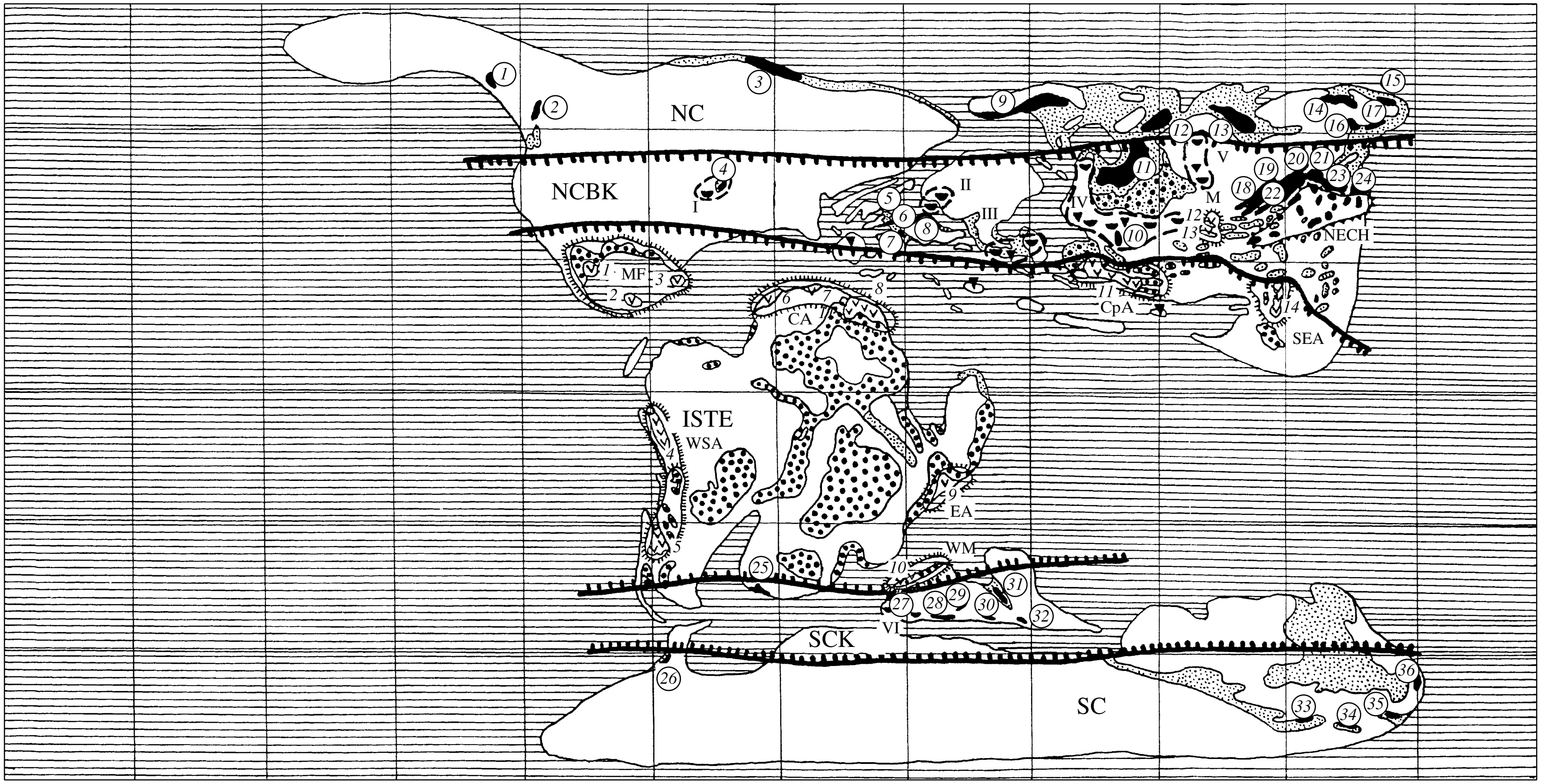

Fig. 8.

1988; Balkwill *et al.*, 1983; Malumian *et al.*, 1983; Dingle *et al.*, 1983; Petri and Mendes, 1983; Thomson, 1983; Emery and Uchupi, 1984; Cahen *et al.*, 1984; *Atlas*..., 1985; Salomon and Drillien, 1985; *Stratigrafiya*..., 1986; Chen Pei-Li, 1987; Frazier and Schwimmer, 1987; Liu Qun *et al.*, 1987; Petri, 1987; Reyment and Dingle, 1987; Riccardi, 1987; Zirsmeister, 1987; Blakey *et al.*, 1988; Butterwarth *et al.*, 1988; Hutchison, 1989; Smith, 1989; Arthur *et al.*, 1990; Bardossy and Aleya, 1990; Bardossy and Dercourt, 1990; Bussert *et al.*, 1990; Luger *et al.*, 1990; Wycisk *et al.*, 1990; Acharyya and Lahari, 1991; Basov and Vishnevskaya, 1991; Wycisk, 1991; *Atlas paleogeograficheskikh*..., 1992; Tashliev and Tovbina, 1992; Dercourt *et al.*, 1993; Kavun and Vinnikovskaya, 1993; Shulgina *et al.*, 1994; Rehakova *et al.*, 1995; Sitian *et al.*, 1995). These schemes allow the main features of zonal arrangement of arid and humid sedimentation environments on continents to be distinguished and the position of climatic belts throughout the indicated time interval to be reconstructed (Figs. 5–8).

In the Berriasian, the environments of arid sedimentation prevailed over all of western Gondwana, along the southern margin of Laurasia, and in adjacent areas of the Tethys (Fig. 5). Various evaporite basins with predominant sulfate sedimentation existed in these regions either as floodplain, lacustrine, limnoalluvial, deltaic, lagoonal, coastal, and continental sebkhas or as evaporite–carbonate platforms. Simultaneously, the red-bed terrigenous sedimentation was characteristic of spacious areas of the West Gondwanan interiors, as well as of the southwestern and southeastern parts of Laurasia.

The extended evaporite-accumulation belt became traceable at that time also along the entire southern margin of Laurasia and northern periphery of the Tethys. It was spread over more than 15 000 km from the Caribbean region in the west to Southeast Asia in the east within the limits of the northern subtropical and tropical zones. The belt comprised a series of isolated evaporite basins located in the Mexican–Floridan, North Iberian, Georgian–Moesian, Central Asian, and Southeast Asian regions, where many of them, e.g., the Yucatan, Sabinas, South Floridan, Soria, Moesian, Georgian, Central Asian, and Lanpan-Simao basins, had variable sedimentation enviroments.

Three isolated regions of Berriasian evaporite sedimentation are distinguished in the territory of western Gondwana. In the western part of the continent, the western province of South America is outlined by the distribution of evaporites of the Akra basin. The spacious North African region of evaporite accumulation encompasses the Moroccan, Algerian–Tunisian, and a series of smaller continental and coastal evaporite basins distinguished in the north. In the east, the extended East African evaporite region is traceable along the past continental margin running through boundary areas of Kenya, Somalia, and Ethiopia and comprising the Mandera and some other smaller basins. Some peculiar features of the spatial distribution of evaporite-accumulation regions in western Gondwana attract attention. For instance, the North African region is located north of the equator, mostly in the northern tropical belt. Two other evaporite regions in western South America and East Africa extend to the southern tropical belt approximately between 10° S and 30° S. It is seen that the North African evaporite region is situated near the South Laurasian evaporite belt, and, in fact, it is a part of the northern tropical to subtropical zone of evaporite sedimentation. In its western half, this zone covered not only the southern areas of Laurasia but also the entire western and central Tethys, along with adjacent areas of Gondwana, whereas in its eastern half, it occupied the southern and southeastern areas of Laurasia and the northern periphery of the eastern Tethys.

These peculiarities in the spatial distribution of the Berriasian evaporite basins and areas reveal their confinement to two latitudinal belts: the northern Tethyan–South Laurasian belt and the southern one, which is tentatively termed as the Southwestern Gondwanan belt encompassing the western South American and East African evaporite-accumulation regions. Environments of continental red-bed sedimentation of the arid type prevailed between these belts and in many interior basins of western Gondwana. They were widespread in many equatorial, tropical, and subtropical areas. Thus, it is evident that almost all of western Gondwana,

Fig. 8. Belts and provinces of arid and humid sedimentation in the Barremian Age of the Early Cretaceous (symbols as in Fig. 5). *Evaporite basins*: *1*, Sabinas; *2*, Yucatan; *3*, South Floridan; *4*, Altiplano (Chicamos, Hunin, and others); *5*, Neuken; *6*, Tindouf–Ayun; *7*, Moroccan; *8*, Algerian–Tunisian; *9*, Mandera; *10*, Murundava; *11*, Central Asian; *12*, Dzabhan; *13*, Banernur; *14*, Lanpang-Simao. *Evaporite provinces*: MF, Mexico–Floridan; WSA, Western South American; NA, North African; EA, East African; WM, Western Madagascar; M, Mongolian; SEA, Southeast Asian. *Coal-bearing basins*: *1*, Saint Elias; *2*, Bowser, Sastus, and others; *3*, Sverdrup; *4*, Moose River; *5*, Celtic; *6*, Bristol, Wild, Channel; *7*, Parisian; *8*, Western Netherlands, Lower Saxonian, Altmark–Branderburg; *9*, Northern Barents; *10*, Karakamys; *11*, West Siberian; *12*, Khatanga; *13*, Lena; *14*, Zyryanka; *15*, Anui; *16*, Omsukchan; *17*, Taigonos; *18*, West Transbaikalian; *19*, Olekma–Vitim; *20*, Southern Yakutia; *21*, Amur–Zeya; *22*, East Transbaikalian; *23*, Bureya; *24*, Partizansk, Razdol'naya; *25*, Algoa; *26*, Alexander; *27*, Sakoa; *28*, Palar, Eluri, Ongole; *29*, Wardha, Nagpur; *30*, Talcher; *31*, Narmada (Satpura and others); *32*, Damodor and others; *33*, Otway; *34*, Bass; *35*, Gippsland, Strzelecki; *36*, Clarence, Moreton, Miscellaneous; (NECH) Northeastern Chinese coal-bearing province. *Provinces of kaolinite and kaolinite–bauxite formation*: I, Moose River; II, Western Baltic; III, Northern Black Sea–Donets; IV, Uralian–Western Siberian; V, Eastern Siberian; VI, Southern Madagascar–Southern Hindustan. *Climatic belts*: NC, northern coal-bearing belt of the circumpolar humid zone; NCBK, northern coal–bauxite–kaolinite belt of the humid zone in middle latitudes; ISTE, intersubtropical evaporite belt of the arid zone; SCK, southern coal–kaolinite belt of the humid zone in middle latitudes; SC, southern coal-bearing belt of the humid zone.

except for its extreme southern areas, was under the influence of the predominantly arid climate of the Berriasian. In general, the Berriasian was the formation period of a single and very wide belt of arid sedimentation, which covered not only subtropical and tropical regions of the northern and southern hemispheres of the Earth but also the equatorial zone of western Gondwana. This arid belt is recognized as the intersubtropical evaporite belt (ISEB). Its northern boundary was near 30° N, and the southern one was approximately between 40° S and 50° S.

The ISEB retained its boundaries almost unchanged throughout the Valanginian, Hauterivian, and Barremian times (Figs. 6–8). Only the number of evaporite basins and areas changed, and the spatial distribution of red-bed arid terrigenous sedimentation insignificantly varied. For instance, beginning in the Valanginian, the evaporite accumulation stopped in the northern Iberian region and, beginning in the Hauterivian, in the Georgian–Moesian region. A new evaporite accumulation area appeared in their place in the central Tethys. Configuration and boundaries of the North African region also somewhat changed, as it became more spacious in the Barremian time owing to the appearance of evaporite sedimentation in the Tindouf–Aayun basin. The configuration of the western South American evaporite region also changed, when the center of evaporite accumulation moved here southward into the Neuken basin during the Hauterivian and Barremian. However, despite all these changes, the spatial distribution of evaporite basins and areas was persistent in its general patterns, and they were steadily confined to two latitudinal belts: the northern Tethyan–South Laurasian and the southern Southwest Gondwanan. During the Valanginian, Hauterivian, and Barremian ages, environments of red-bed arid sedimentation also continued to exist not only in tropical but also in equatorial areas of western Gondwana.

During the first half of the Early Cretaceous, humid areas and belts comprised coal-bearing basins, areas of kaolinite and bauxite formation, and regions of gray-colored terrigenous sediments. The zonal patterns in distribution of areas with humid sedimentation were most clear in the northern hemisphere, within the Laurasian continent. Two latitudinal humid belts were pronounced here through all the Neocomian ages. There were the northern mid-latitude coal–bauxite–kaolinite (NCBK) belt and the northern circumpolar coal-bearing (NC) belts.

The NCBK belt is traced both in the Eurasian and North American parts of Laurasia. In the eastern part of Asia, it corresponds to the spacious East Asian coal-bearing province comprising more than 300 coal-bearing basins formed in a system of parallel and subparallel flow-through freshwater lakes and river valleys and also in internal-drainage depressions separated by extended ridges. The following coal-bearing regions are distinguished within this province: West Transbaikalian (Gusinoe Ozero, Uda, Eravnoe, Hilok-Chikoi, and other basins), East Transbaikalian (the Chikoi, Chita–Ingoda, and numerous smaller coal-bearing basins), Olekma–Vitim (the Ukshum, Vitim, and other basins), Northeastern China (Hailar, Erlian, Songliao, and a number of other coal-bearing basins), and also the South Yakut, Udsk, Amur–Zeya, Bureya, and other regions. The Partizansk and Razdol'naya basins appeared here in the Hauterivian and Barremian, whereas the Weihe and Central Qinling basins near the southern boundary of the belt were formed in the Valanginian and Hauterivian. Thick black-shale bituminous sequences of argillite, siltstone, and marl were intermittently formed during almost the entire Neocomian period in many lake basins (Gusinoe Ozero, Zaza, Eravnoe, Unda–Onon, Songliao, and others). The system of coal-bearing and black-shale lacustrine basins extended far westward to Mongolia.

In the rest of Eurasia, the humid belt of middle latitudes comprised not only the basins of continental and coastal coal-accumulation but the provinces and areas of kaolinite- and bauxite-formation as well. Five major kaolinite and kaolinite–bauxite provinces always existed there in the Neocomian, through they changed their configuration and dimensions with time. They were the Moose River, West Baltic, and northern Black Sea region (beginning in the Hauterivian, the Northern Black Sea–Donets province) and also the Central Asian–West Siberian (in the Hauterivian–Barremian, Uralian–West Siberian) and East Siberian provinces. These regions were constantly or, probably, intermittently marked by the formation of lateritic weathering crusts, secondary kaolinites, bauxite-bearing deposits, kaolinite-to-bauxite clays, and kaolinite–quartz sands and also by the accumulation of other reworked weathering products. The Neocomian coal-bearing basins in the central and western areas of Eurasia were mostly confined to the southern zones of the midlatitudinal belt. This can be exemplified by the Celtic, Bristol, Wild, Channel, Paris, Western Netherlands, Lower Saxonian, Altmark–Branderburg, and Karakamys basins. In the Hauterivian–Barremian, coal formation was also characteristic of spacious areas of the West Siberian basin.

In the North America territory, the Neocomian humid belt of northern middle latitudes includes only the Moose River basin, where the Mattagami Formation encloses the Onakawana lignite beds alternating with kaolinite clays and quartz sands.

The humid belt in question was peculiar because of the the simultaneous development of coal-, kaolinite-, and bauxite-formation environments in continents and specific sedimentation in spacious epicontinental seas confined to it (Figs. 1–4). The most characteristic in this respect were the East European, West Siberian, and Enisei–Khatanga seas, which represented typical marine basins of terrigenous sedimentation with autigenic glauconite, phosphate, and iron minerals combined, sometimes with black-shale accumulation (the West Siberian basin of the Berriasian and Valanginian ages).

The southern boundary of the NCBK belt remained almost stable during the entire Neocomian and is now reliably traceable in the central areas of Laurasia. There, it passes near 28°–30° N between closely spaced evaporite provinces on the one side, and coal-bearing, kaolinite, and kaolinite–bauxite provinces on the other side. In eastern Asia, this boundary turns to the south, where the belt comprises a number of continental basins of eastern China with volcanogenic and gray-colored terrigenous sediments of the humid zone. In North America, the southern boundary of the belt is not far north of the Mexican–Floridan evaporite province. The northern boundary of the belt is arbitrarily drawn near 57°–60° N with due regard for the position of both the areas of coal-accumulation and kaolinite-formation and the epicontinental seas with glauconite, phosphate, and iron-oxide terrigenous sedimentation.

The northern circumpolar coal-bearing belt of the Berriasian, Valanginian, Hauterivian, and Barremian ages encompassed marginal regions of Laurasia located north of 57°–60° N. It is established on the basis of distribution of coal-bearing basins there. In the Berriasian–Valanginian, these basins were concentrated in two regions of the opposite continental margins of Laurasia corresponding to northwestern North America and northeastern Asia. The first of these regions comprises the Saint Elias, White Horse, Bowser, Sastut, Skeena, and Eastern Mackenzie basins and coal deposits of the foothills and Front Ranges of the Rocky Mountains. The other belt includes the Lena, Zyryanka, and Pegtymel' basins. In the Hauterivian and, particularly, Barremian, environments of coastal coal accumulation were characteristic of almost the entire territory of coastal regions of the circumpolar belt, where the Sverdrup, North Barents, Khatanga, Anyui, and Omsukchan coal-bearing basins were formed in addition to the basins mentioned above.

The data available for the southern hemisphere are also sufficient for recognizing and tracing two Neocomian humid belts similar to those outlined in the northern hemisphere. The southern coal–kaolinite (SCK) humid belt can be detected in the middle latitudes of the southern hemisphere. It is recognized as comprising many coal-bearing basins, such as the Sakoa, Palar, Eluri, Ongole, Vardha, Nagpur, Talcher, Narmada, and Damodor deposits in the northern regions of eastern Gondwana (southern margins of Madagascar and southeastern and eastern parts of Hindustan), and also the kaolinite and kaolinite-bearing deposits in the spacious territory tentatively termed as the Southern Madagascar–Southern Hindustan province. The southern margin of Africa, where the Algoa coal-bearing basin was discovered, also belongs to this coal–kaoilinite belt. The northern boundary of the belt is quite unambiguously traced along the eastern margin of the Western Madagascar evaporite province, as well as along the periphery of the arid areas with the red-bed deposits in Africa and South America. This boundary is located near 40°–50° S. The southern boundary of the belt is less obvious and arbitrarily placed at approximately 60° S, because only a few areas and basins of coal formation have been located south of this latitude for all the Neocomian ages.

The southern coal-bearing (SC) humid belt is distinguished by the presence of continental and coastal basins of red-bed humid sedimentation in Australia and some areas of the Antarctic continent, also including isolated coal-bearing basins spaced from each other. In the western margin of eastern Gondwana, only one coal-bearing basin, the Alexander, is known in the island of the same name near the West Antarctic coast, whereas a series of the Otway, Bass, Gippsland, Strzelecki, and other coal-bearing basins in Australia is located in the eastern part of Gondwana. Despite the limited number of coal-bearing basins, the peculiarities of their spatial distribution allow us to define rather reliably the southern coal-bearing humid belt with the northern boundary located near 60° N.

CONCLUSION

The presented analysis of original lithologic–paleogeographic maps compiled for the Berriasian, Valanginian, Hauterivian, and Barremian ages of the Early Cretaceous allows the following conclusions to be drawn.

(1) The Neocomian was the period of the final formation of the Tethys Ocean, the sublatitudinal seaway between Laurasia and Gondwana for the global western current. Hemipelagic clayey–calcareous sediments prevailed in the deep Tethyan basins, where shallow-water carbonate platforms and reefs also existed. In the incipient Southern Ocean and also in the narrow seaway between Hindustan and Antarctica that emerged beginning in the Hauterivian, hemipelagic terrigenous sediments were deposited. The central part of the Pacific was separated by a system of midocean ridges (spreading zones) into several deep basins with prevailing red-bed pelagic clayey–siliceous sedimentation, while ridges and submarine rises accumulated pelagic calcareous sediments. Subalkalic basaltic volcanism occurred in several areas of the Pacific plate.

(2) From the Berriasian through the Barremian time, the convergent boundaries of lithospheric plates were represented by a combination of marginal continental and island-arc (ensialic and ensimatic) volcanic belts, in the frontal part of which fore-arc basins and deep-sea trenches with turbidite sedimentation represented the successive lateral morphostructures related to volcanic belts. One of the peculiar environmental features of this period was the moderate crustal extension behind the volcanic belts of continental margins, where it resulted in the formation of back-arc and marginal sea basins.

These environments existed until the Aptian–Albian time, when the Middle Cretaceous orogeny substantially changed the paleogeography of the ocean–continent transition zones.

(3) The revealed spatial distribution of arid and humid sedimentation areas allows us to distinguish five latitudinal climatic belts of the Berriasian–Barremian time: the northern circumpolar coal-bearing humid zone, the northern coal–bauxite–kaolinite belt in the humid middle latitudes, the intersubtropical evaporite belt of the arid zone, the coal-bearing–kaolinite belt of the southern middle latitudes, and the southern coal-bearing belt. Two peculiar features of the Neocomian climatic zoning are interesting. The first, the asymmetric distribution of the Earth's humid belts, is evident. In the northern hemisphere, the humid belt occupies the largest territory of all the regions of Laurasia located north of 30° N, whereas humid areas of the southern hemisphere are displaced to the south beyond 40°–50° S. This was probably related to the particular position of Laurasia and eastern Gondwana in the northern and southern hemispheres, respectively, and also the position of the Tethys in the northern tropical belt. In addition, a single very wide intersubtropical arid belt between 30° N and 40°–50° S is unambiguously defined as the zone of evaporite and red-bed sedimentation in both the tropical and equatorial areas. The prevalence of arid environments in this spacious zone probably resulted from the fact that the vast western Gondwana continent was located near the equator.

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