CAMBRIAN-NEOGENE PLATE TECTONIC MAPS.

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Abstract:

Thirty two maps have been constructed which depict the plate tectonic configuration, paleogeography and selected lithofacies for Phanerozoic time intervals from the earliest Cambrian through the Neogene. The plate tectonic maps illustrate geodynamic evolution of the Earth from the disassembly of Rodinia-Pannotia during Sauk time through closure, assembly, reorganization and formation of Pangean supercontinent during Tippecanoe, Kaskaskia and Early Absaroka time, rifting, spreading and disassembly during the Late Absaroka and Zuni times, and new closure during Tejas time.

The Earth's climate reflects the plate tectonic phases of continental breakup and assembly. The climate changed from a greenhouse with short icehouse interlude through icehouse with warming interludes, and another greenhouse, to the present day icehouse. Carbonate sedimentation during the Early Paleozoic is related to the existence of large continental platform. The Mesozoic is the time of the equatorial Tethyan realm with the abundant fragmented carbonate platforms. Carbonate sedimentation prevailed in the Southeast Asia, the Pacific realm and on the narrow continental margins during the Cenozoic Tejas time.

Abstrakt:

Skonstruowano trzydzieści dwie mapy, przestawiające konfigurację tektoniki płyt, paleogeografię i wybrane litofacje dla przedziałów czasowych fanerozoiku poczynając od najwcześniejszego kambru, a kończąc na neogenie. Mapy tektoniki płyt ilustrują geodynamiczną ewolucję Ziemii od rozpadu superkontynentu Rodinia-Pannotia w czasie

sauk, poprzez zamykanie oceanów, łączenie kontynentów i tworzenie się superkontynentu Pangea w czasie tippecanoe, kaskaskii i wczesnej absaroki, ryfting, spreding i rozpad kontynentów w czasie późnej absaroki i zuni, do okresu nowego zamykania oceanów w czasie tejas.

Klimat Ziemii odzwierciedla etapy tektoniczne rozpadu i łączenia się kontynentów. Klimat zmieniał się od ciepłego z krótkim interwałem zlodowaceniowym, poprzez zimny, lodowcowy z krótkimi interwałami cieplejszymi, poprzez następny okres ciepły, do współczesnego okresu zimnego. Sedymentacja węglanowa w okresie wczesnego paleozoiku jest związana z istnieniem rozległej platformy kontynentalnej. Mezozoik jest czasem oceanu Tetydy z licznymi porozdzielanymi platformami węglanowymi. W kenozoiku (tejas) sedymentacja węglanowa przeważała w południowo-wschodniej Azji, na Pacyfiku i na wąskich obrzeżach kontynentów.

Keywords: plate tectonics, extensional tectonics, collisional tectonics, orogeny, geodynamic evolution of Earth, Phanerozoic, Pangea, Tethys, sea level, paleoclimate, carbonate sedimentation.

INTRODUCTION

The plate tectonic maps presented constitute the newest, most advanced version of the global paleogeographic maps. The first version of paleogeographic maps was published in 1994 in the Pangea volume (Golonka *et al*., 1994). The author generated the intermediate version in 1996-1998 with the goal to aim the Phanerozoic Reef Project. They are available at the internet site of the University of Erlangen.

The Jurassic maps were published in 1996 (Golonka *et al*., 1996). Selected paleogeographic maps with reef distribution were published in AAPG Bulletin in 1999 (Kiessling *et al*. 1999).

The maps presented in this paper were constructed by the author in 1999-2000. They depict distribution of mountains, landmasses, icesheets, shallow seas and slopes, deep oceanic basins, present day coastlines, plate boundaries (sutures), oceanic spreading centers, subduction zones, thrust faults, normal faults, and transform faults. The base maps, (past position of present day coastlines lat/long tick marks, and plate boundaries) were generated by PLATES and PALEOMAP computer software (see next chapter, Methodology). The paleogeographic maps in color, containing also information about mountains, landmasses, icesheets, shallow seas and slopes, deep oceanic basins, oceanic spreading centers, subduction zones, thrust faults, normal faults, and transform faults were assembled by the author in 2000 in the Institute of Geological Sciences, Jagiellonian University using Microstation graphic program.

The map discussion presents the author's ideas of the development of the convergent and extensional tectonics as well as changes of the sea level and climate from the global point of view and time-slice approach. The aim of this paper is to provide the plate tectonic evolution and position of the major crustal elements within the global framework. Therefore, the author restricted the number of plates and terranes modeled, trying to utilize the existing information and degree of certainty. The author tried to apply geometric and kinematic principles, using computer technology, to model interrelations between tectonic components. This general framework will provide a basis for the future integration of the local tectonics.

The inclusion of carbonate sedimentation was caused by the author involvement with the reef project (see Kiessling *et al*., 1999). Selected enlarged regional maps depict also paleolithofacies. The two Tethyan maps (Figs. 22, 27) are based on work by *Golonka et al*., 2000). The other three maps (Figs.3, 8, 19) have been derived from the author's contribution to a major project, which encompasses 32 Phanerozoic paleoenvironment and lithofacies maps with their interpretation aimed to evaluate petroleum systems in time and space. The detailed maps will be the subjects of future special publication in an atlas form.

METHODOLOGY

The maps were constructed using a plate tectonic model, which describes the relative motions between approximately 300 plates and terranes. This model was constructed using PLATES and PALEOMAP software (see A. M. Ziegler *et al*., 1997, Scotese, 1991, Scotese & McKerrow, 1990, Lawver & Scotese, 1987; Lawver & Gahagan, 1993; Golonka *et al*., 1994; Golonka & Gahagan, 1997) which integrate computer graphics and data management technology with a highly structured and quantitative description of tectonic relationships. The heart of this program is the rotation file, which is constantly updated, as new paleomagnetic data become available. Hot-spot volcanics serve as reference points for the calculation of paleolongitudes (Morgan, 1971; Müller *et al*., 1993; Golonka & Bocharova, 2000). Magnetic data have been used to define paleolatitudinal position of continents and rotation of plates (see Irving, 1979; Tarling, 1983; Aifa *et al*., 1990; Westphal *et al*., 1986; Van der Voo, 1988, 1993; Kent & Van der Voo, 1990; Besse and Courtillot, 1991; Harbert, 1990, 1991; Rapalini & Villas, 1991; Enkin *et al*., 1992; Didienko *et al*, 1993; Lewandowski, 1993, 1997, 1998; Torsvik *et al*, 1995, 1996; Bachtadse *et al*., 1995; Morris & Tarling, 1996; Channell, 1996; Smethurst *et al*., 1998; Xu *et al*., 1997; Lemaire *et al*., 1998). Ophiolites and deep-water sediments mark paleo-oceans, which were subducted and included into foldbelts.

Information from several general and regional paleogeographic papers were filtered and utilized (Cook, 1990; Cope *et al*., 1992; Dalziel, 1997; Dercourt *et al*.; 1993; Doré, 1991; Ford *et al*., 1998; Fraser *et al*., 1997; Green *et al*., 1984; Garcia & Walbert, 1994; Golonka, 1993, 1998; Golonka & Ford, 1997, 2000, Golonka *et al*. 1994, 1996, 1999; Hongzen, 1985; Lawver & Gahagan, 1993; Lee & Lawver, 1994; Kiesling *et al*., 1999; Kraus *et al.* (1997); McKerrow and Scotese, 1990; Metcalfe, 1984, 1994; Müller *et al.,* 1997; Nairn *et al*., 1996; Nikishin *et al*., 1996; Nie *et al*., 1990; Parfenov, 1997; Parfenov *et al*., 1993; Puchkov, 1991;

Robertson , 1998; Robertson *et al*., 1991, 1996; Ronov *et al*. 1984, 1989; Sengör & Natalin, 1996; Sloss *et al*., 1960; Stampfli *et al*., 1991; Stampfli, 1996; Veevers, 1994; Vinogradov, 1968a, b, c; Williams, 1995; A. M. Ziegler, 1990; Ziegler *et al*., 1997; P. Ziegler, 1982, 1988, 1989; Zonenshain & Natapov, 1990; Zonenshain *et al*., 1990). I have also utilized the unpublished maps and databases from the PALEOMAP group (University of Texas at Arlington), PLATES (University of Texas at Austin), University of Chicago, Institute of Tectonics of Lithospheric Plates in Moscow, Robertson Research in Llandudno, Wales, and the Cambridge Arctic Shelf Programme. The plate and terrane separation was based on the PALEOMAP and PLATES systems with modifications, mainly in the Tethys area (Golonka & Gahagan, 1997, Golonka *et al*., 1999).

The calculated paleolatitudes and paleolongitudes were used to generate computer maps in the Microstation design (.dgn) format using the equal area Molweide projection. The Molweide projection has been commonly utilized in the paleogeographic global reconstructions (e. g., Golonka *et al*, 1994; Scotese & McKerrow, 1990; Veevers, 1994; Crowley, 1994, Kiessling *et al*., 1999). It has a problem of relatively high distortion and lost of details in the marginal areas, for example in the areas near the South Pole during the early Paleozoic.

Table I is showing the time slices presented and defining the used time scale. The stratigraphic chart was based on Haq *et al*. (1988), and Harland *et al.* (1990) modified by more recent times scales like Gradstein & Ogg (1996), McKerrow, 1993, Tucker & McKerrow (1995), Landing *et al*. (1998), Davidek *et al*. (1998), Sandberg & Ziegler (1996), Claoué-Long *et al*. (1995), Roberts *et al*. (1995), Menning (1995), Gradstein *et al*. (1995), and Berggren *et al*. (1995). I have applied the Sloss' (1988) sequence names to time slices. Time slices are equivalent to supersequences representing second order tectono-eustatic sea level fluctuations. Boundaries of supersequences are distinguished by large relative falls in sea levels (Haq *et al*., 1988, Vail *et al*., 1977). Second order supersequences were deposited during second order transgressive-regressive cycles of sea-level (supercycles). I have followed Haq *et al*. (1988) to subdivide Sloss' megasequences using „Lower" and „Upper" to define supersequence sets and used Roman numerals to define the supersequences. There are three to four supersequences in a supersequence set. A maximum of seven supersequences makes up a megasequence. The definition of supersequences is based on Haq *et al*. (1988) for the Mesozoic/Cenozoic and Ross & Ross (1988) for the Paleozoic, but has been modified in some details. Thirty-two Phanerozoic supersequences are subdivided with duration between 8 and 33 Ma. The names of time slices are given in the following order: number of time slice, modified megasequence name of Sloss (1988) followed by a roman number indicating the supersequence name and total stratigraphic range of time slice. The more detailed stratigraphic work is in preparation by Golonka and Kiessling.

The data from the numerous regional papers were used to verify author's geotectonic concepts, especially timing and mode of rifting, separation of plates and other terranes, collisions and terrane suturing. The author's unpublished observations have also been utilized, especially in the Mediterranean area, Atlantic, Arctic, Black Sea, Caspian Sea, Central Asia and Far East. The maps are more accurate in the areas of Mobil's special regional interest. Little more emphasis was put in this paper on the Tethys realm than on other regions because of its importance. The glossary with the definition of the plate tectonic is attached at the end of the paper.

MAP DISCUSSION

Slice 1: Sauk I – Nemakit/Daldynain – Toyonian (Early Cambrian) – 544-511 Ma

This was the time of the breakup of the Pannotia supercontinent (Fig. 1). During this time, the Gondwana (du Toit, 1937) continent already existed, as a result of the Pan-African and Cadomian orogenies (Late Precambrian). The continents forming the core of Gondwana were: South America, Africa, Madagascar, India, Antarctica and Australia. The location of numerous smaller continental blocks that bordered Gondwana is less certain. The following have all been 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 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. Three continental plates were already distinguished at this time during the Early Paleozoic (Scotese & McKerrow, 1990; Golonka *et al*., 1994). 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. The Laurentian continent included major parts of North America, northwest Ireland, Scotland, Greenland, and Chukotka peninsula. The Early Paleozoic margin of Laurentia can be recognized in the Appalachians. The paleocontinent of Siberia 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 Verkhoyansk (Kolyma-Okhotsk) terranes were most probably connected with Siberia during the Early Paleozoic time (Parfenov, 1997). The relative positions of Laurentia, Baltica and Siberia are somewhat uncertain. Numerous small plates existed between Baltica, Siberia and Gondwana in the Paleoasian Ocean (Pechersky & Didenko, 1995; Zonenshain *et al*., 1990). These plates were later accreted to different continents. Some of them became parts of the Kipchak arc of Sengör & Natalin (1996) and later during the Early Paleozoic, the Kazakhstan continent. It appears that some plates also existed in the western ocean. These were later accreted to South America and North America.

Convergent Tectonics

The Cadomian orogeny in Gondwanian Europe is a continuation of the Precambrian Pan-African event (Cogné, 1990). This orogeny caused deformation and magmatic events of terranes from Iberia through Armorica (NW France), Erzgebirge (Saxoturingian zone in Germany), Bohemian massif and Małopolska massif (Czechia and southern Poland), Carpathians to the Transcaucasus area (Chalupsky, 1989; Neugebauer, 1989; Dallmeyer *et al*., 1996; P. Ziegler, 1990; Moczydłowska, 1997; Zakariadze *et al*., 1998). Southern Poland (the Małopolska Massif) was at this time situated southwest of Iberia and belonged to the

Avalonian terranes (Moczydłowska, 1997). Moesia and some parts of the Scythian Platform (Ukraine-SW Russia) could have been located west and north of Iberia. 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; Roberts *et al*.; 1997, Puchkov, 1997; Vernikhovsky, 1997, 1998) are equivalent of the Cadomian belt. The inversion of the Mid-Russian aulacogenic belt is also attributed to this event. (Nikishin *et al*., 1996; Zonenshain *et al*., 1990). Siberia collided with minor continental blocks in Baikal-Sayan Area (Zonenshain *et al*., 1990). The Baikalian and Cadomian-Timanian orogenies took place at the end of the previous Vendian stage and preceded the Cambrian Sauk I supersequence. Damara Orogeny (Miller, 1983) in southern Africa represents the latest Pan-African event (Tankard *et al*., 1995). The subduction zone developed along the margin of Gondwana between Northwestern South America and the Chinese terranes. Another subduction zone located north of western Laurentia, the Arctic plates and Siberia was a driving force for the northward movement of continents in this area. The connection between Siberia, the Verkhoyansk (Kolyma-Okhotsk) terranes (northeastern Russia) and Barentsia (Svalbard and adjacent part of the Barents Sea) remain very speculative.

Extensional Tectonics

Laurentia and Baltica, according to Torsvik *et al*. (1996) drifted apart from Gondwana during the Late Vendian Time. Their breakup led to the formations of new oceans. The Iapetus Ocean originated at the triple junction somewhere between Baltica and Laurentia. The Tornquist Sea, initially opened between Baltica and Laurentia, was later situated between Baltica and Avalonia (part of Gondwana). The Pleionic Ocean opened between Siberia and Baltica, the Phoibic Ocean between Laurentia and Gondwana (Scotese & McKerrow, 1990;

Golonka *et al*., 1994). The Paleoasian Ocean between Siberia and Gondwana (Chinese plates) also existed at this time (Pechersky & Didenko, 1995; Zonenshain *et al*., 1990). The opening of the Iapetus Ocean occurred according to Torsvik *et al*. (1996) around 600-580 Ma, the opening of Pleionic Ocean prior to 580 Ma. Drifting between Siberia and East Gondwana took place after 725 Ma. Alternative reconstruction by Dalziel at al. (1994) postulates the Gondwana-Laurentia connection and existence of the Pannotia supercontinent at 550 Ma. On the presented reconstruction, there is (in already rough agreement with McKerrow *et al*., 1991, Torsvik *et al*., 1996, as well as with Dalziel, 1997) a latitudinal separation between the South American margin of Gondwana and the eastern (in present day coordinates) margin of Laurentia. It is quite possible, that this separation and the break-up of Pannotia mark the beginning of Sauk megasequence and general transgression of the Cambrian time. On the Dalziel (1997) reconstruction, the opening of the ocean between Laurentia and Gondwana) reaches 3000 km during the Sauk I time slice. The position of Baltica in relation with Gondwana's Cadomian terranes agrees roughly with Puchkov's (1997) analysis, suggesting Vendian rifting, following the Cadomian-Timanian orogeny.

Rift grabens and sag basins occurred in Laurentia, Greenland, East Siberia, and Arabia (Pelechaty, 1996; Al Husseini, 1988). Rift related magmatism took place on the Laurentia margin in eastern Canada and Greenland and in Australia (Cook, 1990).

Sea Level and Climate

This was a time of the incipient global sea level rise following the initial break-up of the Rodinia-Pannotia supercontinents (Dalziel, 1997), and the beginning of subsidence in some areas, for example Siberia. The lower boundary of this age slice is a sequence boundary of Knoll *et al*., (1995) between the Staraya Rechka and the Manykai formations in Siberia. The boundary is also distinguished by the regional transgression on Baltica (Nikishin *et al*., 1996) and synrift sequences in Greenland, coeval with the opening of Iapetus Ocean (Torsvik *et al*., 1996; Soper *et al*., 1992) and the separation of Laurentia and Gondwana (Dalziel, 1997). The boundary is related to the late breakup of the Rodinia-Pannotia supercontinent between Laurentia and Baltica (see Torsvik *et al*., 1996).

Glaciation happened on the Rodinia supercontinent (Young, 1995, Torsvik *et al*., 1995) first during the Varanger Ice Age (circa 650 Ma), and later, during the Ice Brook event (625-580 Ma). The transition between the Late Precambrian glacial conditions and a warmer climate occurred while Baltica and Siberia drifted northward from the southern polar zone, reaching temperate and tropical zones. The opening of seaways also contributed to slow warming.

Carbonate Sedimentation

The beginning of this time slice is marked by rapid development of the carbonate platform in the epicontinental sea on Siberia (Puchkov, 1996). The carbonate deposits changed into evaporites toward the center of the craton. Carbonate and mixed carbonate/clastics were deposited in the northern part of North America and in the eastern regions of the Greenland shelf (Trettin & Balkwill, 1979; Harland, 1979; Ronov *et al*., 1984). This is possible, that a connection existed between Laurentian and Siberian carbonate platforms, through the Barentsia and Verkhoyansk terranes. Mixed carbonate/clastics facies are present in the margins of South America, locally on the Cadomian terranes in Europe, on Chinese and South-East Asian terranes (Shouxin & Yongyi; 1991; Ronov *et al*., 1984) and eastern Australia (Cook, 1990).

Slice 2: Sauk II - Middle Cambrian – Dresbachian – 511-497 Ma

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 (Figs 2, 3).

Convergent Tectonics

Some of the late Vendian/ Early Cambrian events may have reached a conclusion at this time, like the Damara Orogeny (Miller, 1983; Henry at al., 1990; Tankard *et al*., 1995) in southern Africa or the orogenic events in the Ural, Timan-Pechora, Novaya Zemlya, and Pay-Khoy areas on the northeastern margin of Baltica. The collision of the Trans-Ural microcontinent with Baltica in the Ural area (Zonenshain *et al*., 1990) was perhaps related to adjustment of continents during the drifting stage. The subduction zone along the margin of Gondwana between Northwestern South America and the Chinese terranes, and the subduction zone located north of western Laurentia, Arctic plates and Siberia continued to develop.

Extensional Tectonics

Advanced seafloor spreading occurred in the Iapetus-Tornquist ocean between Laurentia and Baltica, and in the Phoibic Ocean between Laurentia and Gondwana

(McKerrow *et al*., 1991; Torsvik *et al*.; 1996, Dalziel, 1997). Laurentia rapidly drifted northward and rotated counter-clockwise, reaching low latitudes. Seafloor spreading also occurred within the Pleionic Ocean between East Siberia and Baltica. Rifting events occurred along the Northern Urals and Pay Khoy belts on the eastern margin of Baltica (Nikishin *et al*., 1996), perhaps following the orogenic events mentioned above. The relationship between Laurentia and Siberia, including the mapped strike-slip, remains quite speculative (Fig.3). Extensive continental rifting occurred in Gondwana (e.g., East Arabian plate), East Siberia and Avalonia. In Laurentia intracontinental rifting affected the Wichita Mountains area in Oklahoma (Hamilton, 1989). Back-arc spreading in eastern Australia could have happened at this time (Powell *et al*., 1990, Veevers & Powell, 1990).

Sea Level and Climate

Sauk II was a time of continuous global sea level rise, related to advanced drifting of the continents and significant subsidence and submergence of most continental margins. Warm, humid climatic conditions, limited continental aridity, and no known continental glaciation exemplified the time of transition from icehouse to greenhouse conditions. The northward drift of Laurentia placed this continent in low latitudes. The global Ocean Anoxic Event (OAE), during the Middle and Late Cambrian, is related to climatic and sea-level conditions.

Carbonate Sedimentation

Carbonate deposition at that time was widespread, with carbonate platform occurrences distributed between 40^{o}N and 60^{o}S latitudes. Carbonate depositional systems, located along narrow continental margins or on isolated platforms typically consisted of oolitic grainstone-bearing, shallowing-upward depositional sequences that contain or are capped by peritidal dolomites.

Siberia was almost completely submerged (Fig. 3) and was characterized by shaly carbonate sediment accumulation which continued from the previous time slice (Puchkov, 1996). Carbonate and mixed carbonate/clastic facies were widespread in the northern part of North America and proto-Arctic area (Ronov *et al*., 1984). Carbonates also appeared on eastern North America margins, in connection with the Laurentia drift to the lower latitudes. A large carbonate platform existed on the South China plate (Shouxin Yongyi, 1991) and was connected with the carbonate deposition area on the Arabia plate margin (Ronov *et al*., 1984). Mixed carbonate/clastic facies prevailed in South-East Asia (Brookfield, 1996). Carbonates are present within terrigenous complexes in the northern India-Himalayan area (Gupta & Brookfield, 1991). Carbonate/evaporite sediments were deposited on the Gondwanian margins in South America. Carbonate and mixed carbonate/clastic facies also occurred in Eastern Australia (Cook, 1990).

Slice 3: Sauk III – Franconian – Tremadocian (Latest Cambrian – Early Ordovician) – 497-482 Ma

This was the time of maximum dispersion of continents during the Paleozoic. The continents of Gondwana, Baltica, Laurentia and Siberia continued to exist. Baltica, Laurentia and Siberia drifted further northward. Laurentia was situated on equator at this time (Fig. 4).

Convergent Tectonics

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 Atholian orogenies (P. Ziegler, 1990; Neuman & Max, 1989). 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. 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. 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). The Świętokrzyska Phase caused the folding of Cambrian sediments in the northern part of the Holy Cross Mts. in Poland (Lewandowski, 1993).

Subduction zone along the margin of Gondwana between Northwestern South America and the Chinese terranes and the subduction zone located north of western Laurentia, Arctic plates and Siberia continued their development. The subduction along the central margin of Gondwana caused the onset of rifting of the Avalonian terranes (Golonka *et al*., 1994). The subduction along the northern margin of Baltica was perhaps related to the Ordovician rotation of this plate (see Golonka *et al*., 1994;Torsvik *et al*., 1996; McKerrow *et al*., 1991).

Extensional Tectonics

The rapid northward drift of Laurentia widened the Phoibic or Western Iapetus Ocean (Dalziel, 1997). The distance between Gondwana and Laurentia reached 5000 km (Kent & Van der Voo, 1990). The Iapetus - Tornquist Sea oceanic system also widened significantly

(Torsvik *et al*., 1995, 1996). The estimated width of the ocean between Baltica and Laurentia depends upon the latitudinal position of Laurentia. Rapid northward movement of Laurentia possibly caused separation of Laurentia and East Siberia. The widening of the Paleoasian Ocean could also have happened at this time (Zonenshain *et al*., 1990). The western part of Paleoasian Ocean evolved into Uralian Ocean (Puchkov, 1997).

Rifting activity occurred on the eastern margin of Baltica and in the West Ural Basin between the Pechorian and Pericaspian areas (Nikishin *et al*., 1996). There is also a possibility of Late Cambrian-Early Ordovician rifting in the Pericaspian Basin (Nikishin *et al*. 1996). Sauk III was the time of the onset of rifting between Avalonia and Gondwana (McKerrow *et al*., 1991). Rifting of arcs (Oliverian/Midland Valley terrain), off the eastern coast of Laurentia, occurred in Late Cambrian - earliest Ordovician time (McKerrow *et al*., 1991).

Sea Level and Climate

The continents were dispersed and in the most advanced drifting stage during the Early Paleozoic time. The global sea level rise was related to drifting of the continents. The significant subsidence and submergence of most of continental margins was a continuation of the Cambrian trend. Sea-level was probably at one of its highest points during the entire Phanerozoic, however, according to Algeo & Seslavinsky (1995) the sea-level estimates could have been exaggerated. Greenhouse conditions prevailed. Likewise the global OAE continued from the previous time slice.

Carbonate Sedimentation

A stable tectonic regime and a hot climate resulted in the deposition of limestones and dolomites on the North America plate, particularly in the southern part of the Mid-continent, as well as on the Barentsia plate and on the eastern Greenland shelf (McKerrow *et al*., 1991; Mellen, 1977; Chafetz, 1980; Stewart & Pool, 1974). Carbonate and evaporite sedimentation continued on the Siberian craton (Puchkov, 1996, Ronov *et al*., 1984). Mixed carbonate/clastic sediments were deposited on Baltica in Poland and Scandinavia (McKerrow *et al*., 1991; Ronov *et al*., 1984). Limestones, dolomites and evaporites were deposited in South China. Mixed carbonate/clastic sediments were deposited in North China, South-East Asia, Iran, Iraq (Ronov *et al*., 1984) and on the northwestern Indian plate (Gupta & Brookfield, 1991).

Slice 4: Sauk IV – late Early – early Middle Ordovician – 482-465 Ma

This was a time of major plate reorganization. The Cambrian oceans began to narrow. Laurentia reversed its northward drift. Baltica rotated counterclockwise. Western Gondwana began to drift northwards. New oceans and continents like Avalonia appeared. The emergence of the South Pole icecap was related to this plate reorganization (Fig. 5).

Convergent Tectonics

By the Early Ordovician, the Iapetus Ocean and the Tornquist Sea had begun to narrow, with arcs present in the east of Laurentia and in Avalonia. According to Torsvik *et al*. (1996), Baltica rotated significantly during the Ordovician and the ocean width between Avalonia and Laurentia was reduced from 5000 to 3000 km by Llanvirnian time. West Gondwana began to move northwards during the Early Ordovician, and it began to cross the South Pole in the Caradocian.

During the Early Ordovician, 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 (Atholian orogeny) and ending with the Caradocian Taconian Orogeny (McKerrow *et al*., 1991). A large landmass west of present-day South America or north of Western Gondwana is known as Patagonia block (Ramos, 1988; Williams, 1995). According to Dalziel (1997) this block could have been part of Laurentia (Texas).

The formation of the Mongolian (Amuria) plate was concluded at this time (Zonenshain *et al*., 1990). The Kazakhstan continent began to develop from the Kipchak arc (Sengör & Natalin, 1996). A subduction zone was present along the Antarctic and Australian margins (Williams (1995).

Extensional Tectonics

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). The continent of Avalonia consists of northwestern and possibly southeastern Poland (Moczydłowska, 1997), Moesia and some accreted terranes in the basement of East Carpathian and their foredeep, 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 (McKerrow *et al*., 1991). Between Gondwana, Baltica, Avalonia and Laurentia, a large longitudinal oceanic unit, known as the Rheic Ocean (McKerrow *et al*., 1991), was formed. The separation of crustal fragments of Baltica and Siberia followed the Late Arenigian onset of sea-floor spreading in the Ural area (Zonenshain *et al*., 1990, Nikishin *et* *al*. 1996). The relationships between the different parts of the Rheic Ocean as well as connections with Paleoasian and Phoibic Ocean remain uncertain. Intracratonic rift basins originated in Bolivia and northern Argentina (Williams, 1995)

Sea Level and Climate

After the initial rise, the level dropped dramatically and remained quite low during Llanvirnian time. The transition from greenhouse to icehouse conditions was associated with the emergence of the Gondwana supercontinent, near the South Pole. A large ice cap was located in central Africa (Williams, 1995).

Carbonate Sedimentation

Carbonate sedimentation was dominant in the Northern Canadian basins, on Barentsia and on the eastern Greenland shelf (McKerrow, *et al*., 1991; McGill, 1974; Henriksen, 1978; Surlyk *et al*., 1980). Carbonates also prevailed in the North American Mid-Continent, southwestern United States and adjacent part of Mexico (Ronov *et al*., 1984). Terrigenous-carbonate rocks with prevailing dolomites were deposited in the Tunguska basin on Siberian craton. Large amounts of limestones were also deposited on the Verkhoyansk terranes (Puchkov, 1996; Ronov *et al*., 1984).

Carbonate sedimentation was also dominant on the South Chinese plate, Tarim, North China-Korea (Shouxin & Yongyi, 1991) and on most of the South-East Asia plates (Ronov *et al*., 1984). Mixed shaly/carbonate sediments were deposited on Baltica in Scandinavia, Poland and the Baltic republics (McKerrow, *et al*., 1991).

Slice 5: Tippecanoe I – Darriwilian – Ashgillian (late Middle – Late Ordovician) – 465-443 Ma

This was the time of collision of the Patagonia block with Gondwana, collision of Laurentia with Siberia and Taconian island arc and the onset of collision of Avalonia and Baltica, with the wide opening of Rheic ocean. Baltica, Laurentia and Siberia were located at low and equatorial latitudes. Central Gondwana was located at the South Pole. A significant ice cap existed on Gondwana (Fig. 6).

Convergent Tectonics

Baltica rotated counterclockwise, which 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 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 southward movement of Laurentia positioned this plate in close proximity to the Verkhoyansk (Okhotsk-Kolyma) superterrane, at that time connected with Siberia (Cecile *et al*., 1998). The northward movement of Siberia caused the collision of Siberia and Laurentia, along the strike slip in the area of Barentsia. The tectonothermal event was recorded in the Svalbard as the Middle Ordovician M'Clintock orogeny (Ohta *et al*., 1989). 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.

Extensional Tectonics

During Tippecanoe I time, the Rheic Ocean between Gondwana and Avalonia-Baltica widened significantly (McKerrow *et al*., 1991). This ocean was connected in the west with the Phoibic or West Iapetus Ocean, and in the east and northeast with the Paleoasian and Ural Oceans. The large latitudinal ocean system began to emerge. Rifting of Bohemia and other central European tectonic terranes from Gondwana (Tait *et al*., 1995; Torsvik *et al*., 1996) could have begun at this time. The position of the tectonic units, which were later involved in the Late Paleozoic tectonic events and included in the epi-Hercynian platforms, remains uncertain. On the presented reconstruction, the Armorican, Saxoturingian, Central German, and Bohemian blocks are positioned relatively close to Gondwana during the Early Paleozoic. This is mainly based on the paleobiogeographical data (Scotese & McKerrow, 1990; Robardet *et al*., 1993). It is also possible that these terranes were rifted away and formed separate units - Cadomia floating within the Rheic Ocean (Lewandowski, 1993).

Sea Level and Climate

Sea-level was rising continuously, with several fluctuations. The climate was in the icehouse period in Gondwana, while the ice cap was located in Africa (Williams, 1995). The sea level fluctuations were probably related to Gondwana glaciers melting and increasing.

Carbonate Sedimentation

Most of the North American plate was submerged at this time, with domination of carbonates in the United States and Canada (Ross, 1976). Carbonate also dominated in the proto-Arctic area, on Barentsia and Eastern Greenland (Henricksen, 1978; McGill 1974; Surlyk *et al*., 1980). Carbonate sedimentation still existed on the Siberian plate. The basins became smaller, and more clastic sediments were deposited. Carbonate deposition also continued on the Verkhoyansk terranes (Ronov *et al*., 1984). Ordovician deposits on the North China-Korean plate were formed almost entirely by carbonates. Mixed carbonate-clastic sediments were deposited on parts of the South China Plate, on Tarim and on the South Asian terranes (Ronov *et al*., 1984). Carbonates occurred in the deposits of the southern part of the peri-Andean zone in South America (Dalla Salda, 1982).

Slice 6: Tippecanoe II – Llandoverian (Early Silurian) – 443-428 Ma

This was time of the convergence and collision of Baltica, Avalonia and Laurentia - beginning of the Caledonian-Scandian Orogeny. Baltica, Laurentia and Siberia were clustered together straddling the Equator. They were separated from Gondwana by the large latitudinal Rheic Ocean (Figs 7, 8).

Convergent Tectonics

During the early Silurian, Baltica moved northwestward, relative to Laurentia, and the Iapetus Ocean narrowed significantly (Fig. 8). 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 Llandoverian, west-verging nappes were emplaced in northeast 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).

The continent of Kazakhstan was formed in the Silurian by the accretion of the Kipchak arc and then grew during the Paleozoic by the accretion of the volcanic arcs, related trench deposits and exotic terranes (Zonenshain *et al*., 1990). Major subduction zones were still active along the western margin of Gondwana. Accretionary continental margin orogen along the Antarctic and Australian margin of Gondwana is referred to as Borchgrevink-Tasman orogen (Williams, 1995) or Tasman Orogenic Belt (Gray, 1997). This is related to the Benambran orogeny in eastern Australia (Cook, 1990), perhaps caused by an arc to continent collision.

Extensional Tectonics

Gondwana drifted across the South Pole and was separated from the other continents by the rapidly spreading Rheic Ocean (McKerrow *et al*. 1991). The main part of the Rheic Ocean had a latitudinal orientation between 30^{o} and 60^{o}S, and must have spanned 160 degrees of longitude. The Rheic Ocean was connected in the northeast with the Paleoasian Ocean (Zonenshain *et al*., 1990), and in the west with the remnants of the Phoibic Ocean. East Siberia drifted almost northwestward (Smethurst *et al*., 1998) along a major strike-slip fault zone within close proximity to Laurentia. Minor continental rifting occurred in the Gulf of Carpentaria region of Australia (Cook, 1990). The onset of rifting could have occurred between Gondwana and the Chinese plates. Rifting between Gondwana and the Armorican-Bohemian plates is also possible (Lewandowski *et al*., 1993, 1997, 1998).

Sea Level and Climate

According to Loydell (1998), global sea-level, fluctuated markedly during the early Silurian as a result of the waxing and waning ice-sheets. Glaciation existed in Africa and Brazil (Grahn & Caputo, 1992; Williams, 1995). The ice-cover was widespread during the middle Silurian time. This was also a time of continued significant submergence of the Laurentian, Siberian and Baltican cratons. Likewise the Tippecanoe II time slice included a global oceanic anoxic event (OAE).

Carbonate Sedimentation

Carbonate sedimentation was widespread between 30^{o}N and 30^{o}S latitude. Major carbonates formed on Laurentia (Fig. 8) at low latitudes in the rain shadow, east of the Taconian/Scandian mountain range (Ronov *et al*. 1984). Carbonate deposition was widespread in the north part of Laurentia and in the proto-Arctic area. Shallow-water carbonate muds were deposited in Southern Scandinavia and adjacent parts of Poland (McKerrow *et al*., 1991; Ronov *et al*. 1984). Carbonate-terrigenous facies with evaporites existed in the eastern part of Baltica, in Timan-Pechora and in the peri-Uralian area (Nikishin *et al*., 1996). Carbonates dominate sedimentation in the Tunguska basin in Siberia (Puchkov, 1996; Ronov *et al*., 1984). Terrigenous and carbonate rocks were deposited in northern India

(Gupta & Brookfield, 1991) and Southeast Asia, and on parts of South China and the Tarim plates (Shouxin & Yongyi, 1991).

Slice 7 - Tippecanoe III –Wenlockian – middle Pridolian (Late Silurian) – 428-418 Ma

This was the time of the major development of the Caledonian orogeny, final closure of the Iapetus ocean and formation of the equatorial supercontinent Laurasia I, which developed as a result of the collision of Avalonia, Baltica, Laurentia and Siberia (Fig. 9).

Convergent Tectonics

During the Late Silurian, the collision between Baltica and Greenland continued. 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*., 1993; 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 Mid-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 Baltic, Avalonia, and Laurentia formed the continent of Laurussia (P. Ziegler, 1989).

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). 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 rock deformed during Carboniferous and Permian time (Zonenshain *et al*., 1990). P. Ziegler (1989) has mapped an orogenic belt at the southern border of Baltica, from Late Silurian to Permian time. Nikishin at 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 northwestern 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 Sengör & Natalin, 1996, Nikishin *et al*. 1996). 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.

Extensional Tectonics

Rifting began to develop in the Rheno-Hercynian basin in Central Europe. This back-arc type basin was formed on the southern margin of the newly formed Laurussian continent, behind the north-dipping subduction zone (P. Ziegler, 1989; Franke, 1992; Franke *et al*., 1995). An extensional regime began to be established in the eastern part of Laurussia, which led to the Devonian development of numerous rifts and back-arc basins in this area (Nikishin *et al*., 1996).

It is quite possible, that at that time several microplates rifted away from the Gondwana margin to arrive at Laurussia and Kazakhstan, at the Devonian-Permian time. These plates include Alpine - Inner Carpathian terranes (P. Ziegler, 1988, 1989, Dallmeyer *et al*., 1996), Rhodopes (Yanev, 1992), Pontides (Ustaömer & Robertson, 1997), the Greater Caucasus plate (Belov, 1986, 1989), Ust-Urt, Kara-Bogaz, Karakum, Gissar and the North Pamir plates (Zonenshain *et al*., 1990; Sengör & Natalin, 1996; Alexeiev, 1998; Allen & Tull, 1997). The exact time and the nature of rifting of these terranes remain speculative.

Sea Level and Climate

According to Ross & Ross (1987) the second highest global 1st-order sea-level highstand for the Paleozoic occurred at this time. General regression occurred on parts of the Laurasia I continent, especially on the North American craton. Large areas in the Gondwana were submerged at the same time. The equatorial location of Laurasia I and submergence of the Gondwana caused the climate warming. Although the Gondwana ice cap still existed, it was diminishing towards the end of the time slice (Williams, 1995).

Carbonate Sedimentation

On the North American craton, marine basins became small, internal, semi-closed seas in which carbonates were the dominant deposits. Their thickness did not exceed tens of meters (Ronov *et al*., 1984). The Tunguska basin, on the Siberian platform, became smaller, restricted with the accumulation of mixed carbonate-evaporitic facies (Puchkov, 1996). The large area between Siberia and Laurentia was covered by carbonate and mixed carbonate-clastic deposits (Cecile *et al*., 1998). Carbonates covered the Baltic Sea area on Baltica (McKerrow *et al*., 1991). In the east of Iran and in the south of Afghanistan, a carbonate-terrigenous complex, with a thickness of 200-300 m, was formed. Almost permanent subsidence continued on the shelf north of India, where the deposition of terrigenous and carbonate rocks occurred in a shallow marine basin. Mixed carbonate-clastic facies covered some areas of South China and Indochina (Ronov *et al*. 1984). The carbonates were absent on the remaining part of Gondwana.

Slice 8: Tippecanoe IV – middle Pridolian – middle Pragian (latest Silurian – Early Devonian) – 418-402 Ma

This was the time of the final phase of the Caledonian orogeny, transpressional collision of Gondwana and Laurentia and formation of the Oldredia supercontinent, which included all major plates. Most of Oldredia was located between the South Pole and the Equator (Fig. 10).

Convergent Tectonics

Collision of South and North America occurred during Early Devonian time. The exact location of the collision and the exact time remain uncertain (see McKerrow *et al*., 1991; Keppie, 1989; Keppie *et al.*, 1996; Dalziel *et al*., 1994). Orogenic events were prevalent in Venezuela, Columbia, Peru, and northern Argentina (Gallagher & Tauvers, 1992; Marton & Buffler, 1994; Williams, 1995). Paleomagnetic data (Kent & Van der Voo, 1990; Van der Voo, 1993, Lewandowski, 1998) and paleobiogeography (Young, 1990) support the hypothesis about the proximity of South and North America. The late stage of the collisional events, involving western Avalonia and Laurentia, is known as the Acadian orogeny

(McKerrow *et al*., 1991; Rast & Skehan, 1993). It is also possible that an element of collision and transpression between South and North America existed in the region southwest of Carolina. According to Rast & Skehan (1993), the Carolina block acted as an indentor in the transpressive regime, with a dextral strike-slip component. As a result of these orogenic events, the Western Rheic Ocean was closed at this time. With Siberia still in contact with Laurentia and Baltica, through the Canadian Arctic Islands-Barentsia, all major continents were together forming the supercontinent. This megacontinent could be easily compared with the Carboniferous-Jurassic Pangea. I propose the name "Oldredia", derived from the Old Red continent after the Scottish Old Red Sandstone (McKerrow *et al*., 1991; P. Ziegler, 1989). However the traditional Old Red Continent and Ziegler's Laurussia are much smaller.

Late Caledonian deformation was also noted in Polish and German Caledonides (Pożaryski *et al*., 1982; P. Ziegler, 1982). A late stage of thrust related deformation occurred in northern Scandinavia (Soper *et al*., 1992). According to Milnes *et al*. (1997), eclogites formed about 410 Ma in Norway, in an over-deepened root of Baltica, which had developed in the ductile lower crust, as a response to extreme crustal shortening.

Siberia began a clockwise rotation gradually closing the Ural-Paleoasian Ocean (Smethurst *et al*., 1998). The southern (in present day coordinates) margin of Siberia collided with several microcontinental plates, causing an uplift of a part of the platform (Zonenshain *et al*., 1990). Laurentia and Siberia were in the near collisional contact. Obduction of ophiolites occurred in the southern part of the Ural. The Bowning orogeny was recorded in Australia (Cook, 1990).

Extensional Tectonics

A new rifting phase and reactivation of the Cambrian-Ordovician rift system began to develop in the Timan-Pechora Basin on Baltica (Nikishin *et al*., 1996). The extensional phase began in the development of the Scandinavian Caledonides (Milnes *et al*., 1997; Rey *et al*., 1997). The Rhenohercynian Basin was established on the former Avalon terrane, along the South Laurussian margin (P. Ziegler, 1989; Franke, 1992; Franke *et al*., 1995).

The clockwise rotation of Siberia caused rifting between the Chukotka-North Slope and the Verkhoyansk terranes (Parfenov, 1997). The mapped spreading remains quite uncertain and speculative. This was perhaps also a time of the onset of rifting of South China, Tarim, and Indochina from Gondwana (Metcalfe, 1996).

Sea Level and Climate

This was the time of low sea level stand and the emergence of continents following the Caledonian and Acadian orogenies, as well as the formation of the Oldredia supercontinent. A dry, arid climate lad abundant, widespread red sediments (Old Red). The Gondwanian glaciers existed continuously during Silurian – Early Devonian time (Williams, 1995, Veevers & Powell, 1987).

Carbonate Sedimentation

The area of carbonate sedimentation was decreasing on the Laurussian continent (Ronov *et al*., 1984). The relatively narrow seaway between Northern Canada and the Mid-continent area in North America was covered with mixed carbonate-clastic sediment. Carbonates were also deposited along the western margin of Laurussia. On the Siberian continent, carbonates occurred in the North (in present day coordinates) and in the Verkhoyansk area (Vinogradov, 1968a). The mixed carbonate sedimentation was widespread on Eastern Gondwana, in Indochina, North India and part of South China and Tarim (Ronov *et al*., 1984). Carbonate sedimentation occurred for the first time in the Phanerozoic, on the Central European part of Gondwana (P. Ziegler, 1989), due to the movement of these terranes to lower latitudes.

Slice 9: Kaskaskia I – late Pragian – Eifelian (Early – Middle Devonian) – 402-380 Ma

This was time of the beginning of significant plate reorganization and rifting of continental margins of Oldredia, which led to disassembly of the supercontinent. The low stand of sea-level continued, changing to global continental flooding toward the end of the period (Fig. 11).

Convergent Tectonics

Late stages of compressional events of the Acadian orogeny (McKerrow, 1988; McKerrow *et al*., 1991) occurred in the orogenic belt, from Central Scotland to New York. Sinistral displacement in Scandinavia and Greenland was a result of transtensional orogenic collapse (Soper *et al*., 1992). According to Milnes *et al*. (1997), final stage of contraction of the Caledonides in Norway took place between 410-395 Ma, and, at the end of this phase, the strain field in the upper crust changed from contraction to extension. Early to middle Devonian convergence is detected in the Mid-German crystalline high terrane and in the Bohemian massif in Central Europe (Franke, 1992). Collisional activities were also detected in the Alpine area (Dallmeyer *et al*., 1996). The oldest deformation and metamorphic event in the Western Tatra Mts. in the Carpathians took place around 400 – 380 Ma (Gawęda *et al.*, 1998). The Western Rheic Ocean became quite narrow. Tectonic activities of Franklinian-Innuitian orogenies continued in the Arctic area between Siberian and Laurussia (P. Ziegler, 1989). Transpressional tectonics continued along the Gondwana-Laurentia collisional zone.

The subduction zone was active in Eastern and Western Gondwana (Dalziel *et al*., 1994; Yin & Nie, 1996).

Extensional Tectonics

Rifting occurred on some continental margins, back arc basins developed along the northern margin of Gondwana, in the north eastern CIS, and the Donetz aulacogen originated on the southern margin of Baltica (Zonenshain *et al*., 1990, Nikishin *et al*., 1996). The Rhenohercynian basin continued to spread (P. Ziegler, 1989).

It is also likely that South China, Indochina and Tarim had started to drift away from eastern Gondwana by the Early or Middle Devonian times (Golonka *et al*., 1994, Metcalfe, 1994, 1996). The position of Chinese plates and Tarim, prior to their assembly and suturing with Eurasia during Late Paleozoic - Mesozoic, is quite speculative and controversial (compare Scotese & McKerrow, 1990; Golonka *et al*., 1994; Zonenshain *et al*., 1990; Metcalfe, 1994; Sengör & Natalin, 1996; Nie *et al*., 1990; Yin & Nie, 1994; Eide & Torsvik, 1996).

Siberia passed over a hot spot. Rifting and fracturing of the Siberian platform was associated with hot spot activity, expressed by the intrusions of kimberlites. The Vilyuy Trough formed at that time. Kazakhstan began to converge with Siberia, consuming the Paleoasian Ocean floor (Zonenshain *et al*., 1990). Our reconstruction shows separation of Siberia, together with the Verkhoyansk (Kolyma-Okhotsk) terranes, from Laurentia, following the Franklinian-Innuitian orogeny (P. Ziegler, 1989; Golonka & Scotese, 1995; Sengör & Natalin, 1996; Eide & Torsvik, 1996). This is also possible that Verkhoyansk stayed together with Laurentia (Cecile *et al*., 1998), while Siberia drifted away, rotating clockwise toward Kazakhstan (Parfenov, 1997).

Sea Level and Climate

Sea-level low stand continued, with the temporary rise toward the end of the supersequence. Climate was still arid with abundant red beds deposited. The northward drift of the central Gondwana contributed to the warming of the climate and transition from icehouse to greenhouse. A small icecap still existed in Gondwana (Williams, 1995).

Carbonate Sedimentation

The carbonate deposition area in the western and northwestern part of North America increased, where the large West Canadian basin appeared during the early Devonian time (Ronov *et al*., 1984; McKerrow *et al*., 1991). Mainly carbonates were accumulated in the basin, while a salt-bearing complex was formed in its southern gulf.

In the southwestern part of Laurussia, in the peri-Caspian and peri-Ural area, mixed carbonate-clastic facies occurred. The carbonate platform increased in the northern and eastern part of Siberia and adjacent Verkhoyansk terranes (Vinogradov, 1968a). Limestones, dolomites and mixed clastic-carbonate facies were present in the central European terranes (P. Ziegler, 1989). Marginal basins existed in northern India, near the Himalayas and in Southern Tibet, with the deposition of terrigenous and carbonate rocks of shelf type in the shallow sea. Mixed carbonate sedimentation was widespread on Eastern Gondwana, in Indochina, parts of South China and Tarim (Ronov *et al*., 1984).

Slice 10: Kaskaskia II – (Givetian – Fammenian)Middle – Late Devonian – 380-359 Ma

This was the time of disassembly of the Oldredia supercontinent, onset of the Hercynian orogeny, period of major carbonate buildups, anoxia and a major extinction event (Fig. 12).

Convergent Tectonics

Gondwana drifted northward and rotated clockwise (Scotese & McKerrow, 1990; Scotese & Barret, 1990). At the same time, Laurussia was rotating clockwise (Torsvik *et al.*, 1996) at a somewhat faster rate. The first contact between Laurussia and the Central European promontory of Gondwana occurred in the Tornquist-Teisseyre zone (Fig. 12). This contact marks the onset of Hercynian orogeny. The Bohemian, Saxoturingian and Małopolska High terranes (Lewandowski, 1993, 1997, 1998) moved along the strike-slip faults towards Laurussia. The Moesia plate could have been accreted to Baltica during the early Paleozoic (Yilmaz *et al.*, 1996). According to Tari *et al.* (1997), the Moesian rocks, younger than Devonian, show no signs of metamorphism and are relatively undeformed. Accretionary Devonian complex in the North Dobrogea shows that Moesia could have join Laurussia in Late Devonian or post-Devonian time (Kazmin, *pers. comm.*).

Siberia continued its clockwise rotation (Smethurst *et al.*, 1998) and was still in contact with Laurentia and Baltica, through the Canadian Arctic Islands-Barentsia. The Ellesmerian Orogeny occurred, reflecting convergence between Siberia and northern Laurussia (Trettin & Balkwill, 1979; Trettin, 1989). Also Siberia continued to converge with Kazakhstan (Zonenshain *et al.*, 1990, Bush & Filippova, 1998).

The Antler Orogeny occurred in western Laurussia. Evidence for the Antler orogeny is primarily derived from Nevada and California, where, during the Late Devonian to Early Carboniferous time, the contents of the Antler basin were deformed and thrust to the east. Sporadic evidence exists in the rocks of British Columbia, Yukon Territory and Alaska

(Oldow *et al*., 1989). This orogeny was perhaps a result of the collision of the eastward advancing island arc with the western margin of North America (Hamilton, 1989).

Extensional Tectonics

South and North America were again separated. The early Devonian Oldredia supercontinent was disassembled. The gap was not very large according to the Gondwana position of Scotese & Barret (1990; see also Scotese & McKerrow; 1990; Golonka *et al*., 1994; Williams, 1995). With an alternative position of Gondwana (e. g., Bachtadse *et al*., 1995), the gap seems much larger, particularly between Africa and Armorica. Using the reconstruction, based on the pole of rotation in central Africa, suggest, however, a very rapid movement of the northern margin of Africa from near the Equator (Kent & van der Voo, 1990), during early Devonian, to 60^o S, during the late Devonian, and back to Equator, in the Carboniferous (Bachtadse *et al.*, 1995). Such a movement is very hard to explain considering existing geological and paleoclimatological records. On Lewandowski's (1998) reconstructions, Africa was at 30^o S, Baltica at Equator, Armorica converging with Baltica. The latitudinal position of continents is similar to the presented model. The large gap between Gondwana and Laurussia still exists due to differences in longitude for South and North America. Paleontological data (Robardet *et al*., 1993) suggest affinities between the fauna in Armorica and Africa and differences between Armorican and Avalonian margins of Laurussia. Detailed plate tectonic models of the Late Paleozoic terranes between Gondwana and Laurussia should be constructed in future work.

Development of major rift systems took place throughout Baltica and Siberia. The Dnepr-Donetsk-Pripyat system (Fig. 12) went through the main phase of rifting on Baltica (Nikishin *et al*., 1996). The rifting was coupled with the uplift of large domes and widespread, partly kimberlitic magmatic activity. Rifting could have occurred in the Peri-

Caspian Basin, which may have progressed to crustal separation and the opening of a limited back-arc type ocean basin (Zonenshain *et al*., 1990; Nikishin *et al*., 1996; Sengör & Natalin, 1996). The timing of rifting is somewhat speculative, because of lack of good seismic limes support (Kazmin, pers. comm.). Rifting activity resumed during the Middle Devonian along the eastern margin of Baltica, in the Barents Sea, Kola, Timan, Vyatka and Soligalich areas. Late Devonian rifting was associated with volcanic activity. The Eastern Barents Basin is underlain by a thin, high velocity crust of possibly oceanic nature, which was formed as a result of Middle Devonian-Early Carboniferous crustal extension (Aplonov *et al*., 1996, Nikishin *et al*., 1996). All the above rifts were back-arc extensions, associated with subduction zone dipping towards the Baltica continent. Rifting occurred between the Siberian plate and the Verkhoyansk (Kolyma-Okhotsk) terranes (Khudoley & Guriev, 1994; Parfenov, 1997). It is possible that the Barents Sea and Verkhoyansk rifts were connected.

Drifting of Tarim from South China, in direction towards Kazakhstan could has occurred at this time (Metcalfe, 1994). The end of the time slice may be was marked by the onset of drifting of the other Chinese plates.

Sea Level and Climate

The global, 1st-order highstand of sea-level occurred during this time. The onset of a global cooling trend, near the end of the Kaskaskia II period, marked the transition from greenhouse to icehouse conditions. Kaskaskia II climates were generally warm and equable, but minor alpine and continental ice was present in the south polar regions. A global oceanic anoxic event (OAE) occurred at this time. A major extinction event took place at the end of the Kaskaskia II time slice (Buggisch, 1991; Joachimski & Buggisch, 1993; Racki, 1998a, b).

Carbonate Sedimentation

Most carbonate depositional systems were restricted to low latitudes. Carbonate sediment distribution increased in eastern Laurussia (Fig. 12) and in Australia, with respect to previous time slices (Ronov *et al*., 1984; Vinogradov, 1968a, Cook, 1990). High relief platform margins occurred around many intrashelf basins (e.g., Western Canada Basin, and Canning Basin, Australia). Known carbonate-buildup trends occurred along the north African, Iranian, and central European continental shelves. Also Devonian buildups were prominent along the margins of the North Caspian Basin, the eastern margin of the Volga-Urals Platform, and within the Timan-Pechora region (Nikishin *et al*., 1996). Carbonates also occurred in the northern part of Siberia, the Verkhoyansk terranes, South China, Iran, Kazakhstan, and Mongolia (Puchkov, 1996; Ronov *et al*., 1984). The carbonate buildups exist in proximity to the organic rich deposition, during the time of anoxia.

Slice 11: Kaskaskia III – late Fammenian – early Visean (latest Devonian – Early Carboniferous) – 359-338 Ma

This was the time of the continuation of the Hercynian orogeny in Europe and of the drift of Chinese plates away from Gondwana. The climate changed into the icehouse with the increase of icecap on Gondwana (Fig. 13).

Convergent Tectonics

The ongoing Hercynian convergence in Europe led to large scale dextral shortening, overthrusting and emplacement of parts of the accretionary complexes (Edel & Weber, 1995). The amount of convergence was modified by large, dextral and sinistral transfer faults. The thrusting took place in the Tatra Mts. in the Carpathians (Gawęda *et al.*, 1998). Suturing of the Arctic terranes with the northern margin of Laurussia, along the Innuitian-Lomonosov orogen, was completed during the earliest Carboniferous (Nikishin *et al*., 1996). The Antler orogeny was concluded in western North America (Oldow *et al*., 1989, Hamilton, 1989). Siberia rotated clockwise (Smethurst *et al*., 1998). Kazakhstan continued to converge with Siberia. Only a narrow strait remained from the former Paleoasian Ocean (Zonenshain *et al*., 1990; Bush & Filippova, 1998). The Tarim plate moved further westwards coming close to Kazakhstan. The Salair block was thrust over the Siberian margin in the Altay area. The Alice Spring Orogeny began in central Australia (Cook, 1990).

Extensional Tectonics

The Verkhoyansk (Kolyma-Okhotsk-Chersky) terranes had broken off Siberia (Zonenshain *et al*., 1990; Khudoley & Guriev, 1994). Perhaps Siberia rotated clockwise, drifting towards the Kazakhstan plate (Smethurst *et al*., 1998), while the Verkhoyansk terranes stayed in place. Gondwana also rotated clockwise and the Chinese plate drifted further away from Gondwana (Scotese & McKerrow, 1990; Golonka *et al*., 1994). Grabens formed between Greenland and Norway (Stemmerik *et al*., 1991)

Sea Level and Climate

Global sea level was relatively high, especially towards the end of the time slice. Sea level was affected by frequent glacioeustatic fluctuations. Icehouse conditions prevailed with cool temperatures extending to low latitudes. The southern polar icecap increased significantly in size (Williams, 1995). The global anoxic event continued.

Carbonate sediment distribution continued in eastern Laurussia and in Australia from the previous time slices (Ronov *et al*., 1984; Vinogradov, 1968a; Cook, 1990). Carbonates were also widespread along the margins of the North Caspian Basin, Volga-Urals Platform, and Timan-Pechora region (Nikishin *et al*., 1996). Mixed carbonate-clastic facies also occurred in the northern part of Siberia, the Verkhoyansk terranes, South China, Iran, Kazakhstan, Mongolia, and North China (Puchkov, 1996; Ronov *et al*., 1984). Carbonate buildups, for example reef mounds, were rare and mostly composed of muddy, non-framework algal and skeletal components. The overlying major unconformity and contemporary glacioeustatic sea-level fluctuations subjected carbonates of this age to episodes of erosion and karstification.

Slice 12: Kaskaskia IV – middle Visean – Serpukhovian (Lower Carboniferous) – 338-323 Ma

This was the time of the initiation of the collision of Laurussia and Gondwana, closing of the SW remnants of the Rheic Ocean, and icehouse climatic conditions, with glacioeustatic fluctuations of sea-level (Fig. 14).

Convergent Tectonics

The clockwise rotation of Gondwana (Smethurst *et al*., 1998), during the collision with Laurussia closed the southwest remnant of the Rheic Ocean. The Hercynian orogeny in Europe was a result of collision of several separate blocks with the Laurussia margin (Franke, 1989, 1992; Franke *et al*., 1995; Lewandowski, 1998), followed by the involvement of

Gondwana continent. Widespread orogenic deformation occurred across western and central Europe in Iberia, Ligerian, Central Massif, Sardinian - Corsican, Armorican, Harz Mts., Saxoturingian, Bohemian, and Silesia areas (Yilmaz *et al*., 1996). The Rheno-Hercynian basin turned into foredeep, with flysch deposition.

The Alleghenian orogeny in North America was a result of the collision of the Gondwanian and Laurussian cratons (Dewey & Burke, 1973). This orogenic event was prolonged and polyphase. The thrusting transported remnants of previously deformed rocks to the northwest. In the northern Appalachians, the strongest effects of the Alleghenian orogeny are peripheral to eastern Canadian provinces and American states. In the southern and central Appalachians the Alleghenian orogeny was widespread and pervasive (Rast, 1990). The circum-Pangean rim-of-fire began to develop. As a result of Antler orogeny, perhaps an island arc collision with the western margin of North America (Hamilton, 1989), eastward dipping subduction developed along the newly formed margin.

The main collision of Kazakhstan and Siberia began at this time, as well as the collision of Tarim with Kazakhstan (Zonenshain *et al*.,1990; Sengör & Natalin, 1996). According to Adamia (1991), the collision of the Greater Caucasus terrane with Baltica occurred during the mid-Carboniferous and was associated with the partial closure of the Rheic ocean in this area and formation of the Scythian platform. The Amuria arc continued accretion between northern China and Siberia.

The amalgamation of South China and Indochina occurred, demonstrated by large scale folding and thrusting along the Song Ma suture in North Vietnam (Metcalfe, 1994, 1996; Sengör & Natalin, 1996). The Alice Orogeny continued in Australia (Cook, 1990).

Extensional Tectonics

Rifting was initiated between Laurentia and Baltica along the old Caledonian suture (P. Ziegler, 1988; Stemmerik *et al*., 1991). The initial opening of the Sverdrup Basin, in Northern Canada, occurred (Trettin, 1989). A passive margin developed along the newly opened oceanic basin between Siberia and the Verkhoyansk terranes (Khudoley & Guriev, 1994).

Further drift of the Chinese plates off Gondwana continued (Metcalfe, 1994; Golonka *et al*., 1994), North China arrived in the vicinity of Mongolia (Sengör & Natalin, 1996). The easternmost remnants of the Rheic Ocean and the newly formed ocean between Gondwana and the South China plates had been called Paleotethys (Sengör, 1984; Sengör & Natalin, 1996; Stampfli *et al*., 1991; Dercourt *et al*., 1993; Ricou, 1996, Scotese & Lanford, 1995; Golonka & Gahagan, 1997).

Sea Level and Climate

Global sea-level was relatively high at the beginning of Kaskaskia IV and dropped dramatically towards the end of supersequence. The sea level was affected by high-amplitude, high frequency glacioeustatic fluctuations. Icehouse conditions prevailed, with cool temperatures extending to low latitudes. The southern polar ice cap continued to exist, with similar size to that of the Kaskaskia III glaciation.

Carbonate Sedimentation

The emergence of continents and increased input of clastics decreased the areas of carbonate deposition. Carbonates were replaced by clastics and mixed carbonate facies in the eastern part of Laurussia (Nikishin *et al*., 1996). Mixed carbonate-clastic and carbonate sedimentation prevailed on relatively broad shelf-seas (Ronov *et al*., 1984), especially on the Gondwana margins east of Arabia, on Chinese plates, Eastern Europe and on the northern margin of Canada. Carbonate facies still prevailed in the westernmost part of Laurussia. Carbonate buildups were composed of muddy, non-framework algal and skeletal components. The glacioeustatic sea-level fluctuations subjected carbonates to episodes of erosion and karstification.

Slice 13: Lower Absaroka I – Bashkirian – Kasimovian (Late Carboniferous) – 323-296 Ma

This was the time of the initial assembly of the Pangea supercontinent following the major continental collision of Gondwana and Laurussia. This was also the time of the onset of Ural orogeny, domination of ice over the southern pole area and foreland basin development (Fig. 15).

Convergent Tectonics

The collision between Gondwana and Laurussia continued to develop. The intercontinental collision began to affect the northwestern part of Africa. According to Lécorché *et al*. (1989), the age of the West African orogens (Mauretinides, Bassarides, Rokelides) is Late Carboniferous to Early Permian (ca 300 to 275 Ma). The collision resulted in eastward translation of previously tectonized Mauretinides units over their foreland and emplacement of imbricated nappes. The Alleghenian orogeny in North America continued (Hatcher *et al*., 1989; Rast, 1990), prograding westwards to the Ouachita foldbelt in Arkansas, Oklahoma, Texas and adjacent part of Mexico (Arbenz, 1990, Golonka, 1988). The Hercynian orogeny in Europe continued (Franke, 1989; P. Ziegler, 1989). The clockwise rotation of Gondwana resulted in the involvement of this continent in the European deformation. The SW-NE stress direction was added to the northern one. This Gondwanian influence resulted in the convoluted shape of the Hercynian orogen, strike-slip zones (Franke *et al*., 1995) and

Hercynian deformation at the eastern end in Poland. The European foreland basin was elevated or changed its sedimentation regime from flysch to molasse.

The central Pangean mountain range was formed, which extended from Mexico to Poland (Golonka & Ford, 2000). Southwards the mountain system extended to Morocco (Pique, 1989). Late Carboniferous events were also marked in the Alps, Carpathians (Dallmeyer *et al*., 1996, Gawęda *et al*., 1998) and Rhodopes (Yanev, 1992). Probably, the Pontides terranes had also been sutured to Eurasia, before the Permian time (Ustaömer & Robertson, 1997). According to Okay *et al*. (1996), the Western Pontides Paleozoic sequence was folded and possibly thrust-faulted, during the late Carboniferous-Permian time. Mountains formed on the northern margin of Paleotethys, as results of these events, were connected with the Hercynian orogen in Europe. Northdipping subduction developed along the Paleotethys margin.

The collision of East Siberia and Kazakhstan was near completion, forming the Irtysh and Dzungar fold belts (Zonenshain at al., 1990). Siberia also began to collide with the Kara Sea plate in the Taimyr area in the Arctic (Vernikhovsky, 1995, 1997). The collision between the Kazakhstan plate and Laurussia began in the Late Carboniferous (Puchkov, 1991, 1997) in southern and central Urals, later progressing into the northern parts of Urals. The onset of the Ural suture marked the formation of the supercontinent Pangea (Wegener, 1912). The late Carboniferous Pangea included Australia, India, Antarctica, Africa, Arabia, the Cimmerian plates, South America, Europe, Kazakhstan and Siberia. The Cape Fold Belt in southern South Africa (Visser, 1987; Veevers *et al*., 1994) was one of the other Circum-Pangean orogenies. The subduction zones existed along the western coast of Pangea (present day South and North America).

Extensional Tectonics

Rifting continued along the old Caledonian suture, between Scandinavia and Greenland in Laurussia (P. Ziegler, 1988). Perhaps the onset of rifting of the Cimmerian plates (Sengör, 1984) occurred during this time slice. The Chinese plates, which were already rifted, drifted away from Gondwana. The position of the Chinese plates and Amuria (Mongolia) remains somewhat speculative (Nie *et al*., 1990; Yin & Nie, 1996; Golonka *et al*., 1994). These plates were located somewhere east of the Paleotethys and were not incorporated into the Pangean supercontinent.

Sea Level and Climate

Global sea level was quite low at the beginning of supersequence, with progressive continental emergence and occurred during a time of overall 1st-order sea level fall. The sea level was affected by glacioeustatic fluctuations, but with somewhat lower frequency, comparing to that of the Kaskaskia III and IV time.

Icehouse conditions prevailed, with cool temperatures extending to low latitudes. The southern polar icecap reached its maximum size (Crowell, 1995; Crowell & Frakes, 1975, Crowley & Baum, 1992; Frakes *et al*., 1992; Francis, 1994; McClure, 1978, 1980; Veevers & Powell, 1987). The icecap covered Southern Australia, Antarctica, southern India and Arabia, Madagascar, eastern and southern Africa and southeastern part of South America. Smaller independent alpine and continental glaciers also existed. Less frequent sea-level fluctuations indicate the stabilization of the icecap.

Carbonate Sedimentation

Mixed carbonate-clastic and carbonate sedimentation prevailed on the relatively broad shelf-seas (Ronov *et al*., 1984), especially on the Gondwana margins east of Arabia, on the

Chinese plates, Eastern Europe and on the northern margin of Canada and Eurasia (Golonka & Ford, 2000).

Slice 14: Lower Absaroka II – Gzhelian – Asselian (latest Carboniferous – earliest Permian) – 296-285 Ma

This was the time of the mature stage of continental collisions and the development of the Pangean Rim of Fire (Fig. 16).

Convergent Tectonics

Many of the continental collisions, which began in the Carboniferous, reached maturity in the Early Permian. A major part of Pangea was assembled, and the new supercontinent, ringed by subduction zones, moved steadily northwards. The formation of Laurasia reached a main phase, with the suturing of Kazakhstan and Siberia with Laurussia (Nikishin *et al*., 1996; Zonenshain *et al*., 1990; P. Ziegler, 1989). The Ouachita Mountains of Oklahoma reflected the final phase of collision between Laurentia and Gondwana in the Early Permian (Hatcher *et al*., 1989). Collisional compression was still active in the Ural area, North America, and the Cape Fold Belt. The Hercynian Mountains, in the Western and Central Europe, became inactive. Continued closure between the Gondwanian and Laurussian elements of Pangea eliminated the equatorial seaway between the Paleotethys and western oceans.

Subduction zones existed along the coasts of Pangea, forming the Pangean Rim of Fire (Lawver & Gahagan, 1993; Scotese & Lanford, 1995; Golonka & Ford, 2000) in North America (Burchfiel at al., 1992) and South America (Forsyth, 1982), Antarctica (Milne &

Miller, 1991), and Western Australia (Veevers, 1984, Cook, 1990).The subduction zone along the northern coast of the Paleotethys continued to exist (Zonenshain *et al*., 1990; Sengör & Natalin, 1996; Scotese & Lanford, 1995).

The position of the Chinese plates remained relatively unchanged. The Solonker Ocean between North China and Amuria (Mongolia) narrowed (Sengör & Natalin, 1996; Scotese & Lanford, 1995). Tarim was in collision with the southern margin of Laurasia in the Tyanshan-Dzungar basin area (Nie *et al*., 1990, Yin & Nie, 1996). West of Tarim, the Northern Pamir-Gissar terranes docked into Kazakhstan during the Permian time (Puchkov, 1991).

Extensional Tectonics

Carboniferous-Earliest Permian rifting of the Cimmerian Plates (see Sengör & Natalin, 1996; Dercourt *et al*., 1993; Golonka *et al*., 1994; Golonka & Ford, 2000) from Gondwana turned into drifting during the Permian, marking the inception of the Neotethys Ocean. Rifting and oceanic type of basin opening could also have occurred in the Mediterranean, recorded by the deep water sediments of Sicily (Catalano *et al*., 1991; Kozur, 1991) Lago Negro (Marsella *et al*., 1993) and Crete (Kozur & Krahl, 1987).

There are some slight indications of initial Karoo rifting in South Africa and volcanic activity prior to the Early Jurassic massive basalt lava flows. This rifting started probably as early as the early Permian and continued throughout the Permian and Triassic (Veevers, 1994; Bangert *et al*., 1997; Stollhofen & Stanistreet, 1997). Back-arc extension and graben development occurred along western South America (Forsyth, 1982). Opening of the proto-North Sea was initiated between East Greenland and Baltica (Stemmerik *et al*., 1991). Strike-slip, pull-apart grabens developed in Central Europe (P. Ziegler, 1988).

Sea Level and Climate

The Asselian supersequences represented 2nd-order transgressive-regressive events that developed during a period of 1st-order sea level fall and continental emergence. Sea level at this time was further affected by glacioeustatic fluctuations.

Icehouse conditions prevailed with steep polar-equatorial temperature gradients, a mature-to-retreating southern polar ice cap (Crowell, 1995; Crowell & Frakes, 1975; Frakes *et al*., 1992; Francis, 1994; McClure, 1978, 1980; Veevers & Powell, 1987), dry continental interiors, and high-latitude wet belts. A Central Pangean mountain belt created a substantial rain shadow at low and mid latitudes. Cooling occurred in the Arctic (Beauchamp, 1994).

Carbonate Sedimentation

Carbonates occurred at low to mid-latitudes and were dominated by muddy facies and algal/Palaeoaplysina buildups (Ronov *et al*., 1984; Flügel, 1994; Beauchamp, 1995). Carbonates prevailed on the Tethys platforms (Dercourt *et al*., 1993; Sengör & Natalin, 1996), on the South China plate (Enos, 1995), in Eastern Europe and the adjacent Arctic (Golonka & Ford, 2000).

Slice 15: Lower Absaroka III – Sakmarian – Kungurian (Early Permian) – 285-269 Ma

This was the time of the first phase of intensive rifting of Pangea, including drifting of the Cimmerian Plates off Gondwana (Fig. 17).

Convergent Tectonics

The formation of the Pangean supercontinent continued. Pangean movement was characterized by an overall northward drift and clockwise rotation. Formation of Laurasia by the collision of Kazakhstan and Siberia with Laurussia was finalized (Nikishin *et al*., 1996; Zonenshain *et al*., 1990; P. Ziegler, 1989). Laurasia constituted the northern part of Pangea at this time. The closing of the Uralian Ocean involved capture of oceanic crust, which formed ophiolitic belts in the basement of the West Siberian Basin (Zonenshain *et al*, 1990). Uralian ocean closure also involved foreland basin development and craton margin subsidence, which allowed the continuation of the north-south seaway across the Volga-Ural platform, from the Boreal realm to the North Caspian/Paleotethys region (Nikishin *et al*., 1996; Puchkov, 1991). The Turan microcontinent collided against the southern margin of Kazakhstan (Zonenshain *et al*., 1990; Alexeiev, 1998), forming the Turan Platform. The capture of North Caspian oceanic crustal basement occurred, thereby stabilizing the overall geometry of this important oil province. Initial collision occurred between north and south China. The Solonker Ocean between Amuria (Mongolia) and North China was closed (Sengör & Natalin, 1996). The mapped position of the Amuria-North China assembly and Tarim Plate agrees approximately with the recent paleomagnetic results of Xu *et al*. (1997). Continuing uplift of orogenic belts at continental margins produced internal drainage and isolated arid interior basins. The entire Pangean supercontinent was rimmed by subduction zones and volcanoes (Golonka & Ford, 2000).

Extensional Tectonics

Minor spreading continued in the central Paleotethys while the mature stage of drifting of Cimmeria resulted in the widening of the Neotethys Ocean. A large rift extended from Tunisia to Syria (Burollet1991; Bouaziz *et al*., 1998) and was connected to the opening of the Neotethys. Extension in the Central Apennines was marked by the Verrucano Formation

(Marcou & Baud, 1996). According to Ustaömer & Robertson (1997), the back-arc basin development could have been initiated during the latest Paleozoic time at the southern margin of Eurasia, between Pontides and Scythian Platform.

The weak and somewhat speculative early Karoo rifting could have continued in central Gondwana (Veevers, 1994; Bangert *et al*., 1997; Stollhofen & Stanistreet, 1997). Back-arc extension and graben development occurred along western South America. Opening of the proto-North Sea continued between East Greenland and Baltica (Stemmerik *et al*., 1991, 1993). Strike-slip, pull-apart grabens developed in Central Europe (P. Ziegler, 1988). Initial rifting occurred in central Australia.

Sea Level and Climate

Relative sea level was high, than plunged dramatically to its minimum, at the end of this time slice (Ross & Ross, 1988, 1995, Ross *et al.,* 1994). Icehouse conditions continued, with steep polar-equatorial temperature gradients (Crowell, 1995; Crowell & Frakes, 1975; Frakes *et al*., 1992; Francis, 1994; McClure, 1978, 1980; Veevers & Powell, 1987), dry continental interiors, and high-latitude wet belts. This was a waning time of the Permian glaciation in Gondwana.

Carbonate Sedimentation

Carbonate platforms occurred on most active and passive marine margins between 40°N and 30°S latitude. Most carbonate platforms exhibited backstepping geometry and most associated buildups tended to be isolated, rather than platform rimming. Carbonates prevailed on the Tethys platforms (Dercourt *et al*., 1993, Sengör & Natalin, 1996), on the South

Chinese plate (Enos, 1995), in Eastern Europe and the adjacent Arctic (Golonka & Ford, 2000).

Slice 16: Lower Absaroka IV – Roadian – Changhsingian (Late Permian) – 269-248 Ma

This was a time of the sea-level near the Phanerozoic minimum, stress-release events of very large magnitude, flood basalt eruptions, and biological extinction (Figs 18, 19).

Convergent Tectonics

The central Pangean belt was no longer active. In particular, the Hercynian mountains in Europe were subject to erosion, continental deposition, and even locally covered by marine transgression (P. Ziegler, 1982, 1989). Crustal shortening continued in the northern part of the Ural Mountains, in Pay-Khoy and Novaya Zemlya, while the central and southern part of the Urals had became tectonically inactive (Puchkov, 1991; Nikishin *et al*., 1996). The evidence of Permian compression was also found in the Taimyr Peninsula (Vernikhovsky, 1995). The Northern Chinese plate was sutured, during the Permian time, to the Amurian (Mongolia) terranes (Nie *et al*., 1990; Yin & Nie, 1996; Scotese & Lanford, 1995). The south dipping subduction, which existed prior to this collision along the North China plate jumped south forming the north-dipping subduction along the northern coast of the Paleotethys (Golonka & Ford, 2000).

The Pangean Rim of Fire, mentioned above, continued to exist. Mountain belts and subduction related arcs spread along the western margin of Pangea in North and South America. The southwestern margin of Gondwana was affected by a major orogenic episode (Lawver & Scotese, 1987; Williams, 1995) which began during the Moscovian and continued during Asselian time. Mountains were created in South America (Sierra de la Ventana, South

Africa (Cape Fold Belt) and Antarctica, resulting from oceanic-continental plate reactions. Their structural style reflects the inversion of the older basins (Tankard *et al.*, 1995). Basalt lava flows and volcanoclastics were abundant in Argentina. The volcanoes were related to a continentward dipping subduction. Left lateral components of shearing in South America is, according to Williams (1995), attributed to the adjustment of the Patagonia terrane.

Extensional Tectonics

According to Beauchamp (1997), the Permian-Triassic boundary marked stress-release event of very large magnitude, probably associated with plate reorganization like shifts from convergent to divergent plate tectonics. This stress release event was evidently visible in the Canadian Arctic, but affected, perhaps, all of the Pangea.

At this time the Neotethys Ocean was already opened and widening (Dercourt *et al*., 1993; Ricou, 1996; Sengör & Natalin, 1996). This ocean had Arabia, Greater India and Australia on one side, and Lut - Qiantang - Southeast Asia on the other.

The spreading was driven by trench-pulling forces related, to the north-dipping subduction, as well as the ridge-pushing forces, related to mantle upwelling, expressed by hot spot activity (Golonka & Bocharova, 2000).

The episode of very strong, hot spot related, flood basalt eruptions in the Western Siberian basin (Zonenshain *et al*., 1990) began towards the end of the Late Permian, within an extremely short period from 255 to 245 Ma. During 10 million years 1,200,000 km^3 of basalts were extruded. According to Sharma (1997), the bulk of the Siberian lavas erupted within one million years at 250 Ma.

Sea Level and Climate

The Guadalupian supersequence represents a time when the sea was near its relative minimum level in the Phanerozoic (Ross & Ross, 1988, 1995, Ross *et al*., 1994). Icehouse conditions continued, however, only small glaciers were present in Antarctica, as a remnant of the retreating southern polar ice cap. Permian climatic conditions, like steep polar-equatorial temperature gradients (Crowell, 1995; Frakes *et al*., 1992; Francis, 1994; McClure, 1980; Veevers & Powell, 1987), dry continental interiors, and high-latitude wet belts still existed. The Gondwana glaciation waned during the Sakmarian and died out during the Kazanian, about 254-252 Ma (Crowell, 1995). The warming which followed seems, according to Crowell (1995), to correspond closely with the extinction event at the Permian-Triassic boundary (Sepkoski, 1989). This climatic change and biological extinction was perhaps related to the plate reorganization mentioned above.

Carbonate sedimentation

Carbonate deposits with reefs and with evaporites and phosphorites were dominant in the western United States (Wardlaw *et al*., 1995). The sedimentological conditions in these deposits changed significantly, while the area drifted northwards across the Equator (Walker *et al*., 1994). In the western Barents area (Fig. 19), carbonates and cyclic spiculitic sediments (Svalbard) prevailed (Stemmerik & Worsley, 1995). Carbonate, mixed carbonate clastics and siliceous deposits dominated in the Arctic area north of Canada (Ronov *et al*., 1984, Beauchamp, 1995). Large shallow carbonate platforms characterized the Guadalupian paleofacies of the Tethyan realm (Dercourt *et al*., 1993; Alsharhan & Nairn, 1995, Marcoux & Baud, 1996). The carbonates covered the Taurus, Iranian plates, eastern Arabia, and the Indonesian plates (Golonka & Ford, 2000).

The changing sea level caused the cyclic deposition of the clastic-carbonates-evaporitic sequences (Fig. 19). Four of such large cyclothems are evident within the European Zechstein sediments. Some of them contain a substantial amount if carbonate deposits - dolomites and limestones.

Slice 17: Upper Absaroka I – Induan – lower Carnian (Early – earliest Late Triassic) – 248-224 Ma.

At this time Pangea begin to stretch, initiating the rifting and future breakup of the supercontinent. The author arbitrarily posted speculatively the position of several terranes west of North America. These terranes were not on the Paleozoic maps, because of lack of data, but they are mapped on all Mesozoic maps (Fig. 20).

Convergent Tectonics

The last collisional events of the Uralian orogeny took place during the Triassic and Early Jurassic time, in the Pay-Khoy-Novaya Zemlya area (Puchkov, 1991, 1997; Zonenshain *et al*., 1990; Nikishin *et al*. 1996). The conclusion of the Uralian orogeny was accompanied by uplift of the adjacent areas of Eastern Europe and Western Siberia. The Late Carboniferous - Triassic (Vernikhovsky, 1995, 1997, 1998; Parfenov, 1992, 1997; Parfenov *et al*., 1993) collision between Siberia and the Kara Sea platform (may be part of Laurussia) in the Taimyr peninsula was perhaps an extension of the Uralian collision (P. Ziegler, 1989; Nikishin *et al*., 1996; Gee *et al*., 1998).

The Pangean Rim of Fire continued to exist in the relatively unchanged Late Paleozoic configuration (Golonka & Ford, 2000). According to Lawver & Gahagan (1993), a cratonward subduction zone operated off central California, Nevada and Arizona, from the Triassic to the early Middle Jurassic. During Jurassic time, farther north off western North America, subduction polarity was reversed, away from the Pangean margin and under the offshore exotic terrane of Stikinia. The arc terrain was thrust eastward in Nevada during the Early Triassic Sonoma orogeny (Hamilton, 1989).

The continued northward drift of the Cimmerian continent corresponded with the closing and progressive consumption of Paleotethys oceanic crust and the opening of the Neotethys Ocean (Golonka & Ford, 2000). Active subduction existed along northern Paleotethys convergent margins (Stampfli *et al*., 1991; Dercourt *et al*., 1993; Ricou, 1996). The Maker block was accreted in the Caucasus area, as was the Kurgovat microcontinent in the Pamir (Zonenshain *et al*., 1990). The Indonesian part of the Cimmerian continent and southern China drifted northwards, and folded inwards towards the northern Chinese plates (Metcalfe, 1994). During the Late Permian, the South Chinese plate began to collide with the North Chinese block (Yin & Nie, 1996). This collision continued during the Triassic. Consolidation of the North Chinese and Amurian blocks left open a large embayment of Panthalassa, between Amuria and Laurasia, the so-called Mongol-Okhotsk Ocean (Zonenshain *et al*., 1990). Active subduction existed along the margin of this ocean, dipping cratonwards towards East Siberia.

Extensional Tectonics

The stress-release mentioned above initiated stretching, rifting and future breakup of Pangea. Rifts developed in the Gulf of Mexico area, and in maritime Canada (Manspeizer, 1988, 1994). In northwestern Africa, Western Europe, and the proto-North Atlantic area, the Late Paleozoic fracture system was reactivated (P. Ziegler, 1982, 1989; Doré, 1991). The North Sea rift system underwent development, together with the formation of the Polish/Danish Aulacogen.

The subduction zone along the Paleotethys margin caused back-arc rifting in the proto-Black Sea area and along the margins of Scythian-Turan platform (Zonenshain *et al*., 1990; Kazmin, 1990, 1991). The Tauric basin was formed between the Pontides and the Dobrogea-Crimea segment of the Scythian platform. The Meliata-Halstatt Ocean, between the Eurasian margin and the Hungarian Tisa block (Kazmer & Kovacs, 1989; Kozur, 1991, Plašienka and Kováč, 1999), was geodynamically related to this event. In the proto-Mediterranean area, rifting and fragmentation of separated blocks continue to progress (Ricou, 1996; Golonka & Gahagan, 1997; Golonka *et al.,* 2000). In the Eastern Mediterranean area rifting occurred during the Permian and Triassic time (Stampfli *et al*., 1991; Guiraud & Bellion, 1996), accompanied by Mid-Late Triassic, extensive, alkaline basalt flows evident between Levant and Morocco. The rifting was followed by sea-floor spreading recorded by Triassic Mamonia ophiolites from Cyprus (Robertson & Woodcock, 1979, Robertson, 1998). The West Siberian flood basalts were already deposited at this time (Zonenshain *et al*., 1990, Sharma, 1997). The hot spot volcanic activity then progressed towards Yenisey-Khatanga through south of Taimyr Peninsula, where Middle Triassic lava flows were emplaced (Khain & Balukhovski, 1993). The South Anui Ocean opened between the Taimyr and Siberian plates. This ocean continued eastwards to the area between the Chukotka and Verkhoyansk terranes (Zonenshain *et al*., 1990; Sengör & Natalin, 1996).

The Karoo Rift System (Lawver & Gahagan, 1993) developed along the eastern coast of Africa. About 230 Ma, the rifts and seaway between India, Madagascar and the horn of Africa were already developed (Veevers, 1994; Manspeizer, 1994).

Sea Level and Climate

Scythian supersequence development corresponds with the lowest 1st-order sea-level stand during the Mesozoic and the time of maximum continental emergence (Ross & Ross, 1988; Haq *et al*., 1988). The sea level slowly rose from the lowest stand at the Permian-Triassic boundary. This boundary was marked by a dramatic extinction event (Sepkoski, 1989; Francis, 1994). According to Veevers (1994), a catastrophic discharge of CO_2 into the atmosphere from the eruption of Siberian traps was related to mass extinction and the change from icehouse to greenhouse conditions. Transitional icehouse-greenhouse conditions prevailed, characterized by cool, arid climates. Humid and wet conditions were restricted to high latitudes. No evidence of significant continental glaciation exists (Frakes *et al*., 1992).

Carbonate sedimentation

Carbonates were limited to a narrow equatorial belt, separating the Paleotethys and Neotethys, and to narrow platforms, along convergent margins of Western Pangea. Large carbonate platforms existed in the Tethys area (Dercourt, 1993; Marcoux & Baud, 1996; Sengör & Natalin, 1996). Following the Permian-Triassic extinction, biogenic communities were revived by the Middle Anisian (Flügel, 1994; Kiessling *et al*., 1999; Marcoux & Baud, 1996.) Rifting and block-fragmentation in Tethys played an important part in this revival. The carbonate platform included blocks of the margin of the Circum-Mediterranean Area, Iranian, Qiantang, Indonesian blocks, the South Chinese plate, the southern margin of the Scythian plate and margins of Arabia (Golonka & Ford, 2000). Dolomitization occurred quite commonly on the carbonate platforms. Thin, deeper-water, shaly carbonates were interbeded, with fine-grained clastics in back-arc basins of western South America.

Slice 18: Upper Absaroka II – late Carnian – middle Hettangian (Late Triassic – earliest Jurassic) – 224-203 Ma.

This was the time of the consolidation of Chinese blocks and of rifting between Gondwana and Laurasia (Figs 21, 22).

Convergent Tectonics

The most significant convergent event was the Indosinian orogeny, the consolidation of Chinese blocks. According to Yin & Nie (1996), the Late Triassic (220-208 Ma) was the time of the collision of South Chinese and North Chinese plates and a generation of sutures and mountain belts in this area. Also, Indochina and Indonesia were sutured to South China, and Qiantang block approached the Eurasian margin.

In the western Tethys area, several blocks of the Cimmerian provenance (Sengör, 1984, Sengör & Natalin, 1996) collided with the Eurasian margin in the so-called Early Cimmerian orogeny (Fig. 22). Alborz, and South Caspian Microcontinent collided with the Scythian platform, at an earlier time (Carnian), while the Serbo-Macedonian block collided with the Moesia-Rhodopes (Tari *et al*., 1995, 1997), and the Lut block collided with the Turan platform, at a later phase (Zonenshain *et al*., 1990, Kazmin, 1990, 1997). The collisions continued in the Pay-Khoy-Novaya Zemlya area (Puchkov, 1997).

Extensional Tectonics

Rifting and breakup of Pangea, initiated during the Early Triassic, continued and intensified at the beginning of the Norian time slice (Veevers, 1994; Manspeizer, 1994; Withjack *et al*., 1998). Initiation of the Karoo Rift System (Cox, 1992), formation of ocean basins, rifts and microplates in the western Tethys region (Ricou, 1996), and rapid northward drift of the Cimmerian continent, by active seafloor spreading within the Neotethys Ocean (Sengör, 1984), occurred during this time.

In the western Tethys area (Fig. 22), Late Paleozoic and Triassic rifting and seafloor spreading resulted in several separated carbonate platforms (Dercourt *et al*., 1993; Philip *et al*., 1996, Golonka & Gahagan, 1997; Golonka *et al*., 2000). The main Neotethyan oceanic branch separated the Cimmerian blocks (Serbo-Macedonia, Lut and Qiantang) from the Gondwana margins (Sengör, 1984; Sengör *et al*., 1984; Ricou, 1996). The western part of the Neotethys is known as the Vardar Ocean (Sengör, 1984; Kazmer & Kovacs, 1989). The narrow branch of Neotethys separated the Apulia-Taurus platform from the African continent. This branch is recorded by deep water sediments of Sicily (Catalano *et al*., 1991; Kozur, 1990), Lago Negro (Marsella *et al*., 1993), and Crete (Kozur & Krahl, 1991), as well as by the Mamonia ophiolites complex in Cyprus (Robertson & Woodcock, 1979; Morris; 1996; Robertson, 1998. The Apulia platform was connected with European marginal platforms. Its northernmost part was possibly separated from the Umbria-Marche region by a rift. The incipient Pindos Ocean separated the Pelagonian, Sakariya and Kirsehir block from the Ionian-Taurus platform (Robertson *et al*., 1991, 1996; Stampfli *et al*., 1991).

The Calcareous Alps and Inner Carpathians formed the marginal platform of Europe. The Tisa block was fully separated from the European margin by the Meliata-Halstatt Ocean (Kozur, 1991; Kazmer & Kovacs, 1989; Stampfli, 1996; Golonka *at al*., 2000). The Eurasian platform, east of the Meliata Ocean, was dissected by rift systems, which extended from the Dobrogea, through the Crimean lowland to the North Caucasus, Mangyshlak and southern Amu-Darya (Zonenshain *et al*., 1990; Kazmin, 1990, 1997; Kazmin *et al*., 1986). The Moesian block, the Western and Eastern Pontides, the Transcaucasus and the South Caspian blocks were located between this rifted zone and the remnants of Paleotethys.

Sea Level and Climate

The Norian supersequence corresponds with a low first-order sea level stand and a time of high continental emergence. The transition from icehouse to greenhouse conditions continued (Frakes *et al*., 1992). The general conditions resemble those of the Scythian-Carnian time with a slight shift towards increased humidity. Humid and wet conditions were restricted to high latitudes. There is no evidence of significant continental glaciation.

Carbonate sedimentation

The carbonates of Cimmeria comprised an algal/coral-dominated reef and shallow-platform limestones and dolomites. Many of the western Tethyan reefs were distributed on a large carbonate platform (Fig. 22), which existed during most of the Mesozoic, spreading from Apulia through the Ionian and Hellenide terranes to the Taurus zone (Dercourt *et al*., 1993). This zone was connected with the Alpine-Inner Carpathian carbonate platforms, containing abundant reefs (Flügel, 1994; Kiessling *et al*., 1999). Dolomitization of the platform limestones was common.

The Tethyan margins of Greater India and Arabia were occupied by mixed carbonate-clastic facies (Alsharhan & Magara, 1994; Marcoux & Baud, 1996). Shaly carbonates interbeded with fine-grained clastics were still common in the western South American basins (Golonka & Ford, 2000).

Slice 19: Upper Absaroka III – late Hettangian – early Aalenian (Early Jurassic – earliest Middle Jurassic) – 203-179 Ma

This was the time of the complete assembly of eastern Pangea and of onset of the break-up of the supercontinent and separation of Gondwana and North America (Fig. 23).

Convergent Tectonics

At this time, the assembly of the Asian part of Pangea was completed through the collision of the Chinese plates. All major continents and major plates were sutured together with an exception of some Tethyan terranes and terranes west and northwest off North America. The closure of Paleotethys was in the last stage. South China, North China, Indochina, and Southeast Asia were amalgamated during the Norian time. Qiantang was in the final stage of collision (Yin & Nie, 1996; Ricou, 1996; Sengör, 1984; Sengör & Natalin, 1996; Dercourt *et al*., 1993; Metcalfe, 1994).

After the collision of the Chinese plates, as well as the Transcaucasus, Alborz and Lut plates in the central Tethyan area, a new northward dipping subduction zone developed along the northern margin of the Neotethys, south of the accreted continent. The Mongol-Okhotsk embayment continued to invade Asia from the Panthalassa Ocean, during the Early Jurassic (Zonenshain *et al*., 1991; Golonka *et al*., 1994, 1996; Golonka & Ford, 2000). According to Puchkov (1997), the Pay-Khoy-Novaya Zemlya foldbelt was formed before the Middle Jurassic. Active volcanism, terrane accretion, and back-arc basin development continued along the Pangean Rim of Fire. Subduction and back-arc spreading occurred in western North and South America, along with associated volcanism and terrane accretion (Golonka *et al*., 1996; Golonka & Ford, 2000).

Extensional Tectonics

The separation of North America and Gondwana, which was initiated by Triassic stretching and rifting phase continued during Early-Middle Jurassic time. According to Withjack *et al*. (1998) the transition from rifting to drifting was diachronous. In the southeastern United States, this transition occurred after the Late Triassic rifting and before the Early Jurassic (~200 Ma) basaltic magmatism. In maritime Canada, the drift-rift transition occurred about 185 Ma. The start of seafloor spreading in the Central Atlantic, Gulf of Mexico and Ligurian Ocean of Tethys is dated as 175 Ma (Lawver & Gahagan, 1993; Golonka *et al*., 1996). The sinistral strike-slip regime was established between Africa and Europe (Yilmaz *et al*., 1996). Extension and formation of rifts occurred in the High Atlas area in Morocco (El Kochri & Chorowicz, 1996).

Karoo rifting between South Africa and Antarctica was accompanied by an extrusion of flood-basalts, which, according to Cox (1992), were generated, from a large-scale mantle plume. Substantial eruptive activity occurred between approximately 198 Ma and 173 Ma. The onset of the breakup of Africa, India and Antarctica occurred during this time. The East African seaway developed between Africa and India. According to Lawver & Gahagan (1993), the seafloor spreading in the Western Somali Basin and the Mozambique basin began at 175 Ma. This was probably accompanied by seafloor spreading in the South Weddell Sea. The seaway extended southwards to Madagascar.

Continued seafloor spreading occurred within the Neotethys. At this time, the Lhasa plate (Yin & Nie, 1996; Ricou, 1996; Sengör, 1984; Sengör & Natalin, 1996 Dercourt *et al*., 1993; Metcalfe, 1994) drifted away from Gondwana. The Pelagonian plate, Kirsehir and Sakariya (Robertson *et al*., 1991, 1996), and perhaps the Lesser-Caucasus-Sanandaj-Sirjan plate (Adamia, 1991; Golonka & Gahagan, 1997; *Golonka et al*., 2000) were drifting off the Apulia-Taurus-Arabia margin. The Neotethys Ocean was divided into northern and southern branches.

The Ligurian Ocean, as well as the central Atlantic, Penninic Ocean and Pieniny Klippen Belt Ocean (Dercourt *et al*., 1993; Channell, 1996) were opening at the end of this time. Rifting continued in the North Sea and the northern Proto-Atlantic (P. Ziegler, 1989; Doré, 1991). Continued subsidence occurred in the West Siberian Basin.

Sea Level and Climate

The Pliensbachian-Toarcian supersequence forms correspond to the uppermost part of the Absaroka Sloss megasequence, called here the Upper Absaroka III. This was the time of the initiation of the 1st-order sea-level rise in the mid-Mesozoic. There was generally a transgressive trend that would continue throughout the entire Jurassic. There were two maxima of which one, the Pliensbachian at 195 Ma, was chosen as a time for plate reconstruction. The upper boundary of the time slice corresponds with the well-distinguished mid-Cimmerian tectonic unconformity in Europe. Greenhouse conditions prevailed with a warm, humid environment, and moderate temperatures into high latitudes, generally arid continental interiors, and no evidence of significant continental glaciation.

Carbonate Sedimentation

Carbonate sedimentation predominated along all Neotethyan margins, between 35^{o}N and 35^{o}S latitude (Dercourt *et al*., 1993; Fourcade *et al*., 1996). The northwestern Neotethys region consisted of numerous horst blocks capped by carbonate platforms, with adjacent grabens filled with deeper-water black mudstone and organic-rich shale facies. Shallow-platform grainstones to argillaceous deeper-water carbonates accumulated on the passive margin shelves of the western Neotethys. Isolated carbonate platforms were associated with the microplates of the northern Neotethys. Platform interiors may have been partially dolomitized, particularly in areas associated with evaporite deposits.

Slice 20: Lower Zuni I – middle Aalenian – middle Bathonian (Middle Jurassic) – 179-166 Ma

This was the time of the final closure of Paleotethys and of the opening of the central Atlantic and Ligurian-Penninic ocean system (Fig. 24).

Convergent Tectonics

At this time, after the final closure of Paleotethys Ocean, the new Eurasian margin began to be active. A new subduction zone developed along the northern Neotethyan margins.

Extensive volcanism occurred along this zone. The African-Arabian margin began to converge with Eurasia, gradually closing the Neotethys Ocean.

The Mongol-Okhotsk embayment was significantly reduced in size. The main part of the basin was already closed (Zonenshain *et al*., 1990). Continental collision in the western segment of the belt produced an orogenic system of nappes, folds, granitic domes and batholiths. A subduction zone was developed along the northern margin of the Anui Ocean (Zonenshain *et al*., 1990). This subduction dipped towards the Taimyr and Chukotka. The Anui volcanic arc was associated with the subduction zone.

The Pontides Plates (North Turkey) collided with the southern margin of Eurasia closing the Triassic rift and back-arc system of basins and causing deformations in the Crimea and adjacent areas (Zonenshain *et al*., 1990; Yilmaz *et al*., 1997). Compression also took place in Bulgaria (Sengör & Natalin, 1996). In the Carpathian and eastern Alpine areas, the Meliata-Halstatt ocean began to narrow and subduct northwards under the Inner Carpathian and Eastern Alpine plates (Dallmeyer *et al*., 1996). Compression continued between North and South China blocks (Yin & Nie, 1996).

The Pangean Rim of Fire was still active. Volcanism, terrane accretion, and back-arc basin development continued along the western margin of North and South America, as well as along the southern margin of Antarctica and Australia. According to Lawver & Gahagan (1993), the terranes of western North America began to collide with North America. Thrusts and transpressional deformations occurred in western North America (Oldow *et al*., 1989). This collision disturbed the westward movement of the North American plate and caused the stress and inversion on the eastern coast of America (Withjack *et al*., 1998).

Extensional Tectonics

Rifting was initiated between Australia and Antarctica (Cook, 1990). Rifting and spreading began between Antarctica and Africa in the Mozambique Channel and between Madagascar and Africa in the Somali Basin (Rabinowitz at al., 1983; Simpson *et al*., 1979; Lawver *et al*., 1992; Lawver & Gahagan, 1993; Golonka & Bocharova, 2000). It is possible, that seafloor spreading likewise occurred in the Weddell Sea. LaBrecque & Barker (1981) propose that the Weddell Sea contains oceanic crust of middle Jurassic age.
Extension of Neotethys to the northwest into the proto-Mediterranean, produced a connection with the central Atlantic. The Central Atlantic was in an advanced drifting stage (Withjack *et al*., 1998). The Ligurian Ocean was opening simultaneously along with the central Atlantic, Penninic Ocean and Pieniny Klippen Belt Ocean (Dercourt *et al*., 1993; Molli, 1996; Channell, 1996). The Inner Carpathian block and the Eastern Alps were moving away from Europe, and, at the same time, Apulia was moving together with Africa (Channell, 1996). A major Jurassic seaway was opened (Ricou, 1996), connecting the Gulf of Mexico and Central America area with Southern Europe and the Tethyan branch of the Pacific Ocean. Rifting continued in the North Sea and in the northern Proto-Atlantic (P. Ziegler, 1989, Doré, 1991).

Advanced seafloor spreading occurred between the Gondwanian margin and the Helmand and Lhasa Blocks (Golonka *et al*., 1996). Seafloor spreading was also discovered in the Northwestern Australian Basin (Lawver & Gahagan, 1993). The Argo plate rifted away from Australia (Ricou, 1996). The spreading continued between the Arabian-Tauric margin and the Pelagonian, Kirsehir, Sakariya and Sinandaj-Sirjan blocks (Robertson *et al*., 1991, 1996; Adamia, 1991; Golonka & Gahagan, 1997). The oldest oceanic crust existing today in the Pacific Ocean was formed (Winterer, 1991).

Sea Level and Climate

The Lower Zuni I supersequence marks the beginning of a period of long-term 1st-order rise in global sea-level. Continental margin flooding was better pronounced in the middle of the time slice. Large continental shelves on the Tethyan margins, as well as the Laurasian seaways began to form at that time (Golonka *et al*., 1994, 1996). The Lower Zuni I ended with regression during the mid-Bathonian time. Greenhouse conditions began to prevail, with the warming of the climate. Arid conditions still prevailed in the continental interiors. No significant continental glaciation was recorded.

Carbonate Sedimentation

Carbonate sedimentation was predominant along all the Neotethyan margins, between 35°N and 35°S, especially in the Central Tethys area (Dercourt *et al*., 1993). Carbonate ramps were large at the southern margin of the Tethyan realm and smaller as well as more isolated along the northern margin (Philip *et al*., 1996). Carbonate platforms developed along the newly formed Ligurian, Penninic and Pieniny oceans, spreading to the cratonic part of Europe (P. Ziegler, 1982, 1990). Carbonates also began to develop on the margin of the spreading Central Atlantic. Numerous horst blocks within the Central Tethys were capped by carbonate platforms, while siliceous sediments were deposited in the basinal areas (Golonka & Sikora, 1981; De Wever *et al*., 1995). Carbonate platform developed in the Arabian basins. A vast marine platform became the setting for a well developed carbonate ramp in which clastic sediments rimmed the western and southern parts of the shallow sea (Alsharhan & Magara, 1994). Carbonates were also present outside Tethys, along the western margin of South America (Riccardi, 1983), in the Northwestern United States (Sloss *et al*., 1960), and in Eastern Asia (Moullade & Nairn, 1983; Ronov *et al*., 1989).

Slice 21: Lower Zuni II – late Bathonian – middle Tithonian (earliest Middle Jurassic - Late Jurassic) – 166-146 ma.

This was the time of the break-up of Gondwana, continued separation of Gondwana and North America and the closing of the Mongol-Okhotsk Ocean (Fig. 25).

Convergent Tectonics

The Mongol-Okhotsk Ocean was closing tightly in the Late Jurassic, and the collision resulted in the folding and intrusion of granitic batholiths in Mongolia and in the trans-Baikal area (Zonenshain *et al*. 1990). The Late Jurassic, E-W trending fold-and-thrust belt in China, between the eastern Tien Shan and the Liaoning region (Yin & Nie, 1996), was associated with the Yanshanian orogeny. This orogeny could be related to the closing of the Mongol-Okhotsk Ocean and ongoing compression between the North and South Chinese blocks. The Lhasa block converged with Asia (Ricou, 1996). The Lhasa block could have been connected with the Sibumasu block in Southeast Asia (Yin end Nie, 1996). The Helmand plate approached Central Asia (Otto *et al*., 1997). The eastern part of the northern branch of Neotethys narrowed significantly and began to close. A new subduction zone began to develop south of the Lhasa plate. In Southeast Asia, numerous peripheral bulges as well as back-arc and foreland basins developed, that became probable sites of active sediment accumulation.

In the Alpine-Carpathian area in Europe, continuous subduction of the Meliata-Halstatt oceanic crust led, at a future time, to the closure of this ocean and collision of the Tisa block with the Inner Carpathian terranes (Froitzheim *et al*., 1996).

Extensive subduction, volcanism, and terrane accretion occurred around the Pangean rim, in North and South America. In the western North America, the assemblage consisting of oceanic arcs and wedges collided with the continent during the Nevadean orogeny (Hamilton, 1989; Oldow *et al*., 1989). According to Lawver & Gahagan (1993) during the collision and obduction of Stikinia, terrane material was also obducted onto the Brooks Range province of Alaska, and the Franciscan formation was accreted onto California.

Extensional Tectonics

Clockwise rotation and northwest drifting of Laurasia initiated intra-Laurasian rifting and central Laurasian subsidence. The development of oceanic crust as well as the major phase of seafloor spreading occurred within the Gulf of Mexico (Martin & Buffler, 1994) and the central Atlantic (Golonka *et al*., 1996). Rifting continued in the North Atlantic (P. Ziegler, 1988; Doré, 1991). The progressive breakup of Pangea resulted in a system of spreading axes, transform faults, and rifts, which connected the ocean floor spreading in the Central Atlantic and Ligurian Sea, to rifting which continued through the Polish-Danish graben to Mid-Norway and the Barents Sea (Golonka, 1998, Golonka & Bocharova, 2000, Golonka *et al*., 1999). Spreading continued in the Ligurian-Pieniny Ocean. The onset of extension occurred in the Balcanic trench in Bulgaria (Bokov & Ognyanov, 1991). Spreading continued in the proto-Black Sea- Greater Caucasus-proto-South Caspian Ocean (Kazmin, 1990, 1991, 1997; Kazmin *et al*., 1986).

Clockwise rotation and southward drifting of southern Gondwana was connected with the continuing, active seafloor spreading in the East African seaway, between India/ Madagascar and Africa (Coffin & Rabinowitz, 1988). Continental rifts developed between India and Antarctica as well as between Australia and Antarctica (Lawver & Gahagan, 1993). Marine embayments formed at the northern and southern margins of South America. Spreading was active in the Weddell Sea (LaBrecque & Barker, 1981). The seaway was formed between Africa, South America and Antarctica-India-Madagascar. This marked the break-up of Gondwana. This was the second stage of the Pangean disassembly.

The West and Central African rift was developed during Late Jurassic time (Guiraud & Bellion, 1996). In southern Yemen, the large NW-SE-trending Marib rift was very active during the late Jurassic. Along the northern margin of Arabia rifting with the Euphrates Trough was initiated (Guiraud & Bellion, 1996). Spreading developed between Australia, the Argo terrane (Ricou, 1996), and several small terranes which were accreted to South East Asia in Late Cretaceous (Metcalfe, 1994). The Baluchistan (Pakistan) terrane might have been rifted away from Gondwana at the same time.

Sea Level and Climate

The Lower Zuni II corresponds with a period of long-term 1st-order rise in global sea level. This slice began with a large transgression in the Late Bathonian. Significant continental margin flooding occurred, together with submergence of both carbonate platforms and the central Laurasian rift basins. Sea-level reached its Jurassic maximum during Kimmeridgian time. Large continental shelves were established on the Tethyan margins, in Europe and in the Arctic (Golonka *et al*., 1994, 1996, 2000). Seaways connected the Tethyan and Boreal (Arctic) realms. Greenhouse conditions prevailed with warm, but generally arid continental interiors. No significant continental glaciation was recorded. A global oceanic anoxic event (OAE) occurred during Lower Zuni II time. Mainly carbonate source rocks were deposited in the Tethys area during Bathonian-Oxfordian time. In the Boreal realm, the Kimmeridgian-Tithonian organic rich shales were deposited (Ulmishek & Klemme, 1990, Baudin & Herbin, 1996, Ettensohn, 1994).

Carbonate Sedimentation

Carbonates occurred along the Neotethys margins within a band from 35°N to 35°S latitude. Ramp-like carbonate depositional profiles predominated. A carbonate platform developed on both sides of the Central Atlantic. Primary occurrences of major carbonate depositional systems in the Gulf of Mexico were recorded. A large platform developed in the Cuba-Bahamas-Florida area. An almost continuos band of carbonate platform was present on the Gondwanian margin, from eastern Venezuela to Arabia and Greater India (Philip *et al*., 1996). A large carbonate platform was located between New Foundland and Iberia (Sinclair *et al*., 1993). On the Arabian platform the carbonate shelf environment became dominant and was differentiated into broad shelves and local intrashelf basins (Alsharan & Magara, 1994). Widespread carbonate deposits were also present on the northern Tethyan margin, from Western Europe (P. Ziegler, 1990) to Central Asia, and, further eastwards on the Lhasa bock and adjacent margin of Asia (Philip *et al*., 1996; Golonka *et al*., 1996, 2000).

Slice 22: Lower Zuni III – late Tithonian – early Valanginian (latest Late Jurassic – earliest Lower Cretaceous) – 146-135 Ma

This was time of plate reorganization marked by a cessation of spreading in the Gulf of Mexico and Ligurian Ocean, turning of the North Sea rift into an aulacogen and the initiation of rifting in the Arctic. New spreading developed in the proto-Caribbean area and in Atlantic between Iberia and Canada (Figs 26, 27).

Convergent Tectonics

Collisional margins along the Pangean-rim experienced active plate subduction, volcanism, and terrane accretion. Subduction and the development of volcanic-rich, fore-arc and back-arc basins continued around the northern margin of the Neotethys. Abundant strike-slip tectonics created intermontane basins in China. The final closure of the Mongolian-Okhotsk Sea in the Early Cretaceous (Filipova, 1998) resulted from the collision of North China and East Siberia. North China and Siberia became parts of the Eurasian margin adjacent to the Pacific Ocean.

The collision of the Lhasa block with Asia continued (Metcalfe, 1994; Ricou, 1996). According to Yin & Nie (1996) this events took place in the Late Jurassic. According to Metcalfe (1994), the collision of Lhasa and Qiantang took place along the Banggong Suture, around the Jurassic/Cretaceous boundary. The collision of the Helmand (Afghanistan), with the Turan Platform and S. Pamir, Karakorum and Lhasa plates took place approximately about the same time (Otto *et al*., 1997, Golonka, 2000). The eastern part of the northern branch of Neotethys was closed. In the Alpine-Carpathian area in Europe (Fig. 27), the subduction of the Meliata-Halstatt Ocean and the collision of the Tisa block with the Inner Carpathian terranes was concluded at this time (Froitzheim *et al*., 1996; Dallmeyer *et al*., 1996, Plašienka, 1999). Subduction jumped to the northern margin of the Inner Carpathian terranes and began to consume the Pieniny Klippen Belt Ocean (Birkenmajer, 1986; Golonka et al., 2000). In the area south of the Rhodopes in southeastern Europe, subduction was characterized by northward polarity (Shanov *et al*., 1992). A northward-dipping subduction existed also along the southern margin of Eurasia, between Bulgaria and Lhasa (Ricou, 1996; Kazmin *et al*., 1986; Sengör & Natalin, 1996).

The Izanagi oceanic plate, which was a part of the Jurassic-Cretaceous Pacific Ocean plate, continued to subduct beneath East Asia, with accompanying volcanism along the Asian margin (Yui *et al*., 1996). The Jurassic collision of the inboard terranes of western North America with the American craton was concluded (Lawver & Gahagan, 1993). After this collision, from the very early Cretaceous through the Oligocene time, the oceanic lithosphere continued to subduct beneath California.

Extensional Tectonics

Present day hot spots of Iceland and Jan Mayen were located in the Late Jurassic time, in the vicinity of the Chukchi borderland. This was a place of the future opening of the Canadian basin (Golonka & Bocharova, 2000). Rifting in the Arctic region, which was initiated at this time, was caused by mantle convection and upwelling cell, marked by the hot spot volcanics in the Alpha Ridge and Chukchi Borderland. The trench-pulling forces, which consumed the Anui-Anvil Ocean (Zonenshain *et al*. 1990), also played the active role in this rifting event. A system of narrow-margin troughs and exposed, rift-shoulder uplifts developed parallel to the Laurasian Margin (Grantz & May, 1987; Grantz at al., 1990, 1996; Kos'ko, 1984; Polkin, 1984). The central rift later developed into the Canadian Basin.

The North Sea-Poland rifts turned into aulacogens. Initial rifting occurred between eastern Canada and western Greenland (P. Ziegler, 1988; Doré, 1991). The drifting in the Gulf of Mexico ceased by the Late Berriasian time (Ross and Scotese, 1988; Marton & Buffler, 1994). M21 was the last magnetic anomaly (Klitgord & Shouten, 1986). Sea floor spreading developed in proto-Caribbean region (Dercourt *et al*., 1993; Ricou, 1996). Narrow transcontinental seaways developed across Europe and the North Atlantic. The Atlantic began to propagate to the area between Iberia and Canada (P. Ziegler, 1988; Sinclair *et al*., 1993). According to Driscoll *et al*. (1995) see-floor spreading did not propagate beyond the Figueiro Fracture until the Aptian Time.

The Ligurian-Pieniny Ocean (Fig. 27) reached its maximum width and stopped spreading (Golonka *et al*., 1996, 1999, 2000). The Tethyan plate reorganization resulted in extensive gravitational faults movement. Several tectonic horsts and grabens were formed, rejuvenating some older, Eo- and Meso-Cimmerian faults. Initial stages of subduction of the oceanic crust of the Pieniny Klippen Belt, under the northern, active margin of the Inner Carpathian plate, may have been related to these movements (Birkenmajer, 1986, 1988; Krobicki, 1996). The Outer Carpathian rift had developed with extensional volcanism (Golonka *et al*., 1997, 1999, 2000; Książkiewicz, 1977). Rifting developed in the Balkan Area (Bulgaria), between Moesia and Rhodopes (Tchoumatchenko & Sapunov, 1994). The Jurassic extension in the Vardar-Balcanic trench preceded flysch sedimentation during the Tithonian and Early Cretaceous (Bokov & Ognyanov, 1991). Along the northern African margin, east-west rifts were initiated between Egypt and Tunisia (Guiraud & Bellion, 1996).

Gondwana was in the advanced stage of breakup (Lawver & Gahagan, 1993). Post-rift to drift-stage basins, with marine incursions existed between Africa and India, Africa and Antarctica and India and Australia. A narrow transcontinental seaway developed across southern Gondwana (Malvinas/Falklands area). Pre-rift structural lineaments and sags were present between South America and Africa. These structural features became sites for continental and lacustrine sedimentation.

Sea Level and Climate

This was time of high and falling 1st-order global sea level, characterized by submerged continental margins and established continental interior seaways. The Lower Zuni III supersequence ended with a dramatic drop of sea-level, during the mid-Valanginian time. This drop was related to global plate tectonic reorganization. Global greenhouse conditions prevailed (Frakes & Francis, 1990), with rising aridity inside continents and in the marginal seaways. The climate was latitudinally controlled, with arid conditions at mid-latitudes, cool and wet conditions at high latitudes and warm and wet conditions at low latitudes. The Late Jurassic OAE continued, with the widespread deposition of the organic-rich marine dark shales in the northern Pangea, especially in the boreal shallow seas like the North Sea area between Norway and Greenland, and West Siberia. No evidence for continental glaciation has been recorded.

Carbonate Sedimentation

Carbonates were restricted to an equatorial band between 35°N and 25°S latitude. Major carbonate platforms with adjacent deep-water basinal facies occurred around the margins of the Gulf of Mexico, North Africa and the northern Neotethys. The drop of the level decreased the extent of carbonate platforms in Europe and in Central Asia. Reservoir facies within shallow-marine carbonate platforms were mainly grainstones with minimal coral-dominated buildups. In many marginal Tethyan areas carbonates gradually changed into evaporites (Ronov *et al*., 1989). The carbonate platforms on Tethyan blocks continued their development. The deep-water carbonate-siliceous majolica facies, with planctonic *Nannoconus* as the main builder (Golonka & Sikora, 1981; Wieczorek, 1988) were widespread in the central Tethyan basins.

Slice 23: Upper Zuni I – late Valanginian – early Aptian (Early Cretaceous) – 135-117 Ma

This was time of the opening of the Canadian Basin and Eastern Mediterranean. The initial oceanic opening of South Atlantic and accretion in northeast Asia also took place at this time (Fig. 28).

Convergent Tectonics

In the Alpine-Carpathian area in Europe, the movement of the Briançonnais terrane started the closing of the Ligurian Ocean (Stampfli, 1993, 1996), which then entered into its compressional phase (Marchant & Stampfli, 1997). Subduction was active on the southern margin of the Pieniny Klippen Belt Ocean (Birkenmajer, 1986; Golonka & Krobicki, 1995; Golonka et al., 2000), causing northward movement of the Inner Carpathian terranes and the closing of the ocean.

In eastern Tethys the West Burma terrane was accreted to South-East Asia (Metcalfe, 1994). Suturing of Lhasa with Central Asia was concluded during the previous time slice. Compressional deformations still continued.

Accretion in eastern and northeastern Asia continued. The Verkhoyansk (Kolyma-Okhotsk-Cherski) superterrane was accreted with the North Asian craton (Parfenov, 1992, 1997; Parfenov *et al*., 1993). According to Zonenshain *et al*. (1990), this accretion was caused by the nearly simultaneous convergence of continental and different exotic terranes with each other and with the Verkhoyansk fan along the Siberian margin. According to Parfenov (1992), the time of accretion was from the latest Jurassic to the Late Neocomian (pre-Albian). The opening of the Canadian Basin was associated with the movement of the Chukotka terrane towards Asia and with the subduction of the South Anui Ocean under Chukotka plate (Zonenshain *et al*., 1990, Bocharova *et al*., 1995). South Anui Ocean was closed between 130 and 120 Ma. Translational movement took place in East Asia (Cox *et al*., 1989; Zonenshain *et al*., 1990; Sengör & Natalin, 1996). In western North America, strong compression of the Cordilleran belt followed the Late Jurassic accretion of terranes along the Pacific margin (Oldow *et al*., 1989).

Extensional Tectonics

Pangea and Gondwana were in advanced stage of breakup. Dispersal of the continents and development of the passive margins and rift basins continued. Development of the interior sag basins in South America, Africa, and Asia was associated with the renovation of ancestral failed rifts.

Seafloor spreading occurred in the southernmost part of the South Atlantic. According to Wilson (1992), at least two major mantle plumes, defined by the hot spots of St Helen and Tristan da Cunha were influential in the weakening of the lithosphere along the line of the developing South African rift. The Tristan plume was associated with large volumes of flood basalt on the South American side in Parana and smaller volumes on the African side in Etendeka (Hawkesworth *et al*., 1992). Seafloor spreading opened the Falklands/Malvinas seaway between Antarctica, Africa, and South America (Lawver & Gahagan, 1993). Rifting propagated from this seaway towards the Equator, roughly along the future South Atlantic margin.

The Central Atlantic was spreading and propagating towards the area between Iberia, the Grand Banks and the Flemish Cap (P. Ziegler, 1988; Golonka & Bocharova, 2000). Rifting occurred in the North Atlantic area between Newfoundland, Greenland, Ireland, United Kingdom and France (P. Ziegler, 1988; Sinclair, 1995). Rifting in the Labrador Sea propagated northwards towards the Davies Strait and also probably into the southern Baffin Bay (P. Ziegler, 1988). Active seafloor spreading continued in the proto-Caribbean Sea, between North and South America (Ricou, 1996).

Early seafloor spreading began between Antarctica and India as well as between Australia and India (Lawver & Gahagan, 1993; Ricou, 1996). According to Lawver & Gahagan (1993), the basalt floods in India, known as the Rajmahal Traps, as well as Kerguelen Plateau (Baksi, 1995; Houtz *et al*., 1977; Davies *et al*., 1989), were created after seafloor spreading commenced between India and East Antarctica. According to Kent (1991), a mantle plume existed in this area, long before the spreading had started. The pushing force caused by mantle upwelling could explain the initial phase of the northward drift of India. In a later phase, the Eurasian subduction could have become the major force driving the motion of India (Lawver & Gahagan, 1993).

The rifting initiated in the Arctic during the previous time slice turned into drifting. Advanced sea-floor spreading occurred in the central rift, which later developed into the Canadian Basin (Lawver *et al*., 1990; Lane, 1994; Embry, 1994; Zonenshain *et al*., 1990; Grantz *et al*., 1998). This basin was formed by the drifting of the North Slope-Chukotkan plate, which included continental shelf, Chukchi Borderland and New Siberian Islands (Green *et al*., 1986), across the North Pole. Some elements of counterclockwise rotation, not exceeding 30 degrees could have been present.

In the Black Sea area in southeastern Europe a rift developed between the Western Pontides and adjacent parts of Ukraine. Spreading continued in the Greater Caucasus - proto-Caspian Ocean (Kazmin, 1990, 1997; Banks & Robinson, 1997). Spreading occurred between the Lut and Turan platforms and the Sebzevar Ocean was formed. This ocean is known from the ophiolites in the northern Iran (Ricou, 1996; Sengör & Natalin, 1996). Perhaps all intra-Iranian basins were open at that time (Dercourt *et al*., 1986). Rifting and drifting of the Taurus plate from Africa-Arabia was associated with flow basalts along the northern margin of Arabia (Robertson *et al*., 1996; Ricou, 1996; Guiraud & Bellion, 1996). The drift of the Taurus plate opened again the Eastern Mediterranean basin and formed its oceanic crust (Bogdanov *et al*., 1994a, b; Robertson, 1998).

In the Alpine-Carpathian area, the Rhenodanubian and Outer Carpathian troughs, on the partially oceanic crust and partially on the attenuated continental crust, were open during this time (Golonka & Gahagan, 1997; Faupl & Wagreich, 1992; Winkler & Ślączka, 1992; Ślączka, 1996a). To the west, this troughs extended into the Valais ocean, which entered into a seafloor spreading phase (Marchant & Stampfli, 1997; Froitzheim *et al*., 1996), and further into the area between Spain and France and to the Biscay Bay (Stampfli, 1993, 1996). To the east, the through system was connected with the subsiding Balkan area.

The basic plate configurations of the Pacific Ocean was formed, with three spreading ridges separating the Pacific plate from three adjacent plates, the Izanagi, Farallon, and Phoenix plates (Winterer, 1991).

Sea Level and Climate

The Upper Zuni I supersequence began with a rapid transgression. The sea-level had reached the maximum 1st-order highstand and stabilized during Hauterivian and Barremian times, then dropped again during mid-Aptian time. Global greenhouse conditions prevailed, with warm equable climates, humid continental interiors and no continental glaciation. A relatively cool period occurred at the end of the time slice (Frakes & Francis, 1990). The Upper Zuni I OAE had terminated. Limited occurrence of organic-rich rocks was possible.

Carbonate Sedimentation

Most carbonates were restricted to the locations between 25°S to 35°N latitude. The majority of the carbonates occurred in mixed carbonate/clastic systems on ramps and non-rimmed passive margins of the southern Neotethys and on convergent margins of the northern Neotethys, away from major sources of deltaic clastics. Pure carbonate systems, represented by rudistid-rimmed shelves, developed along the Tethyan margins in Europe, Anatolia and Central Asia (Dercourt *et al*., 1993, Golonka et al., 2000). A large platform in the Florida-Bahamas area existed. Carbonate shelves also rimmed the newly formed Gulf of Mexico. Extensive deep-water flysch and pelagic carbonates occurred in the basins marginal to the carbonate platforms. The first seamounts and reefs began to be formed in the Pacific Ocean (Winterer, 1991).

Slice 24:Upper Zuni II – lateAptian – middle Cenomanian (Early Cretaceous – earliest Late Cretaceous) – 117-94 Ma

This was the time of advanced continental break-up with the rift to drift transition between South America and Africa, extensive sea-floor spreading and increasing submergence of continents (Fig. 29).

Convergent Tectonics

In the Arctic, North Alaska terranes collided with southern Alaska (Grantz *et al*., 1990; Oldow *et al*., 1989). At the same time, the Chukotkan plate collided with the Verkhoyansk (Kolyma-Okhotsk) superterrane, which was at this time already a part of Siberia. According to Parfenov (1992), accretion of the Chukotka terrane and the formation of the South Anui Suture occurred during pre-Albian time and was related to the opening of the Canadian basin. The Albian to Late Cretaceous Okhotsk-Chukotka volcano-plutonic belt marked the position of the active Asian margin at this time (Bocharova *et al*., 1995).

Complex tectonics began to take place in the future Alpine belt zone, between southern Europe and North Africa/Arabia. Continued closure of the western part of Neotethys was related to the subduction along the northern Neotethys margin. This closure was marked by collisional deformation, in the early stage of Trupchun phase in Alps (Froitzheim *et al*., 1996) and by the formation of eclogites in Austroalpine units. The thrusting and shortening was also noted in the Inner Carpathians (Plašienka, 1999). Convergent margin and northdipping subduction along the Western Pontides block caused the southward movement of this terrane and the opening of the western Black Sea as a back-arc basin (Kazmin, 1990, 1997; Banks & Robinson, 1997). The north-dipping subduction consumed the main branch of Neotethys, between the Pontides, Sakarya and Kirsehir plates (Yilmaz *et al*., 1997).

Pacific rim convergent remained very active. Intensive volcanic activity and deformations were recorded within the Rockies, Andes, Kamchatka and southern margins of Eurasia (Oldow *et al*., 1989; Pindell & Tabbutt, 1995; Zonenshain *et al*., 1990). According to

Yin & Nie (1996), the formation of the eastern Sichuan fold-and-thrust belt could have been the result of combined thermal weakening, due to the subduction of the Izanagi plate beneath eastern Asia and the compression following the collision of the Lhasa plate and the closure of the Mongol-Okhotsk ocean.

The subduction zone between North and South America flipped polarity . A westward dipping subduction developed along the eastern side of the Greater Antilles arc, associated with the creation of blueschists and other metamorphic rocks (Pindell & Tabbutt, 1995). The arc began to migrate eastwards, consuming the proto-Caribbean oceanic crust.

Extensional Tectonics

Pangea and Gondwana were in the advanced stages of breakup (drift phase). The sea-floor spreading phase was initiated in the equatorial Atlantic (Nürnberg & Müller, 1991), concomitant with continued widening of the South Atlantic. Continued drift of the Northern Hemisphere was concurrent with the onset of the separation of Laurentia from Eurasia (P. Ziegler, 1988). According to Driscoll *et al*. (1995), the sea-floor spreading phase of the break-up between the northern portion of Newfoundland and northern Iberia began after the early Aptian. Opening of the Canadian Basin was completed (Lawver & Müller, 1994; Lane, 1994). The oceanic seaways between India/Madagascar and Antarctica and between Australia and India widened significantly (Lawver & Gahagan, 1993; Golonka *et al*., 1994).

The Benue Trough opened in West Africa. Interior continental rifts of Africa remained active. Africa was divided into three parts in the Early Cretaceous (Ricou, 1996). Some Karoo troughs of Southeast Africa were rejuvenated (Guiraud & Bellion, 1996). Rifts were also rejuvenated in northern Africa between Morocco and Tunisia.

Spreading continued in the Eastern Mediterranean (Ricou, 1996; Robertson *et al*., 1991, 1996) and also in the area between Arabia and the Taurus plate of Southern Turkey

(Giraud & Bellion, 1996). Rifting continued in the Euphrates Basin and the Palmyrides. The proto-South Caspian - Greater Caucasus ocean was widely open and according well data from Turkmenistan (Golonka, 1999, 2000) may have been connected with the Sebzevar- Sistan Ocean between Lut (Central Iran), Turan platform and Afghanistan. Opening of the Western Black Sea occurred by rifting and drifting of the Western-Central Pontides away from the Moesian and Scythian platform of Eurasia (Kazmin 1990, 1997; Banks & Robinson, 1997).

The plate tectonic history of South-East Asia before the Paleogene is poorly known and very speculative. According to Hutchinson (1989) and Longley (1997), rifting and spreading in the proto-South China Sea was possible during the Early Cretaceous. Eastern Asia experienced continued E-W extension, which resulted in the development of numerous basins.

According to Winterer *et al*. (1990), little can be deduced about the Pacific Ocean during the Upper Zuni II time, due to Cretaceous, magnetic quiet time. Changing of spreading patterns before and after this time indicated the major plate reorganization. The Izanagi plate moved to the northwest to an unknown fate, and the Kula plate was created. The Pacific plate increased in size. Mantle plumes in the Pacific Ocean emplaced volcanic plateaus or Large Igneous Provinces (LIPS), including the enormous Ontong Java Plateau (Winterer, 1991; Coffin & Eldholm, 1994).

Sea Level and Climate

The global sea-level was closest to the maximum 1st-order highstand for the entire Phanerozoic. This was also the period of increasing continental submergence. The sea-level continuously increased, reaching its maximum level near the end of the supersequence. Global greenhouse conditions prevailed. Hot, equable climates occurred with generally humid continental interior settings. This was the peak of temperature during Cretaceous time (Frakes

& Francis, 1990). Local aridity was associated with orographic effects. There is no evidence of extensive continental glaciation. This was also the time of another global oceanic anoxic event (OAE). Organic rich sediments were deposited along various continental margin basins.

Carbonate Sedimentation

Carbonates were much more widespread latitudinally than during the previous Mesozoic time slices. The records show their location to be between 40°S to 50°N latitude. Carbonates occurred in mixed carbonate/clastic systems and continued to develop on ramps, non-rimmed passive margins of the southern Neotethys and on convergent margins of the northern Neotethys (Philip *et al*., 1996). Carbonates also occurred, for the first time during the Mesozoic, in the North Sea area, northwestern India and off Australia (Ronov *et al*., 1989; P. Ziegler, 1988, 1990; Cook, 1990). Pure carbonate systems, such as the rudistid-rimmed shelves, were limited to isolated platforms in the Gulf of Mexico, Anatolia, and Iberia (Fig. 29). The rudist buildups were especially well developed around the Gulf of Mexico (Sloss *et al*., 1960; Philip *et al*., 1996). Extensive, deep-water flysch and pelagic carbonates were deposited in the basins adjacent to the carbonate platforms.

Slice 25: Upper Zuni III – late Cenomanian – early Campanian (Late Cretaceous) – 94-81 Ma

This was the time of the maximum global level of the sea during the Phanerozoic, maximum disassembly and submergence of the continents, of global greenhouse conditions and an oceanic anoxic event. The disassembly process began to reverse, with the narrowing of the Tethys Ocean (Fig. 30).

The opening of the South Atlantic Ocean caused the drift and counterclockwise rotation of Africa. The Arabian margin of the African-Arabian plate moved northeastwards and the western Neotethys narrowed. The northeastward movement of India caused the narrowing of the eastern Neotethys (Golonka *et al*., 1994). This reversed the geotectonic process. After reaching the maximum dispersion phase, the continent began to slowly assemble in a new configuration.

The regime between the Arabian margin and the Sanandaj-Sirjan plate, changed from passive to convergent (Ricou, 1996; Sengör & Natalin, 1996; Guiraud & Bellion, 1996). The north-dipping subduction under the Sanandaj-Sirjan plate is marked on this slice, but it is also possible it have been active since Jurassic time. The small Kohistan plate collided with Eurasia (Sengör & Natalin, 1996). The rotation of Africa and spreading in the Eastern Mediterranean caused the Apulian plate to converge with Europe. Later phases of the Cretaceous Trupchun orogeny in the Alps (Froitzheim *et al*., 1996) caused a subduction of the small terranes together with the oceanic crust of the Ligurian ocean. These terranes were subject of an eclogite metamorphism. The subduction was accompanied by the decollement of ophiolites and the Ligurian-Piemont sediments and their emplacement as the earliest nappes of the Alpine evolution (Debelmas, 1989).

The Pacific rim margins were very active with a continued period of orogeny within the Rocky Mountains and Andes. A volcanic arc existed along the Andean and the North American convergent margins, where the Farralon plate was subducted beneath the American continents (Lamb *et al*., 1997; Winterer *et al*.,1990). Subduction persisted also off the Antarctic Peninsula (Lawver & Gahagan, 1993).

Eastward movement of the Caribbean arc between North and South America and subduction of the Proto-Caribbean oceanic crust beneath the advancing Greater Antilles island arc continued (Ross & Scotese, 1988, Pindell & Tabbutt, 1995). The northeast active margin of the Pacific and Eurasia was defined by the Okhotsk-Chukotka volcanic belts (Parfenov, 1992; Parfenov *et al*., 1993). The Izanagi plate was subducting under Eurasia. Small plates and volcanic arcs like Koni-Murgal, Koryak and Khatyrka (Zonenshain *et al*., 1990) were moving towards the Eurasian margins. By the end of the supersequence, the Izanagi plate was subducted and terranes accreted to Eurasia. The Kula plate appeared at the northeastern margin of Asia. The renewed compression in the Verkhoyansk fold-and-thrust belt was associated with the terranes collision. Further south, the Sikhote Alin terrane collided with the Asian margin. The collision resulted in intense folding and thrusting, followed by sinistral strike-slip faulting (Zonenshain *et al*., 1990). In the south Pacific, New Zealand collided with the Pacific-Aluk spreading center (Lawver & Gahagan, 1993).

Extensional Tectonics

Pangea and Gondwana were in the advanced stages of breakup (drift phase). The spreading of the Central and Southern Atlantic continued, with a significant increase in the size of the Equatorial Atlantic (Nürnberg and Müller, 1991). The central Atlantic Ocean widened, propagating towards the Labrador Sea and the Rockall Trough in the North Atlantic (Doré, 1991). Spreading in the Rockall trough was accompanied by intensive downwarping along the West Shetland and Mid-Norway margin. This spreading ceased around 84 Ma with the development of a new spreading center in the Labrador Sea (Doré, 1991). The onset of seafloor spreading in the Labrador Sea occurred either at 95 Ma, according to Scotese (1991), or at 84 Ma according to Lawver & Gahagan (1993). The Biscay Bay also opened. The main line of spreading in the Atlantic realm began to be established along the Biscay Bay -

Labrador Sea line (P. Ziegler, 1988; Golonka & Bocharova, 2000). After the completion of the opening of the Canadian Basin in the Arctic, the Makarov basin opened by rifting the Alpha ridge away from the Barents platform (Green *et al*., 1986).

Spreading continued in the Eastern Mediterranean and between the Arabian and Taurus plates (Ricou, 1996, Robertson *et al*., 1991, 1996). The proto-South Caspian - Greater Caucasus Ocean was actively spreading. Spreading also continued in the Sebzevar-Sistan Ocean, between the Lut Turan platform and Afghanistan (Ricou, 1996; Sengör & Natalin, 1996). The Indian plate continued rapid northeastward movement, opening the Indian Ocean (Royer & Sandwell, 1989; Lawver *et al*., 1992). The separation of India from Madagascar began. The onset of seafloor spreading between Australia and Antarctica occurred at 95 ma (Lawver & Gahagan, 1993). The Kerguelen volcanic plateau was emplaced at the time when India was already separated from Antarctica. Interior continental rifts of Africa remained active. In the Southwest Pacific, seafloor spreading began in the Bounty Trough between the Campbell plateau and the Chatham Rise (Lawver & Gahagan, 1993).

Sea Level and Climate

This was the time of the maximum 1st-order highstand of global sea level during the Mesozoic and perhaps during the entire Phanerozoic. This was also the period of maximum continental submergence. This supersequence was highly asymmetric, with a sea-level lowstand in the middle. Global greenhouse conditions prevailed with a cooling interval (Frakes & Francis, 1990). Hot, equable climates dominated, with high humidity and rainfall. The continental interiors were humid and local aridity was associated with orographic effects. There is no evidence of extensive continental glaciation. This was the time of a short-lived yet intensive global oceanic anoxic event (OAE), during the Turonian.

Carbonate Sedimentation

Carbonates were widespread throughout the northern hemisphere equatorial belt. They reached high latitudes, up to 69^o on the southern and northern hemispheres. The aerial extent of carbonate deposition had expanded in the Neotethys region, but had contracted in the Gulf of Mexico. On flooded shelves, most carbonate sediment consisted of deep-water marls and chalks. Large areas were covered by chalk in Western and Central Europe and in the Central Asian area, as well as in the internal seaway in North America (P. Ziegler, 1982, 1988, 1990, Vinogradov,1968b; Sloss *et al*., 1960) . Large areas were covered by carbonates in North Africa and Arabia. Platform carbonates continued to accumulate on the north Indian margin. Carbonates were deposited in the New Guinea area, Kerguelen Plateau and the Malvinas (Dercourt *et al*., 1993; Ronov *et al*., 1989; Philip *et al*., 1996). In the northern equatorial belts, carbonate facies included a shallow-marine, platform-interior and rudistid buildups and grainstones; platform exterior and platform margin microporous, mud-rich lithologies; and platform slope and basinal, carbonate flysch. Rudistid-rimmed shelf margins were developed on isolated platforms and on the micro-plates of the northern Neotethys region. Platform interiors were commonly flooded and accumulated deep-water, muddy, carbonate facies.

Slice 26: Upper Zuni IV – middle Campanian – Selandian (Late Cretaceous – earliest Paleogene) – 81-58 Ma

This was the time of the rapid movement of India, formation of the Caribbean plate, active orogenesis, convergence in Tethys, inversion in Europe and mass extinction (Fig. 31).

Convergent Tectonics

Throughout the time period Africa was moving northwards closing the gap between its northern margin and the Taurus plate and causing a cessation (Campanian time) of spreading in the East Mediterranean (Ricou, 1996; Sengör & Natalin, 1996). The collision between Kirsehir, Sakariya and the Pontides (Yilmaz *et al*., 1997) closed the northern branch of Neotethys. The oceanic basins between Taurus and Kirsehir remained open. The northward movement of the Shatski terrane began closing of the proto-Black Sea (Kazmin, 1997).

According to Froitzheim *et al*. (1996), the collision between the Austroalpine units and the Briançonnais terrane in the Alps started in the early Paleocene. Latest Cretaceous-earliest Paleocene was also the time of the closure of the Pieniny Klippen Belt Ocean and the collision of the Inner Carpathians terranes with the Czorsztyn Ridge in the Carpathians (Golonka & Sikora, 1981; Birkenmajer, 1986; Winkler & Ślączka, 1992, Golonka *et al*., 1999). The primary shortening events in the Balkans occurred in Bulgaria (Sinclair *et al*., 1997). The Vardar Ocean was closed during Paleocene time (Sengör & Natalin, 1996).

Compressional episodes occurred along the African-Arabian plate margin. These events included thrusting in the Moroccan High Atlas, folding of the Syrian arc, compression in the Sinai area (Fizon de Lamotte *et al*., 1998. Moustafa & Khalil, 1990; Guiraud & Bellion, 1996) and inversion on the Central African Rift System.

Obduction of ophiolites on the Arabian margin was caused by the convergence of the Sanandaj-Sirjan with Arabian plates (Ricou, 1996; Guiraud & Bellion, 1996; Robertson & Searle, 1990). The exotic rocks of the Oman ophiolitic nappes reflect different stages of the evolution of the Tethyan Ocean and its branches from the Permian to the Cretaceous (Pillevuit *et al*., 1997). Ophiolites were also obducted in Turkey and emplaced on the Taurus block (Sengör & Natalin, 1996). Baluchistan collided with Eurasia. The movement of the Indian plate narrowed significantly the Neotethys in this region (Royer & Sandwell, 1989; Lawver *et al*., 1992).

At the Pacific margin the Kula plate was being subducted under Eurasia at a high rate of speed (Zonenshain *et al*., 1990). The East Sakhalin arc collided with the Eurasian margin. The Brooks-Herald fold-and-thrust belt developed in the northern part of Alaska and on the Eurasian shelf, north of Chukotka (Grantz *et al*., 1990, 1994). According to Parfenov (1992), in Late Cretaceous to Paleocene time, the active margin of the Pacific was displaced 300 km east, towards the Pacific Ocean. A subduction zone developed along the Kamchatka-Koryak volcanic belt. Further south, the subduction-accretionary terranes were sutured to Japan (Sengör & Natalin, 1996). South-dipping subduction developed along the southern margin of proto-South China Sea in South-East Asia north of Borneo (Lee & Lawver, 1994).

A volcanic arc existed along the Andean margin convergent margin, where the Farralon plate was subducted beneath the South American continent (Lamb *et al*., 1997). Eastward movement of the Caribbean arc between North and South America, as well as the subduction of the Proto-Caribbean oceanic crust beneath the advancing Greater Antilles island arc continued (Ross and Scotese, 1988). This arc collided with the Bahama platform during the latest Cretaceous, resulting in the capture of the Caribbean plate and the initiation of subduction along the Panama Arc (Scotese, 1991). The trapped Caribbean seafloor had been a part of the Farallon plate of the Pacific (Lawver & Gahagan, 1993). The Amiache-Chaucha terrane was accreted to South America (Pindell & Tubutt, 1995). The western North American Cordillera continued to compress during the Cretaceous and Cenozoic, until the Eocene. This compression resulted in thrusting and margin-parallel, transcurrent faulting (Oldow *et al*., 1990).

The Atlantic passive margins were uplifted (Wernicke & Tilke, 1989). The widespread inversion in the North Sea (Huyghe & Mugnier, 1994; Dronkers & Mrozek, 1991) and in Central Europe (P. Ziegler, 1988, 1990, 1994; Baldschuhn *et al*., 1991) could have been a result of the stress induced by the movement of Europe and ridge push from the

Bay of Biscay spreading. The direction of the Late Cretaceous Subhercynian and Laramide structures (P. Ziegler, 1988, pl.16) was parallel to the Bay of Biscay and perpendicular to the Alpine-West Carpathian front, as well as to the future spreading in the North Atlantic, between Norway and Greenland. According to Baldschuhn *et al*.(1991), the Coniacian to Campanian time of inversion in north-western Germany did not coincide with the continent-continent collision events in the Alpine realm. Unternehr & Van Den Driessche (1977) argue that the North Sea compressive tectonics were not restricted to basin inversion, but instead involve crust and/or lithospheric buckling, and that there was a close connection between the North Atlantic opening and compression in the southern North Sea during the Late Cretaceous. The Eurekan Orogeny in the Arctic (Okulitch *et al*., 1998) was also a related event.

Extensional Tectonics

The Indian plate was moving rapidly, widening the Indian Ocean (Royer & Sandwell, 1989; Lawver *et al*., 1992). The direction of spreading in the Indian Ocean changed from NE to N. India drifted further away from Madagascar, opening the Mascarene Basin (Scotese, 1991). The movement of India over the Reunion hot spot resulted in the emplacement of large volumes of flood basalts, known as the Deccan traps (Coffin & Eldholm, 1994).

The location of Iceland between the Baffin Island and Greenland, approximately during the time span between 100 and 70 Ma (Lawver & Müller, 1994), resulted in the spreading of the Labrador Sea, rifting in the Baffin Bay and emplacement of volcanics on the western coast of Greenland (Gill *et al*., 1992, 1995; Holm *et al*., 1992, Larsen *et al*., 1992). The main line of spreading in the Atlantic realm, adjacent to Europe, extended from the Biscay Bay to Labrador Sea (see P. Ziegler, 1988; Huyghe & Mugnier, 1994). Spreading in the Makarov Basin was perhaps also related to the opening of the Labrador Sea. The Makarov spreading affected rifting in on the Eurasian continent, in the Zyrianka Basin (Bocharova *et al*., 1995). The Central and South Atlantic continue to widen (Golonka *et al*., 1994).

Rifting between Australia and New Zealand took place at Anomaly 33, about 80.2 Ma (Scotese, 1991). According to Lawver & Gahagan (1993), seafloor spreading originated between the Campbell Plateau and the Marie Byrd Land at about 84 Ma and then extended into the Tasman Sea region. Australia was drifting away from Antarctica.

The Central African rifts were rejuvenated once again. Movements of rifts on the Trans-African Fault occurred (P. Ziegler, 1993). Back-arc extension in East China contributed to the formation of East China Sea Basin (Kong, 1998). The northward movement of the Shatski terrane began the opening of the eastern Black Sea (Robinson *et al*., 1996).

Sea Level and Climate

The Upper Zuni IV supersequence began with a high sea-level, which slowly lowered, then dropped dramatically at the Danian-Thanetian boundary. Global greenhouse conditions continued, with hot, equable climates and generally humid continental, interior settings. Cooling occurred at the end of the time slice. Local aridity was associated with orographic effects. No evidence of extensive continental glaciation was recorded, although the polar temperatures were low enough to allow the formation of seasonal ice or even permanent glaciers (Frakes & Francis, 1990).

The uplifted African Atlantic margin created internal drainage and narrow continental margins. Marine transgression reached its maximum in North Africa, during Late Campanian time (Philip *et al*., 1996). A major mass extinction event happened took place during this time.

Carbonate Sedimentation

Carbonates occurred throughout the northern and southern hemisphere, reaching relatively high latitudes, up to almost 60 degrees. Similarly to the situation in Cenomanian and Turonian times, most carbonate sediment consisted of marls and chalks on broad shelf areas. According to Philip *et al*. (1996), the Late Campanian transgression left a large area covered by carbonate platforms over the African-Arabian plate. Chalks were widespread in Western and Eastern Europe including the North Sea area (P. Ziegler, 1982, 1988, 1990; Vinogradov, 1968b). Chalks were also present in the North America seaway north of Gulf of Mexico (Sloss *et al*., 1960). Carbonates and mixed carbonates-clastic facies were widespread in Central Asia and the West Siberian seaway (Vinogradov, 1968b, Ronov *et al*., 1989). Platform carbonates continue to accumulate on the north Indian margin, on Malvinas, on the New Guinea plate and the adjacent parts of Australia (Dercourt *et al*., 1993; Ronov *et al*., 1989; Cook, 1990). In the northern Tethys area, the Maastrichtian was a period of widespread development of carbonate platform. Carbonate flysch was deposited in the basinal areas. At the end of the time slice, a drastic collapse of carbonate platforms occurred (Philip *et al*., 1996) due to increased tectonic activity, which resulted in regression or drowning.

Slice 27: Lower Tejas I – Thanetian – Ypresian – 58-49 Ma

This was the time of the collision of India and Eurasia, formation of the Indian Ocean and breakup of North America, Greenland and Eurasia. The Philippine terranes appear on the map for the first time (Fig. 32).

Convergent Tectonics

The process of the closing of Neotethys by the Alpine and Himalayan orogenies continued. The Apulian plate was continuously moving northwards together with the Eastern Alpine (Austroalpine) and Inner Carpathian blocks. The Ligurian Ocean in the Alps was closed and subducted, and the closure of the Valais ocean began (Froitzheim *et al*., 1996). Thrusting in the Eastern Alps was initiated in the Austroalpine upper plate, at about 55 Ma (Decker & Peresson, 1996). The closing of the Pieniny Klippen Belt basin in the Carpathians was also concluded, and Pieniny domain accreted to the Magura basin (Winkler & Ślączka, 1992). Foreland basin development proceeded in southern Europe, coinciding with a general uplift of European continent. The closure of the Pindos Ocean began (Robertson *et al*., 1991,). Compression continued in the Balkan area in Bulgaria (Tari *et al*., 1997).

Collision between Kirsehir, Sakariya and Pontides was concluded (Yilmaz *et al*., 1997). The Lesser Caucasus, Sanandaj-Sirjan and Makran plates were sutured to the Iranian-Afghanistan plates in the Caucasus-Caspian Sea area (Adamia, 1991; Golonka, 1999, 2000). A north dipping subduction zone jumped to the Scythian-Turan Platform. The Shatski terrane moved northward, closing the proto-Black Sea - Greater Caucasus. The onset of the collision of India with Asia occurred near the Paleocene-Eocene boundary (Gaetani & Garzanti, 1991; Longley, 1997). According to Searle (1996), this collision may have been diachronous, occurring earlier in northern Pakistan (60 Ma) then in Ladakh-southern Tibet.

The Laramide Orogeny and foreland basin development took place in western North America (Oldow *et al*., 1989). The Alaskan terranes continued their accretion process.

South America moved westwards, encroaching on the Caribbean plate, creating volcanic arc and foredeep along the northwestern shelf (Pindell & Tubbutt, 1995). Further development of the Panamanian arc took place along the western Caribbean plate margin. Central parts of the back-retro-arc basins in the Andes were inverted and uplifted (Lamb *et al*., 1997).

The Eurekan orogeny, primarily a response to sea-floor spreading in the Labrador Sea and Baffin Bay, affected much of the Arctic, from the Late Paleocene to the Eocene (Okulitch *et al*., 1998; Tessensohn & Piepjohn, 1988, Tessensohn *et al*., 1998). A compressive foldbelt had been developed in West Spitzbergen, and North Greenland. Compression also affected the Canadian Arctic; mainly Ellesmere Island and the adjacent areas.

The accretion of terranes in NE Asia continued. The Anadyr-Bristol arc terrane was formed between Chukotka and Alaska at the northern Pacific margin (Zonenshain *et al*., 1990; Bocharova *et al*., 1995). Pull-apart basins and strike-slip faulting occurred in China (Kong, 1998). Indochina moved southeastwards, with respect to South China along the left-lateral Red River Fault (Lee & Lawver, 1994). Subduction of the Proto-South China Sea continued (Lee & Lawver, 1994). Southward directed subduction resulted in crustal accretion along the northern margin of the Kalimantan and along the South Palawan Arc. A major strike-slip fault developed between the Indochina-Sumatra-plate and Borneo-Java (Longley, 1997). The paleo-Ryukyu arc moved eastwards with the growth of the East China Sea Basin. The Philippine terranes (Seno & Maruyama, 1984) appear for the first time on the Tejas I slice map. According to Longley (1997), during Eocene time, the motion of the Philippine plate changed, and a major transform fault developed into a subduction zone.

Extensional Tectonics

The breakup of North America, Greenland and Eurasia occurred during the Tejas I time. The Northern Atlantic and the Norwegian-Greenland Sea basins opened, during the early Eocene (P. Ziegler, 1988; Lawver & Gahagan, 1993) This opening was initiated at the Paleocene/Eocene transition and was accompanied by extensive volcanism along the plate boundaries (Skokseid *et al*., 1992; Planke *et al*., 1991; Eldholm *et al*., 1990). White & McKenzie (1989) relate this opening to the activity of the Iceland mantle plume. According to

Lawver & Müller (1994), Greenland moved over the Iceland hot spot during the time span of 60 - 40 Ma. The east coast of Greenland was affected by an Iceland mantle plume (White & McKenzie, 1989; Holm *et al*., 1992). Extrusion occurred in East Greenland mainly between 57 and 53 Ma (Noble *et al*., 1988). At the same time, oceanic spreading was still active west of Greenland. The opening of the Arctic Ocean (Eurasian Basin) was initiated, in the late Paleocene (Kristofferson, 1990). Back-arc extension, behind the Aleutian arc, formed the Bering Sea between Chukotka and Alaska. According to Oldow *et al*. (1989), fragments of the Cretaceous Kula plate were captured behind the volcanic composite complex, formed at 55 to 50 Ma. These fragments are also trapped within the Bering Sea.

The Central and South Atlantic increased their widths, with westward movement of North and South America. Seafloor spreading continued between Australia and Antarctica. The Indian Ocean was formed, as a result of the northward movement of India (Golonka *et al*., 1994). The extension was active in the central African rift basins.

Back-arc extension in southeastern Asia led to rifting and seafloor spreading in the Celebes Sea basin and the Makassar basin, east of Borneo (Weissel, 1980; Lee & Lawver, 1994, Longley, 1997). Rifting and stretching also occurred along the South Chinese platform. Back-arc extension and rapid subsidence continued in the East Chinese Sea Basin (Kong, 1998). Marine basins developed in the Philippines and in the proto-South Chinese Sea (Seno & Maruyama, 1984).

Sea Level and Climate

The sea level was at its highest 1st-order stand during the Cenozoic. Greenhouse conditions still prevailed, with generally warm temperatures. Equable climates dominated, with variable conditions due, to local orographic and oceanic circulation effects. No evidence significant for continental glaciation was recorded. Abundant mid- to high-latitude floras were present, with tropical affinities.

Carbonate Sedimentation

Carbonate platforms were limited in areal extent, but exhibited wide geographic distribution. High-latitude, cold-water carbonates were abundant on small oceanic platforms. Northern hemisphere platforms were more restricted than during Late Cretaceous time, because of increased orogenesis and clastic input. Many platform tops were drowned and accumulated deep-water marl/chalk facies. Clastic sedimentation prevailed in Western Europe and the North Sea area (P. Ziegler, 1982, 1990). Carbonate flysch, derived from isolated marginal platforms, accumulated in the Alpine foreland basin. Sedimentation continued on platforms in the Florida-Bahama and Yucatan areas (Ronov *et al*., 1989). The northern African platform continued its existence, along with restricted carbonate platforms in the Tethys area (Dercourt *et al.*, 1993). Carbonates in India, Central Asia and the Arabian Peninsula were less frequent then in the Zuni time. Carbonates were deposited in Central Asia and the West Siberian seaway (Vinogradov, 1968c; Ronov *et al*., 1989). Carbonate sedimentation began on the Philippines terranes (Ronov *et al*., 1989. High latitude platforms in the southern hemisphere were mostly made up of ramps, with minimal clastic input.

Slice 28: Lower Tejas II – Lutetian – Bartonian – 49-37 Ma

This was a time of active orogenesis, with the closure of oceanic basins in the Alpine-Himalayan area, continental-oceanic collisions in the Andes, reorganization of Pacific plates motion and of global volcanism (Fig. 33).

Convergent Tectonics

Inversion of the High Atlas Mts. in Morocco marked a new, convergent boundary between stable Africa and the Moroccan and Oran mesetas (Ricou, 1996). A major compressive event took place at the Mid-Late Eocene transition (Guiraud & Bellion, 1996). The Apulian and Alpine-Carpathian terranes continued to move northwards. Their collision with the European plate began in the Alps about 47 Ma (Decker & Peresson, 1996). The Valais Ocean in the Alps finally closed (Froitzheim *et al*., 1996; Stampfli, 1996). The main phase of compression and formation of the thrust belt of the Balkanides in Bulgaria occurred during the Eocene time (Tari *et al*., 1997; Sinclair *et al*., 1997). The collision of India and Eurasia continued. Metamorphism and crustal thickening reached a peak about 40 Ma in northern Pakistan, propagating later southward (Searle, 1996). Oceanic subduction ceased beneath the Indian-Eurasian collision zone (Longley, 1997).

The Okhotsk Sea block and Olutor arc collided with the Eurasian Pacific margin in Russia (Zonenshain *et al*., 1990; Bocharova *et al*., 1995). Subduction of the Proto-South China Sea continued (Lee & Lawver, 1994). The bend in the Hawaii-Emperor seamounts (Seno & Maruyama, 1984; Winterer *et al*., 1990; Lawver & Gahagan, 1993) indicate a change of Pacific Plate motion from NWW to WNW around 43 Ma.

According to Pindell & Tabbutt (1995), the westward movement of South America across the mantle accelerated. This triggered the Incaic phase of the Andean tectonics, with a drastic uplifting of the mountain chain. Further, relative, eastward movement of the Caribbean plate continued, with significant transpressive deformation along the northern and southern strike-slip boundaries (Guiraud & Bellion, 1996). Cuba had docked with North America. Boldreel and Andersen (1993) observed compressional structures at several locations in the Faeroe-Rockall area, which may have been associated with seafloor spreading of the Atlantic and with the complex, Miocene spreading history of Iceland.

Extensional Tectonics

Seafloor spreading finally shifted from western to eastern Greenland and the North Atlantic. The opening of the North Atlantic was linked to mantle plume, associated with the Iceland hot spot as postulated by White & McKenzie (1989). According to White (1992), shortly after the Iceland plume was reactivated, the extension between Greenland and the northwestern European margin continued until its development into a full oceanic spreading center. The voluminous volcanic complexes, containing wedges of seaward-dipping reflectors, were deposited in the vicinity of the continental-oceanic transition (Coffin & Eldholm, 1994; Skogseid *et al*., 1992; Planke *et al*., 1991).

Spreading in the South Atlantic accelerated. Likewise the spreading accelerated to 20 mm/year between Australia and Antarctica. Spreading in the Indian Ocean switched from the old ridge between Australia and India, related to the movement of India, to new position between Australia and Antarctica. This spreading extended westwards towards the Kerguelen Plateau (Lawver & Gahagan, 1993). The old ridge began to be subducted beneath the Sunda Arc (Indonesia). Rifting in the Celebes Sea continued (Lee & Lawver, 1994). East China Sea reached its maximum size (Kong, 1998). In the Caribbean, east-west rifting began in the Cayman Trough (Bally *et al*., 1989). Spreading continued in the Bering Sea (Zonenshain *et al*., 1990; Oldow *et al*., 1989). The Farallon plate, in the Pacific Ocean, began to fragment when the northern part broke off forming the Vancouver plate (Winterer *et al*., 1989).

Sea Level and Climate

The Tejas II supersequence began with rapid transgression. The sea reached a relatively high level then dropped slowly towards the end of the time slice. Sea-level underwent a 1st-order fall from this time continuing to the present day. Late greenhouse to early icehouse conditions prevailed. The first evidence of the existence of an ice sheet in Antarctica was observed, at the base of the Lutetian stage (Abreu & Baum, 1997). Temperatures were generally still warm, followed by the onset of a long-term cooling trend. Generally equable climates dominated, with variable conditions due to local orographic and oceanic circulation effects.

Carbonate Sedimentation

The trends initiated during the Lower Tejas I time, continued. Widespread distribution of carbonates occurred in the central and eastern parts of North Africa. Carbonate platforms continued to existed on the Apulian/Adrian plate, but, in the remaining part of the northern Tethys were replaced by a clastic sedimentation (P. Ziegler, 1989; Dercourt *et al*., 1993). Limited shelf carbonates and marls developed in the Paratethys area in Eastern Europe, Central Asia and West Siberian seaway (Vinogradov, 1968c; Ronov *et al*., 1989). In the Caribbean area shallow-water carbonates were well developed on the Florida-Bahama platform, as well as on Yucatan. Carbonates were also deposited on the northwestern margin of South America (Ronov *et al*.,1989). On the Indian plate, carbonate deposition become more restricted due to the ongoing collision with Eurasia. Platform carbonates continued to accumulate on the Lord Howe rise, parts of New Zealand, Philippines, the New Guinean plate and adjacent part of Australia.

Slice 29: Lower Tejas III – Priabonian – Rupelian – 37-29 Ma.

This was the time of continuing collision in the Alpine-Himalayan belt, rifting in Europe, initiation of the opening of the Western Mediterranean, South Caspian Sea, South

China Sea and the Sea of Japan. This was also the time of glaciation of the Antarctica, related to the opening of the circum-Antarctic Seaway (Fig. 34).

Convergent Tectonics

Collisions continued in the area between Africa and Eurasia. The conclusion of the compression of the Balkanides, in Bulgaria, occurred during the Oligocene time (Sinclair *et al*., 1997). The Pindos Ocean was finally closed (Robertson *et al*., 1991). The collision of Apulia as well as the Alpine-Carpathian terranes with the European plate continued (Decker & Peresson, 1996, Frasheri et al. 1996). The metamorphism of the undercrusted Penninic nappes in the Alps reached peak thermal conditions at about 30 Ma (Kurz *et al*., 1996). The Calabrian terranes in the Western Mediterranean began to progress eastward (Van Dijk & Okkes, 1991).

The Paratethys sea developed in Europe and central Asia, ahead of the progressing northwards orogenic belts (Dercourt *et al*., 1993). Geodynamic evolution of the basins in the Alpine-Carpathian belt led to a transition from flysch to molasse type of sedimentation (Golonka *et al*., 2000).

The collision of India and Eurasia continued. Metamorphism and crustal thickening reached their peak in the Zanskar area (Searle, 1996). The subduction zone beneath the Scythian-Turan margin of Eurasia (Sobornov, 1994) produced a trench-pull force which caused northward movement of the plates between the Black Sea and Afghanistan, closure of the Greater Caucasus, Sebzevar and Sistan Oceans and reorganization of the South Caspian Sea (Golonka, 1999, 2000). The Sistan Ocean was closed in eastern Iran, between Helmand and Lut plates (Sengör & Natalin, 1996). The development of the molasse basins continued in the Himalayan belt foreland (Burbank *et al*., 1996). Collision and suturing of India to Asia caused extensive strike-slip faulting in Asia (Kopp, 1997). Active volcanism and subduction took place in the Philippine island arc.

Subduction of Kula plate was completed along the northwestern margin of North America (Zonenshain *et al*., 1990; Winterer *et al*., 1989). Continuation of the Laramide

Orogeny in western North America led to further development of the foreland basins and back-arc extension (Oldow *et al*. 1989). The last major terrane fragments were accreted to Alaska, at this time. The development of the eastern Caribbean island arc occurred, while the Panamanian arc nearly collided with South America (Ross & Scotese, 1988). Andean folding and thrusting continued (Lamb *et al*. 1997).

The Central Kamchatka terrane collided with the Eurasian Pacific margin in Russia (Bocharova *et al*., 1995). The closing of the proto-South Chinese Sea continued (Lee & Lawver, 1994). Inversion and folding in East China and the first phase of formation of the Taiwan-Sinzi Folded zone was caused by a collision between the paleo-Ryukyu Arc and the northern part of the Philippine Sea plate (Kong, 1998). The Luconian terrane collided with NW Borneo (Longley, 1997).

Extensional Tectonics

Mature seafloor spreading in the Southern Hemisphere led to northward movement of the continents. Rapid spreading continued between Australia and Antarctica (Lawver & Gahagan, 1993). Formation of the Scotia Sea plate reached the Drake Passage, which allowed the circum-Antarctic seaway to develop (Lawver *et al*., 1992; Macdonald, *pers. comm*.). Seafloor spreading continued in the North Atlantic, with further opening of the Eurasian Basin in the Arctic (Zonenshain *et al*., 1990). This basin was separated from the Canadian basin by the Lomonosov Ridge.

Initial rifting occurred between Africa and Saudi Arabia, in the Gulf of Aden. The Afar plume influenced the opening of the Red Sea and the Gulf of Aden (White & McKenzie, 1989; Menzies *et al*., 1992).

Rifting events were initialized during the Oligocene time in the several countries in Europe between France and Ukraine (P. Ziegler, 1988, 1990, 1992; Bois, 1993; Wilson, 1994; Wilson & Downes, 1991; Rutkowski, 1986; Żytko *et al*., 1989) and were associated with the alkaline volcanism. According to Bois (1993), extension occurred in part of the European plate, with the rifting of the Rhine, Limagne and Bresse Trough, contemporaneous of the climax of Alpine compression. Part of this rift system included the Gulf of Lions, associated with the mantle plume, expressed by volcanics in the Massif Central and Provence and on Corsica and Sardinia (Wilson & Downes, 1991). Rifting in this area was followed by oceanic seafloor spreading and drifting of the Corsican and Sardinian plates (Bois, 1993; Ricou, 1996). North Sea subsidence, renewed during the Tertiary (Joy, 1992) could have been related to Central European rifting. The Alborz trough began to open in the South Caspian area, as a new basin of oceanic type (Golonka, 1999, 2000).

In South-East Asia, the opening of the Celebes Sea was concluded (Lee & Lawver, 1994). Spreading in the Sulu Sea (Longley, 1997) and in the present South China Sea began (Taylor & Hayes, 1980, 1983; Holloway, 1982; Lee & Lawver, 1994; Fraser & Matthews, 1997; Fraser *et al*., 1997). This spreading separated the North Palavan-Paracel Island Microcontinent from the continental South China. Initial rifting began in the Japanese Sea (Ingle, 1992; Tamaki *et al*., 1992; Kong, 1998).

Sea Level and Climate

A supersequence developed during the long-term 1st-order Cenozoic lowering of relative sea-level and corresponds with the turn-around phase of the Tejas Megasequence. The largest and most rapid 2nd-order sea level drop in the Cenozoic occurred at the Lower Tejas III supersequence unconformity. The supersequence developed during the onset of the Cenozoic icehouse conditions. A major cooling trend took place, with highly variable continental climates, associated with latitudinal and orographic effects. An ice sheet formed on the southern hemisphere. According to Abreu & Baum (1997), the isotope curve indicates that the ice sheet on Antarctica experienced phases of growth during the late Eocene to early

Oligocene, followed by a decrease in volume in the late Oligocene. The onset of Antarctica glaciation was related to the opening of seaway around Antarctica (Lawver *et al*., 1992).

Carbonate Sedimentation

Low latitude coral/algal carbonate depositional systems were restricted to the Gulf of Mexico, the circum-Mediterranean, the Neotethys/Middle East region, and northern Australia, whereas high latitude bryozoan/mollusk carbonate depositional systems dominated in the southern margins of Australia and in New Zealand. Equatorial carbonates were typically made of coral reef and sand-rimmed platforms, with adjacent shaly basinal facies. Major reef trends existed along the Neotethys margin (e.g., Iraq) and along the northeastern margin of Australia. Other carbonate occurrences took place on Madagascar and on platforms in the northern part of the Indian Ocean.

Slice 30: Upper Tejas I – Chattian – Aquitanian – 29-20 Ma

This was the time of continental collisions in the Alpine-Himalayan belt, mature seafloor spreading with local rifting and spreading events and reorganization in South-East Asia (Fig. 35).

Convergent Tectonics

Collisions continued in the area between Africa and Eurasia. Thrusting occurred in the Riff area in Africa and the Betic area in the southern Spain, due to the collision of the Alboran Sea arc (Morley, 1993; Vissers *et al*., 1995). Transpressive thrusting in the Balearic margin was related to the displacement of the Alboran block (Vegas, 1992). The movement of

Corsica and Sardinia (Montanari *et al*., 1997) caused the plates to push eastwards in the future, resulting in deformation of the Alpine-Carpathian system. This deformation reached as far as to Romania (Ellouz & Roca, 1994; Royden, 1988) and continued throughout the Neogene. The Calabrian terranes in the Western Mediterranean continued to progress eastwards (Dewey *et al*., 1989; Van Dijk & Okkes, 1991). Corsica and Sardinia, pushed the Umbria-Marche terrane towards collision with the Apulian block. The thrust-and-foldbelt of the Apennines began to develop (Pialli & Alvarez, 1997).

The Apulia and the Alpine-Carpathian terranes were moving northwards, colliding with the European plate, until 17 Ma (Decker & Peresson, 1996). This collision caused the foreland to propagate north. The north to NNW-vergent thrust system of the Eastern Alps was formed. Oblique collision between the North European plate and the overriding Western Carpathian terranes led to the development of the outer accretionary wedge, the built up many flysch nappes and the formation of a foredeep. (Kováč *et al.*, 1993; Ślączka, 1996a,b). These nappes were detached from their original basement and thrust over the Paleozoic-Mesozoic deposits of the North European platform. This process was completed during the Upper Tejas I slice in the Vienna basin area and then progressed northeastwards (Oszczypko, 1997a, b, Golonka *et al.*, 2000).

The Eastern Mediterranean Sea began to be subducted beneath the newly formed Eurasian margin (Vrielynck *et al*., 1997). The subduction zone was active north of the Ionian and Levantine basins (Bogdanov *et al*., 1994a, b) The Sinandaj-Sirjan plate began to thrust over the Arabian Platform forming the Zagros Mountains (Dercourt *et al*., 1993; Vrielynck, 1997). Collision of the Lut block with the Turan platform in Central Asia caused onset caused the Kopet Dagh foldbelt to form (Kopp, 1997). The collision of India and Eurasia continued. Metamorphism and crustal thickening reached a peak pre-20 Ma in eastern Kashmir (Searle, 1996).

Subduction and orogenesis continued along the entire Cordillera of North and South America. Strike slip displacement began along the dextral, strike-slip, San Andreas fault in California (Oldow *et al*., 1989; Atwater & Stock, 1998). The rate of motion of South America, relative to the mantle, slowed during the Upper Tejas I time (Pindell & Tubbutt, 1995). The Panamanian Isthmus was established. Termination of folding and thrusting in the Central Andes was a result of this change of the rate of motion (Lamb *et al*., 1997).

Wide-spread Pacific-Rim volcanism and terrane accretion continued with intense subduction in East Asia. The Lesser Kuriles and East Kamchatka terranes collided with the Kuriles-Kamchatka islands arc (Zonenshain *et al*., 1990). Back-arc spreading in the Sea of Japan was accompanied by rotation and movement of the Japanese plates (Ingle, 1992; Tamaki *et al*., 1992; Jolivet *et al*., 1994; Kong, 1998). Closing of the proto-South China Sea continued (Lee & Lawver, 1994). A large strike-slip Alpine Fault developed across New Zealand. The Australian plate continued a rapid northward movement, until the onset of the collision of its northern New Guinea margin with the Melanesian arc slowed down this motion (Longley, 1997). Seafloor spreading and subduction occurred in the Scotia Sea (Lawver *et al*. 1992).

Intracontinental deformation in Eurasia led to the uplift and formation of the modern Ural Mountains (Puchkov, 1997). The Atlantic margin in Norway was uplifted during the Neogene time (Jensen & Schmidt, 1993).

Extensional Tectonics

This was a time of mature seafloor spreading globally, with local rifting events. Spreading in the North Atlantic and Arctic Eurasian Basin continued, and Iceland formed as a volcanic platform astride the North Atlantic spreading ridge (Lawver & Müller, 1994). Strike-slip motion was initiated between Greenland and Svalbard. Rifting continued in the Red Sea and in the Gulf of Aden while continental rifting continued in Ethiopia (Vrielynck *et al*., 1997). The East Africa Rift System was in early stages of development.

The Alboran Sea extensional basin developed in the western Mediterranean behind the arc located between Iberia and Northern Africa (Watts *et al*., 1993; Morley, 1993; Vissers *et al*., 1995). The first stage of rifting in Valencia Trough (Vegas, 1992) was initiated. Crustal extension of the internal zone of the Alps started in the Early Miocene, during the continued thrusting (Decker & Peresson, 1996). Early to Middle Miocene extension and back-arc type rifting resulted in the formation of a intramountain, Pannonian basin in Central Europe (Royden, 1988; Decker & Peresson, 1996, Tari *et al*., 1996). A new period of extension began in the Pontides-Sakariya continent in Turkey (Yilmaz *et al*., 1997).

The Indo-Chinese pull-apart basins continued to develop. Subsidence was rejuvenated in the East China Sea (Kong, 1998). The opening of the South China Sea continued, with a change in the direction from north-south to NW-SE (Lee & Lawver, 1994). Sea-floor spreading began in the Japanese Sea (Ingle, 1992; Tamaki *et al*., 1992; Jolivet *et al*., 1994). Extension occurred in the western part of the Sea of Okhotsk and in the Tatar Strait, between Sakhalin and the eastern margin of Russia (Zonenshain *et al*., 1990; Bocharova *et al*., 1995). Initiation of strike-slip and pull-apart basins in California was related to the movement along the San Andreas fault (Oldow *et al*., 1989; Atwater & Stock, 1998).

Sea Level and Climate

The low stand of relative sea level corresponded to the near maximum phase of continental emergence for the Cenozoic. Supersequence development occurred during the continuation of the long-term 1st-order Cenozoic lowering of relative sea level. This supersequence followed a Lower Tejas III 2nd-order, lowstand, base level shift. The supersequence developed during the Cenozoic early icehouse conditions and was characterized by cool climatic settings. Widely variable continental climates were a result of latitudinal and orographic effects. A major ice sheet existed in Southern Hemisphere, and the presence of sea ice was possible in the Arctic.

Carbonate Sedimentation

Carbonates were distributed between 50^{o}N and 60^{o}S latitude. Equatorial carbonates were mainly muddy depositional systems, with minor reefal components. Reef-related depositional systems were dominated by scleractinian corals and sediment-producing, red and green algae. Most mid- and high-latitude carbonates were cold-water, grain-rich depositional systems dominated by red algae, benthic foraminifers, mollusks and bryozoans. Australia was at low stand, with most of its continental shelf area dominated by carbonate sedimentation (Cook, 1990).

The Seychelles platform in the Indian Ocean, the volcanic archipelagos of the Western Pacific, as well as the Florida/Bahamas platform were characterized by shallow-water carbonate deposition. Platform interiors were distinguished by muddy carbonates and patch reefs while platform margins were signified by coral reef buildups and associated skeletal sands. Northern and western portions of the Gulf of Mexico contained composite algal/coral patch reefs and skeletal mud-rich facies. A carbonate platform still persisted in the former Tethyan region in North Africa, the Taurus-Zagros area and in small areas in Turkey and Greece (Philip *et al*., 1996). Brackish carbonates appeared in the Paratethys area, reaching relatively high latitude.

Slice 31:Upper Tejas II – Burdigalian – Serravallian – 20-11 Ma

This was the time of mountain formation in Central Asia, the Alpine-Carpathian area and in the Andes, the opening of the Tyrrhenian, Red, and South China Seas, as well as the Sea of Japan (Fig. 36).

Convergent Tectonics

This was the time of the major Alpine orogenic phase, the formation of mountains in the Alpine-Carpathian area, the Mediterranean, Central Asia and the Himalayans. The continued of thrusting occurred in the Riff area in Africa and in the Betic area in southern Spain as a result of the collision of the Alboran Sea arc with the Africa and Iberian plates (Morley, 1993; Vissers *et al*., 1995). The Calabrian arc and subduction zone collided with Africa and the Southern Sicilian-Maltese platform (Dewey *et al*., 1989; Van Dijk and Okkes, 1991; Ricou, 1996). The wing of this collision formed the southern Apennines. Thrusting also continued in the northern Apennines. The formation of the West Carpathian thrusts was completed (Kováč *et al*., 1993; Ślączka, 1996a,b; Oszczypko, 1997a). The thrust front was still migrating eastwards in the Eastern Carpathians (Golonka *et al*., 2000. The Carpathian foredeep developed as a peripheral foreland basin. The main cause of thrusting in the Zagros Mountains (Sengör & Natalin, 1996) was the counterclockwise rotation of the Arabian plate. The collision of India and Eurasia continued, with a strong, northwest motion component. Thrusting was active in the High Himalayas about 21-18 Ma. This collision continued to influence the Central Asia Area through the development of far-reaching strike-slip faults. Several blocks were deformed and thrust over the Turan platform in the Pamir, Afghan-Tadjik and Gissar areas. The Miocene phase of thrusting and folding of Kopet-Dagh Mountains in Central Asia, with a strong strike-slip component was a result of the final stage of collision of the Lut plate with Eurasia. The Greater Caucasus Ocean was closed as a result of the collision of the Lesser Caucasus and Transcaucasus blocks with the Scythian platform, and the Caucasus Mountains began to form (Zonenshain *et al*., 1990; Kazmin, 1991; Kopp, 1997).

The rate of motion of South America again increased relative to the mantle (Pindell & Tubutt, 1995). The Andes were rejuvenated with crustal shortening, uplift and an increase of volcanic activity. A strike slip regime was established in California (Oldow *et al*., 1989; Atwater & Stock, 1998). A major uplift phase of the Colorado Plateau in the United States began.

In Southeast Asia, the North Palawan microcontinent collided with Kalimantan and with the West Philippine Archipelago (Taylor & Hayes, 1980, 1983; Holloway, 1982; Lee & Lawver, 1994). The collision with the Philippines resulted in a change of subduction polarity to a westward one, along the east margin of Philippines, at the Philippine trench (Lee & Lawver, 1994). An eastward-dipping subduction zone developed along the Manila Trench. The left-lateral, Philippine fault initiated motion between the East and West Philippines. Motion began along the Sumatra Fault System, at this time, and was responsible for crustal shortening in northwestern Sumatra (Huchon & LePichon, 1984; Lee & Lawver, 1994). Southwestern Japan rapidly rotated in a clockwise direction (Ingle, 1992; Tamaki *et al*., 1992; Jolivet *et al*., 1994). The Izu-Bonin Arc collided with central Japan (Kong, 1998). The Kuriles arc as well as the eastward-dipping subduction zone were formed the Pacific margin of Russia (Zonenshain *et al*., 1990; Bocharova *et al*., 1995).

Extensional Tectonics

Spreading in the Atlantic and Indian oceans continued, with a westward drift of the Americas and northward drifting of Africa, Eurasia and Australia. South America moved faster than North America while Australia moved faster than Eurasia (Müller *et al*., 1997; Nürnberg and Müller, 1991; Royer & Sandwell, 1989). .

The opening of the Tyrrhenian Sea (Spadini *et al*., 1995) as well as Valencia Trough (Vegas, 1992, Torres *et al*., 1993) was initiated. Extension in the Alpine-Carpathian system continued. Extension also occurred in the Apennines (Anelli *et al*., 1996, Carmignani *et al*., 1994). Strike-slip, in the Pannonian basin (Decker & Peresson, 1996), contributed to the formation of pull-apart elements of the Pannonian system. In Central Europe, the NW-SE trending rift system was perpendicular or diagonal to the thrust front of the Carpathians (Żytko *et al*., 1989). Tertiary magmatism was crossing the Carpathians between Moravia and Upper Silesia, on one side, and the Pannonian Basin, on the other. Mantle doming contributed to crustal stretching (Golonka & Bocharova, 2000). The Alborz trough in the South Caspian Sea opened, and extension progressed into the West Turkmen Depression in Central Asia (Golonka, 1999, 2000).

The opening of the South China Sea ended (Taylor and Hayes, 1980, 1983; Holloway, 1982; Lee & Lawver, 1994). The Sulu Basin in SE Asia opened as a result of the subduction along the northeastern margin of Kalimantan (Lee & Lawver, 1994). Spreading in Marianas, in the Eastern Pacific, began at 15 Ma (Scott & Kroenke, 1980). The northward movement of India caused the opening of the Andaman Sea (Curray *et al*. 1982; Lee & Lawver, 1994). The Japanese Sea went through its second episode of opening (Ingle, 1992; Tamaki *et al*., 1992; Jolivet *et al*., 1994). Extension in the Kuriles Trough formed a back-arc extensional basin in the Sea of Okhotsk, at the Pacific margin in Russia (Zonenshain *et al*., 1990, Bocharova *et al*., 1995).

Rifting continued in the Afar triangle (Beydoun &Sikander, 1992). Movement on the Aquaba-Levant Fault and the formation of the Red Sea pull-apart basin began around 16 Ma (Beydoun & Sikander, 1992). East Africa Rift activity commenced at 10-12 Ma (Ebinger *et al*., 1991).

Sea Level and Climate

The relative sea level corresponded to the opening of several basins and to an increase in the volume of the Antarctic glaciers. The fluctuations of sea-level reflected the waxing and waning of the Antarctica ice. The sea-level dropped dramatically at the end of this time slice. Upper Texas II developed during the Cenozoic icehouse conditions and was characterized by relatively cool climatic settings. Widely variable continental climates were due to latitudinal and orographic effects. A major Southern Hemisphere ice sheet was present with sea ice possibly at the North Pole. According to P. Ziegler (1988), the Gulf Stream began to flow the warm Atlantic water into the Norwegian-Greenland Sea by mid-Miocene time. This event was demonstrated by the ingression of warm water faunas into the North Sea Basin.

Carbonate Sedimentation

Carbonates were distributed between 50^{o}N and 40^{o}S latitude. This represented a reduction in the latitudinal distribution on the Southern Hemisphere, comparing with the distribution during the Upper Tejas II time. Carbonate shelves were widespread on Australian margins, South East Asian (Fig. 37) and West Pacific Plateaus (Cook, 1990; Philip *et al*., 1996). Reef-related depositional systems, made of corals and red algae, dominated on these shelves. Carbonates became more restricted in the Mediterranean and the Middle East. Marine *Lithothamnium* cold-water, grain-rich systems dominated by red algae, large foraminifers and bryozoans appeared at relatively high latitudes in the northern Paratethys. In the Caribbean-Gulf of Mexico area shelf sedimentation consisted of carbonates with abundant, large Foraminifera. Continuous carbonate shelves lined the northern Brazilian margin. Carbonates were also deposited on the narrow shelves in Western Africa, Southern Brazil, Western India and Eastern Africa.

Slice 32: Upper Tejas III – Tortonian – Gelasian) – 11-2 Ma.

This was the time of the assembly of continents. Large masses of continents and continental shelves were situated around the North Pole. This was also an ice period as well as the time of a salinity crisis (Fig. 37).

Convergent Tectonics

Continuation of thrusting occurred in the Riff area in Africa as well as the Betic area in southern Spain, due to the collision of the Alboran Sea arc (Morley, 1993). This thrusting temporarily cut off the Mediterranean Sea from the Atlantic, in the Gibraltar Strait area, causing the Messinian salinity crisis.

Compressional thrusting continued in the Calabrian Arc, with the accompanying strike-slip faulting and change of rotation to SE (Dewey *et al*., 1989; Van Dijk & Okkes, 1991).

The main folding and thrusting phase occurred in northern Africa, along with the formation of nappes (Burollet, 1991). Carpathian thrusting progressed east and southeastwards, with a strong element of translation (Ellouz and Roca, 1994; Royden, 1988; Linzer, 1996). The thrusting was completed during the Pliocene-Quaternary in the Vrancea Mountains in Romania. The eastward movement of the orogen was related to the movement of Corsica and Sardinia and subsequent opening of the Ligurian and Tyrrhenian Sea (Montanari *et al*., 1997; Keller *et al*., 1994). The extrusion caused by collision of Apulia plate with Europe could have played a role in the eastward movement of the orogen (Decker & Peresson, 1996).

A symmetrical escape of the Caucasian and Kopet-Dagh blocks towards the South Caspian depression followed northward movement of the Lut, Transcaucasus and lesser Caucasus blocks in the Iran - Central - Asia region (Kopp, 1997). The present day system of large strike slip faults continues to be active in Central Asia as a result of northeastern movement of the India plate. Process of mountain building in Himalayas and Central Asia continued. Metamorphism and crustal thickening reached a peak about 11- 4 Ma, in Nanga Parbat in the High Himalayas (Searle, 1996). Uplift, exhumation and formation of topographic highs followed. The mountain building process also continued in the Andes (Pindell & Tubbutt, 1995). Late Miocene-Pliocene compression occurred also in East Venezuela (Eva *et al*., 1989). Shortening took place in Central Andes (Lamb *et al*., 1997).

Subduction along the Manila Trench was caused the collision of the North Luzon Arch with the East Asian continental margin at Taiwan (Suppe; 1981, Teng; 1990; Lee & Lawver, 1994). The Taiwanese thrustbelt was formed during this second phase of collision, with an estimated 200-300 km of crustal shortening. Northward movement of Australia continued with compression in the New Guinea-Melanesian Arc. The Timor area of the Australian continent collided with the Sunda Arc (Longley, 1991). Likewise, Africa and Eurasia moved northwards. Large continental masses were situated on the northern hemisphere and around the North Pole. All the continents were by now connected. America was separated from Eurasia, in the Atlantic area, but connected by a large continental shelf, in the Alaska-Chukotka area. Australia was in contact with South-East Asia. Only Antarctica remained separated. We could describe this process as and onset of assembly of the Present day Pangea. The continental masses moved from their South Pole position during the late Phanerozoic, to their North Pole position today.

Extensional Tectonics

Spreading in the Atlantic and Indian oceans continued with a westward drift of the Americas and northward drift of Africa, Eurasia and Australia. The spreading in the Gulf of Aden became a part of the main spreading of the Indian Ocean (Royer & Sandwell, 1989). Spreading in the South Atlantic occurred more rapidly then in the North Atlantic (Müller *et al*., 1997; Nürnberg and Müller, 1991).

The Tyrrhenian Sea (Channell & Mareschal; 1989, Spadini *et al*., 1995) as well as the Valencia Trough (Vegas, 1992; Torres *et al*., 1993) went through the main phase of opening. The rifting in the Pantelleria Trough, between Africa and Sicily occurred in the Pliocene and Quaternary. The rift depicted by Casero & Roure (1994) cut the Sicilian-North African thrust front perpendicularly. A back-arc basin formed in Aegean area behind the subduction zone (Bogdanov *et al*., 1994a, b). Maximum subsidence took place in the South Caspian area.

Back-arc extension in the central-north Okinawa trough as well as in the East China Sea Basin was caused by the subduction of the Philippine Sea Plate beneath East Asia (Kong, 1998). The South Okinawa trough opened around 3 Ma (Teng, 1990). The opening of the Andaman Sea continued to the present day (Lee & Lawver, 1994).

Basin formed in western North America, as a result of rifting in the Basin and Range Province, and strike slip pull-apart tectonics in California (Oldow *et al*., 1989, Atwater & Stock, 1998). The Gulf of California opened in northwestern Mexico. During the Cenozoic time, the Farallon plate was fragmented by the origination of new spreading centers. The new plates formed from North to South were the Juan de Fuca, the Cocos, and the Nazca (Winterer *et al*., 1990). Spreading in the Gulf of California was an extension of the spreading between the Cocos and Pacific plates.

Sea Level and Climate

The Upper Tejas III began with a very low sea-level, one of the lowest during the Phanerozoic. The continents were fully emerged. After a temporary increase, the sea-level dropped again and continental margins narrowed during this time slice. The sea-level was affected by high-amplitude, high frequency glacioeustatic fluctuations. The climate changed from cool to cold, with extremal temperatures between the continental equatorial and polar areas. The interiors of the continents became arid, especially in the subtropical zones. Large glaciers developed on the Northern Hemisphere at the end of supersequence. Antarctica was likewise covered by large continental glaciers.

Carbonate Sedimentation

Carbonates were distributed between 50^{o}N and 45^{o}S. Relatively high latitude, cool water carbonates were deposited in the Paratethys, in the conditions of reduced and increased salinity. On the Southern Hemisphere, high-latitude, marine carbonates were deposited on the southern tip of Africa and between Australia and Tasmania (Ronov *et al*., 1989; Cook, 1990). As compared to the Upper Tejas II time, the distribution of carbonates was reduced, due to increased clastic and evaporite sedimentation, particularly on the eastern margin of South America, on the Indian margin and in the Mediterranean area. Large amounts of evaporites were deposited in the Mediterranean area, during the Messinian salinity crisis (P. Ziegler, 1988). The Australian margins, as well as the South East Asian and West Pacific Plateaus were the areas of the main carbonate deposition (Cook, 1990; Philip *et al*., 1996). Reef-related depositional systems were dominated by scleractinian corals and sediment-producing red and green algae. The Caribbean-Gulf of Mexico-Bahama platform represented another area with broad carbonate shelves sedimentation. The Gulf of Aden-Red Sea area favored the development of small carbonate platforms (Philip *et al*., 1996). Worldwide carbonate sedimentation worldwide was affected by glacioeustatic sea-level fluctuations.

CONCLUSIONS

1. The supercontinent Gondwana and three major continental plates: Baltica (NE Europe), Laurentia (N. America) and Siberia were distinguished at the beginning of the Phanerozoic. Laurentia and Baltica drifted apart from Gondwana during the latest Vendian to earliest Cambrian time at the beginning of the Sauk supersequence The breakup of the Rodinia-Pannotia supercontinent led to the formation of oceans, which widened significantly during the Sauk Supersequence. Sauk was the time of the disassembly of continents.
2. The Tippecanoe was the time of assembly of continent leading to the formation of the Oldredia supercontinent. The Caledonian Orogeny during the Silurian and Early Devonian

was the result of the collision of Baltica, Laurentia, and Avalonian terranes. These plates were sutured together to form the large Laurussia continent. The transpressional collision between Gondwana and Laurussia occurred during the early Devonian time. Siberia was perhaps sutured to Laurentia at this time.

3. The Kaskaskia was a time of plate reorganization and formation of the supercontinent Pangea. Oldredia was disassembled during the Devonian time. The series of orogenies during the Carboniferous time (Hercynian, Alleghenian and others) resulted in suturing of Gondwana and Laurussia and onset of Pangea.

4. The Absaroka was a time of Pangea reorganization and final suturing. Almost all parts of Pangea were sutured together for a brief time during Early Jurassic. The large Tethys Ocean was formed between the Laurasian and Gondwana part of Pangea. The Pangean Rim of Fire from North America through South America, Antarctica was active through all Absaroka time slices. The break-up of the main part of Pangea began with the stress release at the Permian-Triassic boundary; extensive rifting occurred during the Triassic-Early Jurassic time, spreading began at the Middle Jurassic time.

5. The Tethyan realm was tectonically active during Absaroka, Zuni and Tejas . The dominant driving forces were north-dipping subduction along the Eurasian margin and mantle upwelling, causing rifting and drifting on the Gondwana margin. Several plates drifted away from Gondwana and docked to Eurasia during Late Carboniferous-Middle Jurassic.

6. Zuni was the time of disassembly of Pangea. This disassembly began with the origin of the Central Atlantic Ocean and breakup between Laurentia and Gondwana during the Jurassic time. Gondwana was fragmented during the Jurassic-Cretaceous time. The main stages of the Gondwana breakup are opening of the oceanic seaway between Africa, India and Antarctica, opening of the South Atlantic and, finally northward drift of Australia and India. The Indian Ocean was formed as result of the Gondwana break-up.

7. The initial opening of the Arctic Ocean took place in the Canadian basin during the Early Cretaceous and was follow by the Late Cretaceous opening of the Makarov Basin and Tertiary of the Eurasian Basin. This opening is related to the orogenic events in the Northeast Asia and northwest North America. These events sutured Asian and America in the Chukotka-Alaska area.

8. Tejas is the time of the assembly of the continents into modern „Pangea". The Alpine Orogeny formed numerous orogenic belts in Europe, North Africa, and the Middle East. This orogeny was most intense during the Miocene. It involved numerous plates and terranes between Africa, Arabia and Central Asia. The Himalayan orogeny occurred as a result of the continental collision, which took place in the Tertiary between India and Eurasia. It formed Himalayans and adjacent mountain belts and strike-slip systems in Asia. This orogeny has had the major impact on Southeast Asian plate tectonic development during the Tertiary. Influencing the widespread formation of extensional basins. The collision of Australia and the Philippines with Eurasia during the Neogene initiated compressional tectonics in Southeast Asia.

9. The Earth's climate reflects the plate tectonic phases of the continental breakup and assembly. The warm times are related to breakups, the icehouse conditions are related to assembly. The climate changed from the greenhouse with short icehouse interlude through icehouse with warming interludes, another greenhouse, to the present day icehouse.

10.Carbonate sedimentation during the Early Paleozoic is related to the existence of the large continental platform. The Mesozoic is the time of the equatorial Tethyan realm with the abundant fragmented carbonate platforms. Carbonate sedimentation prevailed in the Southeast Asia, Pacific realm and on the narrow continental margins during the Cenozoic Tejas time.

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FIGURE CAPTIONS

Table I. Phanerozoic time scale.

Fig.1. Plate tectonic map of Sauk I - Early Cambrian - 544-511 Ma. 1 - oceanic spreading center and transform faults, 2 - subduction zone, 3 - thrust fault, 4 - normal fault, 5 - transform fault, 6 - mountains, 7 - landmass, 8 - icesheet, 9 - shallow sea and slope, 10 - deep ocean basin.

Fig. 2. Plate tectonic map of Sauk II - Middle Cambrian - 511-497 Ma. Explanations on Fig. 1.

Fig. 3. Plate tectonic and lithofacies map of Siberia during Sauk II time. Abbreviations: Sc – Scotland. Explanations on Figs 3a, 3b.

Figs. 3a, 3b - Explanations to Figs 2, 8, 13, 20, 23, 28, 31 and 39.

Fig. 4. Plate tectonic map of Sauk III - Latest Cambrian - Early Ordovician – 497-482 Ma. Explanations on Fig. 1.

Fig. 5. Plate tectonic map of Sauk IV - late Early - early Middle Ordovician – 482-465 Ma. Explanations on Fig. 1.

Fig. 6. Plate tectonic map of Tippecanoe I - late Middle - Late Ordovician - 465- 443 Ma. Explanations on Fig. 1.

Fig. 7. Plate tectonic map of Tippecanoe II – Early Silurian - 443-428 Ma. Explanations on Fig. 1.

Fig. 8. Plate tectonic and lithofacies map of Laurentia, Iapetus, and parts of Baltica and Avalonia during Tippecanoe II time. Explanations on Figs 3a, 3b. Abbreviations: En - England.

Fig. 9. Plate tectonic map of Tippecanoe III - Late Silurian - 428-418 Ma. Explanations on Fig. 1.

Fig. 10. Plate tectonic map of Tippecanoe IV - latest Silurian - Early Devonian - 418-402 Ma. Explanations on Fig. 1.

Fig. 11. Plate tectonic map of Kaskaskia I - Early - Middle Devonian - 402-380 Ma. Explanations on Fig. 1.

Fig. 12. Plate tectonic map of Kaskaskia II Middle - Late Devonian - 380-359 Ma.

Fig. 13. Plate tectonic map of Kaskaskia III - latest Devonian - Early Carboniferous – 359-338 Ma. Explanations on Fig. 1.

Fig. 14. Plate tectonic map of Kaskaskia IV - Early Carboniferous - 338-323 Ma. Explanations on Fig. 1.

Fig. 15. Plate tectonic map of Early Absaroka I - Late Carboniferous - 323-296 Ma. Explanations on Fig. 1.

Fig. 16. Plate tectonic map of Early Absaroka II - latest Carboniferous - earliest Permian - 296-285 Ma. Explanations on Fig. 1

Fig. 17. Plate tectonic map of Early Absaroka III – Early Permian - 285-269 Ma. Explanations on Fig. 1.

Fig. 18. Plate tectonic map of Early Absaroka IV - Late Permian - 269-248 ma. Explanations on Fig. 1.

Fig. 19. Plate tectonic and lithofacies map of Laurussia and Siberia during Early Absaroka IV time. Explanations on Figs 3a, 3b.

Abbreviations: En – England, Pl - Poland, Uk – Ukraine, PC – peri-Caspian basin, PT – Paleotethys, NZ – Novaya Zemlya.

Fig. 20. Plate tectonic map of Late Absaroka I – Early - earliest Late Triassic - 248-224 Ma. Explanations on Fig. 1.

Fig. 21. Plate tectonic map of Late Absaroka II – Late Triassic - 224 -203 Ma. Explanations on Fig. 1.

Fig. 22. Plate tectonic and lithofacies map of Tethys during Late Absaroka II time. Modified from Golonka *et al*. (2000). Explanations on Figs 3a, 3b. Abbreviations: Ib – Iberia, EA - Eastern Alps, IC - Inner Carpathians, Ti - Tisa, Ml – Meliata-Halstatt Ocean, Ba - Balearic, Si - Sicily, Ca - Calabria-Campania, UM - Umbria-Marche, Ad - Adria (Apulia), Di - Dinarides, Mo - Moesia, Rh -Rhodopes, SM – Serbo Macedonian, WP - Western Pontides, EP - Eastern Pontides, BS - proto-Black Sea-Tauric Ocean, Al – Alborz, SCM – South Caspian Microcontinent, Sa -Sakariya, Ki - Kirsehir, SS – Sanandaj-Sirjan, Pe - Pelagonian, Pi - Pindos Ocean, Gr - Greece, Ta - Taurus, EM - Eastern Mediterranean.

Fig. 23. Plate tectonic map of Late Absaroka III - Early Jurassic - earliest Middle Jurassic - 203-179 Ma. Modified from Golonka *et al*. (1996). Explanations on Fig. 1.

Fig. 24. Plate tectonic map of Early Zuni I - Middle Jurassic - 179-166 Ma. Modified from Golonka *et al*. (1996). Explanations on Fig. 1.

Fig. 25. Plate tectonic map of Early Zuni II - latest Middle Jurassic - Late Jurassic-166 - 146 ma. Modified from Golonka *et al*. (1996). Explanations on Fig. 1.

Fig. 26. Plate tectonic map Early Zuni III - latest Late Jurassic - earliest Early Cretaceous - 146-135 Ma. Modified from Golonka *et al*. (1996). Explanations on Fig. 1.

Fig. 27. Plate tectonic and lithofacies map of Tethys during Early Zuni III time. Modified from Golonka *et al*. (2000). Explanations on Figs 3a, 3b. Abbreviations: Ib – Iberia, Li - Ligurian (Piemont Ocean), OC - Outer Carpathian Basin, PKB - Pieniny Klippen Belt Basin, Cr - Czorsztyn Ridge, EA - Eastern Alps, IC - Inner Carpathians, Ti - Tisa, Ba - Balearic, Si - Sicily, Ca - Calabria-Campania, UM - Umbria-Marche, Ad - Adria (Apulia), Di - Dinarides, Mo - Moesia, Rh -Rhodopes, WP - Western Pontides, EP - Eastern Pontides, BS - proto-Black Sea-Greater Caucasus Ocean, Sa -Sakariya, Ki - Kirsehir, SS – Sanandaj-Sirjan, Pe - Pelagonian, Pi - Pindos Ocean, Gr - Greece, Ta - Taurus, EM - Eastern Mediterranean.

Fig. 28. Plate tectonic map of Late Zuni I - Early Cretaceous - 135-117 Ma. Explanations on Fig. 1.

Fig. 29. Plate tectonic map of Late Zuni II - Early Cretaceous - earliest Late Cretaceous - 117-94 Ma. Explanations on Fig. 1.

Fig. 30. Plate tectonic map of Late Zuni III - Late Cretaceous - 94-81 Ma. Explanations on Fig. 1.

Fig. 31. Plate tectonic map of Late Zuni IV - Late Cretaceous - earliest Paleogene - 81-58 Ma. Explanations on Fig. 1.

Fig. 32. Plate tectonic map of Early Tejas I - Ypresian - 58-49 Ma. Explanations on Fig. 1.

Fig. 33. Plate tectonic map of Early Tejas II - Lutetian - 49-37 Ma. Explanations on Fig. 1.

Fig. 34. Plate tectonic map of Early Tejas III - Rupelian - 37-29 Ma. Explanations on Fig. 1.

Fig. 35. Plate tectonic map of Late Tejas I – Chattian – Aquitanian – 29-20 Ma.

Fig. 36. Plate tectonic map of Late Tejas II - Burdigalian - Serravallian – 20-11 Ma. Explanations on Fig. 1.

Fig. 37. Plate tectonic map of Late Tejas III – Tortonian – Gelasian) – 11-2 Ma. Explanations on Fig. 1.

STRESZCZENIE

Kambryjsko-neogeńskie mapy tektoniki płyt.

Skonstruowano trzydzieści dwie mapy, przestawiające konfigurację tektoniki płyt, paleogeografię i wybrane litofacje dla przedziałów czasowych fanerozoiku poczynając od najwcześniejszego kambru, a kończąc na neogenie. Mapy były skonstruowane przy użyciu programów PLATES i PALEOMAP (zob. A. M. Ziegler *et al*., 1997; Scotese, 1991; Scotese & McKerrow, 1990; Lawver & Scotese, 1987; Lawver & Gahagan, 1993; Golonka *et al*., 1994; Golonka & Gahagan, 1997). Wulkanity znaczące działalność plam gorąca pomagają przy określaniu paleodługości geograficznej (Morgan, 1971; Müller *et al*., 1993; Golonka & Bocharova, 2000). Dane paleomagnetyczne posłużyły dla oznaczenia paleoszerokośći geograficznej (see Irving, 1979; Tarling, 1983; Aifa *et al*., 1990; Westphal *et al*., 1986; Van der Voo, 1988, 1993; Kent & Van der Voo, 1990; Besse & Courtillot, 1991; Harbert, 1990, 1991; Rapalini & Villas, 1991; Enkin *et al*., 1992; Didienko *et al*, 1993; Lewandowski, 1993, 1997, 1998; Torsvik *et al*, 1995, 1996; Bachtadse *et al*., 1995; Morris & Tarling, 1996; Channell, 1996; Smethurst *et al*., 1998; Xu *et al*., 1997; Lemaire *et al*., 1998). Informacje zawarte w szeregu globalnych i regionalnych prac zostały wyselekcjonowane i naniesione na mapy (między innymi, Cook, 1990; Cope *et al*., 1992; Dalziel, 1997; Dercourt *et al*.; 1993; Doré, 1991; Ford *et al*., 1998; Fraser *et al*., 1997; Green *et al*., 1984; Garcia & Walbert, 1994; Golonka, 1993, 1998; Golonka *et al*. 1994, 1996, 1999, 2000; Hongzen, 1985; Lawver & Gahagan, 1993; Lee & Lawver, 1994; Kiesling *et al*., 1999; Kraus *et al.* (1997); McKerrow & Scotese, 1990; Metcalfe, 1984, 1994; Müller *et al.,* 1997; Nairn *et al*., 1996; Nikishin *et al*., 1996; Nie *et al*., 1990; Parfenov, 1997; Perfenov *et al*., 1993; Puchkov, 1991; Robertson , 1998; Robertson *et al*., 1991, 1996; Ronov *et al*. 1984, 1989; Sengör & Natalin, 1996; Sloss *et al*., 1960; Stampfli *et al*., 1991; Stampfli, 1996; Veevers, 1994; Vinogradov, 1968a, b, c; Williams, 1995; A. M. Ziegler, 1990; Ziegler *et al*., 1997; P. Ziegler, 1982, 1988, 1989; Zonenshain & Natapov, 1990; Zonenshain *et al*., 1990,). Użyto 436 prac publikowanych i ogólnie dostępnych a także mapy i banki danych grupy PALEOMAP (University of Texas w Arlington), PLATES (University of Texas w Austin), University of Chicago, Instytutu Tektoniki Płyt Litosfery w Moskwie, Robertson Research w Llandudno, Walia, oraz Cambridge Arctic Shelf Programme.

Mapy tektoniki płyt ilustrują geodynamiczną ewolucję Ziemi od kambru po neogen, rozpady superkontynentów, ryfting, rozrost (spreding) i tworzenie sę oceanów, zamykanie się oceanów, kolizje, łączenie się kontynentów i tworzenie się nowych superkontynentów. Mapy przedstawiają współczesne linie brzegowe, granice płyt (szwy), oraz wybrane uskoki transformacyjne, osie rozrostu, ryfty, normalne uskoki i nasunięcia. Wybrane mapy przedstawiają również paleolitofacje.

W okresie sauk (wczesny kambr – środkowy ordowik, Figs. 1-5) nastąpił rozpad superkontynentu Pannotia (Dalziel, 1997). Rozpad ten nastąpił wkrótce po serii wendyjskich wydarzeń orogenicznych takich jak orogenezy kadomska, bajkalska i panafrykańska (Cogne, 1990; Zonenshain *et al*., 1990; Miller, 1983; Tankard *et al*., 1995). W wyniku tych orogenez, oraz rozpadu Pannotii utworzyły się kontynenty: Gondwana, Laurencja, Bałtyka i Syberia (Scotese & McKerrow, 1990; Golonka *et al*., 1994). W skład Gondwany wchodziły: Południowa Ameryka, Afryka, Madagaskar, India, Antarktyka, Australia, oraz szereg mniejszych bloków kontynentalnych i terranów, takich, jak Jukatan, Awalonia, terrany południowo i środkowo-europejskie (kadomskie), terrany środkowo-azjatyckie, 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 Teisseyra-Tornquista a

Uralem. Płyta Syberii obejmuje większą część Syberii współczesnej. Kontynenty były oddzielone oceanami, takimi jak Iapetus, Pleionic, Phoibic, Morze Tornquista i Ocean Paleoazjatycki (Scotese & McKerrow, 1990; Zonenshain *et al, 1990*; Pechersky & Didenko, 1995). System Iapetus-Tornquist rozszerzał się na skutek dryftu Laurencji i Bałtyki osiągając 5000 km szerokości (Kent & Van der Voo, 1990; Torsvik *et al*., 1995, 1996). Oddzielenie się terranów awalońskich (część Polski, północne Niemcy, Ardeny, Anglia, Walia, południowa Irlandia, część nadmorskich prowincji Kanady i Nowej Anglii) otwarło nowy ocean – Reik (McKerrow *et al*., 1991). Ryft i dryft Awalonii był związany ze strefą subdukcji, która rozwinęła sie wzdłuż centralnej części Gondwany.

Pod koniec okresu Sauk (Figs. 5) nastąpiła reorganizacja płyt. Oceany kambryjskie zaczęły się zwężać. Kolizja łuków wysp z kontynentem Laurencji objawiła się w postaci orogenez atolskiej (Athollian) i takońskiej (McKerrow *et al.,* 1991). W Polsce faza świętokrzyska spowodowała fałdowanie osadów kambru w Górach □więtokrzyskich (Lewandowski, 1993). Mikrokontynent Amuria (Mongolia) utworzył się w wyniku akrecji mniejszych terranów (Zonenshain *et al, 1990).*

W okresie tippecanoe (Figs. 6-10), kontynenty łączyły się tworząc superkontynent Oldredia. W ordowiku (Fig. 6) blok patagoński (Ramos, 1988; Williams, 1995) zderzył się z Ameryką Południową w orogenezie famatyńskiej. Jednocześnie trwał dryft terranów awalońskich i związany z tym rozrost oceanu Reik. Awalonia była przypuszczalnie złączona z Bałtyką przy końcu ordowiku wzdłuż strefy uskoków przesuwczych Tornquista-Teisseyra (Pożaryski, 1988; Tornquist & Trench, 1991). Orogeneza kaledońska w sylurze i wczesnym dewonie była rezultatem kolizji Bałtyki z przyłączonymi terranami awalońskimi i Laurencji. Wczesnopaleozoiczne oceany Iapetus-Tornquist zostały zamknięte. Uworzył się kontynent Laurosji (P. Ziegler, 1989). W sulurze tworzył się kontynent Kazachstanu (Zonenshain *et al.*, 1990), przez akrecję terranów, między innymi łuku kipczackiego (Sengör & Natalin, 1996)

.W dolnym dewonie nastąpiła również transpresjonalna kolizja Ameryki Północnej i Południowej (McKerrow *et al.*, 1991; Keppie, 1989; Keppie *et al.*, 1996; Dalziel *et al.*, 1994). Syberia była w tym czasie prawdopodobnie połączona z Laurencją Kazachstanu (Zonenshain *et al.*, 1990; P. Ziegler, 1989). Kolizje kontynentalne poprzedzały powstanie ryftów na kontynencie Laurosji (Nikishin *et al.*, 1996), a także ekstensyjnych basenów załukowych, takich jak basen renohercyński (P. Ziegler, 1989; Franke, 1992; Franke *et al.*, 1995).

Kaskaskia (Figs.11-14) była okresem reorganizacji płyt i utworzenia superkontynentu Pangea (Wegener, 1912). Oldredia rozpadła się w ciągu dewonu. W dewonie nastąpiło odłaczenie się płyt chińskich od Gondwany (Scotese & McKerrow, 1990; Golonka *et al.*, 1994). Seria orogenez w okresie karbońskim (hercyńska, alegeńska) była wynikiem łączenia się Gondwany i Laurosji. Orogeneza hercyńska w Europie była rezultatem kolizji szeregu bloków z krawędzią Laurosji (Franke, 1989, 1992; Franke *et al.*, 1995; Lewandowski, 1998), po czym nastąpiło zangażownie się kontynentu Gondwany.   Wypiętrzył się potężny łańcuch górski ciągnący się od Meksyku po Polskę. W skład niego wchodziły góry Ouachita i Appalachy w Ameryce Północnej (Hatcher *et al.*, 1989), Mauretanidy w Afryce (Lécorché *et al.*, 1989) i Hercynidy w Europie. Zachodnia część Oceanu Reik została zamknięta, wschodnia zamieniała sie w Paleotetydę. W późnym karbonie rozpoczęła się również kolizja Kazachstanu i Laurosji (Puchkov, 1991, 1997). Utworzenie się superkontynentu, którego część znajdowała się w okolicach bieguna południowego, jak również wypiętrzanie potężnych pasm górskich przyczyniło się do zlodowacenia. Lodowce pokrywały w okresie póżnego paleozoiku znaczne połacie Gondwany - południowego ramienia Pangei (Crowell, 1995; Crowell & Frakes, 1975; Veevers & Powell, 1987).

Absaroka (Figs. 15-23) była okresem reorganizacji Pangei i zakończenia procesu łączenia się jej części składowych. Kolizja Syberii z Kazachstanem, a następnie z Laurosją, spowodowała wypiętrzenie pasm górskich Azji □rodkowej i Uralu (Zonenshain *et al.*, 1990).

Kontynent Pangei obrzeżony był strefami subdukcji. Strefa skierowanej ku północy subdukcji rozciągała się również wzdłuż północnych wybrzeży Paleotetydy. Szereg terranów, zwanych kontynentem kimeryjskim (Sengör, 1984) odrywało się od gondwańskiego ramienia Pangei i podążało w kierunku ramienia północnego, laurazjatyckiego. Terrany kimeryjskie i płyty chińskie zderzyły się w triasie i jurze z Eurazja, zamykając Paleotetydę (Sengör & Natalin, 1996; Scotese & Lanford, 1995; Nie *et al*., 1990; Yin & Nie, 1996). Ruch płyt w kierunku północnym otworzył nowy ocean – Tetydę właściwą (Sengör & Natalin, 1996; Dercourt *et al*., 1993; Golonka *et al*., 1994). We wczesnej jurze niemal wszystkie płyty i terrany Ziemi były połączone w Pangeę. Intensywny ryfting, zapoczątkowany uwolnieniem się naprężeń na pograniczu permu i triasu, poprzedzał późniejszy rozpad supertkontynentu. Ryftowanie i tworzenie się wąskich basenów ze skorupą typu oceanicznego miało również miejsce w obszarze śródziemnomorskim i alpejskim (Catalano *et al*., 1991; Marsella *et al*., 1993; Kozur & Krahl, 1987; Kazmer & Kovacs, 1989; Stampfli; 1996, Kiessling *et al.*, 1999). Uwolnienie się naprężeń jest łączone ze wzmożeniem aktywności pióropuszy płaszcza. Towarzyszyły temu ogromne wylewy wulkaniczne na pograniczy permy i triasu na Syberii, tak zwane trapy syberyjskie (Zonenshain *et al*., 1990; Sharma, 1997).

W okresie Zuni (Figs. 24-31) nąstapił rozpad Pangei. Rozpoczął się on otwarciem w jurze centralnego Atlantyku (Withjack *et al*., 1998). Mezozoiczne ryftowanie utworzyło szereg basenów typu oceanicznego wzdłuż północnej krawędzi Oceanu Tetydy. Oceany Meliata-Halstatt i pienińskiego pasa skałkowego utworzyły się w zachodniej szęści rejonu (Kazmer & Kovacs, 1989; Stampfli, 1996; Plašienka & Kováč, 1999; Birkenmajer, 1986;Winkler & Ślączka 1994). Oceny tauryjski i Wielkiego Kaukazu znajdowały się na wschód od platformy mezyjskiej (Zonenshain *et al*., 1990; Kazmin, 1990, 1997; Kazmin *et al*., 1986). W wyniku jurajskiego oddzielenia się Gondwany i Laurazji utworzył się ocean alborańsko-liguryjsko-pieniński który sięgał aż po Karpaty Ukraińskie. Ocean ten był połączony z Atlantykiem centralnym systemem uskoków przesuwczych stanowiąc fragment tektonicznego sytemu rozpadu Pangei. System ten sięgał poprzez Polskę, Morze Północne, proto-Atlantyk północny do obszaru Arktyki (Ziegler, 1988; Doré, 1991; Golonka *et al*, 1996). Jego zachodnom zakończeniem był basen Zatoki Meksykańskiej.W tytonie nastąpiła generalna reorganizacja płyt. Atantyk zaczął się rozszerzać w kierunku między Iberią i Nową Funlandią (Ziegler, 1988; Sinclair *et al*., 1994). Kierunek liguryjsko-pieniński został zarzucony, czemu towarzyszyło powstanie strefy subdukcji wzdłuż krawędzi basenu pienińskiego pasa skałkowego. Ocean Meliata-Halstatt został zamknięty. W albie pojawiją się pierwsze deformacje kompresyjne w obszarze alpejskim i karpackim (Froitzheim *et al*., 1996; Plašienka, 1999). Rozrost Zatoki meksykańskiej został zatrzymany (Ross & Scotese, 1988; Marton & Buffler, 1994). We wschodniej części Tetydy nastapiła kolizja płyty Lhasy z Eurazją (Metcalfe, 1994; Ricou, 1996; Yin & Nie,1996).

W jurze-kredzie została rozczłonkowana Gondwana (Golonka *et al*., 1994). Głównymi etapami rozpadu Gondwany było otwarcie oceaniczne pomiędzy Afryką, Indią i Australią (Lawver & Gahagan, 1993), otwarcie się południowego Atlantyku (Nürnberg & Müller, 1991) i ostatecznie dryft Australii i Indii w kierunku północnym. Ocean Indyjski utworzył się w wyniku rozpadu Gondwany (Royer & Sandwell, 1989; Lawver *et al*., 1992). Kreda była okresem maksymalnej dyspersji kontynentów i najwyższego poziomu morza.

Otwieranie się Oceanu Arktycznego zostało zapoczątkowane we wczesnej kredzie w basenie kanadyjskim (Lawver *et al*., 1990; Lane, 1994; Embry, 1994; Zonenshain *et al*., 1990; Grantz *et al*., 1998), po czym nastąpiło późnokredowe otwarcie basenu Makarowa i trzeciorzędowe otwarcie basenu eurazjatyckiego. Otwarcie to jest związane z wydarzeniami orogenicznymi w Azji północno-wschodniej i Ameryce północno-zachodniej. Wydarzenia te połączyły Azję i Amerykę w rejonie Czukotki-Alaski (Grantz *et al*., 1990, 1994; Parfenov, 1992).

W okresie tejas (Figs. 32-37) miała miejsce ponowna konwergencja kontynentów i kolizja w pasmach fałdowych alpejsko-himalajskich. Orogeneza alpejska uformowała liczne pasma górskie w Europie, Afryce Północnej i na Bliskim Wschodzie. W paleogenie nastąpiło zamknięcie oceanu ligurujskiego i pienińskiego pasa skałkowego (Fitzheim *et al.*, 1996; Winkler & Ślączka, 1992). Orogeneza alpejska była najsilniejsza w miocenie (Dercourt *et al.*, 1993; Ricou, 1996; Sengör & Natalin, 1996). Orogeneza himalajska była rezultatem czołowego zderzenia się Indii i Eurazji w trzeciorzędzie (Golonka *et al.*, 1994; Searle, 1996). Orogeneza ta miała istotny wpływ na rozwój tektoniczny Azji południowo-wschodniej (Lee & Lawver, 1994), przyczyniając się w trzeciorzędzie do powstania licznych basenów ekstensyjnych. Kolizja Australii (Longley, 1997) i Filipin Archipelago (Taylor & Hayes, 1980, 1983; Holloway, 1982; Lee & Lawver, 1994) z Eurazją w neogenie zapoczątkowała tektonikę kompresyjną w Azji południowo-wschodniej.

Likwidacji Tetydy towarzyszył rozrost Oceanu Indyjskiego (Royer & Sandwell, 1989; Lawver *et al.*, 1992). W zachodnie części Tetyda została zastępiona przez współczesne Morze □rodziemne. Na północ od alpejskich łańcuchów górskich w Europie i Azji Centralnej powstał basen Paratetydy, zlikwidowany następnie niemal całkowicie pod koniec neogenu (Dercourt *et al.*, 1993). Trwał rozrost Oceanu Atlantyckiego (Golonka *et al.*, 1994). Pólnocny Atlantyk i Morze Grenlandzkie otworzyły się w paleogenie (P. Ziegler, 1988; Lawver & Gahagan, 1993), podobnie jak basen earazjatycki w Arktyce (Kristofferson, 1990). Otwarciu się basenów oceanicznych wokół antarktydy (Lawver *et al.*, 1992), towrzyszyło powstanie w paleogenie lodowców na Antarktydzie (Abreu & Baum, 1997). Pod koniec neogenu nastąpiło również zlodowacenie na półkuli północnej.

Klimat Ziemi odzwierciedla etapy tektoniczne rozpadu i łączenia się kontynentów. Klimat zmieniał się od ciepłego z krótkim interwałem zlodowaceniowym, poprzez zimny, lodowcowy z krótkimi interwałami cieplejszymi, poprzez następny okres ciepły, do współczesnego okresu zimnego.

Sedymentacja węglanowa w okresie wczesnego paleozoiku jest związana z istnieniem rozległej platformy kontynentalnej. Mezozoik jest czasem oceanu Tetydy z licznymi porozdzielanymi platformami węglanowymi. W kenozoiku (tejas) sedymentacja węglanowa przeważała w południowo-wschodniej Azji, na Pacyfiku i na wąskich obrzeżach kontynentów.

GLOSSARY OF PLATE TECTONIC AND PALEOGEOGRAPHIC TERMS

Acadian Orogeny - the collision between Avalonia and Laurentia during the Silurian-Devonian, closing the Iapetus ocean. Some Acadian events could have been related to the Gondwana-Laurentia collision.

Afar - hot spot and mantle plume in the Horn of Africa. Afar plume influenced the opening of the Red Sea and the Gulf of Aden.

Alboran Arc - terrane in the western Mediterranean, associated with the Tertiary opening of the Alboran Sea, collided with Spain and Morocco in the Betic-Riff-Gibraltar area.

Alborz - mountains in Iran along the south margin of the Caspian Sea. Alborz formed separate plate, part of the Cimmerian terranes, which collided with Eurasia in the late Triassic, rifted away in Jurassic, amalgamated with the Asian blocks in the Alpine orogeny in the Neogene.

Alborz Trough - part of the South Caspian, opened in the Tertiary, with the possible sea-floor spreading.

Aleutian Arc - island arc with the intensive volcanic activity, between Pacific and the Bering Sea, originated in the Paleogene.

Alice Springs Orogeny - an orogenic event in central Australia during the Early Carboniferous.

Alleghenian Orogeny - Carboniferous deformation events in North America, result of the collision of Gondwana and Laurussia cratons; see also Hercynian orogeny.

Alpha Ridge - see Makarov.

Alpine Fault - strike-slip fault in New Zealand. Active in the Tertiary.

Alpine Orogeny - a series of the Cretaceous through Cenozoic collisional orogenic events between Africa, Europe, Arabia and Central Asia. The orogeny was most intense during the Miocene. It involved continental plates like Iberia, Apulia/Adria, Sardinia, Kabylia, Calabria, Alpine, Carpathian (Inner Carpathians and Tisa), Greek (Ionian, Greece, Pelagonian, Serbo-Macedonian, Turkish Taurus, Kirsehir, Sakariya, Pontides), Iranian (Lesser Caucasus, Alborz, Sanandaj-Sirjan, Lut), Afghan (Helmand, Farah) plates. The Alpine Orogeny formed numerous orogenic belts in Europe, North Africa, and the Middle East.

Amiache-Chaucha - terrane accreted to South America in the latest Cretaceous-Paleogene.

Amuria - a plate accreted during the Late Paleozoic. It was connected with Tarim during the Permian, sutured to the North China-Tarim plate during the Triassic, and collided with Eurasia during the Jurassic time.

Anadyr-Bristol Arc - terrane formed in the Eocene in the northeastern Pacific between Chukotka and Alaska.

Andean Orogeny - a series of numerous orogenic events in western South America during the Tertiary. The Andes formed as a result of continuous continental-oceanic collision during the last 300 million years along the Pangean and, later, Pacific rim.

Antler Orogeny - a continental-oceanic collisional orogenic event in western North America during the Devonian - Early Carboniferous.

Anui - one of the Proto-Arctic oceanic basins which existed during the Mesozoic time between coast of East Siberia (including Verkhoyansk), Taimyr and Chukotka, probably connected with Anvil Ocean, finally closed during Cretaceous time.

Anvil - a back-arc basin that separated island arcs from the northwestern part of the North American craton in the Triassic. It closed in the Middle Jurassic.

Apulia/Adria - a continental plate that was rifted from Gondwana and collided with central Europe during the Alpine Orogeny. It includes Adriatic Sea and adjacent part of Italy, Southern Alps and Dinarides. It existed as a separate plate during Cretaceous-Tertiary time. On a generalized, small-scale global maps Apulia includes Italy, Greece, the Balkan area, the Pannonian Basin, and central (Inner) Carpathian.

Argo - plate, rifted away from Australia in the Jurassic.

Arktida - enigmatic continent including plates existing in the Arctic region. Possibly collided with Laurentia in the Paleozoic.

Atholian Orogeny - Cambrian-Ordovician event, which caused deformation in the eastern North America.

Austroalpine - see Ligurian.

Avalonia - a separate plate in the Early Paleozoic, consisting of the Ardennes of Belgium and northern France, north Germany, northwestern Poland, England, Wales, southeastern Ireland, the Avalon Peninsula of eastern Newfoundland, much of Nova Scotia, southern New Brunswick, and some coastal parts of New England. Sutured with Baltica along the Tornquist-Teisseyre line during the Silurian, and collided with Laurentia in the Silurian - Devonian (Acadian Orogeny).

Baikalian Orogeny - the late Vendian orogenic events, which caused deformations in the Baikal Lake area in southern Siberia.

Baltica - was a separate continental plate in the Early Paleozoic, consisting of the 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 near the Tornquist-Teisseyre line. Collided with Laurentia forming Laurussia in the Silurian (Scandian Orogeny).

Baluchistan - plate, rifted away from Gondwana in the Jurassic, collided with Asian in the Tertiary, presently SW Pakistan.

Banggong Suture - suture between Qiantang and Lhasa.

Barentsia - plate, which included Svalbard and part of the Barents Sea, part of Laurentia during the Paleozoic.

Bassarides - see Mauretinides.

Benambran Orogeny - Silurian event, which caused deformation in eastern Australia.

Benue Trough - Cretaceous fault system (rift and strike-slip faults) in Central Africa.

Borchgrevink-Tasman Orogeny - Silurian event, which caused deformation in Australia Tasmania and Antarctica.

Boreal Realm - northern oceans and seas of somewhat speculative configuration which existed in the Mesozoic era.

Bounty Trough - basin in the southwest Pacific, open in the late Cretaceous by spreading between the Campbell plateau and the Chatham Rise.

Bowning Orogeny - Silurian-Devonian event, which caused deformation in Australia.

Bresse Trough - see Rhine.

Briançonnais - terrane in Alps between Ligurian Ocean and Valais trough.

Cadomian Orogeny - the latest Vendian orogenic events, which caused deformations of Cadomian terranes in Europe from Iberia throughout NW France, Erzgebirge in Germany, Czechia, southern Poland, Carpathians to the Transcaucasus area.

Calabrian Terranes - terranes in the western Mediterranean, associated with the Neogene opening of the Tyrrhenian Sea, collided with Apulia and Sicily.

Caledonian Orogeny - synonym for Scandian Orogeny.

Canadian Basin - the western part of the Arctic Ocean between North America and the Lomonosov Ridge. Originated by seafloor spreading following separation of the North Slope of Alaska/ Chukotka plate from the North American craton in the Cretaceous.

Canning Basin Rift System - Devonian rifts in Australia including the Fitzroy Trough.

Cape Fold Belt - South African Late Paleozoic mountains. These were remnants of a large Gondwana mountain system.

Caribbean Plate - oceanic plate, partially of the back-arc origin, partially captured Farallon plate, with the continental crust fragment, forms the bottom of the Caribbean Sea.

Carolina Terrane - plate, which acted as indentor in the Silurian-Devonian.

Chinese Plates - separate plates of South China and North China, which probably rifted from Gondwana during the Middle Paleozoic and drifted northward and assembled in the Triassic to Early Jurassic.

Chukotka - now, the northeastern part (peninsula) of the Russian Republic. Part of the Chukotka-North Slope of Alaska plate which rifted away from Laurasia in the Early Cretaceous and collided with Siberia in the Late Cretaceous.

Cimmerian Orogeny - a series of collisional events between Laurasia, Cimmerian, and the South-East Asian plates during the Late Triassic-Jurassic.

Cimmerian Terranes (Continent) - series of continental plates rifted away from Gondwana during the opening of the Neotethys Ocean in the Early Permian. They include Turkish, Iranian, Afghan plates, Tibet (Qiantang and Lass), and the Malaya plates; connected with Indochina, and Sibumasu. Some of these plates collided with Laurasia during the Cimmerian orogeny in Late Triassic to Late Jurassic; some were amalgamated into the Alpine orogenic system in Cretaceous and Cenozoic.

Cocos Plate - see Farallon.

Czorsztyn Ridge - intraoceanic ridge between the Pieniny Klippen Belt Ocean and Outer Carpathian trough.

Damara Orogeny - the latest Vendian-Cambrian orogenic events, which caused deformations in southern Africa.

Deccan Traps - late Cretaceous, hot spot related, flood basalts in India.

Dnepr-Donetsk-Pripyat Rifts - rifts in the Eastern Europe, turned into aulacogen, developed during the Devonian time.

Dzungar - see Irtysh.

East China Sea - back-arc basin, opened in the Tertiary with the eastward movement of the paleo-Ryukyu arc.

East Siberia (Angara and Verkhoyansk) - a separate plate in the Early Paleozoic. Was sutured with Baltica and Kazakhstan during the Carboniferous to Permian. It is now bounded on the west by the Urals and the Irtysh crush zone, in the south by the South Mongolian arc and on the northeast by the Verkhoyansk fold belt. Relation of the Angara and Verkhoyansk plates as well as relation of East and West Siberia remain speculative.

Eastern Alps Plate - see Ligurian.

Ellesmerian Orogeny - see Innuitian Orogeny.

Eurasian Basin - the eastern part of the Arctic Ocean between the Lomonosov Ridge and the continental shelf of Eurasia, originated as part of the North Atlantic opening during the Tertiary.

Eurekan Orogeny - compressional Paleogene event in the Arctic (Greenland, Svalbard, Canadian islands), response to the sea-floor spreading in the Labrador Sea and the Baffin Bay.

Farallon Plate - part of the Pacific plate system, large in the Cretaceous, partitioned during the Tertiary into Juan de Fuca, Cocos, and Nazca plates. Part of Farallon plate, captured between South and North America formed the Caribbean Sea basement in the Late Cretaceous to Eocene.

Figueiro Fracture - transform fault in the Central Atlantic between Spain and Canada.

Finnmarkian Orogeny - Cambrian-Ordovician event, which caused deformation in the eastern North America.

Franklinian Orogeny - Silurian orogenic event in the northwestern Canada, possibly a result of the collision between Verkhoyansk part of Siberia and North Slope-Chukotka part of Laurentia.

Gissar - mountains in Central Asia. Plate accreted to Kazakhstan in Carboniferous-Permian time.

Gondwana - supercontinent from Cambrian to Jurassic time. The core of Gondwana includes South America, Africa, Madagascar, India, Antarctica, and Australia. Plates that have been part of Gondwana at some time during the Paleozoic include Yucatan, Florida, Avalonia, central and southern Europe, China (three separate blocks), Tarim, Karakum, Turkey, Iran, Afghanistan, Tibet, and Southeast Asia. Gondwana collided with Laurussia forming Pangea in the Carboniferous, and separated again in the Middle Jurassic. It was fragmented in a series of Middle Jurassic-Cretaceous rifting and seafloor spreading events.

Grampian Orogeny - Cambrian-Ordovician event, which caused deformation in Scotland.

Greater Antilles Arc - island arc between Caribbean plate and Atlantic, moved eastwards during the Cretaceous-Tertiary from the Pacific Ocean to the present position.

Greater Caucasus - Mountains between SE Europe and Asia formed after closing Greater Caucasus -proto-South Caspian Ocean in the Neogene. Greater Caucasus plate collided with Baltica in the late Paleozoic.

Halstatt - see Meliata.

Helmand Plate - Afghanistan, one of the Cimmerian terranes, collided with Asia in the Jurassic.

Hercynian Orogeny - Devonian-Carboniferous collisional events between the European part of Laurussia and terranes from Spain to Poland. The Hercynian Orogeny and related North American events (Alleghenian-Ouachita) formed the central Pangean Mountain Belt during the Permo-Carboniferous.

Himalayan Orogeny - a series of Cretaceous through Tertiary orogenic events, which culminated with the Tertiary collision of India and Eurasia. Formed Himalayan and adjacent mountain belts and strike-slip fault systems in Asia. Has had major impact on southeast Asian plate tectonic development during the Tertiary.

Iapetus Ocean - ocean between Baltica, Avalonia, and Laurentia during the Early Paleozoic, closed in the Devonian.

Inner Carpathians - mountains in Central Europe - separate plate during Jurassic-Cretaceous, accreted to Europe in Late Cretaceous-Paleogene; see Ligurian.

Innuitian (Ellesmerian) Orogeny - a collisional orogenic event in the Canadian Arctic Island and perhaps in the Lomonosov ridge during the Late Devonian - Early Carboniferous.

Ionian Platform - western Greece and the adjacent Ionian sea, in the Mesozoic connected Apulia and Taurus plate; see Pindos.

Irtysh-Dzungar Fold Belt - mountains resulting from the collision between East Siberia and Kazakhstan in the Early Carboniferous.

Izanagi Plate - a fragment of the Cretaceous Pacific Ocean plate system (eastern part), subducted under the Asian craton.

Izo-Bonin Arc - island arc collided with Japan in the Neogene.

Juan de Fuca Plate - see Farallon.

Kara-Bogaz - during the Early Paleozoic time the Kara-Bogaz plate was the fragment of Gondwana, connected with Karakum. It was accreted to Kazakhstan in the Early Permian forming part of the Turan platform in Central Asia.

Karakum - during the Early Paleozoic time Karakum plate was fragment of Gondwana, connected with Tarim. Accreted to Kazakhstan in Early Permian forming Turan platform in Central Asia.

Karoo System - a failed Permian to early Jurassic rift system in eastern Africa.

Kazakhstan - plate originated in the Silurian and grew during the Paleozoic by the accretion of volcanic arcs, especially Kipchak arc, related trench deposits, and exotic terranes; sutured with East Siberia and Baltica in the Permo-Carboniferous. Today includes the Kazakhstan Republic and part of Western Siberia.

Kerguelen Plateau - volcanic plateau (Large Igneous Province) in the Indian Ocean formed in the Cretaceous.

Khatyrka, Koni-Murgal, Koryak - small, enigmatic terranes and volcanic arc accreted to the northeastern margin of Eurasia during the Cretaceous-Tertiary time.

Kipchak Arc - volcanic arc that existed somewhere east of Baltica and Siberian in the Early Paleozoic, amalgamated into the Kazakhstan plate during the Silurian time.

Kirsehir - central Turkey, separate plate in the Mesozoic; see Pindos.

Kohistan – small plate of the Gondwanian origin, accreted to Eurasia in the Pakistan-India area during the Late Cretaceous.

Kolyma-Okhotsk-Cherski Plate - synonym for Verkhoyansk plate.

Koni-Murgal - see Khatyrka.

Koryak - see Khatyrka.

Kula Plate - a fragment of the Pacific plate system (northeast part). It was subducted under the North American craton during the Oligocene.

Kurgovat - see Pamir.

Kurile Arc – island arc between Pacific and the Okhotsk Sea originated in the Neogene.

Laramide Orogeny - orogenic movements in western North America during the Eocene through Oligocene. Term is often incorrectly used for the Late Cretaceous-Paleocene phase of the Alpine Orogeny in Europe; see Subhercynian.

Laurasia - supercontinent from Late Paleozoic to Early Cretaceous time, consisting of Laurentia, central and northern Europe, and Asia (excluding India and Arabia). The assembled Laurasia was the northern part of Pangea from Late Permian to Early Jurassic, it separated from Gondwana in the Middle Jurassic, and continued to fragment into the Tertiary when North America was separated from Eurasia by the opening of the North Atlantic.

Laurasia I - Silurian-Devonian continent, which included Avalonia, Baltica, Laurentia and Siberia.

Laurentia - was a separate plate in the Early Paleozoic, consisting of the major part of North America, northwest Ireland, Scotland, Greenland, Barentsia (Svalbard), and the Chukotka Peninsula. The Early Paleozoic margin of Laurentia can be recognized in the Appalachians.

Laurussia - a separate, large continental plate in Silurian through Devonian time. Originated by collision of Baltica and Laurentia during the Scandian Orogeny. It was the part of Pangea during the Late Paleozoic.

Lhasa Plate - present day southern Tibet, existed as separate plate in the Mesozoic. The relationship between the Lhasa plate and the Cimmerian continent during periods of rifting and collision is speculative. Finally collided with Eurasia during Cretaceous time.

Ligurian, Penninic, Pieniny Klippen Belt Oceans - opened in the Jurassic Time between Apulia Eastern Alps (Austroalpine units), Inner Carpathian plates and Europe, closed during the Alpine orogeny in Tertiary.

Limagne Trough – see Rhine.

Lomonosov Ridge - a topographic high (remnants of Paleozoic continental crust, see Innuitian Orogeny) in the Arctic Ocean between the Canadian and Eurasian Basins.

Luconia - terrane in SE Asia, collided with Borneo in the Oligocene.

Lut - eastern Iran, separate plate, part of the Cimmerian terranes, collided with Eurasia in the Late Triassic, rifted away in Early Cretaceous, amalgamated with the Asian blocks in the Alpine orogeny in the Neogene.

Makarov Basin - narrow, oceanic type basin in the Arctic opened in the Cretaceous, by rifting the Alpha ridge away from the Barents plate. This opening was connected with the rifting in the Zyrianka basin on Eurasian continent.

Maker - block accreted in the Caucasus area in the Triassic.

Małopolska High - southern Poland, perhaps part of Avalonia, collided with Baltica in the Silurian-Devonian.

Mamonia - Triassic ophiolites on Cyprus

Mauretinides, Bassarides, Rokelides - a mountain systems in western Africa, remnants of the central Pangean Mountain Belt, which originated as a result of collision between Gondwana and North America in the Late Paleozoic.

M'Clintock Orogeny - Ordovician event, which caused deformations in the Svalbard area.

Melanesian Arc - an island arc in the southwest Pacific, collided with the Australia-New Guinea plate in the Late Tertiary.

Meliata-Halstatt Ocean - narrow basin with the oceanic crust, opened in the Triassic between Eurasian margin and Hungarian Tisa block.

Moesia - parts of Romania and Bulgaria; plate sutured to Baltica during Paleozoic (Silurian-Devonian?).

Mongolian-Okhotsk Embayment - an oceanic embayment between Amuria and Laurasia (Siberia). Originally formed as the Panthalassa embayment in the Late Paleozoic and closed in the Early Cretaceous. Folding and intrusion of granitic batholiths in the Mongolian and the trans-Baikal area followed this.

Nazca Plate - see Farallon.

Neotethys - large Mesozoic ocean between Gondwana (Australia, India, Arabia, Africa) and Eurasia. It was formed by rifting of the Cimmerian plates away from Gondwana in the Early Permian, enlarged in the Triassic, and connected with central Atlantic during the Jurassic. Several branches: Ligurian-Penninic-Pieniny Klippen Belt, Meliata, Vardar, Pindos, Tauric, Greater Caucasus, Sebzevar, and Sistan oceans existed during the Mesozoic time. Most of Neotethys was closed in the Himalayan-Alpine Orogeny; fragments are included in the present day Indian Ocean and Mediterranean Sea.

Nevadean Orogeny - collision of Stikinia and other terranes with the western United States during the Jurassic.

Newark Rift System - failed Triassic-Jurassic rift basins of the eastern U. S. A.

North Slope - see Chukotka.

Okhotsk Sea Block - block under the Okhotsk sea, accreted to Eurasia in the Paleogene.

Okinawa Trough - back-arc basin in the East China Sea. Opened in the Neogene.

Oldredia - supercontinent, which encompassed all major plates during the latest Silurian-Early Devonian after collision of Gondwana and Laurentia.

Olutor - arc, collided with the Eurasian margin in the Paleogene.

Omolon Massif - microplate accreted to Siberia in the Jurassic, belonged to the Verkhoyansk superterrane.

Ontong Java Plateau - volcanic plateau (Large Igneous Province) in the Pacific formed in the Cretaceous.

Ouachita - Mountains in the southwestern United States, result of Carboniferous-Permian collision of Gondwana and Laurentia, see also Hercynian.

Outer Carpathian Trough - rift with the partially oceanic crust opened in the Late Jurassic-Cretaceous between Inner Carpathians and European margin, closed in the Tertiary.

Outer Carpathians - thrust-and-foldbelt mountains in the central and eastern Europe formed in the Tertiary.

Pacific Plate - oceanic plate born in the Mesozoic, increased its size during Tertiary, today forms most of the Pacific Ocean.

Pacific-Aluk - spreading center in the Cretaceous Pacific Ocean, collided with New Zealand in the Late Cretaceous.

Palavan - see South China Sea.

Paleoasian Ocean - ocean between Kazakhstan and Gondwana in the Paleozoic, closed during the late Paleozoic time.

Paleo-Ryukyu Arc - see East China Sea.

Paleotethys - large Paleozoic ocean between eastern Gondwana and the East Siberia, Kazakhstan, and Baltica plates, originated in the Early Devonian as a remnant of the eastern part of the Rheic Ocean. Paleotethys closed in the Early to Middle Jurassic during the collision of Cimmeria with Laurasia. The limits of the eastern Paleotethys and the relationship with Panthalassa and the Chinese plates are speculative.

Pamir - mountains in central Asia, several Pamir terranes, like North Pamir, Kurgovat, South Pamir, collided with Asia during Paleozoic and Mesozoic time.

Pan-African Orogeny - major Late Precambrian orogenic events related to the formation of the Precambrian Gondwana and Pannotia.

Pangea - a single continent comprising all the world's landmasses. The term Pangea describes the continental configuration from the Carboniferous through Middle Jurassic time. By the Late Paleozoic, Laurussia, East Siberia, Kazakhstan, and Gondwana had collided to form the western, major part of Pangea. The Asian plate was still separate until the Early to Middle Jurassic. Almost all continental plates were assembled for a relatively short time (about 20 million years) in the Early Jurassic following the Early Cimmerian Orogeny.

Pangean Mountain Belt - see Hercynian

Pangean Rim of Fire - system of subductions surrounding the Pangea supercontinent

Pannonian Basin – intermountain basin in the central Europe, behind the Carpathian foldbelt, formed in the Tertiary.

Pannotia - a super continent which possibly existed in the latest Precambrian. In the Early Phanerozoic Pannotia was already fragmented into Laurentia, Siberia, and Baltica. The split of Pannotia marks the beginning of the Phanerozoic. Role of Gondwana remains uncertain.

Pantelleria Trough - rift between Africa and Sicily, opened in the Neogene.

Paracel - see South China Sea.

Paratethys - a large sea in south-central Europe and central Asia formed during the Alpine Orogeny. The Black, Caspian, Azov and Aral Seas are Paratethys remnants.

Patagonia Plate - southwestern part of South America, separate plate, perhaps originally part of Laurentia, collided in the Ordovician with Gondwanian South America.

Pay-Khoy - northernmost part of the Ural foldbelt.

Pelagonian - Mesozoic plate in Greece, see Pindos.

Penninic Ocean - see Ligurian.

Pennobscotian Orogeny - Cambrian-Ordovician event, which caused deformation in eastern North America.

Pericaspian Basin (also Precaspian, North Caspian) - originated, perhaps, as a back-arc basin in the Late Paleozoic. It may be partially underlain by oceanic crust captured in the collision between Kazakhstan, Baltica, and the Ust-Yurt arc.

Phoenix Plate - fragment of the Cretaceous Pacific Ocean plate system.

Phoibic Ocean - enigmatic Early Paleozoic ocean between Laurentia and Gondwana.

Pieniny Klippen Belt - thrust-and-fold belt in Carpathians. Pieniny Klippen Belt Ocean - see Ligurian, Czorsztyn.

Pindos Ocean - branch of Tethys with the oceanic crust, between Pelagonian, Kirsehir and Sakariya blocks and Taurus-Ionian platform.

Pleionic Ocean - ocean between East Siberia and Baltica in the Early Paleozoic.

Polish-Danish Graben - rift in Central Europe, originated during the Jurassic, turned into aulacogen in the early Cretaceous, inverted in the late Cretaceous - Paleogene.

Pontides - northern Turkey. Separate Pontides plates were involved in the opening of the Black Sea. In the Paleogene Pontides were sutured with the other Turkish plates.

Proto South China Sea - a sea along the northeastern margin of Kalimantan in the Paleocene through Oligocene. It closed as the South China Sea opened along the South China margin.

Proto South-Caspian - see Greater Caucasus.

Qiantang Plate - present day northern Tibet, existed as separate plate in the Mesozoic. The relationship between the Qiantang plate, Lhasa plate and the Cimmerian continent during periods of rifting and collision is speculative. Qiantang was probably amalgamated to Eurasian in the Early Jurassic.

Rajmahal Traps - Early Cretaceous basalt eruption in India, related to the hot spot activity.

Red River Fault - transform fault between South China and Indochina, active during the Tertiary.

Rheic Ocean - large ocean between Gondwana, Laurentia, Avalonia, Baltica and East Siberia in the Ordovician to Silurian. Separated into an eastern and western part with the onset of the collision between Gondwana and Laurussia in the Devonian. The western part was closed with continued collision during the Permo-Carboniferous; the eastern part became the Paleotethys Ocean.

Rhenodanubian Trough - rift with partially oceanic crust opened in the Early Cretaceous in Alps, closed in the Tertiary.

Rheno-Hercynian Basin - rift and narrow ocean in the central Europe, opened in the Silurian-Devonian time, closed during Hercynian orogeny.

Rhine, Limagne and Bresse Troughs - Tertiary rift system in Europe, associated with a hot spot activity.

Rhodopes - mountains between Bulgaria, Greece and Turkey. Rhodopes plate was accreted to Europe in the Late Paleozoic.

Rodinia - a super continent which possibly existed in Precambrian, before Pannotia and perhaps before the assembly of Gondwana (Pan-African Orogeny).

Rokelides - see Mauretinides.

Sailarian Orogeny - Cambrian-Ordovician collision between microcontinents in the Mongolia-Tuva area.

Sakariya - central Turkey, separate plate in the Mesozoic, see Pindos.

San Andreas - strike-slip fault in California, active in the Neogene.

Sanandaj-Sirjan - separate plate during the Mesozoic in southern Iran, north of Zagros Mountains, amalgamated with the rest of Asia in Neogene.

Scandian Orogeny - collisional event between Baltica and Laurentia in the Silurian. Synonym for Caledonian Orogeny.

Scythian Platform - parts of Ukraine and SW Russia accreted to Europe in the Paleozoic.

Sebzevar-Sistan - ocean between Lut (Iran), Eurasian (Turkmenistan and Afghanistan) margin and Afghanistan Platform, opened in the Early Cretaceous. Closed in the Tertiary.

Shatski Terrane (Rise) - fragment of the Black Sea with a continental crust basement, related to the Paleogene opening of the eastern Black Sea.

Sibumasu - South Asia plate in Paleozoic-Mesozoic.

Sikhote Alin - Mountains in southeastern Russia, plate of unknown, origin accreted to the Eurasian margin in the Cretaceous.

Sistan Ocean - see Sebzevar.

Solonker - ocean between North China and Amuria in the Paleozoic, closed in the Permian.

Sonoma Orogeny - Early Triassic arc-continent collision in the western United States

South Caspian Microcontinent - separate plate during the Mesozoic, included in the Cimmerian terranes, today block with the continental crust in the Caspian Sea.

South China Sea - a sea between South China and Borneo, opened during the Tertiary spreading event, separating North Palavan – Paracel Island microcontinent from the continental South China.

Stikinia - plate accreted in the Late Jurassic to the western North America. See Western North American Plates.

Subhercynian and Laramide Structures - intracontinental Late Cretaceous-Early Paleogene intracontinental deformations in Europe, affecting, among the others, the Harz and Holy Cross mountains. Subhercynian and Laramide names are sometimes referred to the phases of the Alpine Orogeny.

Świętokrzyska Phase (Orogeny) - Cambrian event, which caused deformation in the Holy Cross Mountains in Poland.

Taconian Orogeny (also Taconic) - orogenic events in the eastern part of Laurentia during the Ordovician, probably due to collision between Laurentia and speculative western island arcs.

Tarim Plate - part of northwest China, probably existed as a separate plate in the Early Paleozoic, sutured to Laurasia during Permian time.

Tauric Basin - proto-Black Sea - back-arc basin opened in the Triassic.

Taurus - mountains in the southern Turkey, separate plate during Mesozoic time.

Teisseyre-Tornquist Line - a major NW-SE striking suture between the east European Platform (ancient Baltica plate) and the remaining part of Europe. Well defined in Sweden, the Baltic Sea, and Poland; probably beneath the Carpathian Nappes in the Ukraine. It terminates in the Black Sea area.

Timanian Orogeny - the latest Vendian orogenic events, caused deformations in the Timan-Pechora-Kola area in NE Europe, perhaps an equivalent of the Cadomian orogeny.

Tisa - Mesozoic plate in Hungary; see Meliata.

Tornquist Sea - ocean between Baltica and Avalonia during the Cambro-Ordovician. It closed by the strike-slip suturing of Avalonia and Baltica during the Silurian.

Transcaucasus - massif in the Caucasus Mountains of the Cadomian origin. Involved in the several rifting and collisional events during the Phanerozoic.

Trupchun Phase - Alpine orogeny deformations in the Cretaceous.

Turan Platform - see Karakum.

Umbria-Marche - western central Italy. Amalgamated with the Apulia platform in Tertiary.

Ural Ocean - ocean between Karakum plate, Kazakhstan, Siberia, Baltica, and Barentsia in Devonian through Carboniferous time, closed during the Uralian Orogeny in the Permian. The Ural Ocean was the western part of the Paleoasian Ocean during Cambrian-Silurian.

Uralian Orogeny - collisional events between East Siberia, Kazakhstan, and Baltica in Late Carboniferous through Permian time.

Ust-Urt - during the Early Paleozoic time Ust-Urt plate was fragment of Gondwana, accreted to Kazakhstan and Baltica in Early Permian forming SE margin of the Peri-Caspian basin.

Valais Trough - basin with the oceanic crust between the Briançonnais terrane and European platform, opened in the Early Cretaceous, closed in the Tertiary.

Valencia Trough - back-arc basin in the western Mediterranean, between Spain and Balearic Island, opened in the Neogene.

Vancouver Plate - fragment of the Pacific plate system off NW North America, during the Paleogene.

Vardar - western part of Neotethys.

Variscan Orogeny - synonym for the Hercynian Orogeny.

Verkhoyansk (Kolyma-Okhotsk-Cherski) Plate - easternmost part of East Siberia, probably Verkhoyansk was rifted from Angara in Late Paleozoic and docked again during the Cretaceous time. Relation of Verkhoyansk and Angara plates remains somewhat speculative.

Verkhoyansk Fold Belt - mountain system in the eastern part of the Russian Republic, originated in the Cretaceous by accretion of Verkhoyansk plates and several other exotic terranes (Omolon for example) to the East Siberian Platform.

Viluy Trough - Devonian rift on Siberia.

West Siberian Basin - formed and underlain by oceanic crust captured during the collision between East Siberia, Barentsia, and the Ural Mountain belt in the Late Paleozoic. Rifting during the Triassic and Jurassic renewed basin development.

Western North American Plates - several plates of unknown origin, amalgamated to the northwestern America during Jurassic-Cenozoic time. The better known plate names are Yukon, Stikinia, Chugatch and Alexander.

Zyrianka - see Makarov.