beginning of the epoch the basin was connected with the Urals basin (Puchkov 1996, 1997). Sandy rocks with the thickness up to 100 m dominated in the Scandinavian basin (Møller & Friis 1999, Giese & Koppen 2001, Ford & Golonka 2003, Golonka *et al*. 2003).

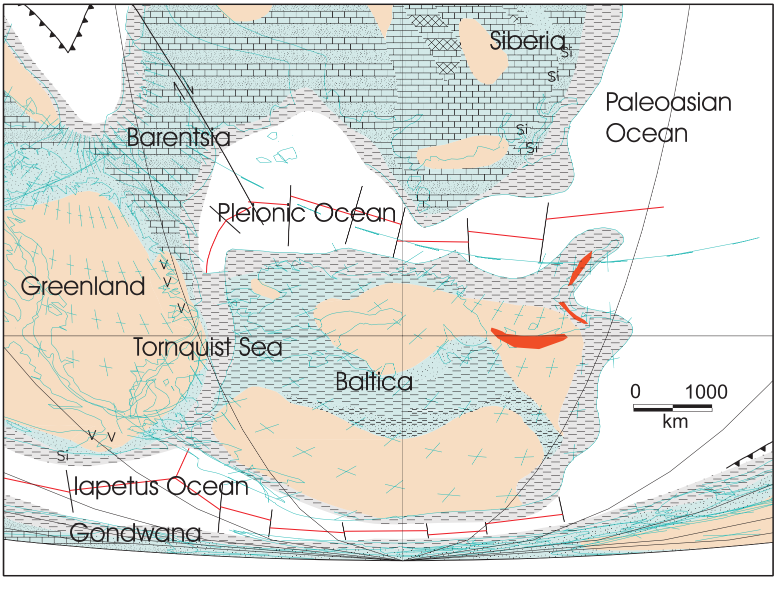

Fig. 4. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Early Cambrian time

Fig. 4. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki i obszarów sąsiednich we wczesnym kambrze

The South China plate (Fig. 5) includes southern part of China and northeastern fragment of Vietnam. It is separated from North China by the Quingling-Dabie suture, from Indochina by Song Ma suture, from Sibumasu terrane by the Ailaoshan suture, from Songpan-Ganzi accretionary complex by the Longmenshan suture (Nie *et al*. 1990, Metcalfe 1998, Golonka *et al*. 2006b). The southeastern margin of South China is a passive margin connected to South China Sea by extended continental crust. To the east, South China plate is bordered by the Taiwan foldbelt and the Okinawa trough passive margin. According to Jishun (1996), the plate was finally formed between 1000–800 Ma with significant tectonothermal events of 2600–24000 Ma and 1900–1700 Ma. According to Yin & Nie (1996), the amalgamation of the western South China (the Yangtze plate) and eastern South China (the Hunan plate) happened during the Latest Precambrian. According to Charvet *et al*. (1996), these plates were welded during a Late Proterozoic orogeny of collisional type. This collision was completed at about 770–800 Ma, earlier than the Pan--African Orogen.

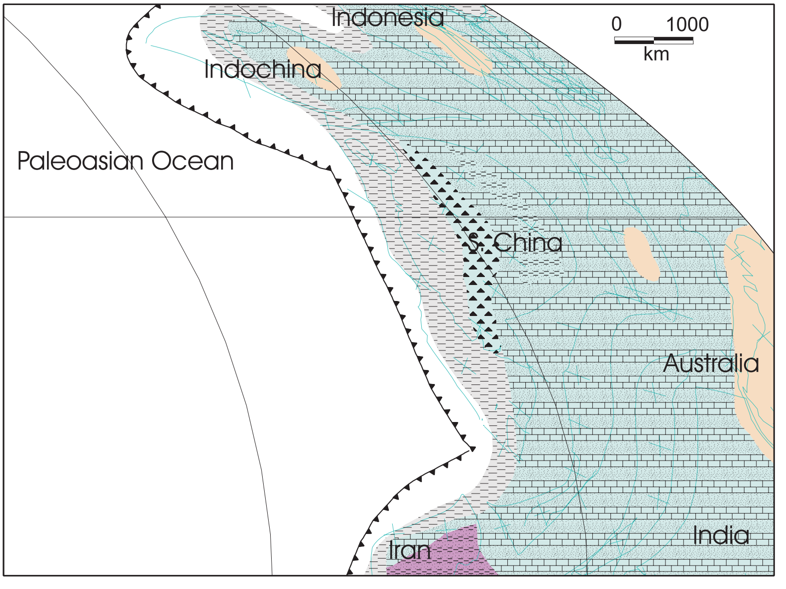

Fig. 5. Plate tectonic, paleoenvironment and lithofacies map of China, Indochina and adjacent areas during Early Cambrian time

Fig. 5. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indochin oraz obszarów sąsiednich we wczesnym kambrze

Figure 5 depicts the position of Indochina, South China and adjacent areas within the northeastern part of Gondwana north of Paleoequator. Mixed carbonate/clastics facies are present in the margins, on Chinese and South-East Asian terranes and eastern Australia (Ronov *et al*. 1984, Cook 1990, Shouxin & Yongyi 1991, Golonka 2000, 2002, Kiessling *et al*. 2003, Veevers 2003, 2004, Collins & Pisarevsky 2005, Glen 2005, Golonka *et al*. 2006b, Mei *et al*. 2006, Wang *et al*. 2007, Ma *et al*. 2008). Almost all territory of the South China craton was covered by the sea in the Early Cambrian; the only exception was the Jangnan ridge which separated the inner basin from the trough of the south-eastern China. Sedimentation of littoral and shelf limestones, dolomites and argillites dominated in the upper Yangtze sedimentary basin. Phosphorite-bearing formation as well as the formation of black shales were distinguished in the northern part of the basin (Tianfu *et al*. 1999, Shi

& Hu 2005, Steiner *et al*. 2005, Jiang *et al*. 2007, Zhang *et al*. 2008). A fraction of terrigenous rocks increased south-eastwards. Usually the total thickness of the Lower Cambrian deposits is few hundreds meters, however in some depressions it can be as large as 1 km and more. Subsidence and marine sedimentation are known during the Cambrian only in northern India (Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Sea boundary gradually moved northwards and in the coastal zone marine facies changed to continental. Thickness of marine terrigeneous and carbonate deposits of the Lower Cambrian in the Lesser Himalayas is 400–500 m.

Middle Cambrian

Laurentia rapidly drifted northward and rotated counter-clockwise, reaching low latitudes (Scotese & McKerrow 1990, Golonka *et al*. 1994, 2006c, Cocks & Torsvik 2005, 2007, McCausland *et al*. 2007) (Figs 6, 7). Subsidence progressed in the Peri-Appalachian and Peri-Cordilleran zones, and marine basins became larger (Stewart & Poole 1974, Mellen 1977, Chafetz 1980, Brett *et al*. 1990, Garzione *et al*. 1997, Keppie *et al*. 1997, Ford & Golonka 2003, Golonka *et al*. 2003, Murphy & Keppie 2005, Murphy *et al*. 2008, Schulz *et al*. 2008). The most pronounced transgression was in the Peri-Cordilleran zone. In that epoch, sea boundary migrated there many times and mainly sedimentary rocks were deposited there in the wide coastal zone. Further to the west they changed to more thin argillaceous and carbonate deposits of an increased thickness, which was as large as 1 km (Rowell *et al*. 1979). In the northern part of the zone, a basin with high-salinity waters existed; salt- and gypsum-bearing formation of Salinia River and Samgvin were deposited there at the end of the Middle Cambrian. The similar pattern of facies and deposits thickness was found for the Peri-Appalachian zone; however in this region volcanism was developed indicating that extension and rifting existed there being associated with a continuing opening of the Iapetus paleo-ocean (Murphy *et al*. 1985, Cawood *et al*. 2001, Golonka 2002, Ford & Golonka 2003, Golonka *et al*. 2003, 2006c, McCausland *et al*. 2007, Murphy & Nance 2008). In the northern and north-eastern parts of the craton, in the basins of the Peri-Innuitian zone, sandy deposits changed to carbonate and terrigeneous-carbonate. Their thickness is not large and exceeds 800 m only in the south-eastern part of Ellesmere Island (Trettin & Balkwill 1979, Trettin 1987, 1989, 1994, 1998, Trettin *et al*. 1987, Long 1989, Estrada *et al*. 2003).

General paleogeography of the Siberian craton was inherited from the previous epoch (Figs 7, 8). The larger part of deposits of this huge basin consisted of carbonates (Ronov *et al*. 1984, Kobayashi 1987, Zonenshain *et al*. 1990, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Mel'nikov & Konstantinova 2005, Kouchinsky *et al*. 2007, Khomentovsky 2008). Sedimentation area became smaller. By the end of the Middle Cambrian, non-compensated Sukhansk and Yudomsk depressions were filled by sediments; thickness of deposits did not exceed 1.5 km there. Regression was developed in the Aldan shield.

In the Peri-Urals zone in Baltica, the Middle Cambrian deposits are unknown (Ronov *et al*. 1984, Puchkov 1991, 1996, 1997). Regression developed there at that time (Fig. 9).

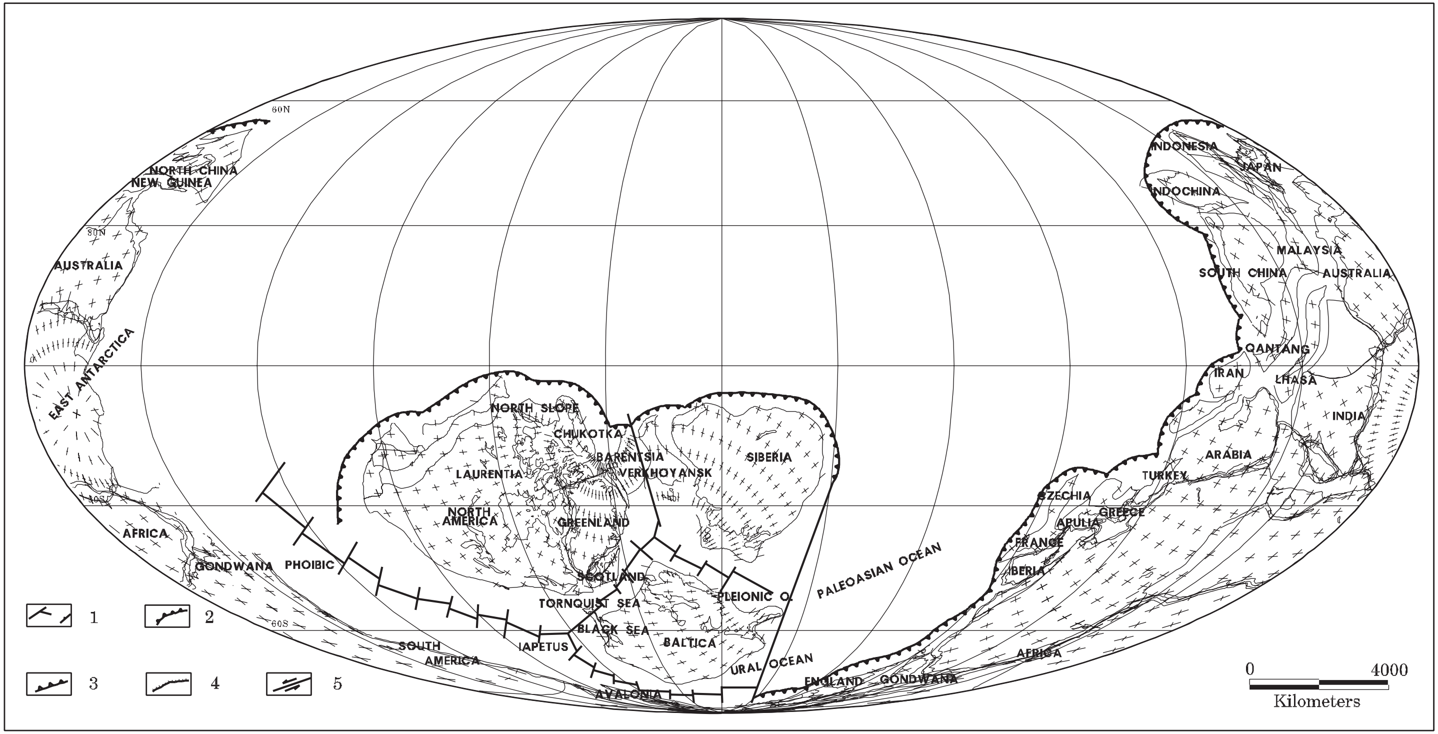

Fig. 6. Plate tectonic map of Middle Cambrian (plates position as of 510 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 6. Mapa tektoniki płyt środkowego kambru (pozycja płyt 510 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

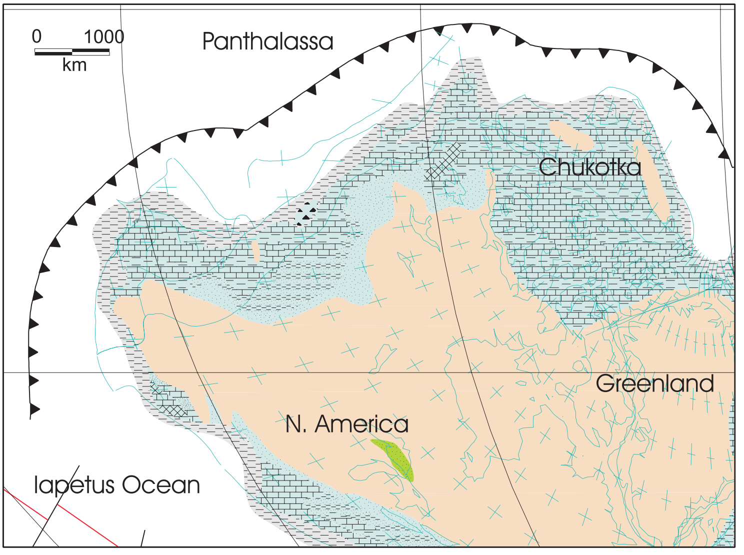

Fig. 7. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Middle Cambrian time

Fig. 7. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji i i przyległego oceanu Iapetus w środkowym kambrze

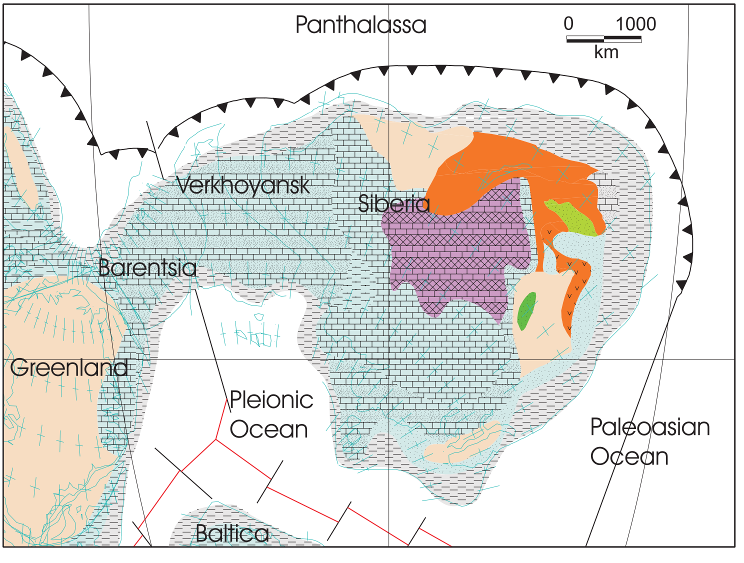

Fig. 8. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Middle Cambrian time

Fig. 8. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii i obszarów sąsiednich w środkowym kambrze

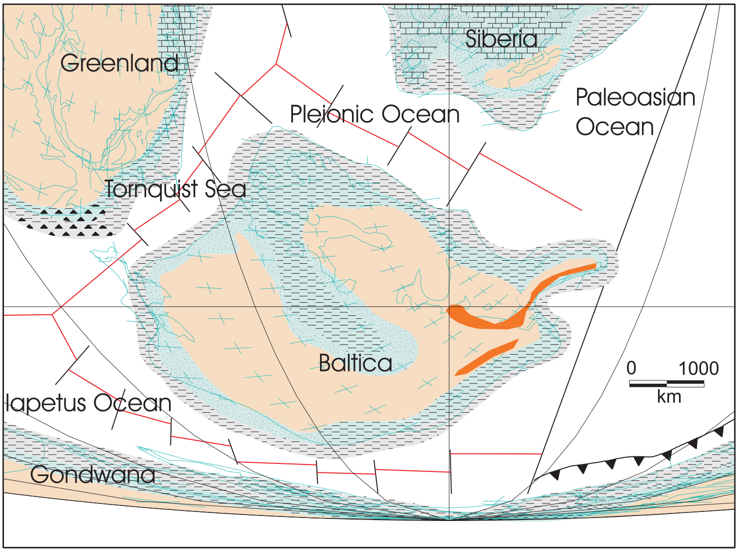

Fig. 9. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Middle Cambrian time

Fig. 9. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki i obszarów sąsiednich w środkowym kambrze

The Baltic-Moscow basin became smaller; at that time it was a shallow silted sea with a very small subsidence rate, which changed to uplifts in the May time (Nikishin *et al*. 1996). Thickness of the Middle Cambrian argillaceous deposits (sandy deposits in the coastal zones) never exceeds first tens of meters. In the sedimentary basin of the western Scandinavia, low-thick argillaceous deposits also dominated (Giese & Koeppen 2001, Ford & Golonka 2003, Golonka *et al*. 2003).

The Upper Yangtze sedimentary basin covered almost the entire South China craton (Fig. 10), except its far west, where the Kham-Dian and Songpan uplifts existed (Ronov *et al*. 1984, Shouxin & Yongyi 1991, Tianfu *et al*. 1999, Golonka 2000, 2002, Kiessling *et al*. 2003, Shi & Hu 2005, Steiner *et al*. 2005, Golonka *et al*. 2006b, Mei *et al*. 2006, Bai *et al*. 2007, Jiang *et al*. 2007, Wang *et al*. 2007, Ma *et al*. 2008, Zhang *et al*. 2008). It is possible that in the south-east the chain of islands separated the basin from the active Cathaysian belt. There, the typical carbonate shallow facies were replaced by terrigeneous turbidites. Thickness of the Middle Cambrian rocks varies from 150–200 m to 600–800 in local troughs, as for example in the southern part of the craton. Carbonates are formed by both limestones and dolomites (sometimes with gypsum interlayers).

As earlier, in the India craton subsidence and sedimentation occurred only in the northern part, in the High and Low Himalayas. Terrigeneous, in rare cases carbonate rocks with the thickness of some hundreds of meters dominated among the deposits (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Slow subsidence occurred almost everywhere in Arabia; sedimentation took place in the north under shallow lagoon conditions and in a vast continental area (Husseini 1989, 1990, McGillivray & Husseini 1992, Abu-Ali *et al*. 1999, Jones & Stump 1999, Garfunkel 2003, Abu-Ali & Littke 2005, Haq & Al-Qahtani 2005). Thickness of carbonate-terrigeneous complexes of Turkey, Iran and Afghanistan is not large and usually does not exceed 500 m; thickness of sediments of the Middle Cambrian subcontinental Lalun formation and its analogies is tens of meters (Ronov *et al*. 1984, Kobayashi 1987, Husseini 1989, Cater & Tunbridge 1992, Hamedi *et al*. 1997, Dean *et al*. 1997, Dronov 1999, Goncuoglu & Kozlu 2000, Kiessling *et al*. 2003, Goncuoglu *et al*. 2004, Ruban *et al*. 2007). It is likely that the regions of Trans-Caucasus and southern Turkestan were also a part of the Arabia craton.

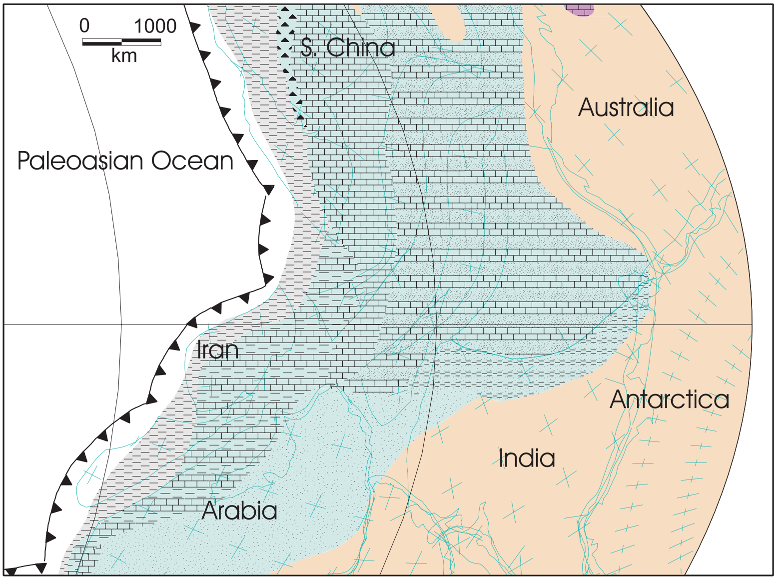

Fig. 10. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Middle Cambrian time

Fig. 10. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich w środkowym kambrze

Late Cambrian

This was a quiet time without any major collisions, but of a continuing sea-level rise. The continents of Gondwana, Baltica, Laurentia and Siberia continued their existence. Siberia and Laurentia drifted northward coming close to the equator (Fig. 11). Advanced sea-floor spreading occurred in the oceans between Laurentia and Baltica, between East Siberia and Baltica and between Laurentia and Gondwana (Scotese & McKerrow 1990, McKerrow *et al*. 1991, Golonka *et al*. 1994 2006c, Torsvik *et al*. 1996, Dalziel 1997, Golonka 2000, 2002, Lewandowski 2003, Cocks & Torsvik 2005, 2006, 2007, McCausland *et al*. 2007). Laurentia rapidly drifted northward and rotated counter-clockwise, reaching low latitudes.

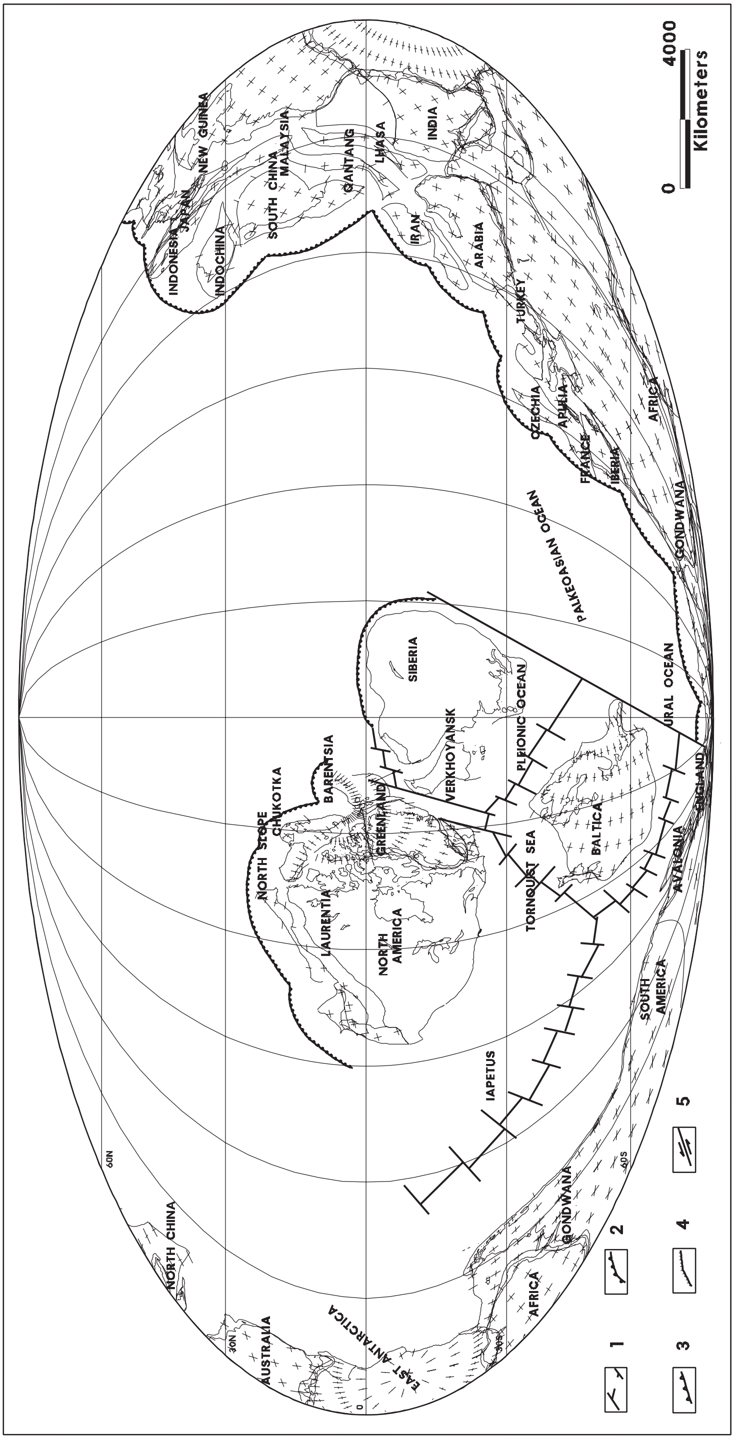

Fig. 11. Plate tectonic map of Late Cambrian (plates position as of 498 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 11. Mapa tektoniki płyt późnego kambru (pozycja płyt 495 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

Subsidence and transgressions occurred on the large area of the Laurentian craton; as the result almost one third of the craton was covered by marine sedimentary basins (Stewart & Poole 1974, Mellen 1977, Chafetz 1980, Brett *et al*. 1990, Garzione *et al*. 1997, Keppie *et al*. 1997, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Murphy & Keppie 2005, Murphy e*t al*. 2008, Schulz *et al*. 2008). The map (Fig. 12) shows the boundaries of these basins taking into account further partial washing out of the Upper Cambrian deposits; their real size could have been even larger. In the Paleozoic, transgression for the first time took place on the large area of the Midcontinent; it resulted in junction of the Peri-Appalachian and Peri-Cordilleran basins. Stable tectonic regime and hot climate resulted in a deposition of mainly limestones and dolomites, especially in the southern part of the Midcontinent and in the basins of the northern Canada (Trettin & Balkwill 1979, Trettin 1987, 1989, 1994, 1998, Trettin *et al*. 1987, Long 1989, Estrada *et al*. 2003). However, sandy-argillaceous deposits dominated in the peripheral parts of sedimentary basins. Thickness of the Upper Cambrian deposits in the vast areas of the inner basins is not large - tens of meters. The exception is the Michigan-Illinois basin, in the southern part of which thickness of carbonates exceeds 1 km. In the south, in the central Texas, carbonates and gypsum were deposited in the basin with an increased salinity (Chafetz 1980). Large thickness (more than 2 km) of carbonate and terrigeneous sediments was accumulated in the wide marginal shelf zone in the Canadian Rocky Mountains. To the south the similar zone is much more narrow and carbonate-terrigeneous complex with 1.5 km thickness was also deposited there (Stewart & Pool 1974).

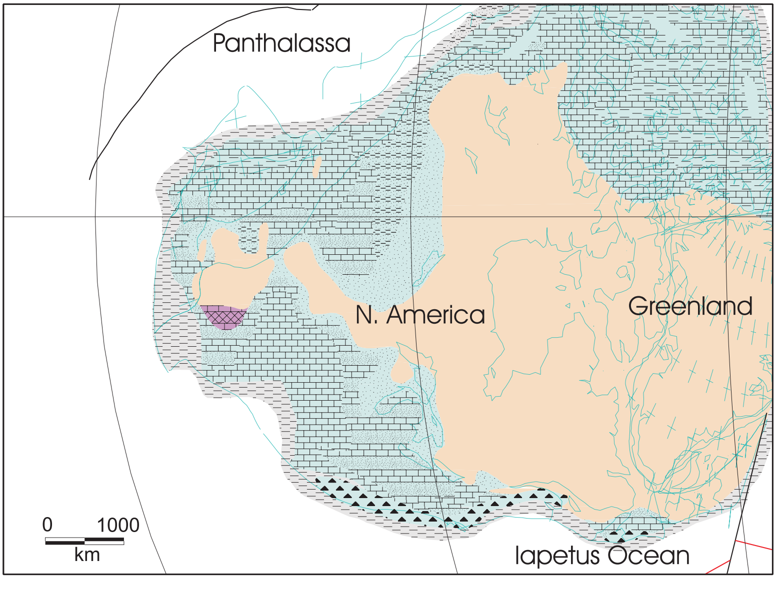

Fig. 12. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Late Cambrian time

Fig. 12. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji oraz przyległego oceanu Iapetus w późnym kambrze

Almost the entire Siberian craton (Fig. 13) was covered by the sea; on the whole, the conditions of shallow carbonate sedimentation dominated in sedimentary basins (Ronov *et al*. 1984, Zonenshain *et al*. 1990, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Mel'nikov & Konstantinova 2005, Kouchinsky *et al*. 2007, Khomentovsky 2008). Evaporites were deposited as well in a wide lagoon in the central part of the craton. In the north, the lagoon was separated from relatively more deep open basins by barrier reefs. A fraction of terrigeneous rocks in the Upper Cambrian deposits is essential in the south and south-west. Fragmented material came from the uplifts in the region of the Yenisei ridge. Thickness of terrigeneous rocks in the southern basins is tens of meters; however, in some depressions near the Yenisei orogen thickness of sandstones and conglomerates exceeds one hundred meters. Thickness of lagoon carbonate-evaporite layers changes from 80–100 m in the south to 700–800 m in the north. Carbonates from the barrier reefs are 1000–1200 m thick.

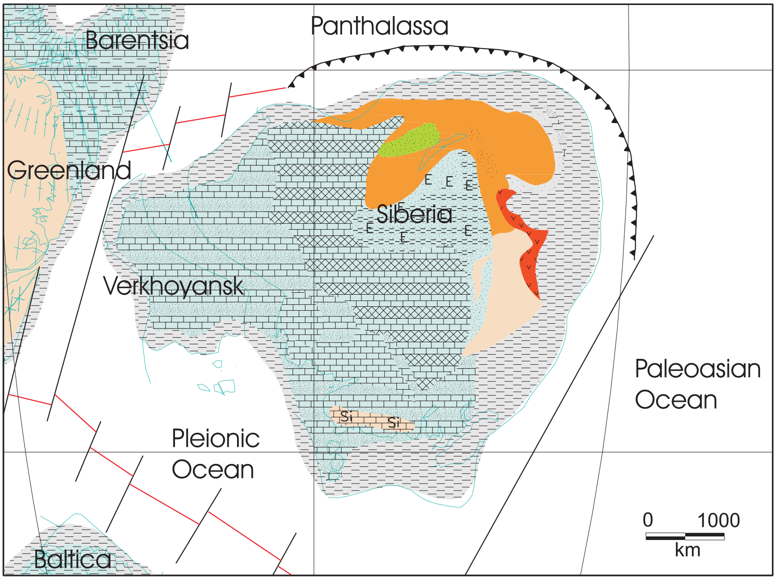

Fig. 13. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Late Cambrian time

Fig. 13. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich w późnym kambrze

Subsidence of the large and extremely shallow Baltic-Moscow basin, which occupied almost one third of the Baltica craton continued in the Late Cambrian (Ronov *et al*. 1984, Puchkov 1991, 1996, 1997, Nikishin *et al*. 1996, Golonka *et al*. 2003) (Fig. 14). Thickness of argillaceous and sandy-argillaceous (in coastal zones) sediments was some meters and rarely exceeded 10–15 m. Clayey sediments of a similar low thickness were in the sedimentary basin which covered a large part of Scandinavia. Their thickness near Oslo graben was about 45 m, and 100 m in the northern part of Poland (Olaussen 1981, Ro *et al*. 1990, Ulmishek 1990, Jaworowski 2000, Sikorska 2000, Ford & Golonka 2003, Golonka *et al*.

2003, Pedersen *et al*. 2007, Szymański 2008). Subsidence of the marginal basin and accumulation of mainly sandy deposits with the thickness of up to 300–400 m started at the end of the Late Cambrian in the Peri-Urals zone.

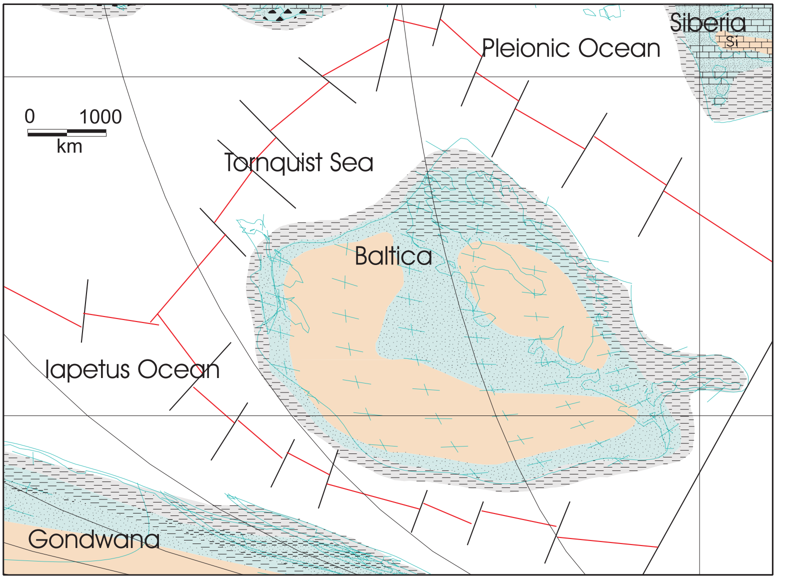

Fig. 14. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Late Cambrian time

Fig. 14. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki oraz obszarów sąsiednich w późnym kambrze

A large carbonate platform with limestones, dolomites and mixed carbonate/clastic facies, existed in the southern and central parts of South China plate (Fig. 15) (Ronov *et al*. 1984, Shouxin & Yongyi 1991, Tianfu *et al*. 1999, Golonka 2000, 2002, Kiessling *et al*. 2003, Shi & Hu 2005, Steiner *et al*. 2005, Golonka *et al*. 2006b, Mei *et al*. 2006, Bai *et al*. 2007, Jiang *et al*. 2007, Wang *et al*. 2007, Ma *et al*. 2008, Zhang *et al*. 2008) and was connected with the carbonate deposition area on the Arabia plate margin (Ronov *et al*. 1984, Golonka 2000). Clastic sedimentation prevailed in the northern part of the plate (Fig. 15). Carbonates and mixed carbonate/clastic facies are present within terrigenous complexes in the northern India-Himalayan area (Gupta & Brookfield 1991). Carbonate and mixed carbonate/clastic facies also occurred in eastern Australia (Cook 1990) and carbonate/clastic facies in South-East Asia (Brookfield 1996). The Cambrian oolitic limestones of Dien Lu Formation (Ding Ming Mong 1978, Tran van Tri 1979, Findlay 1997) are exposed in the northwestern part of Vietnam. In Indostan, marine deposits of the Late Cambrian are known only in the northern part of the peninsula, in the Low Himalayas. Subsidence of a shelf marine basin continued there since the Middle Cambrian; terrigeneous complexes were deposited in its coastal part, while northwards they changed to carbonate and terrigeneous-carbonate deposits. Thickness of the Upper Cambrian rocks does not exceed

300–400 m. Mountain massifs in the north-western part of the Low Himalayas were the source of fragmented material (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Subcontinental sandstones of the Lapun and similar formations, with a thickness of 10–20 m, were formed in the vast area of the central Arabia (Husseini 1989, 1990, McGillivray & Husseini 1992, Abu-Ali *et al*. 1999, Jones & Stump 1999, Garfunkel 2003, Abu-Ali & Littke 2005, Haq & Al-Qahtani 2005). A marine sedimentary basin was located north-eastwards on the place of the contemporary Persian Gulf, Iran and Iraq (Ronov *et al*. 1984, Kobayashi 1987, Husseini 1989, Cater & Tunbridge 1992, Dean *et al*. 1997, Hamedi *et al*. 1997, Dronov 1999, Goncuoglu & Kozlu 2000, Kiessling *et al*. 2003, Goncuoglu *et al*. 2004, Ruban *et al*. 2007). Mainly limestones and dolomites, sometimes sandy and argillaceous rocks of 300–400 m (900 m in Tebes region) thickness were deposited on a shallow shelf there.

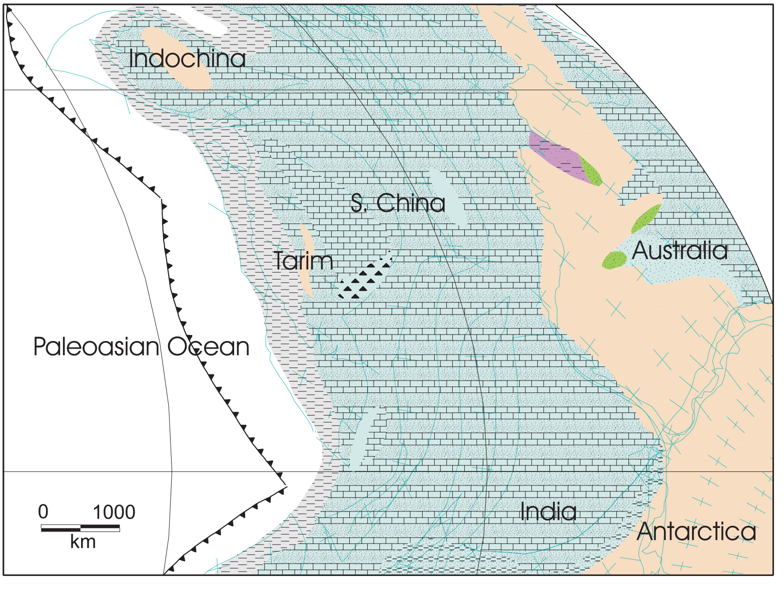

Fig. 15. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Late Cambrian time

Fig. 15. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich w późnym kambrze

Early Ordovician

This was the time of maximum dispersion of continents during the Paleozoic (Fig. 16). The continents of Gondwana, Baltica, Laurentia and Siberia continued to exist. Baltica, Laurentia and Siberia drifted further northward (Scotese & McKerrow 1990, McKerrow *et al*. 1991, Golonka *et al*. 1994, 2006c, Torsvik *et al*. 1996, Dalziel 1997, Golonka 2000, 2002, Lewandowski 2003, Cocks & Torsvik 2005, 2006, 2007, McCausland *et al*. 2007).

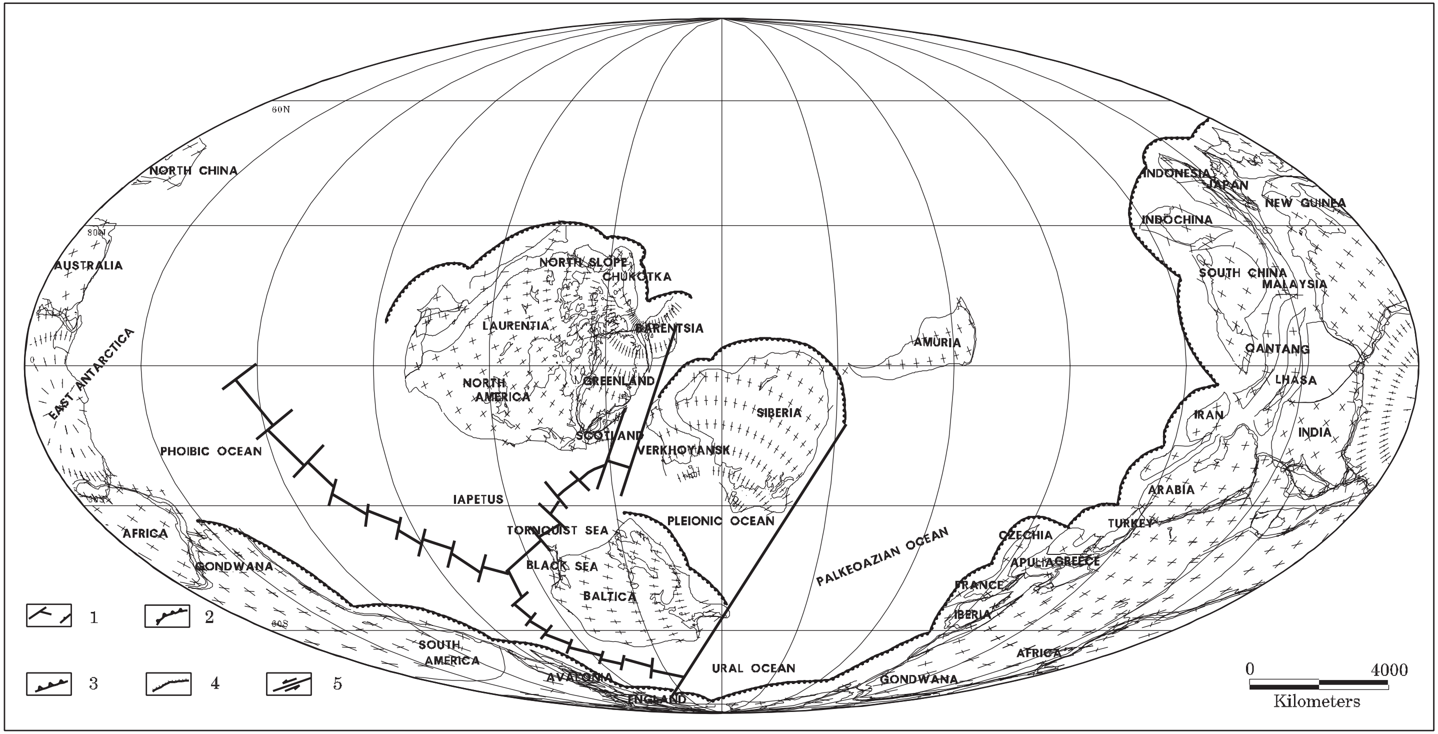

Fig. 16. Plate tectonic map of Early Ordovician (plates position as of 485 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 16. Mapa tektoniki płyt wczesnego ordowiku (pozycja płyt 485 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

The rapid northward drift of continents widened the oceanic systems (Dalziel 1997, Golonka 2000, 2002). Laurentia was situated on equator at that time (Fig. 6). The distance between Gondwana and Laurentia reached 5000 km (Kent & van der Voo 1990). The widening of the Paleoasian Ocean could also have happened at that time (Zonenshain *et al.* 1990).

On the whole, the carbonate sedimentation dominated in the basins of Laurentia craton (Stewart & Poole 1974, Mellen 1977, Chafetz 1980, Ronov *et al.* 1984, McKerrow *et al.* 1991, Garzione *et al.* 1997, Kolata *et al.* 2001, Ford & Golonka 2003, Kiessling *et al.* 2003, Sharma *et al.* 2003, Dixon 2008) (Fig. 17). The Williston basin decreased in size, and only there terrigeneous facies were deposited (Porter & Fuller 1959, Slind *et al.* 1994). Their thickness did not exceed 120–130 m. The eastern part of Greenland has undergone transgression, the thickness of carbonate and rare terrigeneous rocks reched there as much as 1000 m (Henriksen 1978, Harland 1979, Henriksen & Higgins 2000, Golonka *et al.* 2003, Smith *et al.* 2004). In the basins of the northern Canada, carbonate sedimentation dominated as well, evaporites (gypsum) also were deposited there (McGill 1974, Trettin & Balkwill 1979, Trettin 1987, 1989, 1994, 1998, Trettin *et al.* 1987, Long 1989, Estrada *et al.* 2003). Some of the Lower Ordovician sections are very thick, up to 2000 m (Surlyk *et al.* 1980). Evaporites were deposited as well in the Michigan basin; compared to the Late Cambrian time the role of carbonate sedimentation essentially increased (Barnes *et al.* 1996, Howell & van der Pluijm 1990, 1999, Kolata *et al.* 2001, Sharma *et al.* 2003). The thickness of the Lower Ordovician deposits in the central part of the basin is as much as 300–350 m.

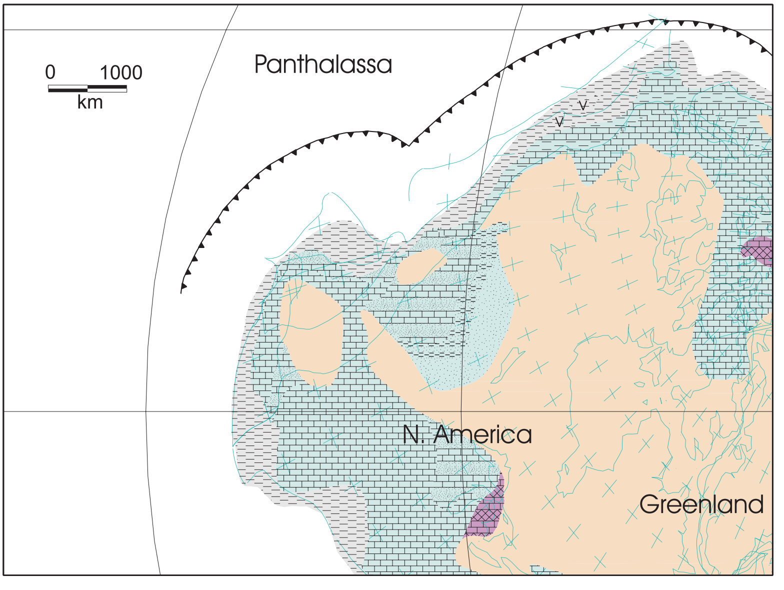

Fig. 17. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Early Ordovician time

Fig. 17. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji oraz przyległego oceanu Iapetus we wczesnym ordowiku

The basin was connected with the Peri-Appalachian basin, where thickness of depositions increases to 600–700 m. In the western part of the continent, narrow epicraton basins were located in the Peri-Cordilleran zone. Carbonates also dominated there; however, in Nevada and some other regions almost a half of section is formed by shallow terrigeneous complexes (Ross 1976). Sometimes their thickness exceeds 1000–1500 m. The basin in the north-western part of Canada covered a larger area and was filled by nearly solely carbonates, with their maximal thickness being 600–700 m. Two different facies were developed in the Early Paleozoic in south-western part of USA: a deep water passive margin facies in the Ouachita orogenic belt, and a predominantly shallow water cratonic facies in the Ouachita foreland (Ham 1959, 1969, Flawn *et al*. 1961, Lowe 1985, 1989, Golonka *et al*. 2006c).

A large Tunguska basin existed in the central part of the Siberian craton in the Early Ordovician (Ronov *et al*. 1984, Kanygin *et al*. 1988, Zonenshain *et al*. 1990, Torsvik *et al*. 1995, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Bogolepova *et al*. 2006, Artyushkov *et al*. 2008) (Fig. 18). Sandstones and argillites dominated in sediments of the southern part of the basin, while terrigeneous-carbonate rocks with prevailing dolomites were developed in its northern part. In the north, the Tunguska basin was connected with the Southern-Taimyr basin, where dolomites, sandstones and argillites with the thickness of the first hundreds of meters were deposited. Besides, in the central part of the southern Taimyr basin, the Khambinsk formation of black bituminiferous schists and carbonates was formed (Ronov *et al*. 1984, Bogdanov *et al*. 1998, Inger *et al*. 1999, Golonka *et al*. 2003, Metelkin *et al*. 2005, Gee *et al*. 2006, Lorenz *et al*. 2008).

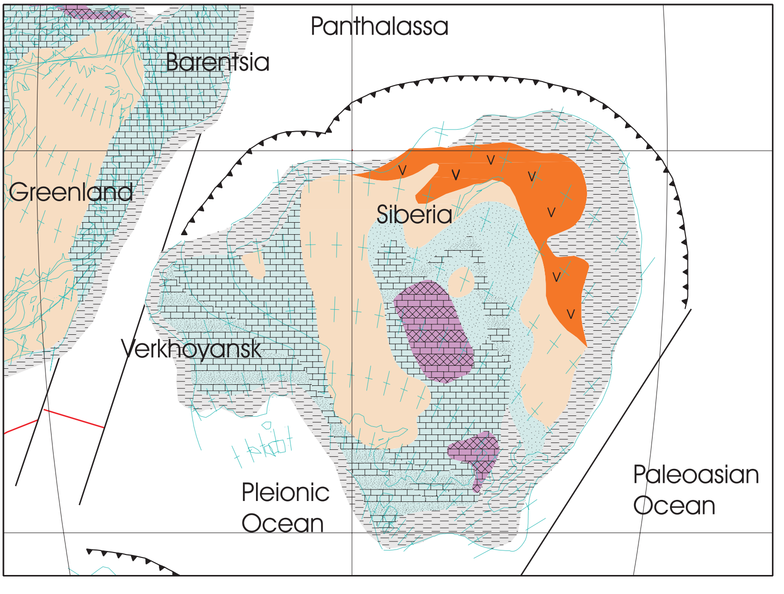

Fig. 18. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Early Ordovician time

Fig. 18. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich we wczesnym ordowiku

In the southern part of the craton, a rapid filling of the Irkutsk basin by thick terrigeneous formations (up to 1400 m) occurred. In the southern Verkhoyansk region (Sette-Daban ridge), only thick layers of carbonate formations were formed (Ronov *et al*. 1984, Zonenshain *et al*. 1990, Parfenov 1991, Prokopiev 2000, Golonka *et al*. 2003). More than 1300 m of limestones and dolomites were accumulated there, in the depression located far from regions of water erosion, under the conditions of normal marine basin. Collision between microcontinents (Salairian orogeny) in the Mongolia-Tuwa area (Zonenshain *et al*. 1990) marked the onset of the formation of the Amuria (Mongolia) microcontinent.

Arc-continent collisions occurred along the margins of Iapetus-Tornquist-Pleionic oceanic system in Baltica and in Avalonia causing deformations of the Penobscottian, Grampian, Finnmarkian, and Athollian orogenies (Neuman & Max 1989, Ziegler 1990). The deformation events in Baltica might have been related to the transformation of a passive margin into a convergent one, due to the development of the subduction zone. Subsidence and transgression on Baltica (Fig. 19) moved gradually from the west to the east, and the Baltic-Moscow basin was formed in the Early Ordovician (Nikishin *et al*. 1996, Golonka *et al*. 2003). It was a large but rather shallow basin where quartz and glauconitic sand, graptolite ooze, and detrital limestone with the total thickness of few tens of meters (no more than 100 m) were deposited. In the Baltic republics, in Estonia and Lithuania, the formations of black diktyonite schists were found (Ronov *et al*. 1984, Kaljo *et al*. 1988, Fortey *et al*. 1995, Zdanavîciuté & Bojesen-Koefoed 1997, Puura *et al*. 1999, Modliński *et al*. 2007, Raudsep 2008).

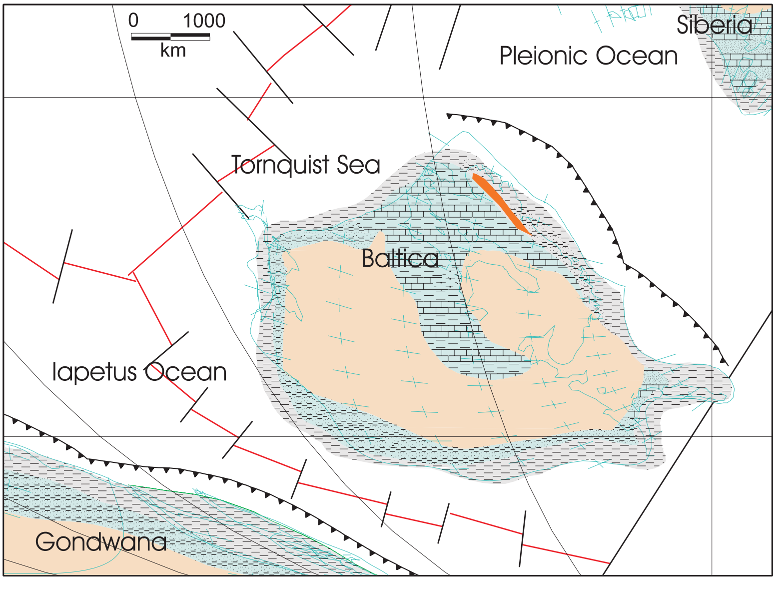

Fig. 19. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Early Ordovician time

Fig. 19. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki oraz obszarów sąsiednich we wczesnym ordowiku

Similar shallow marine conditions were in the north-western, Scandinavian, part of the basin; however, sediments had another composition: they were more clayey and fine--grained in littoral zones, more carbonaceous in the central part, while in the Peri-Scandinavian zone a fraction of sandy rocks increased and thickness of sediments becomes as large as 300–400 m. In the Ruegen-Pomorze depression the special conditions of a fast subsidence existed; the complex of rocks of black-schist formation with the thickness of 800 m was deposited there (Beier *et al*. 2000, Dadlez 2000, Beier & Katzung 2001, Wrona *et al*. 2001, Verniers *et al*. 2002, Winchester *et al*. 2002, Krzemiński & Poprawa 2006, Nawrocki & Poprawa 2006, Podhalańska & Modliński 2006). In the east, along the Urals belt, a narrow zone of marginal basins existed (Ronov *et al*. 1984, Puchkov 1991, 1996, 1997, Nikishin *et al*. 1996, Golonka *et al*. 2003). There, from the west to the east, coarse alluvial depositions with the thickness of up to 1–2 km changed to shelf rhythmic sandy-argillaceous and carbonate rocks of the same thickness, and farther eastwards to terrigeneous complexes of continental slope.

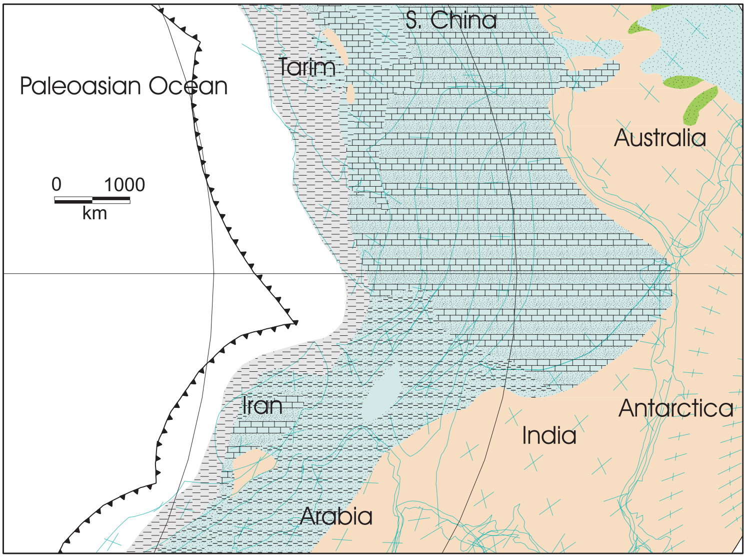

Fig. 20. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Early Ordovician time

Fig. 20. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich we wczesnym ordowiku

A sedimentary basin occupied almost the entire South China plate (Fig. 20). It was bordered by the Kham-Dian and Songpan uplifts from the west, and by the Liangnan islands from the east (Ronov *et al*. 1984, Shouxin & Yongyi 1991, Chen *et al*. 1995, Golonka 2000, 2002, Cocks 2001, Feng *et al*. 2001, Kiessling *et al*. 2003, Golonka *et al*. 2006b). Deposition of carbonates and magnesian carbonates dominated there. Evaporites were formed in the western part of the basin. The amount of terrigenous material in the Upper Cambrian deposits is very small. Carbonates changed to more deep-water complexes (sometimes to turbidites) only in the southeastern part of the plate, adjacent to the Cathaysian mobile belt. On the Shan Plateau within the Sibumasu plate, clastic sedimentation prevailed within Cambro-Ordovician strata (Brookefield 1996). The Early Ordovician was characterized by transgressions in Arabia, Afghanistan and Iran regions (Wolfart & Wittekindt 1980, Ronov *et al*. 1984, Kobayashi 1987, Husseini 1989, 1990, Cater & Tunbridge 1992, McGillivray & Husseini 1992, Hamedi *et al*. 1995, Dean *et al*. 1997, Abu-Ali *et al*. 1999, Dronov 1999, Jones & Stump 1999, Garfunkel 2003, Kiessling *et al*. 2003, Abu-Ali & Littke 2005, Haq & Al-Qahtani 2005, Ruban *et al*. 2007) (Fig. 19). The marine basin in the Arabian peninsula became larger. Contrary to the Upper Carboniferous, there are almost no carbonates in the lower Ordovician depositions; sandy rocks with continental facies in the coastal zone dominate among terrigeneous rocks. Their thickness is 200–400 m. In India, a shallow marine basin existed only in the northern part of the peninsula, where continuous accumulation of carbonate-terrigeneous deposits occurred in the east, and terrigeneous sediments prevailed in the west (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Thickness of these deposits is 100–250 m. The Delamerian-Ross orogeny developed a fold and thrust belt with extensive volcanism along the margin of western Gondwana in southeastern Australia, the Wilson terrane, and from north Victoria Land to the Pensacola Mountains in Antarctica (Cook 1990, Findlay 1991, Findlay *et al*. 1991, Flöttmann *et al*. 1993).

Middle Ordovician

This was a time of major plate reorganization (Scotese & McKerrow 1990, McKerrow *et al*. 1991, Torsvik *et al*. 1996, Dalziel 1997, Golonka 2000, 2002, Lewandowski 2003, Golonka *et al*. 1994, 2006b, c, Cocks & Torsvik 2005, 2006, 2007, McCausland *et al*. 2007). The Cambrian oceans began to narrow. Laurentia reversed its northward drift (Fig. 21). Baltica rotated counterclockwise while Gondwana rotated clockwise. New oceans and continents like Avalonia appeared. The emergence of the South Pole ice cap was related to this plate reorganization.

Avalonia probably started to drift from Gondwana and move towards Baltica in the Late Tremadocian and was in a drift stage by the Llanvirnian (McKerrow *et al*. 1991, Torsvik *et al*. 1996, Golonka 2000, 2002). Between Gondwana, Baltica, Avalonia and Laurentia, a large longitudinal oceanic unit, known as the Rheic Ocean (McKerrow *et al*. 1991, Golonka 2000, 2002) was formed. Traditionally the continent of Avalonia consists of northwestern and possibly southern Poland, terranes in northern Germany, the Ardennes of Belgium and northern France, England, Wales, southeastern Ireland, the Avalon Peninsula of eastern Newfoundland, much of Nova Scotia, southern New Brunswick, and some coastal parts of New England. The Brunovistulicum terrane, some accreted terranes in the basement of the East Carpathians parts of the Scythian platform, parts of Kazakhstan, and southern Mongolia terrane could constitute the eastern extension of the Avalonia (Paul *et al*. 2003a, b). The Turkmen (Zonenshain *et al*. 1990) and Solonker (Şengör & Natalin 1996) oceans in Asia could constitute the eastern parts of this Rheic Ocean. Relationship of eastern Peri-Gondwana terranes and Avalonia plates remain unknown and speculative. Presented maps (Figs 21, 26) suggest the possibility of extension of the Rheic Ocean toward the easternmost part of Gondwana.

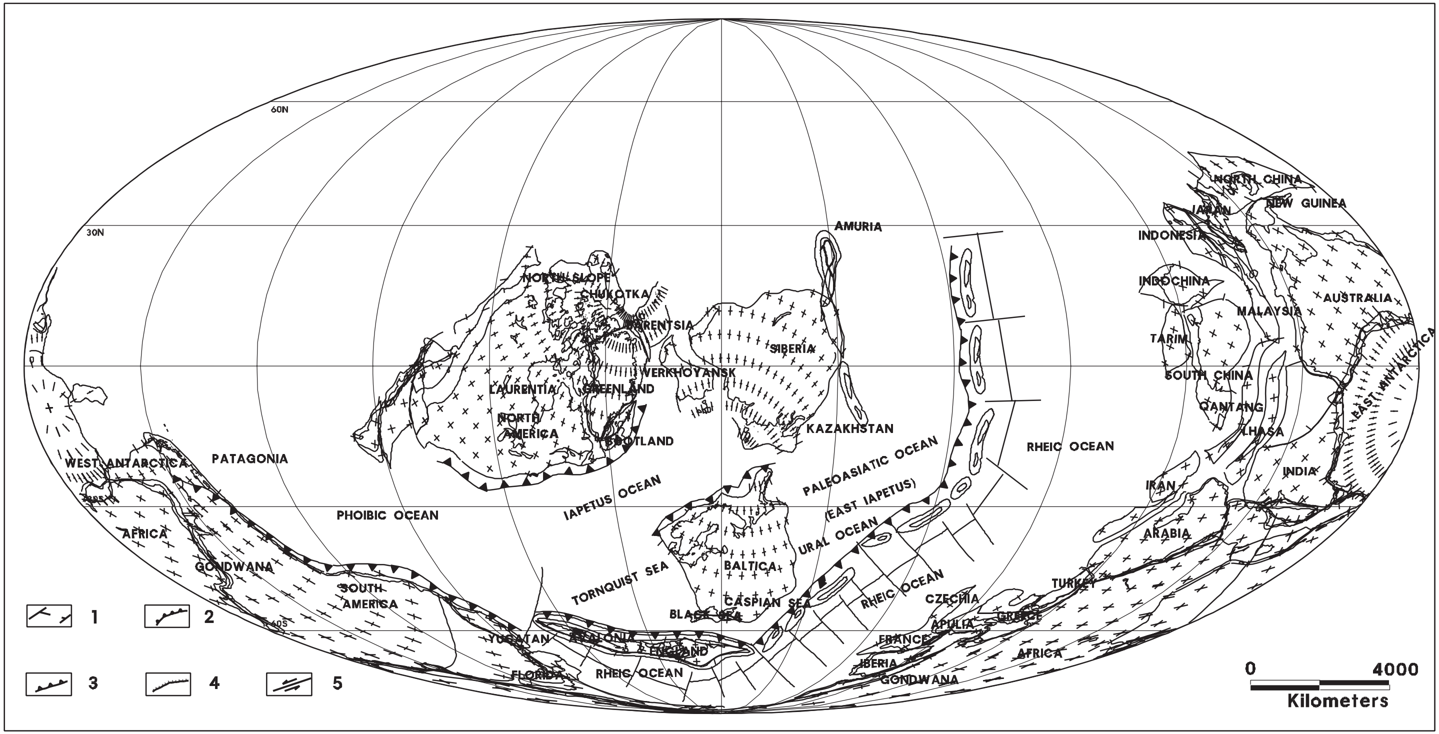

Fig. 21. Plate tectonic map of Middle Ordovician (plates position as of 472 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 21. Mapa tektoniki płyt środkowego ordowiku (pozycja płyt 472 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

During the Ordovician times, several island arcs were present off the eastern margin of Laurentia. They can be readily recognized in the northern Appalachians, but are less certain in the British Isles. These arcs appear to have collided with Laurentia progressively, starting in the north, during the Early Ordovician (Athollian orogeny) and ending with the Caradocian Taconian orogeny (McKerrow *et al*. 1991). The total size of marine basins on Laurentia (Fig. 22) increased due to transgression in the south-east and north of Canada (Stewart & Poole 1974, Mellen 1977, Chafetz 1980, Ronov *et al*. 1984, McKerrow *et al*. 1991, Garzione *et al*. 1997, Kolata *et al*. 2001, Ford & Golonka 2003, Kiessling *et al*. 2003, Sharma *et al*. 2003, Dixon 2008). Erosion increased in the Middle Ordovician; as the result an amount of terrigeneous rocks in sedimentary basins of the central and southern parts of the craton increased, especially in the Williston basin, where sandstones prevailed (Porter & Fuller 1959, Slind *et al*. 1994). However, carbonates dominated in the Michigan basin and in the northern part of the craton. Thickness of the Middle Ordovician rocks is usually tens of meters. High sedimentation rate existed in the peri-craton zones. In the Peri-Appalachian and Peri-Cordilleran zones, thickness of deposits gradually increases to 1000–1500 m (Ross 1976, Brett *et al*. 1990). Thickness of the Middle Ordovician rocks in the Peri--Innuitian zone and the eastern part of Greenland is more than 1000 m (McGill 1974, Henriksen 1978, Trettin & Balkwill 1979, Surlyk *et al*. 1980, Trettin 1987 1989, 1994, 1998, Trettin *et al*. 1987, Long 1989, Henriksen & Higgins 2000, Estrada *et al*. 2003, Golonka *et al*. 2003, Smith *et al*. 2004).

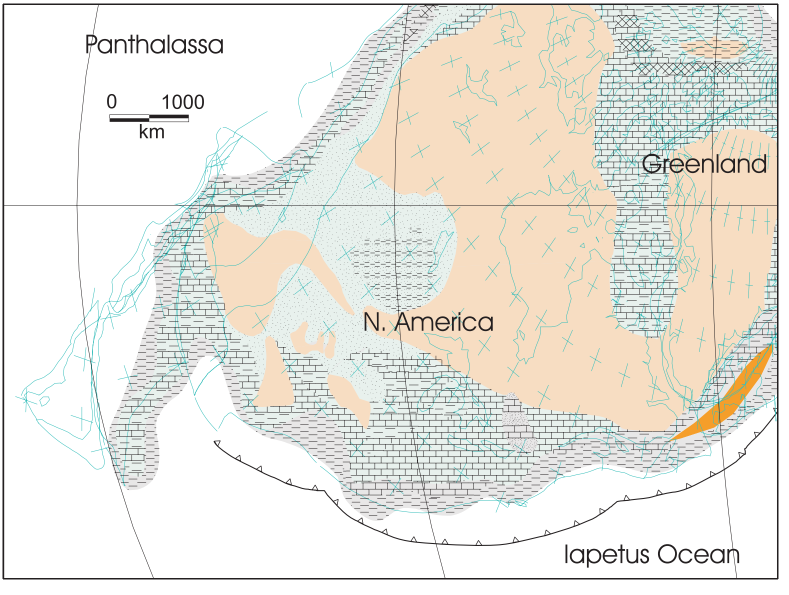

Fig. 22. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Middle Ordovician time

Fig. 22. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji oraz przyległego oceanu Iapetus w środkowym ordowiku

In the Caradocian age, the sea in the northern part of the craton had increased salinity and gypsum and anhydrides were deposited there. Similar paleogeographic conditions existed in the south-west of the Michigan basin (Barnes *et al*. 1996, Howell & van der Pluijm 1990, 1999, Kolata *et al*. 2001, Sharma *et al*. 2003).

The size of the Siberian craton became larger in the south due to accretion of the Selenga-Upper Vitim zone. Marine basins had the same locations but became a little bit smaller (Fig. 23). A fraction of carbonates in the deposits decreased (in the Tunguska and Southern Taimyr basins), while a fraction of terrigeneous, often colored, sediments increased (Ronov *et al*. 1984, Kanygin *et al*. 1988, Zonenshain *et al*. 1990, Torsvik *et al*. 1995, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Bogolepova *et al*. 2006, Artyushkov *et al*. 2008). In the east of the Tunguska basin, the layers and lenses of gypsum exist; it indicates that water had an increased salinity. In the northern part of Taimyr, the terrigeneous-carbonate complexes changed abruptly to deep-marine black schists of a small thickness (Ronov *et al*. 1984, Bogdanov *et al*. 1998, Inger *et al*. 1999, Golonka *et al*. 2003, Metelkin *et al*. 2005, Gee *et al*. 2006, Lorenz *et al*. 2008). It is likely that subsidence was not compensated by sediments there. On the whole, the thickness of the Middle Ordovician rocks is not large and rarely exceeds 100 m. It increased from south to north up to 100 m only in the southern Taimyr basin, however, the thickness of the Middle Ordovician deposits decreased abruptly to tens of meters further to the north, in the zone of a non-compensated subsidence.

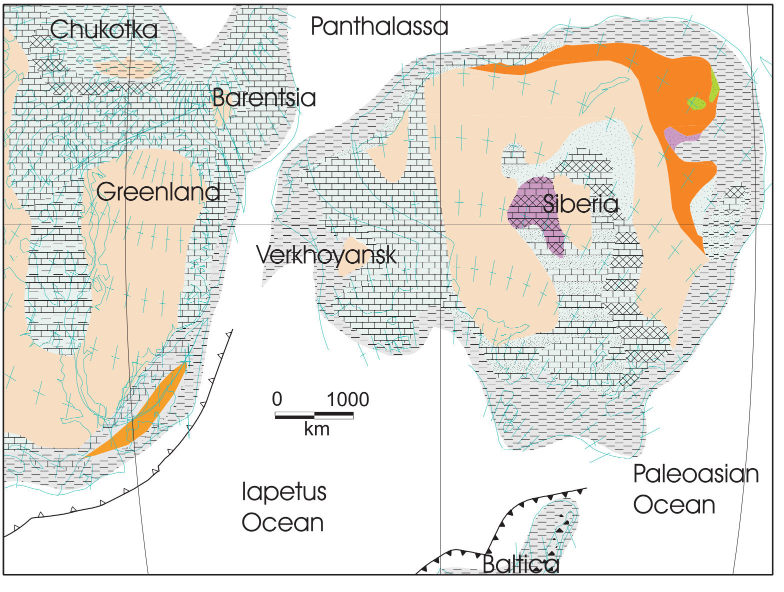

Fig. 23. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Middle Ordovician time

Fig. 23. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich w środkowym ordowiku

Sections of the Middle Ordovician deposits in the Verkhoyansk area and Sette Daban are formed mainly by carbonate rocks (Ronov *et al*. 1984, Zonenshain *et al*. 1990, Parfenov 1991, Prokopiev 2000, Golonka *et al*. 2003). Their thickness is often rather large – up to 2–3 km. General shape of these sedimentary basins and their paleogeography are not clear because of a complex Late Paleozoic and Mesozoic tectonic deformations.

Subsidence and transgression were spreading to the east, and the shallow sea of the Baltic-Moscow basin covered a large area in the central part of the craton (Nikishin *et al*. 1996, Golonka *et al*. 2003) (Fig. 24). It is possible that this basin was connected with the Urals ocean in the north-east (Zoneshain *et al*. 1990, Puchkov 1991, 1996, 1997). Stratified argillaceous and calcareous sediments with a thickness of tens of meters (maximal thickness 180 m) were accumulated in the central part of the basin. Carbonates dominated in the deposits of the Baltic republics and Scandinavia (Jaanusson 1973, Ronov *et al*. 1984, Kaljo *et al*. 1988, Fortey *et al*. 1995, Zdanavîciuté & Bojesen-Koefoed 1997, Puura *et al*. 1999, Tuuling & Flodén 2000, Lewandowski & Abrahamsen 2002, Golonka *et al*. 2003, Kiessling *et al*. 2003, Ainsaar *et al*. 2004, Modliński *et al*. 2007, Pedersen *et al*. 2007, Raudsep 2008). A relatively fast subsidence continued in the Ruegen-Pomorze trough accompanied by sedimentation of thick layers of argillaceous sediments (Beier *et al*. 2000, Dadlez 2000, Beier & Katzung 2001, Wrona *et al*. 2001, Verniers *et al*. 2002, Winchester *et al*. 2002, Krzemiński & Poprawa 2006, Nawrocki & Poprawa 2006, Podhalańska & Modliński 2006). In the south-western part, in the Peri-Carpathian zone, short-term uplifts and regressions occurred in the Middle Ordovician (Buła & Jachowicz 1996, Moryc & Nehring-Lefeld 1997, Maksym *et al*. 2003).

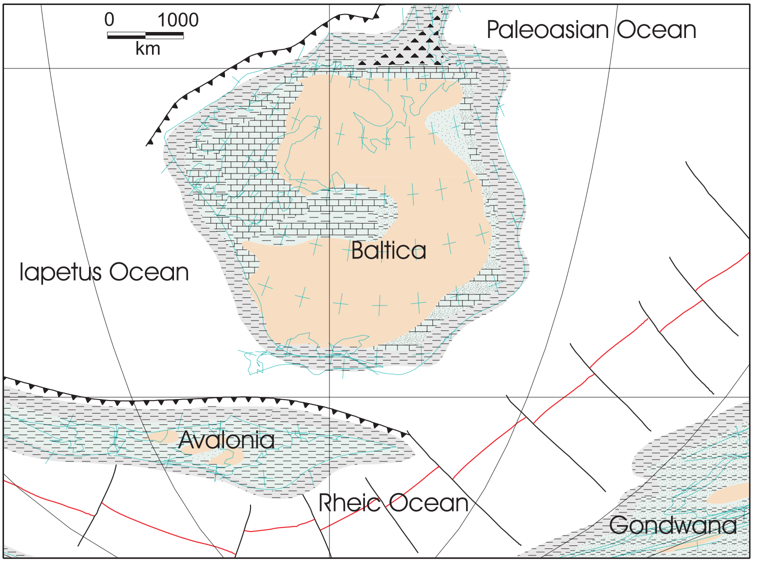

Fig. 24. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Middle Ordovician time

Fig. 24. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki oraz obszarów sąsiednich w środkowym ordowiku

Subsidence of the Peri-Urals zone continued along the entire eastern margin of the craton; a long belt of marginal basins existed there. The sea became essentially wider in the north and the Pechora basin was formed (Ismail-Zadeh *et al*. 1997, Martirosyan *et al*. 1998, O'Leary *et al*. 2004). There, shallow marine and coastal mainly sandy rocks with a thickness of up to 250–400 m were deposited (Zonenshain *et al*. 1990, Puchkov 1991, 1996, 1997, Nikishin *et al*. 1996). From the west to the east along the entire Peri-Urals zone, shallow marine coarse-fragmented deposits were changed to relatively more deep rocks, which included limestones and dolomites with abundant and different marine fauna. Thickness of deposits increased to 800 m in the same direction. In the southern Urals the Middle Ordovician is presented by quartz sandstones, which overlay more ancient rocks transgressively and with a sharp angular unconformity. Marine basin was distinguished conventionally in the Peri-Caspian and in the Scythian plate (Nikishin *et al*. 1996, Vaida & Seghedi 1997, Kostyuchenko *et al*. 2004, Sliaupa *et al*. 2006, van der Voo *et al*. 2006, Golonka *et al*. 2006b, Kleshchev 2007).

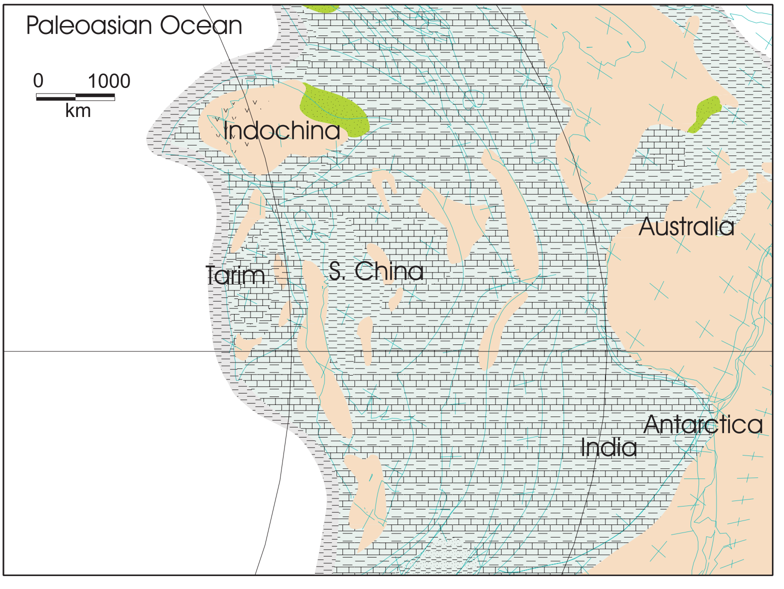

Fig. 25. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Middle Ordovician time

Fig. 25. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich w środkowym ordowiku

According to Shouxin & Yongyi (1991), the Ordovician conformably overlies the Cambrian over most of the South China plate (Fig. 25). The northern part of the plate (Yangzi Platform) was covered with carbonates and its eastern part with mixed carbonate/clastic facies (Ronov *et al*. 1984, Shouxin & Yongyi 1991, Chen *et al*. 1995, Golonka 2000, 2002, Cocks 2001, Feng *et al*. 2001, Kiessling *et al*. 2003, Golonka *et al*. 2006b). The southern part of the plate is partially uplifted and partially covered by deep water synorogenic clastic deposits – more than 4000 m of weakly metamorphosed flysch, sandstones and graptolitic shales. Similar rocks formed on the margins of the Indochina plate (Golonka *et al*. 2006b). They are known as Pa Ham Formation (Ordovician-Silurian). The Arabian basin became smaller and mainly terrigeneous sediments were deposited there (Husseini 1989, 1990, McGillivray & Husseini 1992, Abu-Ali *et al*. 1999, Jones & Stump 1999, Garfunkel 2003, Abu-Ali & Littke 2005, Haq & Al-Qahtani 2005). A wide zone of mixed continental and marine sandy facies was located along the southern margin of the basin. Thickness of the Middle Ordovician rocks is 200–400 m, however in the north-eastern part of Syria (the Palmire Trough) their thickness increased to 2000–3000 m (Ala & Moss 1979, Beydoun 1991, Al-Saad *et al*. 1992, Best *et al*. 1993, Brew *et al*. 2001). The development of the shelf marine basin continues in the northern part of Indostan peninsula with an accumulation of carbonate-terrigeneous deposits, of the total thickness no more than 100–200 m. Terrigeneous rocks prevailed in the western part of the basin; a thick complex of alluvium deposits including conglomerates was accumulated there (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al.* 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Its formation was caused by orogenesis and erosion of the mountain region located southwards.

Late Ordovician

The Rheic Ocean between Gondwana and Avalonia-Baltica widened significantly Scotese & McKerrow 1990, McKerrow *et al*. 1991, Torsvik *et al*. 1996, Dalziel 1997, Golonka 2000, 2002, Lewandowski 2003, Golonka *et al*. 1994, 2006c, Cocks & Torsvik 2005, 2006, 2007, McCausland *et al*. 2007). The large latitudinal ocean system began to emerge (Fig. 26). The Taconian orogeny caused by arc collision with Laurentia continued through the Caradocian (McKerrow *et al*. 1991). The collision of the Patagonia block with Gondwana occurred during the Fammatinian orogeny, in the Ordovician time. It is quite possible that the Patagonia terrane rifted away from Laurentia and then collided with Gondwanian South America. An alternative reconstruction by Dalziel (1997, Dalziel *et al*. 1994) suggests that the Fammatinian orogen exposed as the basement of the Mesozoic-Cenozoic Andes is broadly coeval with the Taconian orogeny. This implies that the collision of Laurentia and Gondwanian South America occurred during Ordovician time.

Subsidence and transgressions occurred on the major part of the Laurentian craton (Fig. 27). The size of marine basins in the Late Ordovician was maximal in the Paleozoic time (Stewart & Poole 1974, Mellen 1977, Chafetz 1980, Ronov *et al*. 1984, McKerrow *et al*. 1991, Garzione *et al*. 1997, Kolata *et al*. 2001, Ford & Golonka 2003, Kiessling *et al*. 2003, Sharma *et al*. 2003, Dixon 2008). Low-lying peneplains formed the land areas; they did not have fragmented rocks and carbonate sedimentation dominated almost everywhere in the marine basins. Thickness of deposits is rather low and usually does not exceed the first tens of meters. It increases to 30 m in the central parts of the Williston and Hudson basins, to 600–700 m in the marginal parts of the craton and up to 1000 m in the Peri--Appalachian zone (Brett *et al*. 1990).

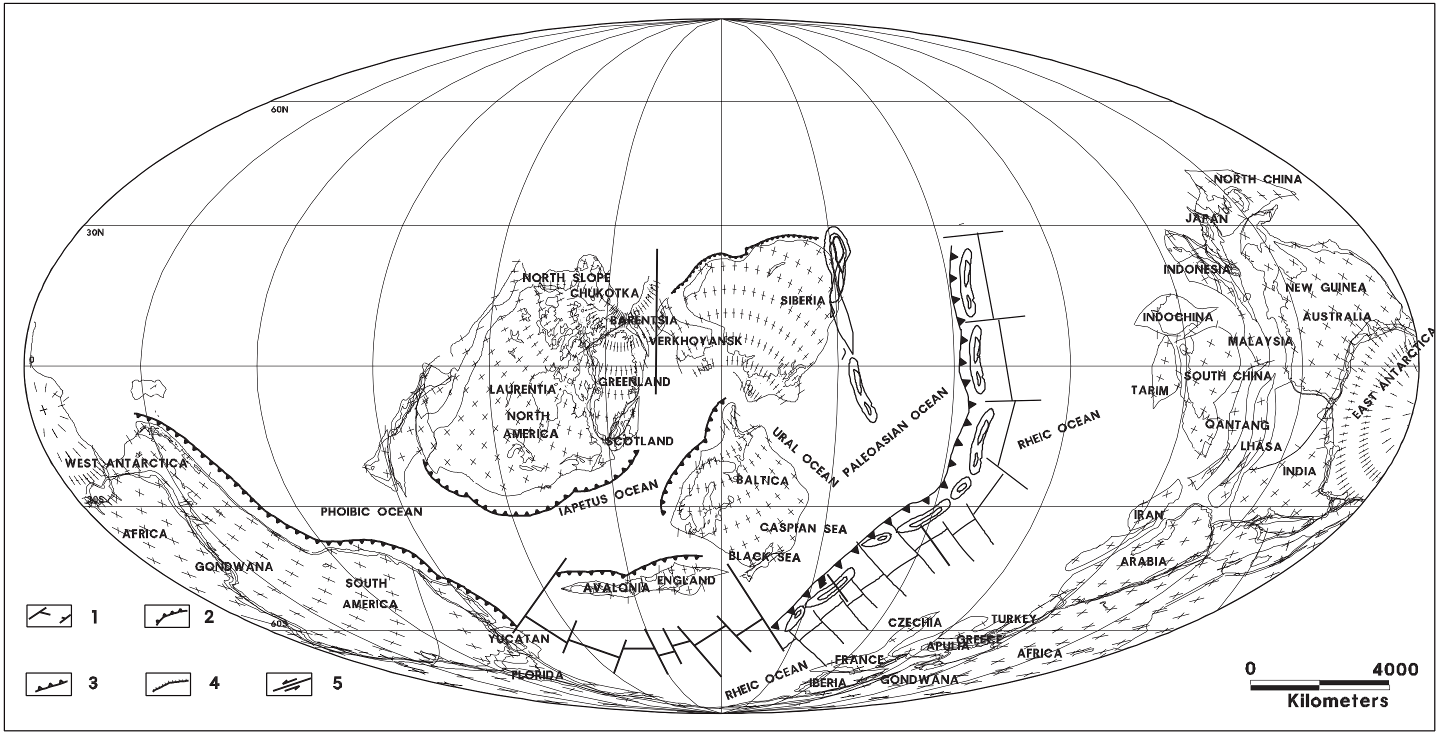

Fig. 26. Plate tectonic map of Late Ordovician (plates position as of 452 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 26. Mapa tektoniki płyt późnego ordowiku (pozycja płyt 452 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

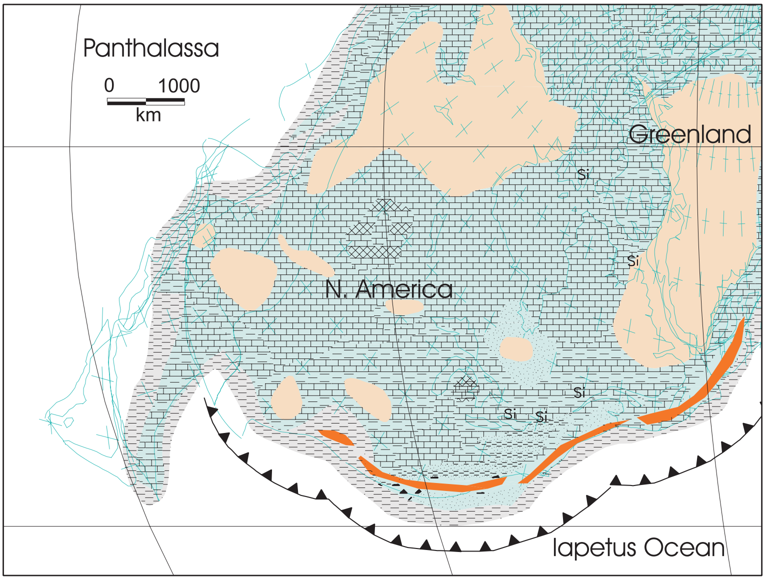

Fig. 27. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Late Ordovician time

Fig. 27. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji oraz przyległego oceanu Iapetus w późnym ordowiku

At the beginning of the Late Ordovician (in the Late Caradocian), carbonate accumulation in the Williston and Hudson basins was under the conditions of an increased water salinity; thin layers of gypsum and anhydrides are met there. A specific thin complex of bituminiferous pelitomorphic limestones and flinty rocks was formed in the southern part of the continent. The Hudson basin is likely to be characterized by an unstable tectonic regime (Norris 1986, Norford 1988, Nelson & Johnson 2002, Hanne *et al*. 2002). It is the only region where sandy facies dominated in sediments; their thickness does not exceed 100 m and a large part of them has continental origin. The basin in the east of Greenland has undergone regression by the Late Ordovician time and its development was finished (Henriksen 1978, Harland 1979, Henriksen & Higgins 2000, Golonka *et al*. 2003, Smith *et al*. 2004). The movement of Laurentia positioned this plate in close proximity to the Verkhoyansk (Okhotsk-Kolyma) superterrane, at that time connected with Siberia (Golonka *et al*. 2003). The northward movement of Siberia caused the collision of Siberia and Laurentia. The tectonothermal event was recorded in the Svalbard as the Middle Ordovician M'Clintock orogeny (Ohta *et al*. 1989, 1996), also the transpression developed along the strike slip along the margin of Barentsia. The Taconian orogeny caused by arc collision with Laurentia continued through the Caradocian (McKerrow *et al*. 1991). On the whole, the area of the inner marine basins on Siberian plate (Fig. 28) became smaller (Ronov *et al*. 1984, Kanygin *et al*. 1988, Zonenshain *et al*. 1990, Torsvik *et al*. 1995, Ford & Golonka 2003, Golonka *et al*. 2003, Kiessling *et al*. 2003, Bogolepova *et al*. 2006, Artyushkov *et al*. 2008). Terrigeneous marine and continental complexes dominated in the south of the Tunguska basin. Lenses and layers of gypsum indicating an increased water salinity were found in some places there. To the north, sandy and clayey rocks changed to pure limestones. This formation continued to the north to the southern Taimyr basin (Ronov *et al*. 1984, Bogdanov *et al*. 1998, Inger *et al*. 1999, Golonka *et al*. 2003, Metelkin *et al*. 2005, Gee *et al*. 2006, Lorenz *et al*. 2008). In the northern part of the southern Taimyr basin, carbonates changed abruptly to black clayey and flinty rocks of a rather low thickness. Such sedimentation conditions existed in that region since the Early Ordovician. Clayey and flinty deposits of the upper Ordovician have the thickness of the first tens of meters, however, in the axial part of the basin their thickness was as large as 50–700 m. Areas of the erosion were smoothed peneplains at that time. The basins in the regions of Sette-Daban and Verkhoyansk were of the special type. Shelf limestones dominated there among deposits; however, their thickness was rather large and sometimes exceeded 1500 m. It is obvious that these regions were epicratonic basins, but their paleogeography is not clear yet.

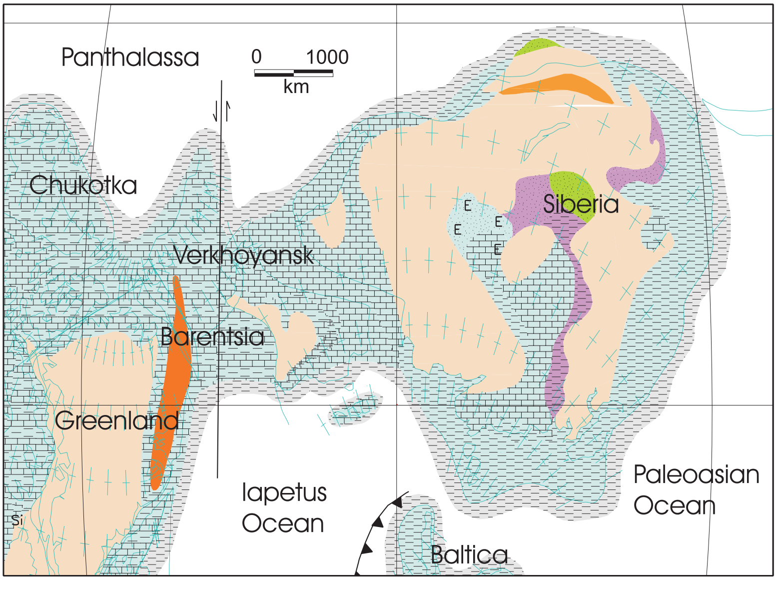

Fig. 28. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Late Ordovician time

Fig. 28. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich w późnym ordowiku

Baltica (Figs 26, 29) rotated counterclockwise, what caused strike-slip deformation in the narrowing ocean between Baltica and Siberia (Torsvik *et al*. 1996). Avalonia was probably sutured to Baltica by the end of Ordovician or in the Early Silurian (Torsvik *et al*. 1996). The closure of the Tornquist Sea was dominated by a strike-slip suturing of the two continents, rather than by full-scale continent-continent collision (Torsvik & Trench 1991). According to Pożaryski (1988), the Polish part of Avalonia was sutured to Baltica, at the end of the Ordovician, along a strike-slip fault zone known as the Tornquist–Teisseyre line. The two blocks formed one larger continent – Balonia. This represents the Early Caledonian orogeny. The Baltic-Moscow basin in the Late Ordovician became smaller because of regression (Nikishin *et al*. 1996). Certainly it was not connected any more with the Ural Ocean in the east. A fraction of argillaceous material in sediments increased, and carbonates were mainly presented by reef facies. Argillaceous sediments dominated in the Scandinavian part of the basin. Their thickness does not exceed the first tens of meters there. In the Late Ordovician, accumulation of sediments started in the Ruegen-Pomorze Trough (Beier *et al*. 2000, Dadlez 2000, Beier & Katzung 2001, Wrona *et al*. 2001, Verniers *et al*. 2002, Winchester *et al*. 2002, Krzemiński & Poprawa 2006, Nawrocki & Poprawa 2006, Podhalańska & Modliński 2006). The thickness of argillaceous deposits exceeds 2600 m there. Subsidence started in the Peri-Carpathian zone; in the marginal basin, in the coastal shallow zone, mainly sandy rocks were deposited (Buła & Jachowicz 1996, Moryc & Nehring-Lefeld 1997, Maksym *et al*. 2003). Compared to the Middle Ordovician, the tectonic development of the Peri-Urals zone did not change (Zoneshain *et al*. 1990, Puchkov 1991, 1996, 1997, Nikishin *et al*. 1996). This margin of the continent continued to subside and fragmented material coming from the central regions was deposited there. To the east, subcontinental alluvium-delta facies were replaced by rhythmic sandy-argillaceous and carbonate-terrigeneous deposits.

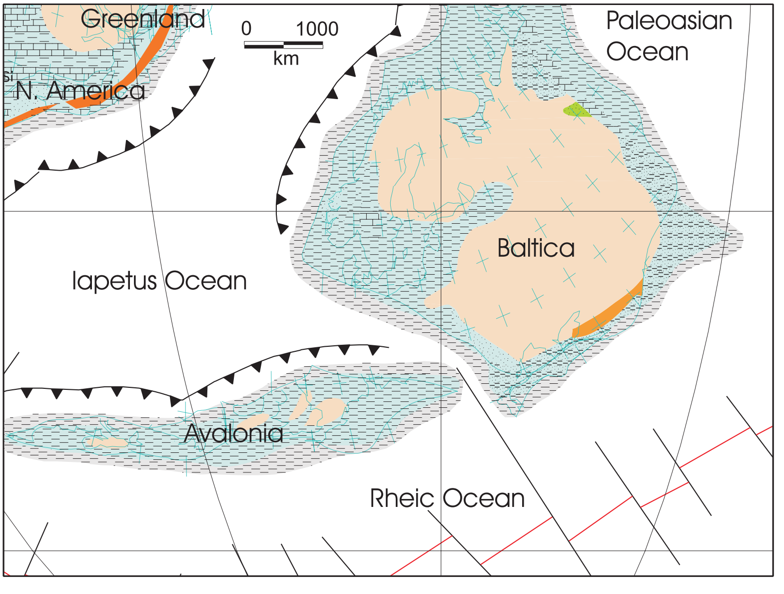

Fig. 29. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Late Ordovician time

Fig. 29. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki oraz obszarów sąsiednich w późnym ordowiku

The facies distribution on the South China and Indochina plates (Fig. 30) during this time was similar to the previous one (Ronov *et al*. 1984, Shouxin & Yongyi 1991, Chen *et al*. 1995, Golonka 2000, 2002, Cocks 2001, Feng *et al*. 2001, Kiessling *et al*. 2003, Golonka *et al*. 2006b). The territory of the Yangtze basin became smaller in the south and west, because upward movements became more intensive there and large land areas were formed (Songpan and Dian-Qian). The Late Ordovician deposits are presented by shallow argillaceous-carbonate associations with the thickness up to 100–150 m. In the northern part of Indostan no changes occurred in the marginal basin compared to the Middle Ordovician time (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Monotonous sedimentation of carbonate-terrigeneous deposits with the total thickness of 150–200 m continued there.

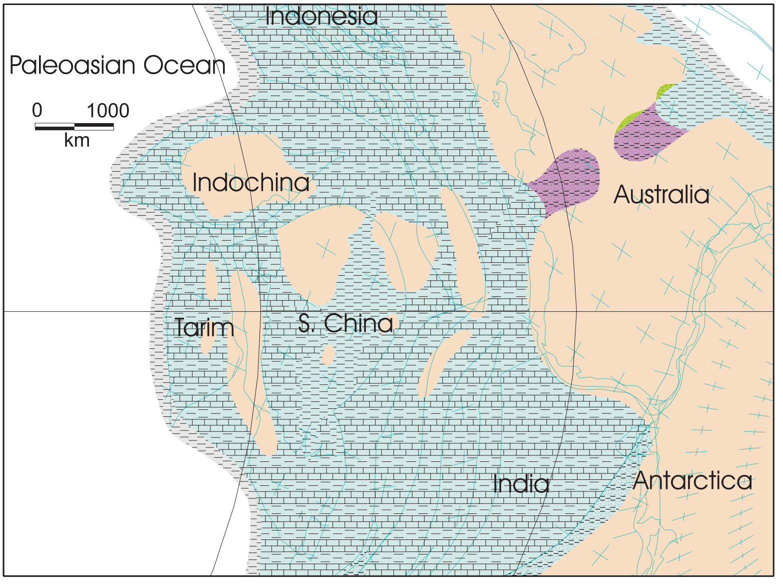

Fig. 30. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Late Ordovician time

Fig. 30. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich w późnym ordowiku

Early Silurian

Gondwana drifted across the South Pole, rotating clockwise and was separated from the other continents by the rapidly spreading Rheic Ocean (Scotese & McKerrow 1990, McKerrow *et al*. 1991, Golonka *et al*. 1994, 2006c, Torsvik *et al*. 1996, Dalziel 1997, Golonka 2000, 2002, Lewandowski 2003, Cocks & Torsvik 2005, 2006, 2007, McCausland *et al*. 2007). The main part of the Rheic Ocean had a latitudinal orientation between 30° and 60°S, and must have spanned 160 degrees of longitude (Fig. 31).

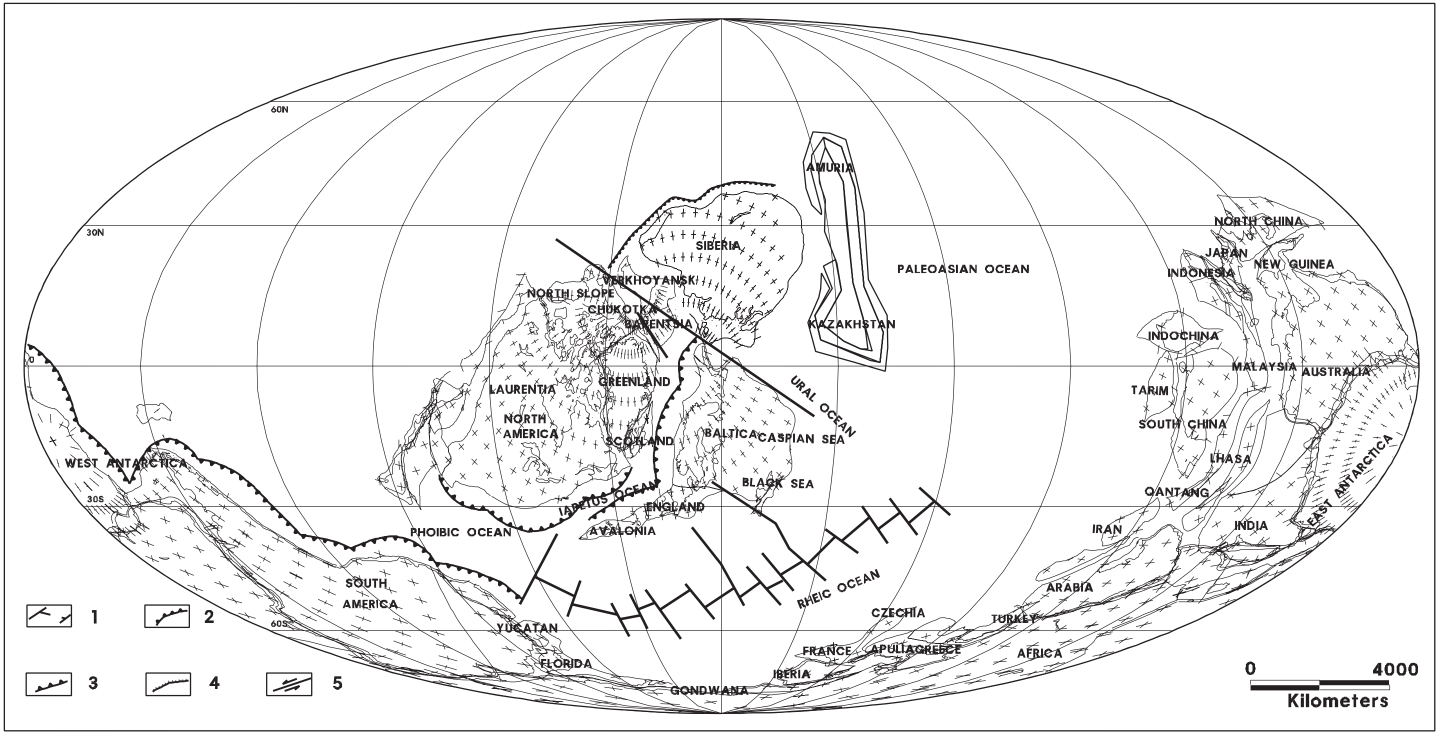

Fig. 31. Plate tectonic map of Early Silurian (plates position as of 435 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 31. Mapa tektoniki płyt wczesnego syluru (pozycja płyt 435 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

The Rheic Ocean was connected in the north-east with the Paleoasian Ocean (Zonenshain *et al*. 1990, Dobretsov *et al*. 2003).

The continent of Kazakhstan was formed in the Silurian and then grew during the Paleozoic by the accretion. The relationship between Kazakhstan and other Asian plates remain uncertain and speculative. Baltica moved northwestward, relative to Laurentia, and the Iapetus Ocean narrowed significantly (Fig. 31). The end of the time slice was marked by the collision between Baltica and Laurentia – the Scandian orogeny (Golonka 2000, 2002, Gee *et al*. 2008). The continent of Kazakhstan was formed in the Silurian and then grew during the Paleozoic by the accretion. The relationship between Kazakhstan and other Asian plates remain uncertain and speculative (Zonenshain *et al*. 1990, Golonka *et al*. 1994, 2006b, Golonka 2000, 2002, Nikitin 2002, Levashova *et al*. 2003, Alexyutin *et al*. 2005, Golonka *et al*. 2006b, van der Voo *et al*. 2006).

After the Late Ordovician transgression, maximal in the Paleozoic time, a wide transgression developed in the Early Silurian on the Laurentian plate (Fig. 32) and the total size of marine basins became essentially smaller. Large land area formed by plains appeared, especially in the Midcontinent region (Johnson 1980, Barrick 1997, Cocks 2001, Cramer & Saltzman 2007). This feature as well as a warm climate resulted in dominating accumulation of carbonates in all marine basins of the craton, often in reef facies. Thickness of the Lower Silurian deposits usually does not exceed 200 m. In the Michigan basin subsidence was not compensated by sediments (Howell & van der Pluijm 1990, 1999).

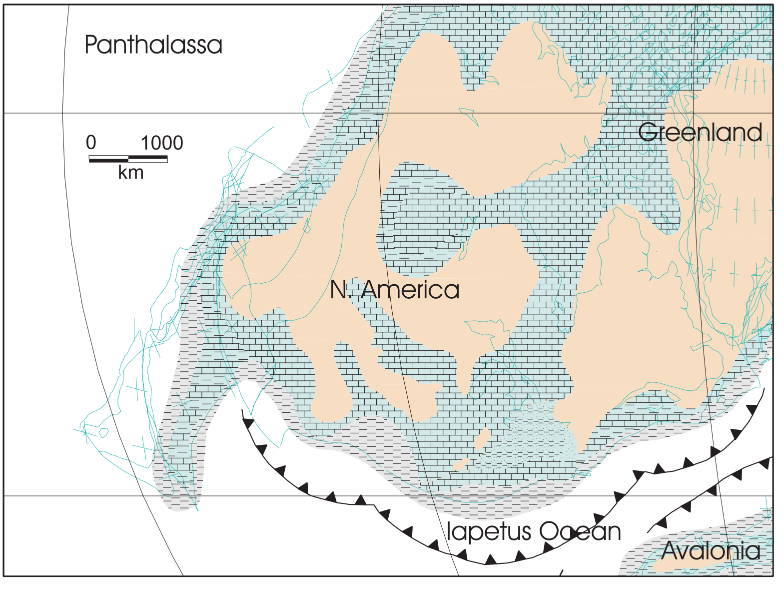

Fig. 32. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Iapetus Ocean during Early Silurian time

Fig. 32. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji oraz przyległego oceanu Iapetus we wczesnym sylurze

Almost no terrigeneous rocks were formed in the region, besides the Peri-Appalachian zone, where sandy, argillaceous, and conglomerate strata removed from uplifts of the southern Appalachian orogenic belt were accumulated in marine and continental facies (Dickinson 1983, Brett *et al*. 1990). Their thickness is as much as 1 km. Increased thickness of deposits was also found for the Peri-Innuitian and Peri-Cordilleran zones (de Freitas *et al*. 1999). Tunguska and Taimyr basins were active in the Late Llandovery (Tesakov *et al*. 1998, 2000, Artyushkov & Chekhovich 2002, 2004). All this vast region was the open marine basin, where carbonates with benthic fauna dominated in sediments. Graptolitic schals were accumulated in more deep marginal parts. In the southern part of the Tunguska basin in Siberia (Fig. 33) semi-closed, periodically dried, salted depression existed where red-colored sands, gypsum-bearing dolomites and gypsum were accumulated. Thickness of carbonate layer in the Tunguska basin is up to 300–400 m. The specific conditions existed in the Taimyr basin (Metelkin *et al*. 2005, Lorenz *et al*. 2008). Its central part was characterized by a long stable regime of non-compensated subsidence; there a formation of graptolitic schales continued. Carbonate reef rocks were deposited to the south, while carbonate-terrigeneous rocks with a thickness of some hundreds of meters – to the north. In the eastern part of Siberia carbonates dominated in deposits of the Sette-Daban and Yana-Kolyma basins. A fraction of terrigeneous rocks gradually increased in the Sette-Daban basin; it is likely that filling of the depression came to the end at that time. Thickness of deposits is rather high there, for example up to 1.6 km in the southern Verkhoyansk area.

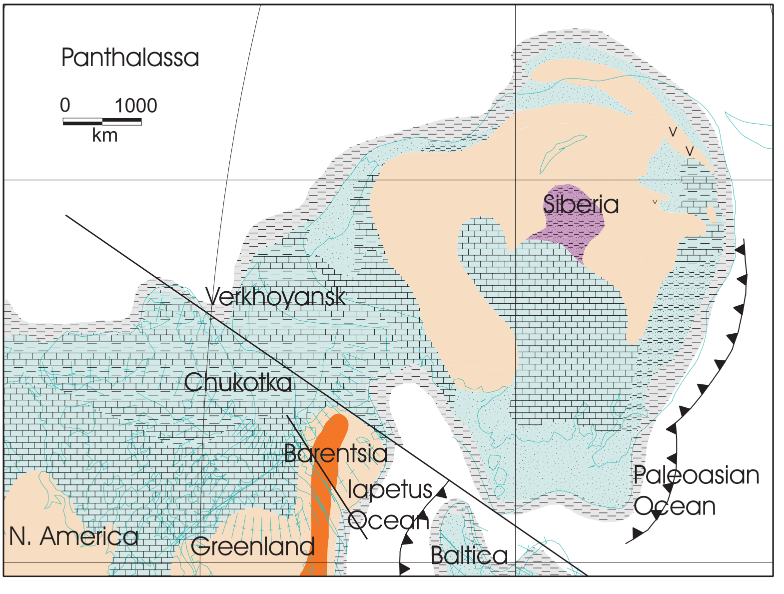

Fig. 33. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Early Silurian time

Fig. 33. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich we wczesnym sylurze

The end of the time slice was marked by the collision between Baltica and Laurentia – the Scandian orogeny. Sedimentary rocks affected by Scandian thrusting and isotopic age data indicate an Early Silurian age for the onset of the orogeny (Soper *et al*. 1992). In the Late Llandovery, west-verging nappes were emplaced in North-East Greenland. After the first phase of the Scandian orogeny, the southern part of the Iapetus Ocean still remained open between Avalonia and Laurentia. The Barentsia microcontinent, which included Svalbard, collided with northern Baltica (Ohta *et al*. 1996).

In the western and south-western parts of the East-European platform a regression was developed in the Early Silurian time (Fig. 34); the Baltic-Moscow basin became wider and it became connected with the Volhyn-Podolia basin (Nikishin *et al*. 1996). Shallow carbonate mud enriched in remains of various fauna dominated in the deposits there. Their thickness is 150–20 m and is as much as 700 m in the southern Scandinavia. This increase marks entire filling of the Ruegen-Pomorze depression (Beier *et al*. 2000, Dadlez 2000, Beier & Katzung 2001, Wrona *et al*. 2001, Verniers *et al*. 2002, Winchester *et al*. 2002, Krzemiński & Poprawa 2006, Nawrocki & Poprawa 2006, Podhalańska & Modliński 2006). Small transgression was also developed in the Pechora basin which extended in its size to the Kanin peninsula (Ismail-Zadeh *et al*. 1997, Martirosyan *et al*. 1998, O'Leary *et al*. 2004). Gypsum and lagoon carbonate-terrigeneous facies are present there in the Lower Silurian rocks. The Peri-Urals zone continued to subside; terrigeneous sedimentation was replaced there by nearly pure carbonate and in the coastal zone – by terrigeneous-carbonate with flints (Zonenshain *et al*. 1990, Puchkov 1991, 1996, 1997, Nikishin *et al*. 1996). Reefogenous facies were developed in the eastern part of the Peri-Urals zone.

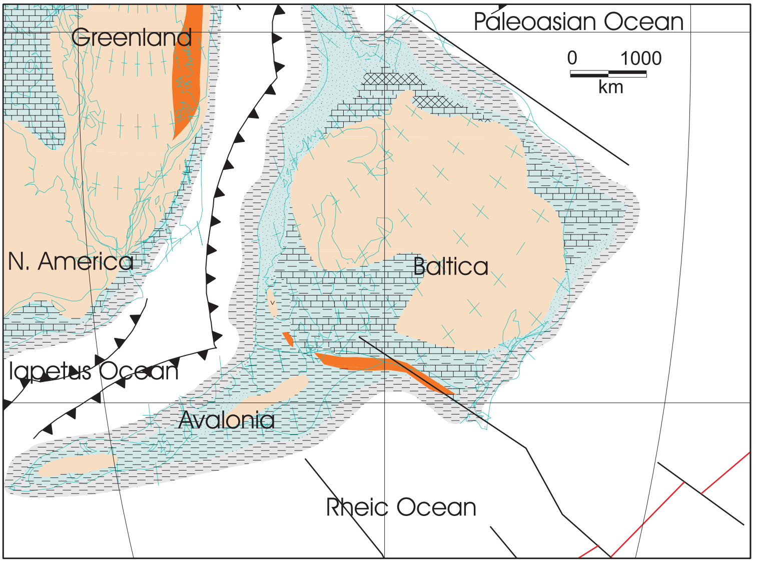

Fig. 34. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Early Silurian time

Fig. 34. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki oraz obszarów sąsiednich we wczesnym sylurze

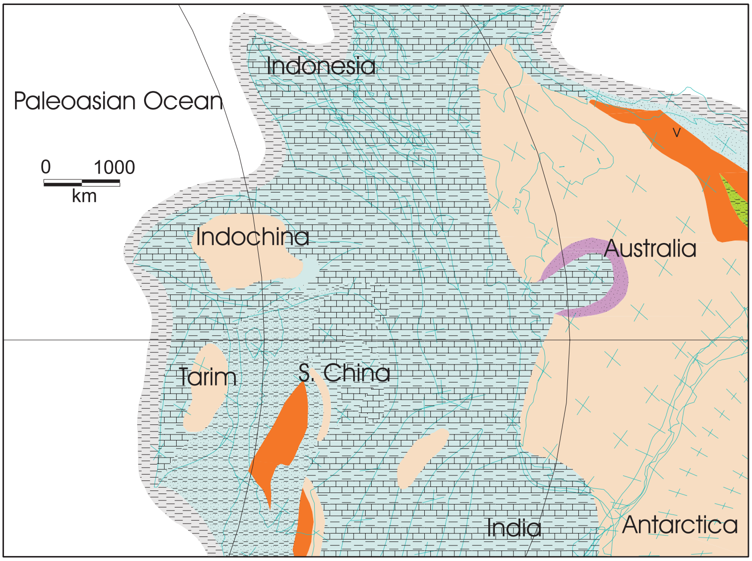

Fig. 35. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Early Silurian time

Fig. 35. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich we wczesnym sylurze

Indochina was located just north of the equator. The ongoing orogenic process within South China and South-East Asia (Fig. 35) is marked by uplifts and synorogenic flysch deposits indicate ongoing orogenic processes. Similar Ordovician-Silurian flysch deposits of the Pa Ham Formation are known from the Indochina plate. Mixed carbonate/clastic rocks were deposited on the Sibumasu plate (Brookfield 1996). Semi-isolated marine basin covered a large part of the South China craton, where black graptolitic schists were deposited (Ronov *et al*. 1984, Shouxin & Yongyi 1991, Chen *et al*. 1995, Golonka 2000, 2002, Cocks 2001, Feng *et al*. 2001, Kiessling *et al*. 2003, Golonka *et al*. 2006b). It was separated from the Cathaysian belt by Jiangnan island; another land Dian-Qian-Gui bordered it from the south, while the Kam-Yunnan meridional uplift was the barrier between the epicontinental sea and the Paleo-Tethys Ocean. In the second half of the Early Silurian, deposition of argillaceous rocks changed to a formation of carbonates which included interlayers of terrigeneous rocks in the north-western part of the craton. The total thickness of the Lower Silurian rocks is 500–600 m and up to 1 km in some troughs. Minor continental rifting occurred in the Gulf of Carpentaria region of Australia (Cook 1990). A small marine Carnarvon basin existed only in the western part of Australia (Fig. 35), where terrigeneous rocks were accumulated, sometimes in alluvial-deltaic facies (Cook 1990, Hocking & Preston 1998, El-Tabakh *et al*. 2004, Ghori *et al*. 2005). Their thickness is not large, 50–100 m, but it exceeds 1.8 km in a small rift.

In the northern part of Greater India almost continuous subsidence of marginal parts of the craton occurred; terrigeneous and carbonate rocks were accumulated under shallow conditions. Their thickness is 200–300 m in the Low Himalayas of India and up to 700 m in

Nepal (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Most part of Arabia was covered by marine basins, where terrigeneous rocks dominated in deposits (Abu-Ali *et al*. 1999, Jones & Stump 1999, Garfunkel 2003, Abu-Ali & Littke 2005). Thickness of the Lower Silurian rocks exceeds 500 m in the central Arabia. Carbonate-terrigeneous deposits with 500–700 m thickness were accumulated in the southern Afghanistan (Wolfart &Wittekind 1980).

Late Silurian

This was the time of the major development of the Caledonian orogeny and final closure of the Iapetus (Fig. 36). After the complete closure of the Iapetus Ocean, the continents of Baltic, Avalonia, and Laurentia formed the continent of Laurussia (Ziegler 1989). It is quite possible that at that time several microplates rifted away from the Gondwana margin to arrive at Laurussia and Kazakhstan during the Devonian-Permian times (Golonka 2000, 2002, Golonka *et al*. 2006b).

General regression continued at the North America craton (Fig. 37); marine basins became small, internal semi-closed seas. The sizes of all marginal seas became smaller. As earlier, carbonates were dominating deposits; their thickness did not exceed the first tens of meters (Isaacson *et al*. 2007). The exception is the Michigan basin where the epoch of non-compensated subsidence was followed by intensive sedimentation of evaporites of the Keyug series, which included carbonates, sulphates and salt. Thickness of the Upper Silurian rocks there is about 1 km. A large thickness (up to 750 m) and essential role of terrigeneous (partially continental) rocks is known for the Peri-Appalachian zone (Brett *et al*. 1990). The second region with an increased water salinity is the Hudson bay, where dolomites, sands (sometimes at continental conditions) as well as gypsum and anhydrites (the Kenogami-River Formation) were accumulated. An intensive accumulation of fragmented material occurred in the central segment of the Peri-Cordilleran zone. It followed after the formation of reef carbonate deposits, and as the result this sedimentary complex increased westwards, as a sedimentary wedge, a size of the platform.

Regression developed in the Tunguska basin (Fig. 38). It became smaller, more shallow, and had a limited connection with an open sea (Ronov *et al*. 1984, Tesakov *et al*. 1998, 2000, Artyushkov & Chekhovich 2002, 2004, Golonka *et al*. 2003, Kiesling *et al*. 2003). There, an accumulation of parti-colored dolomites, sometimes gypsum-bearing, dominated. Northwards, the same as earlier normal marine conditions existed in the Taimyr basin and argillaceous (graptolite) layers were formed in the central part of the Taimyr, while carbonate complexes in its southern part (Metelkin *et al*. 2005, Lorenz *et al*. 2008). Uplifts and regressions developed in the former Sette-Daban basin in the east of the craton. Subsidence became less intensive and the size of the Yana-Kolyma basin became smaller; there limestone-dolomite sediments were deposited, while evaporites and thin basalt layers were formed in the north-east.

During the Late Silurian, the collision between Baltica and Greenland continued (Fig. 39).

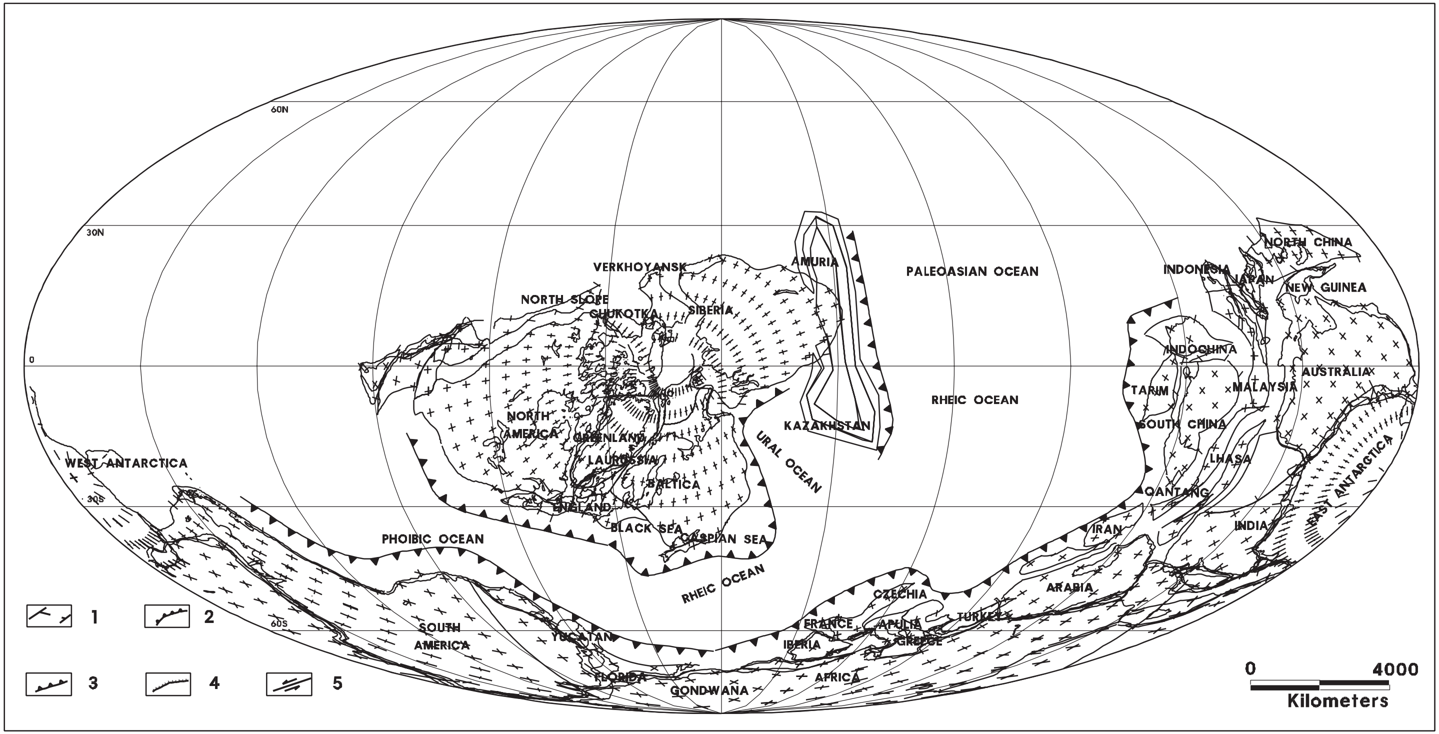

Fig. 36. Plate tectonic map of Late Silurian (plates position as of 425 Ma). Modified from Golonka (2002): 1 – oceanic spreading center and transform faults, 2 – subduction zone, 3 – thrust fault, 4 – normal fault, 5 – transform fault

Fig. 36. Mapa tektoniki płyt późnego syluru (pozycja płyt 425 milionów lat temu). Zmieniony wg Golonki (2002): 1 – centrum spredingu oceanicznego i uskok transformujący, 2 – strefa subdukcji, 3 – nasunięcie, 4 – uskok normalny, 5 – uskok przesuwczy

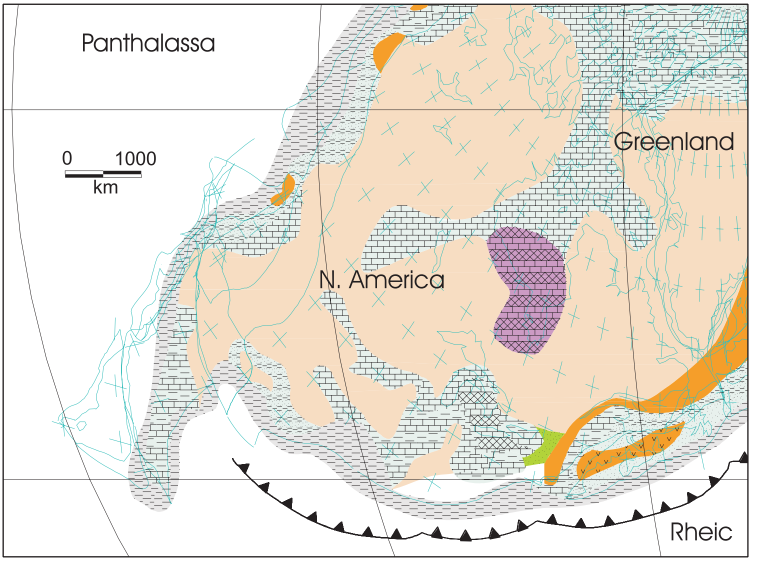

Fig. 37. Plate tectonic, paleoenvironment and lithofacies map of western Laurentia and adjacent Rheic Ocean during Late Silurian time

Fig. 37. Mapa tektoniki płyt, paleośrodowiska i litofacji zachodniej Laurencji oraz przyległego oceanu Reik w późnym sylurze

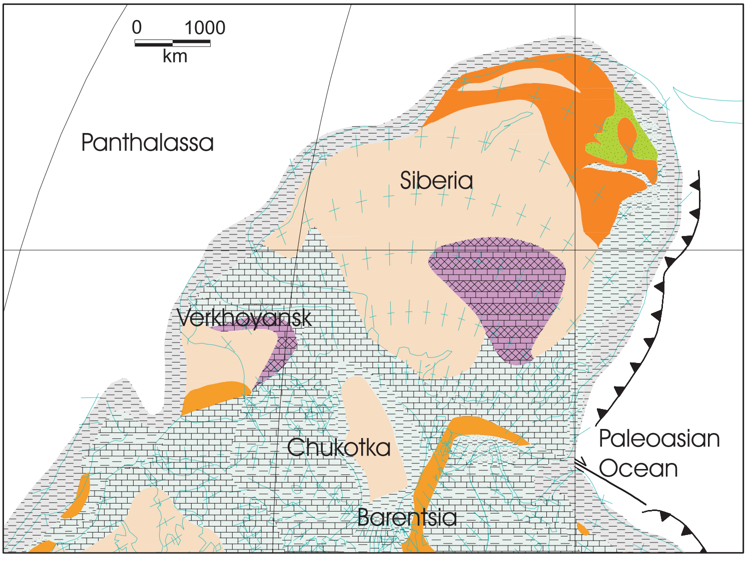

Fig. 38. Plate tectonic, paleoenvironment and lithofacies map of Siberia and adjacent areas during Late Silurian time

Fig. 38. Mapa tektoniki płyt, paleośrodowiska i litofacji Syberii oraz obszarów sąsiednich w późnym sylurze

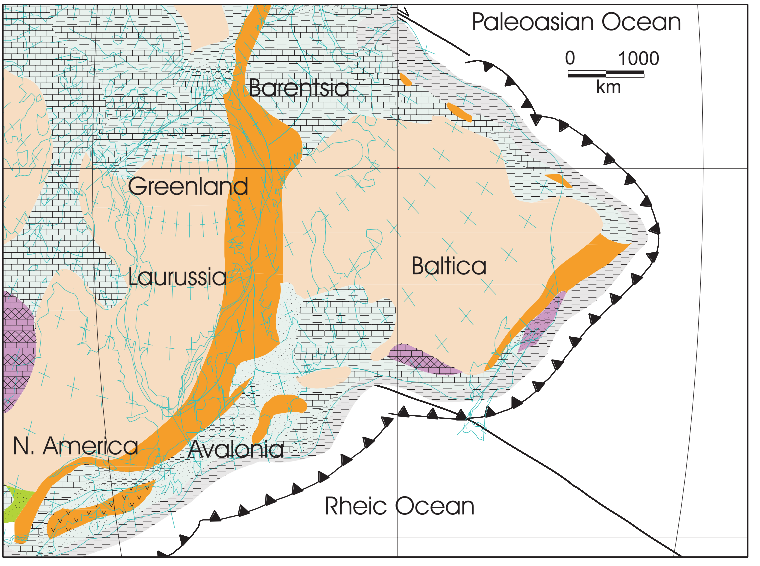

Fig. 39. Plate tectonic, paleoenvironment and lithofacies map of Baltica and adjacent areas during Late Silurian time

Fig. 39. Mapa tektoniki płyt, paleośrodowiska i litofacji Bałtyki oraz obszarów sąsiednich w późnym sylurze

This main phase of the Scandian orogeny is marked by nappes in Norway and Greenland. Laurentian crust was thrust over Baltica, causing large crustal thickening in the Caledonian belt (Dewey *et al*. 1973, Torsvik *et al*. 1996). According to Soper *et al*. (1992), the East Greenland and Scandinavian Caledonides display similar age and kinematic patterns, indicating a change of convergence vector between Baltica and Greenland from sinistrally oblique to nearly orthogonal. During the Middle Silurian, western Avalonia docked sinistrally with New Foundland and eastern Avalonia rotated toward Scotland (Soper *et al*. 1992). After the complete closure of the Iapetus Ocean, the continents of Baltica, Avalonia, and Laurentia formed the continent of Laurussia (Ziegler 1989, Golonka 2000, 2002).

The accretion of several central and eastern European terranes to Baltica during Silurian-Devonian time remains speculative. The Małopolska-High block, which encompasses most of southern Poland, including the southern Holy-Cross Mountains, was perhaps in close proximity to the Tornquist–Teisseyre line moving northwards (Lewandowski 1993 2003). According to Moczydłowska (1997), this block resembles the Cadomian-Avalonian terranes and shows Caledonian (pre-Devonian) deformation. The Scythian platform (southernmost Ukraine and SW Russia) comprises metamorphic sequences of age 470–410 Ma, covered by Devonian and Early Carboniferous rocks deformed during Carboniferous and Permian times (Zonenshain *et al*. 1990). Ziegler (1989) has mapped an orogenic belt at the southern border of Baltica, from Late Silurian to Permian time. Nikishin *et al*. (1996) displayed the Late Silurian accretion of terranes along the southeastern margin of Baltica. It is possible that part of the Scythian platform was accreted to Baltica together with the Avalonian terranes.

The Franklinian orogeny, in the north-western Canada (Plafker & Berg 1994), could be a result of collision of the Verkhoyanskian part of Siberia with the north Slope--Chukotkan part of Laurentia. According to Okulitch (1998), the suturing in the Canadian Islands occurred during Ordovician-Silurian time. Zonenshain *et al*. (1990) postulate the existence of an Arktida continent, which collided with Laurentia (see also Şengör & Natalin 1996, Nikishin *et al.* 1996, Natalin *et al*. 1999). Paleomagnetic data (Smethurst *et al*. 1998) support the latitudinal position of Siberia. A connection of Siberia and Laurentia, through the Verkhoyansk-north Slope-Chukotka terranes, is quite possible and logical. The Barents microcontinent, including Svalbard, collided with northern Baltica (Ohta *et al*. 1996). Thus, the supercontinent Laurasia I was formed. This continent was rimmed by the subduction zones on the southern and eastern margins. A scale of uplifts became larger in the Late Silurian. The size of the Baltic-Moscow basin (Nikishin *et al*. 1996) became essentially smaller; it became shallow and limestone-dolomitic mud was accumulated there (Fig. 39). The Volhyn-Podolia basin had the same shape, carbonate and terrigeneous rocks were formed there with layers of sulphate rocks in its eastern part. The specific complex of coarse-fragmented molasse-type deposits was formed in the south of Scandinavia, in the zone adjacent to the Scandinavian orogen. Thickness of the deposits did not exceed 1 km there. In the north-eastern part of the craton, in the Pechora basin, almost total regression occurred in the Late Silurian time; mainly carbonates with the total thickness of up to 200 m were accumulated in a small bay which remained there (Ismail-Zadeh *et al*. 1997, Martirosyan *et al*. 1998, O'Leary *et al*. 2004). The Peri-Urals zone became wider (Zonenshain *et al*. 1990, Puchkov 1991 1996 1997, Nikishin *et al*. 1996). There, as earlier, mainly limestone-dolomite sediments were formed; an exception was the coastal zone where terrigeneous, sometimes alluvial-deltaic facies were deposited. The widest band of such coastal complexes was formed in the southern Urals.

The orogenic processes known from the previous age slices continued within Asia. Clastic sedimentation prevailed in the Indochina and Sibumasu plates (Fig. 40) (Brookfield 1996). According to Shouxin & Yongyi (1991), following orogenic movements (Guanxi orogenic episodes), the Late Silurian was a time of regression within the South China plate. Shallow argillaceous deposits were accumulated in small narrow troughs in the western and northern parts of the craton. The rest of the craton developed as land.

The Carnarvon basin became shallow and salted in the Late Silurian (Cook 1990, Hocking & Preston 1998, El-Tabakh *et al*. 2004, Ghori *et al*. 2005). Evaporites (gypsum) together with dolomites, sandstones and argillaceous deposits were accumulated there. A subsidence of the Amadeus trough reactivated at the same time (Cook 1990, Li *et al*. 1991, Hocking & Preston 1998). There, eolian and alluvium sandstones of Merini of thickness more than 400 m were deposited in a large internal depression. Almost permanent subsidence of the Lower Himalayas continued in the north of Indostan; deposition of terrigeneous and carbonate rocks occurred in a shallow marine basin (Acharyya & Sastry 1979, Jain *et al*. 1980, Ronov *et al*. 1984, Garzanti 1999, Parcha 1999, Upreti 1999, Myrow *et al*. 2003, 2006, Steck 2003, Veevers 2004, Golonka *et al*. 2006b, McQuarrie *et al*. 2008). Thickness of the Upper Silurian rocks is 100–200 m. In the east of Iran and in the south of Afghanistan a carbonate-terrigeneous complex with the thickness of 200–300 m was formed (Ronov *et al*. 1984, Kobayashi 1987, Husseini 1989, Cater & Tunbridge 1992, Dean *et al*. 1997, Hamedi *et al*. 1997, Dronov 1999, 2001, Kiessling *et al*. 2003, Ruban *et al*. 2007).

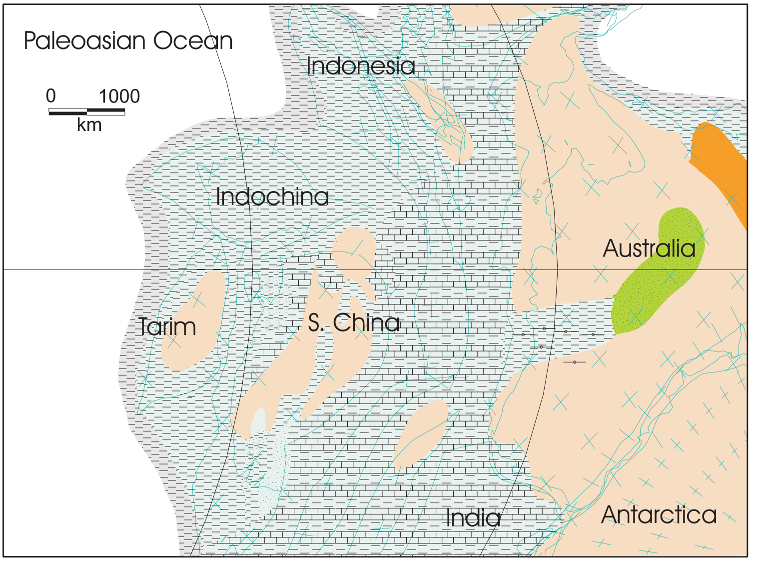

Fig. 40. Plate tectonic, paleoenvironment and lithofacies map of China, India and adjacent areas during Late Silurian time

Fig. 40. Mapa tektoniki płyt, paleośrodowiska i litofacji Chin, Indii oraz obszarów sąsiednich w późnym sylurze

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REFERENCES

Abu-Al M. & Littke R., 2005. Paleozoic petroleum systems of Saudi Arabia: A basin modeling approach. *GeoArabia*, 10, 131–168.

Abu-Ali M.A., Rudkiewicz J.-L.L., McGillivray J.G. & Behar F., 1999. Paleozoic petroleum system of Central Saudi Arabia. *GeoArabia*, 4, 321–336.

Acharyya S.K. & Sastry M.V.A., 1979. Stratigraphy of the eastern Himalaya. *Geological Survey of India Miscellaneous Publications*, 41, 49–65.

Ainsaar L., Meidla T. & Martma T., 2004. The Middle Caradoc Facies and Faunal Turnover in the Late Ordovician Baltoscandian palaeobasin. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 210, 119–133.

Ala M.A. & Moss B.J., 1979. Comparative petroleum geology of SE Turkey and NE Syria. *Journal of Petroleum Geology*, 1, 4, 3–27.

Alexyutin M.V., Bachtadse V., Alexeiev D.V. & Nikitina O.I., 2005. Palaeomagnetism of Ordovician and Silurian rocks from the Chu-Yili and Kendyktas mountains, South Kazakhstan. *Geophysical Journal International*, 162, 321–331.

Al-Saad D., Sawaf T., Gebran A., Barazangi M., Best J.A. & Chaimov T.A., 1992. Crustal structure of central Syria: The intracontinental Palmyride mountain belt. *Tectonophysics*, 207, 345–358.

Artyushkov E.V. & Chekhovich P.A., 2002. Silurian deposition in East Siberia and the absence of large-scale eustatic fluctuations. *Geologiya i Geofizika*, 43, 893–915.

Artyushkov E.V. & Chekhovich P.A., 2004. The nature of sea depth changes in epicontinental sedimentary basins of East Siberia in the Silurian. *Geologiya i Geofizika*, 45, 1273–1291.

Artyushkov E.V., Tesakov Yu.I. & Chekhovich P.A., 2008. Ordovician sea-level change and rapid change in crustal subsidence rates in East Siberia and Baltoscandia. *Russian Geology and Geophysics*, 49, 633–647.

Bai D., Zhou L., Wang X., Zhang X. & Ma T., 2007. Geochemistry of Nanhuan-Cambrian sandstones in southeastern Hunan, and its constraints on Neoproterozoic-Early Paleozoic tectonic setting of south China. *Acta Geologica Sinica*, 81, 755–771.

Barnes D.A., Harrison W.B. III & Shaw T.H., 1996. Lower-Middle Ordovician lithofacies and interregional correlation, Michigan Basin, USA. In: Witzke B.J., Ludvigson G.A. & Day J. (eds), Paleozoic sequence stratigraphy: views from the North American Craton, *Geological Society of America Special Paper*, 306, 35–54.

Barrick J.E., 1997. Wenlock (Silurian) depositional sequences, eustatic events, and biotic change on the southern shelf of North America. *Geological Society of America Special Paper*, 321, 47–65.

Beier H. & Katzung G., 2001. The deformation history of the Rügen Caledonides (NE Germany) – Implications from the structural inventory of the Rügen 5 borehole. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 222, 269–300.

Beier H., Maletz J. & Böhnke A., 2000. Development of an Early Palaeozoic foreland basin at the SW margin of Baltica. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 218, 129–152.

Best J.A., Barazang M., Al-Saad D., Sawaf T. & Gebran A., 1993. Continental margin evolution of the northern Arabian platform in Syria. *American Association of Petroleum Geologists Bulletin*, 77, 173–193.

Beydoun Z.R., 1991. Arabian plate hydrocarbon geology and potential – A plate tectonic approach. *American Association of Petroleum Geologists Studies in Geology*, 33, 1–77.

Bogdanov N.A., Khain V.E., Rosen O.M., Shipilov E.V., Vernikovsky V.A., Drachev S.S., Kostyuchenko S.L., Kozmichev A.B. & Sekretov S.B., 1998. *Explanatory Notes for the Tectonic Map of the Kara and Laptev Seas and Northern Siberia*. Institute of the Lithosphere of Marginal Seas, Russian Academy of Sciences, Moscow, 1–127.

Bogolepova O.K., Gubanov A.P. & Pease V.L., 2006. The Ordovician of the Severnaya Zemlya Archipelago. Russia. *Newsletters on Stratigraphy*, 42, 21–41.

Brett C.E., Goodman W.M. & LoDuca S.T., 1990. Sequences, cycles, and basin dynamics in the Silurian of the Appalachian Foreland Basin. *Sedimentary Geology*, 69, 191–244.

Brew G., Barazangi M., Al-Maleh A.K. & Sawaf T., 2001. Tectonic and geologic evolution of Syria. *GeoArabia*, 6, 573–616.

Brookfield M.E., 1996. Paleozoic and Triassic Geology of Sundaland. In: Moullade M. & Nairn A.E.M. (eds), *The Palaeozoic, B. The Phanerozoic geology of the world, I*, Elsevier, Amsterdam, 183–264.

Buła Z. & Jachowicz M., 1996. The Lower Palaeozoic sediments in the Upper Silesian Block. *Geological Quarterly*, 40, 299–336.

Cater J.M.L. & Tunbridge I.P., 1992. Palaeozoic tectonic history of SE Turkey. *Journal of Petroleum Geology*, 15 , 35–50.

Cawood P.A., McCausland P.J.A. & Dunning G.R., 2001. Opening Iapetus: Constraints from the Laurentian margin in Newfoundland. *Geological Society of America Bulletin*, 113, 443–453

Chafetz H.S., 1980. Evidence for an arid to semi-arid climate during deposition of the Cambrian System in Central Texas, U.S.A. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 30, 83–95.

Charvet J., Shy L., Shi Y., Guo L. & Faure M., 1996. The building of South China: collison of Yangtzi and Cathaysia blocks, problems and tentative answers. *Journal of Southeast Asian Earth Sciences*, 13, 223–235.

Chen X., Rong J.-Y., Wang X.-F., Wang Z.-H., Zhang Y.-D. & Zhan R.-B., 1995. Correlation of the Ordovician rocks of China. *International Union of Geological Sciences Publication*, 31, 1–104.

Cocks L.R.M., 2001. Ordovician and Silurian global geography. *Journal of the Geological Society*, 158, 197–210.

Cocks L.R.M. & Torsvik T.H., 2005. Baltica from the late Precambrian to mid-Palaeozoic times: The gain and loss of a terrane's identity. *Earth-Science Reviews*, 72, 39–66.

Cocks L.R.M. & Torsvik T.H., 2006. European geography in a global context from the Vendian to the end of the Palaeozoic. In: Gee D.G. & Stephenson R.A. (eds), European Lithosphere Dynamics, *Geological Society Memoir*, 32, 83–95.

Cocks L.R.M. & Torsvik T.H., 2007. Siberia, the wandering northern terrane, and its changing geography through the Palaeozoic. *Earth-Science Reviews*, 82, pp. 29–74.

Collins A.S. & Pisarevsky S.A., 2005. Amalgamating eastern Gondwana: The evolution of the Circum-Indian Orogens. *Earth-Science Reviews*, 71, 229–270.

Cook P.I., 1990. *Australia: Evolution of a continent*. Australian Government Publishing Service, Canberra.

Cramer B.D. & Saltzman M.R., 2007. Fluctuations in epeiric sea carbonate production during Silurian positive carbon isotope excursions: A review of proposed paleoceanographic models. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 245, 37–45.

Dadlez R., 2000. Pomeranian Caledonides (NW Poland), fifty years of controversies: A review and a new concept. *Geological Quarterly*, 44, 221–236.

Dalziel I.W.D., 1991. Pacific margins of Laurentia and east Antarctica-Australia as a conjugate rift pair. Evidence and implications. *Geology*, 19, 598–601.

Dalziel I.W.D., 1997. Neoproterozoic-Paleozoic geography and tectonics; review, hypothesis, environmental speculation. *Geological Society of America Bulletin*, 109, 16–42.

Dalziel I.W.D., Dalla Salda L.H & Gahagan L.M., 1994. Paleozoic Laurentia-Gondwana interaction and the origin of the Appalachian-Andean mountain system. *Geological Society of America Bulletin*, 106, 243–252.

Dean W.T., Martin F., Monod O., Günay Y., Kozlu H. & Bozdogan N., 1997. Precambrian? and Cambrian stratigraphy of the Penbegli-Tut inlier, southeastern Turkey. *Geological Magazine*, 134, 37–53.

Dewey J.F. & Burke B.S., 1973. Tibetan, Variscan, and Precambrian basement reactivation, products of continental collision. *Journal of Geology*, 81, 683–692.

Dickinson W.R., 1983. Provenance of North American Phanerozoic sandstones in relation to tectonic settings. *Geological Society of America Bulletin*, 94, 222–235.

Ding Ming Mong, 1978. *To Minh Bin F-48 XXXIV, 1:200 000 Geological Map Series of Socialistic Republic of Vietnam*. Geological Survey of S.R. Vietnam, Hanoi.

Dixon J., 2008. Stratigraphy and facies of Cambrian to Lower Ordovician strata in Saskatchewan. *Canadian Petroleum Geology Bulletin*, 56, 93–117.

Dobretsov N.L. & Buslov M.M., 2004. Fragments of oceanic islands in accretion-collision areas of Gorny Altai and Salair, southern Siberia, Russia: Early stages of continental crustal growth of the Siberian continent in Vendian-Early Cambrian time. *Journal of Asian Earth Sciences*, 23, 673–690.

Dobretsov N.L., Buslov M.M. & Vernikovsky V.A., 2003. Neoproterozoic to Early Ordovician Evolution of the Paleo-Asian Ocean: Implications to the break-up of Rodinia. *Gondwana Research*, 6, 143–159.

Dronov V.I., 1999. Cambrian sediments in the Central Pamirs and adjacent territories of Afghanistan. *Doklady Earth Sciences*, 369, 1073–1075.

Dronov V.I., 2001. New data on Ordovician stratigraphy of the southeastern Central Pamir. *Doklady Earth Sciences*, 381A, 1009–1011.

Dumoulin J.A., Harris A.G., Bradley D.C. & Freitas T.A. de, 2000. Facies patterns and conodont biogeography in Arctic Alaska and the Canadian Arctic Islands: Evidence against juxtaposition of these areas during early Paleozoic time. *Polarforschung*, 68, 257–266.

El-Tabakh M., Mory A., Schreiber B.C. & Yasin R., 2004. Anhydrite cements after dolomitization of shallow marine Silurian carbonates of the Gascoyne Platform, Southern Carnarvon Basin, Western Australia. *Sedimentary Geology*, 164, 75–87.

Estrada S., Piepjohn K., Henjes-Kunst F. & Gosen W. von, 2003. Geology, magmatism and structural evolution of the Yelverton Bay area, northern Ellesmere Island, Arctic Canada. *Polarforschung*, 73, 59–75.

Feiss P.G., Vance R.K. & Wesolowski D.J., 1993. Volcanic rock-hosted gold and base-metal mineralization associated with Neoproterozoic-early Paleozoic back-arc extension in the Carolina terrane, southern Appalachian Piedmont. *Geology*, 21, 439–442.

Feng Z.Z., Peng,Y.M., Jin Z.K., Jiang P.L., Bao Z.D., Luo Z., Ju T.Y., Tian H.Q. & Wang H., 2001. Lithofacies palaeogeography of the Early Ordovician in South China. *Journal of Palaeogeography*, 3, 11–22.

Findlay R.H., 1991. Antarctica. In: Moullade M. & Nairn A.E.M. (eds), *The Palaeozoic, B. The Phanerozoic geology of the world, I*, Elsevier, Amsterdam, 335–407.

Findlay R.H., 1997. The Song Ma Anticlinorium, northern Vietnam: the structure of an allochthonous terrane containing an early Palaeozoic island arc sequence. *Journal of Asian Earth Sciences*, 15, 453–464.

Findlay R.H., Aitchison J.C., Flood P.G. & Kleeman J.D., 1991. Australia. In: Moullade M. & Nairn A.E.M. (eds), *The Palaeozoic, B. The Phanerozoic geology of the world, I*, Elsevier, Amsterdam, 275–334.

Flawn P.T., Goldsten A., Jr., King, P.B. & Weaver C.E., 1961. *The Ouachita System*. Texas University Bureau Economic Geology, Pub. 6120, Austin, Texas.

Flöttmann T., Gibson G.M. & Kleinschmidt G., 1993. Structural continuity of the Ross and Delamerian orogens in Antarctica and Australia along the margin of the Paleo-Pacific. *Geology*, 21, 319–322.

Ford D. & Golonka J., 2003. Phanerozoic paleogeography, paleoenvironment and lithofacies maps of the circum-Atlantic margins. In: Golonka J. (ed.), Thematic set on paleogeographic reconstruction and hydrocarbon basins: Atlantic, Caribbean, South America, Middle East, Russian Far East, Arctic, *Marine and Petroleum Geology*, 20, 249–285.

Fortey R.A., Harper D.A.T., Ingham J.K., Owen A.W. & Rushton A.W.A., 1995. A revision of Ordovician series and stages from the historical type area. *Geological Magazine*, 132, 15–30.

Freitas T.A. de, Trettin H.P., Dixon O.A. & Mallamo M., 1999. Silurian system of the Canadian Arctic archipelago. *Canadian Petroleum Geology Bulletin*, 47, 136–193.

Garfunkel Z., 2003. Early Paleozoic sediments of NE Africa and Arabia: Products of continental-scale erosion, sediment transport, and deposition. *Israel Journal of Earth Sciences*, 51, 135–156.

Garzanti E., 1999. Stratigraphy and sedimentary history of the Nepal Tethys Himalaya passive margin. *Journal of Asian Earth Sciences*, 17, 805–827.

Garzione C.N., Patchett P.J., Ross G.M. & Nelson J., 1997. Provenance of paleozoic sedimentary rocks in the Canadian Cordilleran miogeocline: A Nd isotopic study. *Canadian Journal of Earth Sciences*, 34, 1603–1618.

Gee D.G., Bogolepova O.K. & Lorenz H., 2006. The Timanide, Caledonide and Uralide orogens in the Eurasian high Arctic, and relationships to the palaeo-continents Laurentia, Baltica and Siberia. In: Gee D.G. & Stephenson R.A. (eds), European Lithosphere Dynamics, *Geological Society Memoir*, 32, 507–520.

Gee D.G., Fossen H., Henriksen N. & Higgins A.K., 2008. From the early Paleozoic platforms of Baltica and Laurentia to the Caledonide Orogen of Scandinavia and Greenland. *Episodes*, 31, 44–51.

Geldon A.L., 2003. Geology of Paleozoic rocks in the Upper Colorado River Basin in Arizona, Colorado, New Mexico, Utah, and Wyoming, excluding the San Juan Basin. *US Geological Survey Professional Paper*, 1411A, A1–A85.

Ghori K.A.R., Mory A.J. & Iasky R.P., 2005. Modeling petroleum generation in the Paleozoic of the Carnarvon Basin, Western Australia: Implications for prospectivity. *American Association of Petroleum Geologists Bulletin*, 89, 27–40.

Giese U. & Köppen S., 2001. Detrital record of Early Palaeozoic and Devonian clastic sediments at the southwestern border of the Fennoscandian Shield – Provenance signals for a Caledonian geodynamic evolution. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 222, 215–251.

Glen R.A., 2005. The Tasmanides of eastern Australia. *Geological Society Special Publication*, 246, 23–96.

Golonka J., 2000. *Cambrian-Neogene Plate Tectonic Maps*. Wydawnictwa Uniwersytetu Jagiellońskiego, Kraków.

Golonka J., 2002. Plate-tectonic maps of the Phanerozoic. In: Kiessling W., Flügel E. & Golonka J. (eds), Phanerozoic reef patterns, *SEPM (Society for Sedimentary Geology) Special Publication*, 72, 21–75.

Golonka J., 2007a. Late Triassic and Early Jurassic paleogeography of the world. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 244, 297–307.

Golonka J., 2007b. Phanerozoic Paleoenvironment and Paleolithofacies Maps [Late Paleozoic. Mapy paleośrodowiska i paleolitofacje fanerozoiku. Późny paleozoik]. *Geologia* (kwartalnik AGH), 33, 2, 145–209.

Golonka J., 2007c. Phanerozoic Paleoenvironment and Paleolithofacies Maps. Mesozoic. [Mapy paleośrodowiska i paleolitofacje fanerozoiku. Mezozoik]. *Geologia* (kwartalnik AGH), 33, 2, 211–264.

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 environment and resources, *Canadian Society of Petroleum Geologists Memoir*, 17, 1–47.

Golonka J., Bocharova N.Y., Ford D., Edrich M.E., Bednarczyk J. & Wildharber J., 2003. Paleogeographic reconstructions and basins development of the Arctic. In: Golonka J. (ed.), Thematic set on paleogeographic reconstruction and hydrocarbon basins: Atlantic, Caribbean, South America, Middle East, Russian Far East, Arctic, *Marine and Petroleum Geology*, 20, 211–248.

Golonka J., Gahagan L., Krobicki M., Marko F., Oszczypko N. & Ślączka A., 2006a. Plate Tectonic Evolution and Paleogeography of the Circum-Carpathian Region. In: Golonka J. & Picha F. (eds), The Carpathians and their foreland: Geology and hydrocarbon resources, *American Association of Petroleum Geologists Memoir*, 84, 11–46.

Golonka J., Krobicki M., Pająk J., Nguyen Van Giang & Zuchiewicz W., 2006b. *Global plate tectonics and paleogeography of Southeast Asia*. Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Arkadia, Krakow.

Golonka J., Ślączka A. & Picha F., 2006c. The Western Carpathians and Ouachitas: A comparative study of geodynamic evolution. In: Golonka J. & Picha F. (eds), The Carpathians and their foreland: Geology and hydrocarbon resources, *American Association of Petroleum Geologists Me*

moir, 84, 561–584.

Goncuoglu M.C. & Kozlu H., 2000. Early Paleozoic Evolution of the NW Gondwanaland: Data from Southern Turkey and Surrounding Regions. *Gondwana Research*, 3, 315–324.

Goncuoglu M.C., Goncuoglu Y., Kozur H.W. & Kozlu H., 2004. Paleozoic stratigraphy of the Geyik Dagi unit in the Eastern Taurides (Turkey): New age data and implications for Gondwanan evolution. *Geologica Carpathica*, 55, 433–447.

Gupta J. & Brookfield M.E., 1991. India. In: Moullade M. & Nairn A.E.M. (eds), *The Palaeozoic, B. The Phanerozoic geology of the world, I*, Elsevier, Amsterdam, 71–110.

Gusev G.S. & Shpount B.R., 1987. Precambrian and Paleozoic rifting in northeastern Asia. *Tectonophysics*, 143, 245–252.

Ham W.E., 1959. Correlation of pre-Stanley strata in the Arbuckle-Ouachita Mountains region. In: Cline L.M., Holsweck W.J. & Ferray D.E. (eds), *The Geology of the Ouachita Mountains – a symposium*, Dallas and Ardmore Geological Society, Dallas, Texas, Ardmore, Oklahoma, 71–86.

Ham W.E., 1969. Regional geology of the Arbuckle mountains, Oklahoma. *Oklahoma Geological Survey Guidebook*, 17, 1–52.

Hamedi M.A., Wright A.J., Aldridge R.J., Boucot A.J., Bruton D.L., Chatterton B.D.E., Jones P., Nicoll R.S., Rickards R.B. & Ross J.R.P., 1997. Cambrian to Silurian of East-Central Iran: New biostratigraphic and biogeographic data. *Neues Jahrbuch für Geologie und Paläontologie – Monatshefte*, 7, 412–424.

Hanne D., White N., Butler A. & Jones S., 2002. Phanerozoic vertical motions of Hudson Bay. *Canadian Journal of Earth Sciences*, 41, 1181–1200.

Haq B.U. & Al-Qahtani A.M., 2005. Phanerozoic cycles of sea-level change on the Arabian platform. *GeoArabia*, 10, 127–160.

Harland W.B., 1979. A stratigraphic outline of Greenland. *Geological Magazine*, 116, 145–153.

Harper G.D. & Link P.K., 1986. Geochemistry of Upper Proterozoic rift-related volcanics, northern Utah and southeastern Idaho. *Geology*, 14, 864–865.

Henriksen N., 1978. East Greenland Caledonian fold belt. *Geological Survey of Canada Paper*, 78B, 183–188.

Henriksen N. & Higgins A.K., 2000. Early Palaeozoic basin development of North Greenland – part of the Franklinian Basin. *Polarforschung*, 68, 131–140.

Hocking R.M. & Preston W.A., 1998. Western Australia. Phanerozoic geology and mineral resources. *AGSO Journal of Australian Geology and Geophysics*, 17, 245–260.

Hoffman P.E., 1991. Did the breakout of Laurentia turned Gondwanaland inside-out? *Science*, 252, 1409–1412.

Howell P.D. & Pluijm B.A. van der, 1990. Early history of the Michigan Basin: subsidence and Appalachian tectonics. *Geology*, 18, 1195–1198.

Howell P.D. & Pluijm B.A. van der, 1999. Structural sequences and styles of subsidence in the Michigan basin. *Geological Society of America Bulletin*, 111, 974–991.

Husseini M.I., 1989. Tectonic and deposition model of Late Precambrian-Cambrian Arabian and adjoining plates. *American Association of Petroleum Geologists Bulletin*, 73, 1117–1131.

Husseini M.I., 1990. The Cambro-Ordovician Arabian and adjoining plates: a glacio-eustatic model. *Journal of Petroleum Geology*, 13, 267–287.

Inger S., Scott R.A. & Golionko B.G., 1999. Tectonic evolution of the Taimyr Peninsula, northern Russia: Implications for Arctic continental assembly. *Journal of the Geological Society*, 156, 1069–1072.

Isaacson P.E., Grader G.C., Pope M.C., Montañez I.P., Butts S.H., Batt L.S. & Abplanalp J.M., 2007. Devonian-Mississippian Antler foreland basin carbonates in Idaho: Significant subsidence and eustasy events. *Mountain Geologist*, 44, 119–140.

Ismail-Zadeh A.T., Kostyuchenko S.L. & Naimark B.M., 1997. The Timan-Pechora Basin (northeastern European Russia): Tectonic subsidence analysis and a model of formation mechanism. *Tectonophysics*, 283, 205–218.

Jaanusson V., 1973. Aspects of carbonate sedimentation in the Ordovician of Baltoscandia. *Lethaia*, 6, 11–34.

Jain A.K., Goel R.K. & Nair N.G.K., 1980. Implications of Pre-Mesozoic orogeny in the geological evolution of the Himalaya and Indo-Gangetic plains. *Tectonophysics*, 62, 67–86.

Jaworowski K., 2000. Facies variability in the Cambrian deposits from the Kościerzyna and Gdańsk sections (Pomeranian Caledonides foreland, northern Poland): A comparative study. *Geological Quarterly*, 44, 249–260.

Jiang S.-Y., Zhao H.-X., Chen Y.-Q., Yang T., Yang J.-H. & Ling H.-F., 2007. Trace and rare earth element geochemistry of phosphate nodules from the lower Cambrian black shale sequence in the Mufu Mountain of Nanjing, Jiangsu province, China. *Chemical Geology*, 244, 584–604.

Jishun R., 1996. The continental tectonics of China. *Journal of Southeast Asian Earth Sciences*, 13, 197–204.

Johnson M.E., 1980. Paleoecological structure in early silurian platform seas of the north American mid-continent. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 30, 191–215.

Jones P.J. & Stump T.E., 1999. Depositional and tectonic setting of the Lower Silurian hydrocarbon source rock facies, central Saudi Arabia. *American Association of Petroleum Geologists Bulletin*, 83, 314–332.

Kaljo D., Nestor H. & Polma L., 1988. East Baltic region. *British Museum (Natural History) Bulletin, Geology Series*, 43, 85–91.

Kanygin A.V., Moskalenko T.A. & Yadrenkina A.G., 1988. Ordovician System of the Siberian Platform. *International Union of Geological Sciences Publications*, 26, 1–27.

Keiner K.B., 1998. The nature and timing of tectonism in the western facies terrane of Nevada and California – An outline of evidence and interpretations derived from geologic maps of key areas. *US Geological Survey Professional Paper*, 1592, 1–19.

Kent D.V. & van der Voo R., 1990. Palaeozoic palaeogeography from palaeomagnetism of the Atlantic-bordering continents. In: McKerrow W.S. & Scotese C.R. (eds), Palaeozoic palaeogeography and biogeography, *Geological Society Memoir*, 12, 49–56.

Keppie J.D., Dostal J., Murphy J.B. & Cousens B.L., 1997. Palaeozoic within-plate volcanic rocks in Nova Scotia (Canada) reinterpreted: Isotopic constraints on magmatic source and palaeocontinental reconstructions. *Geological Magazine*, 134, 425–447.

Khomentovsky V.V., 2008. The Yudomian of Siberia, Vendian and Ediacaran systems of the international stratigraphic scale. *Stratigraphy and Geological Correlation*, 16, 581–598.

Kiessling W., Flügel E. & Golonka J., 1999. Paleo Reef Maps: Evaluation of a comprehensive database on Phanerozoic reefs. *American Association of Petroleum Geologist Bulletin*, 83, 1552–1587.

Kiessling W., Flügel E. & Golonka J., 2003. Patterns of Phanerozoic carbonate platform sedimentation. *Lethaia*, 36, 195–226.

Kleshchev K.A., 2007. Main trends of oil and gas exploration in Russia. *Geologiya Nefti i Gaza*, 2, 18–23.

Kluth C.F., 1986. Plate tectonics of the Ancestral Rocky Mountains. *Paleotectonics and Sedimentation in the Rocky Mountain Region*, 41, 353–369.

Kluth C.F. & Coney P.J., 1981. Plate tectonics of the Ancestral Rocky Mountains. *Geology*, 9, 10–15.

Kobayashi T., 1987. The Cambrian and Ordovician systems in the south side of Eurasia and the origin of the Tethys Sea. *Journal of Geography (Tokyo)*, 96, 339–368.

Kolata D.R., Huff W.D. & Bergström S.M., 2001. The Ordovician Sebree Trough: An oceanic passage to the Midcontinent United States. *Geological Society of America Bulletin*, 113, 1067–1078.

Kostyuchenko S.L., Morozov A.F., Stephenson R.A., Solodilov L.N., Vedrentsev A.G., Popolitov K.E., Aleshina A.F., Vishnevskaya V.S. & Yegorova T.P., 2004. The evolution of the southern margin of the East European Craton based on seismic and potential field data. *Tectonophysics*, 38, 101–118.

Kouchinsky A., Bengtson S., Pavlov V., Runnegar B., Torssander P., Young E. & Ziegler K., 2007. Carbon isotope stratigraphy of the Precambrian-Cambrian Sukharikha River section, northwestern Siberian platform. *Geological Magazine*, 144,609–618.

Krzemiński L. & Poprawa P., 2006. Geochemistry of the Ordovician and Silurian clastic sediments of the Koszalin-Chojnice zone and the western Baltic Basin (N Poland). *Prace Państwowego Instytutu Geologicznego*, 186, 123–148.

Larson E.E., Patterson P.E., Curtis G., Drake R. & Mutschler F.E., 1985. Petrologic, paleomagnetic, and structural evidence of a Paleozoic rift system in Oklahoma, New Mexico, Colorado, and Utah (USA). *Geological Society of America Bulletin*, 96, 1364–1372.

Levashova N.M., Degtyarev K.E., Bazhenov M.L., Collins A.Q. & van der Voo R., 2003. Middle Paleozoic paleomagnetism of east Kazakhstan: Post-Middle Devonian rotations in a large-scale orocline in the central Ural-Mongol belt. *Tectonophysics*, 377, 249–268.

Lewandowski M., 1993. Paleomagnetism of the Paleozoic Rocks of the Holy Cross Mts. (Central Poland and the Origin of the Variscan Orogen. *Institute of Geophysics, Polish Academy of Sciences Publications*, A-23, 3–84.

Lewandowski M., 2003. Assembly of Pangea: Combined Paleomagnetic and Paleoclimatic Approach. *Advances in Geophysics*, 46, 199–236.

Lewandowski M. & Abrahamsen N., 2002. Paleomagnetic results from the Cambrian and Ordovician sediments of Bornholm (Denmark) and Southern Sweden and paleogeographical implications for Baltica. *Journal of Geophysical Research B: Solid Earth*, 108, EPM 3-1–EPM 3-17.

Li Z.X., Powell C.M., Embleton B.J.J. & Schmidt P.W., 1991. New palaeomagnetic results from the Amadeus Basin and their implications for stratigraphy and tectonics. *Bureau of Mineral Resources, Geology & Geophysics Bulletin*, 236, 349–360.

Long D.G.F., 1989. Ella Bay Formation: Early Cambrian shelf differentiation in the Franklinian basin, central eastern Ellesmere Island, Arctic Canada. *Canadian Journal of Earth Sciences*, 26, 2621–2635.

Lorenz H., Männik P., Gee D., & Proskurnin V., 2008. Geology of the Severnaya Zemlya Archipelago and the North Kara Terrane in the Russian high Arctic. *International Journal of Earth Sciences*, 97, 519–547.

Lowe D.R. 1985. Ouachita Trough; part of a Cambrian failed rift system. *Geology*, 13, 790–793.

Lowe D.R., 1989. Stratigraphy, sedimentology, and depositional setting of pr-orogenic rocks of the Ouachita Mountains, Arkansas and Oklahoma. In: Hatcher R.D., Jr., Thomas W.A. & Viele G.W. (eds), *The Appalachian-Ouachita orogen in the United States, The Geology of North America, v. F-2*, Geological Society of America, Boulder, Colorado, 575–590.

Löfgren A. & Laufeld S., 2007. Ordovician limestone in Hälsingland, Sweden. *GFF (Formerly known as: Geologiska Föreningens i Stockholm Förhandlingar)*, 129,113–116.

Ma L., Dong Y., Tu X., Sun F., Xia J. & Yang L., 2008. Petroleum prospects of marine sequences in South China. *Frontiers of Earth Science in China*, 2, 105–113.

Maksym A., Śmist P., Pietrusiak M., Staryszak G. & Liszka B., 2003. New data on development of the Lower Paleozoic sediments in the Sędziszów Małopolski-Rzeszów region based on Hermanowa-1 borehole (SE Poland). *Przegląd Geologiczny*, 51, 412–418.

Martirosyan V., Popova L. & Vepreva M., 1998. The petroleum systems of the Pechora Platform Foreland, Russia. *Petroleum Geoscience*, 4, 339–348.

McCausland P.J.A., Voo R. van der & Hall C.M., 2007. Circum-Iapetus paleogeography of the Precambrian-Cambrian transition with a new paleomagnetic constraint from Laurentia. *Precambrian Research*, 156, 125–152.

McGill P., 1974, The stratigraphy and structure of the Vendon Fiord area. *Canadian Society of Petroleum Geologists Bulletin*, 22, 261–386.

McGillivray J.G. & Husseini M.I., 1992. The Paleozoic petroleum geology of central Arabia. *American Association of Petroleum Geologists Bulletin*, 76, 1473–1490.

McKerrow W.S., Dewey J.F. & Scotese C.R., 1991. The Ordovician and Silurian development of the Iapetus Ocean. In: Bassett M.G., Lane P.D. & Edwards D. (eds), *The Murchison Symposium, Proceedings of an International Conference on the Silurian System, Special Papers Palaeontology*, 44, 165–178.

McQuarrie N., Robinson D., Long S., Tobgay T., Grujic D., Gehrels G. & Ducea M., 2008. Preliminary stratigraphic and structural architecture of Bhutan: Implications for the along strike architecture of the Himalayan system. *Earth and Planetary Science Letters*, 272, 105–117.

Mei M.-X., Zhang H., Meng X.-Q. & Chen Y.-H., 2006. Sequence stratigraphic division and framework of the Lower Cambrian in the Upper Yangtze region. *Geology in China*, 33, 1292–1304.

Mellen F.F., 1977. Cambrian System in Black Warrior basin. *American Association of Petroleum Geologists Bulletin*, 61, 1897–1900.

Mel'nikov N.V. & Konstantinova L.N., 2005. Oil-gas prospects of the Vendian and Lower Cambrian of the Baykit oil-gas region of the Siberian craton. *Petroleum Geology*, 39, 126.

Metcalfe I., 1998. Paleozoic 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, 25–41.

Metelkin D.V., Vernikovsky V.A., Kazansky A.Y., Bogolepova O.K. & Gubanov A.P., 2005. Paleozoic history of the Kara microcontinent and its relation to Siberia and Baltica: Paleomagnetism, paleogeography and tectonics. *Tectonophysics*, 398, 225–243.

Moczydłowska M., 1997. Proterozoic and Cambrian successions in Upper Silesia: an Avalonian terrane in southern Poland. *Geological Magazine*, 134, 679–689.

Modliński Z., Nõlvak J. & Szymański B., 2007. Stratigraphy of the ordovician and silurian boundary deposits in northeastern Poland and their correlation with the stratotype sections in Estonia. *Biuletyn Państwowego Instytutu Geologicznego*, 427, 61–78.

Moryc W. & Nehring-Lefeld M., 1997. Ordovician between Pilzno and Busko in the Carpathian Foreland (Southern Poland). *Geological Quarterly*, 41, 139–150.

Møller L.N. & Friis H., 1999. Petrographic evidence for hydrocarbon migration in Lower Cambrian sandstones, Bornholm, Denmark. *Geological Society of Denmark Bulletin*, 45, 117–127.

Murphy J.B. & Keppie J.D., 2005. The Acadian orogeny in the northern Appalachians. *International Geology Review*, 47, 663–687.

Murphy J.B. & Nance R.D., 2008. The Pangea conundrum. *Geology*, 36, 703–706.

Murphy J.B., Cameron K., Dostal J., Keppie J.D. & Hynes A.J., 1985. Cambrian volcanism in Nova Scotia, Canada. *Canadian Journal of Earth Sciences*, 22, 599–606.

Murphy J.B., Dostal J. & Keppie J.D., 2008. Neoproterozoic-Early Devonian magmatism in the Antigonish Highlands, Avalon terrane, Nova Scotia: Tracking the evolution of the mantle and crustal sources during the evolution of the Rheic Ocean. *Tectonophysics*, 461, 181–201.

Myrow P.M., Hughes N.C., Paulsen T.S., Williams I.S., Parcha S.K., Thompson K.R., Bowring S.A., Peng S.-C. & Ahluwalia A.D., 2003. Integrated tectonostratigraphic analysis of the Himalaya and implications for its tectonic reconstruction. *Earth and Planetary Science Letters*, 212, 433–441.

Myrow P.M., Snell K.E., Hughes N.C., Paulsen T.S., Heim N.A. & Parcha S.K., 2006. Cambrian depositional history of the Zanskar Valley region of the Indian Himalaya: Tectonic implications. *Journal of Sedimentary Research*, 76, 364–381.

Natal'in B.A., Amato J.M., Toro J. & Wright J.E., 1999. Paleozoic rocks of northern Chukotka Peninsula, Russian Far East: Implications for the tectonics of the Arctic region. *Tectonics*, 18, 977–1003.

Nawrocki J. & Poprawa P., 2006. Development of Trans-European Suture Zone in Poland: From Ediacaran rifting to Early Palaeozoic accretion. *Geological Quarterly*, 50, 59–76.

Nelson S.J. & Johnson M.E., 2002. Jens Munk Archipelago: Ordovician-Silurian Islands in the Churchill area of the Hudson Bay Lowlands, northern Manitoba. *Journal of Geology*, 110, 577–589.

Neuman R.B. & Max M.D., 1989. Penobscottian-Grampian-Finnmarkian orogenies as indicators of terrane linkages. In: Dallmeyer R.D. (ed.), Terranes in the Circum-Atlantic Paleozoic orogens, *Geological Society of America Special Paper*, 230, 31–45

Nie S., Rowley D.B. & Ziegler A.A., 1990. Constraints on the locations of Asian microcontinents in Paleo-Tethys during the Late Paleozoic. In: McKerrow W.S. & Scotese C.R. (eds), Paleozoic paleogeography and biogeography, *Geological Society of London Memoir*, 12, 397–409.

Nikishin A.M., Ziegler P.A., Cloething S., Stephenson R.A., Furne A.V., Fokin P.A., Ershov A.V., Bolotov S.N., Koraev M.V., Alekseev A.S., Gorbachev I., Shipilov E.V., Lankrejer A. & Shalimov I.V., 1996. Late Precambrian to Triassic history of the East European Craton: dynamics of sedimentary basin evolution. *Tectonophysics*, 268, 23–63.

Nikitin I.F., 2002. Ordovician siliceous and siliceous-basalt formations of Kazakhstan. *Geologiya i Geofizika*, 43,512–527.

Norford B.S., 1988. The Ordovician-Silurian boundary in the Rocky Mountains, Arctic Islands and Hudson Platform, Canada. *British Museum (Natural History) Bulletin, Geology Series*, 43, 259–263.

Norris A.W., 1986. Review of Hudson platform paleozoic stratigraphy and biostratigraphy (Canada). In: Martini I.P. (ed.), *Canadian Inland Seas*, Elsevier, Amsterdam, New York 17–42.

Ohta Y., Dallmeyer R.D. & Peucat J.J., 1989. Caledonian terranes in Svalbard. In: Dallmeyer R.D. (ed.), Terranes in the Circum-Atlantic Paleozoic orogens, *Geological Society of America Special Paper*, 230, 1–15.

Ohta Y., Krasilscikov A.A. & Tebenkov A.M., 1996. Precambrian and Caledonian events in Svalbard, northwestern edge of the Eurasian Plate; a review in a regional context of the North Atlantic and Arctic Ocean. In: Qian X., You Z. & Halls H.C. (eds), *Precambrian geology and metamorphic petrology, Proceedings of the International Geological Congress*, 17, 27–42.

Olaussen S., 1981. Marine incursion in Upper Palaeozoic sedimentary rocks of the Oslo region, southern Norway. *Geological Magazine*, 118, 281–288.

O'Leary N., White N., Tull S., Bashilov V., Kuprin V., Natapov L. & MacDonald D., 2004. Evolution of the Timan-Pechora and South Barents Sea basins. *Geological Magazine*, 141, 141–160.

Olovyanishnikov V.G., Siedlecka A. & Roberts D., 1997. Aspects of the geology of the Timans, Russia, and linkages with Varanger Peninsula, NE Norway. *Norges Geologiske Undersokelse Bulletin*, 433, 28–29.

Okulitch A.V., 1998. The Caledonian Pearya Terrane of the Northern Ellesmere Island, Canadian Arctic. *III International Conference on Arctic Margins, ICAM III, Celle (Germany) 12–16.10.1998. Abstracts*, Celle, Germany, 134–135.

Parcha S.K., 1999. Cambrian biostratigraphy in the Tethyan sequences of the Spiti Valley, Himachal Himalaya. India. *Newsletters on Stratigraphy*, 37, 177–190.

Parfenov L.M., 1991. Tectonics of the Verkhoyansk-Kolyma Mesozoides in the context of plate tectonics. *Tectonophysics*, 199, 319–342.

Paul Z., Golonka J., Wójcik A. & Khudoley A., 2003a. The Iapetus Ocean, Rheic Ocean and Avalonian Terranes in Central Asia. *Geolines*, 16, 79–80.

Paul Z., Khudoley A., Golonka J. & Wójcik A., 2003b. Avalonian terranes between Europe and central Asia. In: Golonka J. & Lewandowski M. (eds), Geology, geophysics, geothermics and deep structure of the West Carpathians and their basement, *Publications of the Institute of Geophysics Polish Academy of Sciences. Monographic Volume*, M-28 (363), 155–156.

Pechersky D.M. & Didenko A.N., 1995. *Paleoaziatskiy okean; petromagnitnoye i paleomagnitnoye informaciye o ego litosfere [Paleoasian Ocean, petromagnetic and paleomagnetic information about its lithosphere]*. RAN, Moscow (in Russian).

Pedersen J.H., Karlsen D.A., Spjeldnæs N., Backer-Owe K., Lie J.E. & Brunstad H., 2007. Lower Paleozoic petroleum from southern Scandinavia: Implications to a Paleozoic petroleum system offshore southern Norway. *American Association of Petroleum Geologists Bulletin*, 91, 1189–1212.

Peryt T.M., Hałas S., Kovalevych V.M., Petrychenko O.Y. & Dzhinoridze N.M., 2005. The sulphur and oxygen isotopic composition of Lower Cambrian anhydrites in East Siberia. *Geological Quarterly*, 49, 235–242.

Pisarevsky S.A., Murphy J.B., Cawood P.A. & Collins A.S., 2008. Late Neoproterozoic and early Cambrian palaeogeography: Models and problems. *Geological Society Special Publication*, 294, 9–31.

Plafker G. & Berg H.C., 1994. Overview of the geology and tectonic evolution of Alaska. In: Plafker G. & Berg H.C. (eds), *The geology of Alaska. The geology of North America, G-1*, Geological Society of America, Boulder, Colorado, 17–48.

Podhalańska T. & Modliński Z., 2006. Stratigraphy and facies characteristics of the Ordovician and Silurian deposits of the Koszalin-Chojnice zone; similarities and differences to the western margin of the East European Craton and Rügen area. In: Matyja H. & Poprawa P. (eds), Facies, Tectonics and Thermal evolution of the Pomeranian sector of Trans-European Suture Zone and adjacent areas, *Prace Państwowego Instytutu Geologicznego*, 136, 39–78.

Poprawa P., 2006. Neoproterpzoic brek-up pf the supercontinent Rodinia/Pannotia recorded by development of sedimentary basins at the western slopes of Baltica. In: Matyja H. & Poprawa P. (eds), Facies, Tectonics and Thermal evolution of the Pomeranian sector of Trans-European Suture Zone and adjacent areas, *Prace Państwowego Instytutu Geologicznego*, 136, 165–188 (in Polish, English summary).

Poprawa P., Šliaupa S., Stephenson R. & Lazauskiene J., 1999. Late Vendian-Early Palaeozoic tectonic evolution of the Baltic Basin: Regional tectonic implications from subsidence analysis. *Tectonophysics*, 314, 219–239.

Porter J.W. & Fuller J.G.C.M., 1959. Lower Paleozoic rocks of northern Williston basin and adjacent areas. *American Association of Petroleum Geologists Bulletin*, 43, 124–189.

Pożaryski W., 1988. The Variscan Phase of platform Tectonic Evolution of the Northeastern Part of Poland and Neighboring Regions. *Geotectonics*, 22, 274–276.

Prokopiev A.V., 2000. Verkhoyansk-Cherskiy collisional orogen. *Geology of the Pacific Ocean*, 15, 891–904.

Puchkov N., 1991. The Paleozoic of the Uralo-Mongolian Fold System. *Occasional Publications ESRI, New Series*, Earth Science and Resources Institute, University of South Carolina, Columbia, South Carolina, 7, 1–69.

Puchkov N., 1996. The Paleozoic Geology of Asiatic Russia and Adjacent Territories. In: Moullade M. & Nairn A.E.M. (eds), *The Palaeozoic, B. The Phanerozoic geology of the world, I*, Elsevier, Amsterdam, 3–107.

Puchkov N., 1997. Structure and geodynamics of the Uralian Orogen. In: Burg J.-P. & Ford M. (eds), Orogeny through time, *Geological Society Special Publication*, 121, 201–236.

Puura V., Vaher R. & Tuuling I., 1999. Pre-Devonian landscape of the Baltic Oil-Shale Basin, NW of the Russian Platform. *Geological Society Special Publication*, 162, 75–83.

Raudsep R., 2008. Estonian georesources in the European context. *Estonian Journal of Earth Sciences*, 57, 80–86.

Ro H.E., Larsson F.R., Kinck J.J. & Husebye E.S., 1990. The Oslo Rift-its evolution on the basis of geological and geophysical observations. *Tectonophysics*, 178, 11–28.

Roberts D. & Siedlecka A., 2002. Timanian orogenic deformation along the northeastern margin of Baltic, northwest Russia and northeast Norway, and Avalonian-Cadomian connections. *Tectonophysics*, 352, 169–184.

Roberts D., Gorokhov I.M., Siedlecka A., Melnikov N.N., Turchenko T.L., Konstantinova G.V., Kutyavin E.P. & Sochava A.V., 1997. Rb-Sr dating of illite fractions from Neoproterozoic shales on Varanger Peninsula, North Norway. *Norges Geologiske Undersokelse Bulletin*, 433, 24–25.

Ronov A., Khain V. & Seslavinski K., 1984. *Atlas of Lithological Paleogeographical Maps of the World: Late Precambrian and Paleozoic of the Continents*. USSR Academy of Sciences, Leningrad.

Ross P.J., 1976. Ordovician sedimentation in the Western United States. In: Bassett M.G. (ed.), *The Ordovician system*, University of Wales Press, Cardiff, 73–105.

Rowell A.J., Rees M.N. & Suczek C.A., 1979. Margin of the North American continent in Nevada during LateCambrian time. *American Journal of Sciences*, 279, 1–18.

Ruban D.A., Al-Husseini M.I. & Iwasak Y., 2007. Review of Middle East Paleozoic plate tectonics. *GeoArabia*, 12, 35–56.

Safonova I.Yu., 2008. Geochemical evolution of intraplate magmatism in the Paleo-Asian Ocean from the Late Neoproterozoic to the Early Cambrian. *Petrology*, 16, 492–511.

Schulz K.J., Stewart D.B., Tucker R.D., Pollock J.C. & Ayuso R.A., 2008. The Ellsworth terrane, coastal Maine: Geochronology, geochemistry, and Nd-Pb isotopic composition – Implications for the rifting of Ganderia. *Geological Society of America Bulletin*, 120, 1134–1158.

Scotese C.R. & McKerrow W.S., 1990, Revised world maps and introduction. In: McKerrow W.S. & Scotese C.R. (eds), Paleozoic paleogeography and biogeography, *Geological Society of London Memoir*, 12, 1–21.

Şengör A.M.C. & Natalin B.A., 1996, Paleotectonics of Asia: fragment of a synthesis. In: An Yin & Harrison T.M. (eds), *The Tectonic Evolution of Asia*, Cambridge University Press, Cambridge, 486–640.

Sekretov S.B., 1999. Southeastern Eurasian Basin termination: Structure and key episodes of tectonic history. *Polarforschung*, 69, 251–257.

Sharma S., Dix G.R. & Riva J.F.V., 2003. Late Ordovician platform foundering, its paleoceanography and burial, as preserved in separate (eastern Michigan Basin, Ottawa Embayment) basins, southern Ontario. *Canadian Journal of Earth Sciences*, 40, 135–148.

Shi C. & Hu R., 2005. REE geochemistry of Early Cambrian phosphorites from Gezhongwu Formation at Zhijin, Guizhou Province, China. *Chinese Journal of Geochemistry*, 24, 166–172.

Shouxin Z. & Yongyi Z., 1991. China. In: Moullade M. & Nairn A.E.M. (eds), *The Palaeozoic, B. The Phanerozoic geology of the world, I*, Elsevier, Amsterdam, 219–274.

Sikorska M., 2000. Provenance petrological study of the Upper Vendian and Cambrian clastic material; foreland of the Pomeranian Caledonides (Northern Poland). *Geological Quarterly*, 44, 237–247.

Slind O.L., Andrews G.D., Murray D.L., Norford B.S., Paterson D.F., Salas C.J. & Tawadros E.E., 1994. Middle Cambrian to Lower Ordovician strata of the Western Canada Sedimentary Basin. In: *Geological Atlas of the Western Canada Sedimentary Basin*, Alberta Geological Survey, Edmonton, Alberta, 87–108.

Smethurst M.A., Khramov A.N. & Torsvik T.H., 1998. The Neoproterozoic and Palaeozoic palaeomagnetic data for the Siberian Platform; from Rodinia to Pangea. *Earth-Science Reviews*, 43, 1–24.

Smith M.P., Rasmussen J.A., Robertson S., Higgins A.K. & Leslie A.G., 2004. Lower Palaeozoic stratigraphy of the East Greenland Caledonides. *Geological Survey of Denmark and Greenland Bulletin*, 6, 5–28.

Soper N.J., Strachan R.A., Holdsworth R.E., Gayer R.A. & Greiling R.O., 1992. Sinistral transpression and the Silurian closure of Iapetus. *Journal of the Geological Society of London*, 14, 871–880.

Steck A., 2003. Geology of the NW Indian Himalaya. *Eclogae Geologicae Helvetiae*, 96, 147–196.

Steiner M., Zhu M., Zhao Y. & Erdtmann B.-D., 2005. Lower Cambrian Burgess Shale-type fossil associations of South China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 220, 129–152.

Stewart J.H. & Poole F.Y., 1974. Lower Paleozoic and uppermost Precambrian Cordilleran miogeocyncline, Great Basin, Western United States. *SEPM (Society of Sedimentary Geology) Special Publication*, 22, 28–57.

Surlyk F., Hurst J.M. & Bjerreskov M., 1980. First age-diagnostic fossils from the central part of the North Greenland foldbelt. *Nature*, 286, 800-803.

Szymański B., 2008. A lithological and microfacies record of the Upper Cambrian and Tremadocian euxinic deposits in the Polish part of the Baltic Depression (Northern Poland). *Biuletyn Państwowego Instytutu Geologicznego*, 430, 113–154.

Šliaupa S., Fokin P., Lazauskien J. & Stephenson R.A., 2006. The Vendian-Early Palaeozoic sedimentary basins of the East European Craton. In: Gee D.G. & Stephenson R.A. (eds), European Lithosphere Dynamics, *Geological Society Memoir*, 32, 449–462.

Tesakov Yu.I., Predtetchensky N.N., Khromych V.G., Berger A.Ya., Kovalevskaya E.O., Lopushinskaya T.V. & Bazarova L.S., 1998. Silurian stratigraphy of East Siberia, *Geologiya i Geofizika*, 10, 1335–1356.

Tesakov Yu.I., Predtechenskii N.N., Khromykh V.G. & Berger A.Ya., 2000. Stratigraphy of the Silurian type areas in East Siberia. *Stratigraphy and Geological Correlation*, 8, 119–136.

Tianfu T., Shkolnik E.L., Yaosong X., Conglin Y., Zhegallo E.A., Zun-Ming Z. & Tingkui H., 1999. Nature of phosphate components of lower Cambrian phosphorites, Yangtze platform. *Geology of the Pacific Ocean*, 14, 789-804.

Toelle B. & Sitchler J., 2008. Pannotian breakup (Iapetan Opening) features in central Oklahoma. *SEG Technical Program Expanded Abstracts*, 27, 929–932.

Torsvik T.H. & Trench A., 1991. The Ordovician history of the Iapetus Ocean in Britain; new palaeomagnetic constraints. *Journal of the Geological Society of London*, 148, 423–425.

Torsvik T.H., Tait J., Moralev V.M., McKerrow W.S., Sturt B.A. & Roberts D., 1995. Ordovician palaeogeography of Siberia and adjacent continents. *Journal of the Geological Society of London*, 152, 279–287.

Torsvik T.H., Smethurst M.A., Meert J.G., Voo R. van der, McKerrow W.S., Brasier M.D., Sturt B.A. & Walderhaug H.J., 1996. Continental break-up and collision in the Neoproterozoic and Palaeozoic; a tale of Baltica and Laurentia. *Earth-Science Reviews*, 40, 229–258.

Tran van Tri (Editor in chief) *et al*., 1979 (1977 in Vietnamese). *Geology of Vietnam (the North part). Explanatory note to the geological map on 1:1 000 000 scale*. Science and Technology Publishing House, Hanoi, 354 pp (in Vietnamese), 78 pp (in English).

Trettin H.P., 1987. Pearya: a composite terrane with Caledonian affinities in northern Ellesmere Island. *Canadian Journal of Earth Sciences*, 24, 224–245.

Trettin H.P., 1989. The Arctic Islands. In: Bally A.W. & Palmer A.R. (eds), *The Geology of North America, A*, Geological Society of America, Boulder, Colorado, 349–370.

Trettin H.P., 1994. Pre-Carboniferous geology of the northern part of the Arctic islands. Part 1. Hazen fold belt and adjacent parts of central Ellesmere fold belt, Ellesmere Island. *Geological Survey of Canada Bulletin*, 430, 1–248.

Trettin H.P., 1998. Pre-Carboniferous geology of the northern part of the Arctic islands: Northern Heiberg fold belt, Clements Markham fold belt, and Pearya; northern Axel Heiberg and Ellesmere islands. *Geological Survey of Canada Bulletin*, 425, 1–401.

Trettin H.P & Balkwill H.R., 1979. Contributions to the tectonic history of the Innuitian Province, Arctic Canada. *Canadian Journal of Earth Sciences*, 16, 748–769.

Trettin H.P., Parrish R. & Loveridge W.D., 1987. U-Pb age determinations on Proterozoic to Devonian rocks from northern Ellesmere Island, Arctic Canada. *Canadian Journal of Earth Sciences*, 24, 246–256.

Tuuling I. & Flodén T., 2000. Late Ordovician carbonate buildups and erosional features northeast of Gotland, northern Baltic Sea. *GFF (formerly known as: Geologiska Föreningens i Stockholm Förhandlingar)*, 122, 237–249.

Ulmishek G., 1990. Geologic evolution and petroleum resources of the Baltic Basin. *American Association of Petroleum Geologists Memoir,* 51, 603–632.

Upreti B.N., 1999. An overview of the stratigraphy and tectonics of the Nepal Himalaya. *Journal of Asian Earth Sciences*, 17, 577–606.

Vaida M. & Seghedi A., 1997. Palynological study of cores from the Borehole 1 Liman (Scythian Platform, Moldavia). *Neues Jahrbuch für Geologie und Paläontologie – Monatshefte*, 7, 399–408.

Veevers J.J., 2003. Pan-African is Pan-Gondwanaland: Oblique convergence drives rotation during 650–500 Ma assembly. *Geology*, 31, 501–504.

Veevers J.J., 2004. Gondwanaland from 650-500 Ma assembly through 320 Ma merger in Pangea to 185–100 Ma breakup: Supercontinental tectonics via stratigraphy and radiometric dating. *Earth-Science Reviews*, 68, 1–132.

Verniers J., Pharaoh T., André L., Debacker T.N., De Vos W., Everaerts M., Herbosch A., Samuelsson J., Sintubin M. & Vecoli M., 2002. The Cambrian to mid Devonian basin development and deformation history of Eastern Avalonia, east of the Midlands Microcraton: New data and a review. *Geological Society Special Publication*, 201, 47–93.

Vernikhovsky A., 1997. Neoproterozoic and Late Paleozoic Taimyr Orogenic and Ophiolitic belts, North Asia: A Review for Models for their Formation. In: Zhiqin X., Yufeng R. & Xiaoping Q. (eds), *Proceedings, 30th International Geological Congress*, 7, 121–138.

Voo R. van der, 1993. *Paleomagnetism of the Atlantic, Tethys and Iapetus oceans. Paleomagnetism of the Atlantic, Tethys and Iapetus oceans*. Cambridge University Press, Cambridge.

Voo R. van der, Levashova N.M., Skrinnik L.I., Kara T.V. & Bazhenov M.L., 2006. Late orogenic, large-scale rotations in the Tien Shan and adjacent mobile belts in Kyrgyzstan and Kazakhstan. *Tectonophysics*, 426, 335–360.

Wang J., Chen D., Wang Q., Yan D. & Wang Z., 2007. Platform evolution and marine source rock deposition during the terminal Sinian to Early Cambrian in the middle Yangtze region. *Acta Geologica Sinica*, 81, 1102–1109.

Winchester J.A., Floyd P.A., Crowley Q.G., Piasecki M.A.J., Lee M.K., Pharaoh T.C., Williamson P., Banka D., Verniers J., Samuelsson J., Bayer U., Marotta A.-M., Lamarche J., Franke W., Dörr W., Valverde-Vaquero P., Giese U., Vecoli M., Thybo H., Laigle M., Scheck M., Maluski H., Marheine D., Noble S.R., Paarish R.R., Evans J., Timmerman H., Gerdes A., Guterch A., Grad M., Cwojdzinski S., Cymerman Z., Kozdroj W., Kryza R., Alexandrowsk, P., Mazur S., Stedrá V., Kotková J., Belka Z., Patoćka F. & Kachlik V., 2002. Palaeozoic amalgamation of Central Europe: New results from recent geological and geophysical investigations. *Tectonophysics*, 360, 5–21.

Wolfart R. & Wittekindt H., 1980. Geology von Afghanistan. *Beiträge Regionale Geologie Erde*, Bd. 14, Berlin, Stuttgart, 1–500.

Wrona R., Bednarczyk W.S. & Stempień-Sałek M., 2001. Chitinozoans and acritarchs from the Ordovician of the Skibno 1 borehole, Pomerania, Poland: Implications for stratigraphy and palaeogeography. *Acta Geologica Polonica*, 51, 317–331.

Yin A. & Nie S., 1996. A Phanerozoic palinspastic reconstruction of China and its neighboring regions. In: An Yin & Harrison T.M. (eds), *The Tectonic Evolution of Asia*, Cambridge University Press, Cambridge, 442–485.

Zdanavîciuté O. & Bojesen-Koefoed J.A., 1997. Geochemistry of Lithuanian oils and source rocks: A preliminary assessment. *Journal of Petroleum Geology*, 20, 381–402

Zhang X., Liu W. & Zhao Y., 2008. Cambrian Burgess Shale-type Lagersta¨tten in South China: Distribution and significance. *Gondwana Research*, 14, 255–262.

Ziegler P.A., 1989. *Evolution of Laurussia*. Kluwer Academic Publishers, Dordrecht, Netherlands.

Ziegler P.A., 1990. *Geological Atlas of Western and Central Europe*. 2nd Edition Shell. Internationale Petroleum Mij. B.V., Distributed by Geological Society Publishing House, Bath, England.

Zonenshain L.P., Kuzmin M.L. & Natapov L.N., 1990. Geology of the USSR: A Plate-Tectonic Synthesis. In: Page B.M. (ed.), *Geodynamics Series*, Vol. 21, America Geophysical Union, Washington, 1–242.

Streszczenie

We wczesnym kambrze (Fig. 1) nastąpił rozpad superkontynentu Pannotia. Rozpad ten nastąpił wkrótce po serii wendyjskich wydarzeń orogenicznych, takich jak orogenezy kadomska, bajkalska i panafrykańska. W wyniku tych orogenez oraz rozpadu Pannotii utworzyły się kontynenty: Gondwana, Laurencja, Bałtyka i Syberia. W skład Gondwany wchodziły: Ameryka Południowa, Afryka, Madagaskar, India, Antarktyka, Australia oraz szereg mniejszych bloków kontynentalnych i teranów, takich jak Jukatan, Awalonia, terany południowoeuropejskie i środkowoeuropejskie (kadomskie), terany środkowoazjatyckie, chińskie i kimeryjskie (Turcja, Iran, Afganistan, Tybet, Azja południowo-wschodnia). Kontynent laurentyjski obejmował większą część Ameryki Północnej, północną Irlandię, Szkocję i Czukotkę. Bałtyka jest północno-wschodnią Europą pomiędzy linią Teisseyre'a–Tornquista a Uralem. Płyta Syberii obejmuje większą część Syberii współczesnej. Kontynenty były oddzielone oceanami, takimi jak: Iapetus, Pleionic, Phoibic, Morze Tornquista i Ocean Paleoazjatycki.

Laurencja (Fig. 2) była wyniesiona, baseny sedymentacyjne znajdowały się w brzeżnych strefach kontynentu. Największy znajdował się na północy w tak zwanej strefie peryinnuickiej. Węglanowe osady tworzyły się na szelfie Grenlandii, a utwory klastyczne w rejonie Apallachów i Gór Skalistych. Utworom osadowym towarzyszyły również wulkanity. Syberia (Fig. 3) była pokryta głównie przez osady węglanowe.

Orogeneza kadomska miała miejsce w częściach Europy należących do superkontynentu Gondwana. Na kontynencie Bałtyka (Fig. 4) deformacje tektoniczne były wynikiem orogenezy w rejonie Peczora – Timan – północny Ural. We wczesnym kambrze istniał duży basen na terenie europejskiej części Rosji i w Skandynawii, z osadami klastycznymi.

Figura 5 przedstawia Indochiny, południowe Chiny i obszary sąsiednie pokryte mieszanymi osadami węglanowo-klastycznymi w obrębie Gondwany. Charakterystyczna facja ciemnych łupków z fosforytami występowała w południowych Chinach.

W środkowym kambrze następuje szybki dryft Laurencji na północ, a baseny na tym kontynencie powiększają się w związku ze zwiększoną subsydencją (Fig. 6, 7). Paleogeografia Syberii (Fig. 8) charakteryzuje się, podobnie jak w poprzednim okresie, rozległym basenem z osadami węglanowymi. Baseny sedymentacyjne Bałtyki (Fig. 9) są natomiast mniejsze niż we wczesnym kambrze. W południowych Chinach (Fig. 10) występują zarówno osady klastyczne, miejscami z turbidytami, jak i węglany. Sedymentacja klastyczna przeważała w północnych Indiach, Afganistanie, Iranie i Turcji. Na terenie Arabii przeważały warunki lagunowe.

W późnym kambrze istnieją w dalszym ciągu kontynenty Gondwana, Laurencja, Bałtyka i Syberia, z zaawansowanym spredingiem oceanów pomiędzy nimi (Fig. 11). Subsydencja Laurencji spowodowała, że niemal cały kontynent był pokryty basenami osadowymi (Fig. 12). Również kraton syberyjski niemal całkowicie pokrywało morze (Fig. 13), a sedymentacja węglanowa dominowała w basenach sedymentacyjnych. Klastyczne osady dominowały na obszarze Bałtyki (Fig. 14), w europejskiej części Rosji, Skandynawii i północnej Polsce. Rozległa platforma węglanowa znajdowała się na obszarze południowych Chin (Fig. 15) i w Indochinach. W północnych Indiach, Afganistanie, Iranie i Turcji i na terenie północnej części kratonu arabskiego przeważała sedymentacja morska z osadami klastycznymi, węglanowymi i mieszanymi.

Wczesny ordowiku był okresem największego rozproszenia kontynentów i istnienia rozległych oceanów pomiędzy kontynentami Gondwany, Laurencji, Bałtyki i Syberii (Fig. 16). Odległość pomiędzy Gondwaną a Laurencją osiągnęła 5000 km. Sedymentacja węglanowa, miejscami z ewaporytami przeważała na obszarem Laurencji (Fig. 17). Na terenie dzisiejszych południowo-zachodnich Stanów Zjednoczonych ukształtowały się dwa odrębne obszary facjalne: epikontynentalny z platformą węglanową i krawędzi pasywnej z klastykami występującymi w późniejszym paśmie orogenicznym Ouachita. Obszerny basen tunguski z klastykami i osadami węglanowymi istniał na obszarze Syberii (Fig. 18).

Deformacje na krawędzi Bałtyki były związane z kolizjami łuków z tą płytą w czasie orogenez penobskockiej, grampiańskiej, finmarkskiej i grampiańskiej (Penobscottian, Grampian, Finnmarkian, and Athollian), kiedy nastąpiła zmiana z krawędzi pasywnej w aktywną. Powstał basen bałtycko-moskiewski, rozległy, raczej płytki, z osadami głównie klastycznymi (Fig. 19). Łupki dikcjonitowe osadziły się w republikach bałtyckich, drobnoklastyczne osady przeważały na terenie Skandynawii oraz Pomorza polskiego i niemieckiego.

Baseny sedymentacyjne południowych Chin zawierały głównie węglany i ewaporaty (Fig. 20). Transgresje wystąpiły na obszarze Arabii, Iranu i Afganistanu, klastyki występowały w północnych Indiach. Fałdowania i nasunięcia objęły obszar południowo-wschodniej Australii i część Antarktydy.

Reorganizacja płyt litosfery nastąpiła w środkowym ordowiku. Oddzielenie się teranów awalońskich (część Polski, północne Niemcy, Ardeny, Anglia, Walia, południowa Irlandia, część nadmorskich prowincji Kanady i Nowej Anglii) otwarło nowy ocean – Reik (Fig. 21). Ryft i dryft Awalonii był związany ze strefą subdukcji, która rozwinęła się wzdłuż centralnej części Gondwany. Kambryjsko-wczesnoordowickie oceany zaczęły się zwężać. Na przedłużeniu Awalonii ku wschodowi znajdował się teran Brunovistulicum, terany wewnątrz Karpat, część platformy scytyjskiej, Kazachstanu i południowej Mongolii. Wzajemne relacje pomiędzy płytami perygondwańskimi i awalońskimi sugerują wschodnie przedłużenie oceanu Reik (Fig. 21, 26).

Kolizje łuków wysp ze wschodnią częścią kontynentu Laurencji miały miejsce w czasie orogenez atolskiej (Athollian) i takońskiej w Appalachach. Wypiętrzenia zwiększyły ilość materiału klastycznego w basenach Laurencji (Fig. 22). Sedymentacja morska trwała na nieco zwiększonym kratonie Syberii (Fig. 23). Występowały tam zarówno osady klastyczne, jak i węglany i ewaporaty. Basen bałtycko-moskiewski pokrywał znaczną część płyty Bałtyki (Fig. 24). Występowały tam osady drobnoklastyczne, miejscami z węglanami. W środkowym ordowiku utworzył się basen peczorski, morskie baseny powstały też na obszarze przykaspijskim i platformy scytyjskiej.

Północna część płyty południowochińskiej była pokryta węglanami, zaś w południowej osadziły się osady synorogeniczne fliszowe (Fig. 25). Podobne, należące do formacji Pa Ham osadziły się w Indochinach. Na terenie Arabii przeważały osady terygeniczne, osiągające znaczną miąższość w północnej części kratonu.

W późnym ordowiku blok patagoński zderzył się z Ameryką Południową w orogenezie famatyńskiej, a dryft Awalonii spowodował znaczne rozszerzenie oceanu Reik (Fig. 26). Transgresja objęła większą część płyty Laurencji, w wyniku subsydencji wzrosła miąższość osadów w basenach (Fig. 27). Przeważała sedymentacja węglanowa.

Ruch Syberii ku północy spowodował kolizję tej płyty z Laurencją wzdłuż uskoku przesuwczego w rejonie między innymi archipelagu Svalbard i płyty Barencji. Baseny Syberii zmniejszyły się (Fig. 28). Przeważała w nich sedymentacja morska i kontynentalna z klastykami, rzadziej węglanami i ewaporatami.

Polska część Awalonii połączyła się z Bałtyką wzdłuż szwu położnego w strefie Tornquista–Teisseyre'a (Fig. 26–29) we wczesnej fazie orogenezy kaledońskiej. Basen bałtycko-moskiewski zmniejszył się na skutek regresji (Fig. 29). Zwiększył się w nim udział frakcji drobniejszej w osadach klastycznych. Drobnoklastyczne osady dominowały też w Skandynawii i na obszarze Pomorza.Rozkład facji w południowych Chinach, Indochinach i w Indiach był podobny jak w okresie poprzednim (Fig. 30).

We wczesnym sylurze zwęził się znacznie ocean Iapetus (Fig. 31), a pod koniec okresu rozpoczęła się orogeneza kaledońska (skandyjska) wywołana kolizją Bałtyki i Laurencji. Utworzył się Kazachstan, rosnąc następnie w ciągu paleozoiku w wyniku akrecji.

Obszar Laurencji został objęty regresją, a morskie baseny zmniejszyły się (Fig. 32). Ciepły klimat stwarzał dobre warunki do rozwoju osadów węglanowych. Węglany dominowały również na obszarze Syberii (Fig. 33), a w centralnej części basenu osadzały się również łupki graptolitowe. Transgresja objęła obszar Bałtyki (Fig. 34), a basen bałtycko-moskiewski zwiększył się. Dominowała w nim sedymentacja węglanowa. Powiększył się również basen peczorski. Na terenie południowych Indochin trwała sedymentacja synorogenicznego fliszu, a łupki graptolitowe osadzały się w południowych Chinach (Fig. 35). Basen Carnarvon z osadami terygenicznymi istniał w zachodniej części Australii. Subsydencja trwała w północnej części Indii, gdzie osadzały się zarówno osady terygeniczne, jak i węglany. Większość Arabii była pokryta basenami morskimi z sedymentacją terygeniczną.

Późny sylur był okresem kulminacyjnego rozwoju orogenezy kaledońskiej. Wczesnopaleozoiczny ocean Iapetus został zamknięty (Fig. 36). Utworzył się kontynent Laurosji z połączenia Laurencji, Bałtyki i Awalonii. Orogeneza franklińska (Franklinian) była być może rezultatem kolizji Laurencji z Syberią. Regresja trwała na obszarze Ameryki Północnej, będącej teraz częścią Laurosji (Fig. 37); morskie baseny zmniejszyły się. Podobnie jak poprzednio dominowała sedymentacja węglanowa. W wyniku regresji zmniejszały się również baseny syberyjskie z sedymentacją głównie węglanów i ewaporatów (Fig. 38).

Kolizja Bałtyki i Laurencji spowodowała utworzenie płaszczowin w Norwegii i Grenlandii (Fig. 39). Kwestia akrecji małych płyt, np. bloku małopolskiego do Bałtyki, pozostaje sprawą dyskusyjną i otwartą. Metamorfizm osadów platformy scytyjskiej wskazuje ma możliwość kolizji na tym obszarze. Basen bałtycko-moskiewski (Fig. 39) w dalszym ciągu się zmniejszał. Węglany osadzały się w zmniejszonym basenie peczorskim. Orogeniczne procesy miały również miejsce w Azji (Fig. 40). W południowych Chinach ruchy orogenezy Guanxi wiązały się z regresją na tym obszarze. Ewaporaty dominowały w basenie Carnarvon w Australii. Terygeniczne i węglanowe osady tworzyły się w północnych Indiach, Afganistanie i Iranie.