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Notes on the Paleogeography and Paleotectonics of the Western Carpathian Area During the Mesozoic

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Bemerkungen zur Paläogeographie und Paläotektonik der Westkarpaten während des Mesozoikums

Zusammenfassung

Während des frühen Mesozoikums gehörten die Westkarpaten zu zwei getrennten Bereichen. Die zentralen Westkarpaten waren im äußersten Osten des alpin-karpatischen Mikrokontinents beheimatet. Durch die aufbrechende penninische Riftzone wurde dieser während des unteren Jura vom europäischen Schild abgetrennt. Anschließend, bis zur späteren Unterkreide bewegte sich dieser Mikrokontinent nach Osten. Während des Alttertiärs kollidierte dieser Block mit dem Teil des paleo-europäischen Randes, dem die äußeren Karpaten zuzurechnen sind. Diese Arbeit diskutiert die Entwicklung der Westkarpaten seit dem Beginn in der mittleren Trias bis zu den neokimmerischen Bewegungen.

Abstract

During the early Mesozoic, the Western Carpathians belonged to two separate domains. The Central Western Carpathians were situated on the easternmost part of the Alpine-Carpathian microcontinent. During the early Jurassic it has been splitted off from the European shelf by the arising Penninic Rift. Then, until the late Early Cretaceous, this microcontinent moved eastwards. During the early Tertiary this block collided with the Outer Carpathian part of the Paleoeuropean margin, which forms the second domain. This paper discusses several indications of this development since the very beginning (or heralding) stage in the middle Triassic until the Neo-Cimmerian disturbances.

1. Introduction

Detailed reconstruction of the bathymetry and facies patterns requires the application of all geological disciplines. However, incompleteness of the fossil record (due to erosion, tectonics, and facies variation) leads to a subjective interpretation causing the growth of contradictions in interregional correlation.

A variety of palinspastic reconstructions of the Western Carpathians in the frame of the Tethyan Mesozoic palinspastic schemes published recently (MAHEL', 1981; MICHALÍK & KOVÁČS, 1982; KOVÁCS, 1982; MICHALÍK, 1984; KÁZMER & KOVÁCS, 1985; MARSCHALKO, 1986; MICHALÍK & MIŠÍK, 1987; RAKÚS et al.. 1988; etc.) reflects the uncertainty arising from their contradicting geodynamic interpretations.

To overcome this uncertainty a broader usage of well constraint paleogeographic reconstructions and paleomagnetics (CHANNELL & HORVÁTH, 1976, etc.) may provide supporting evidence for geodynamic reconstructions.

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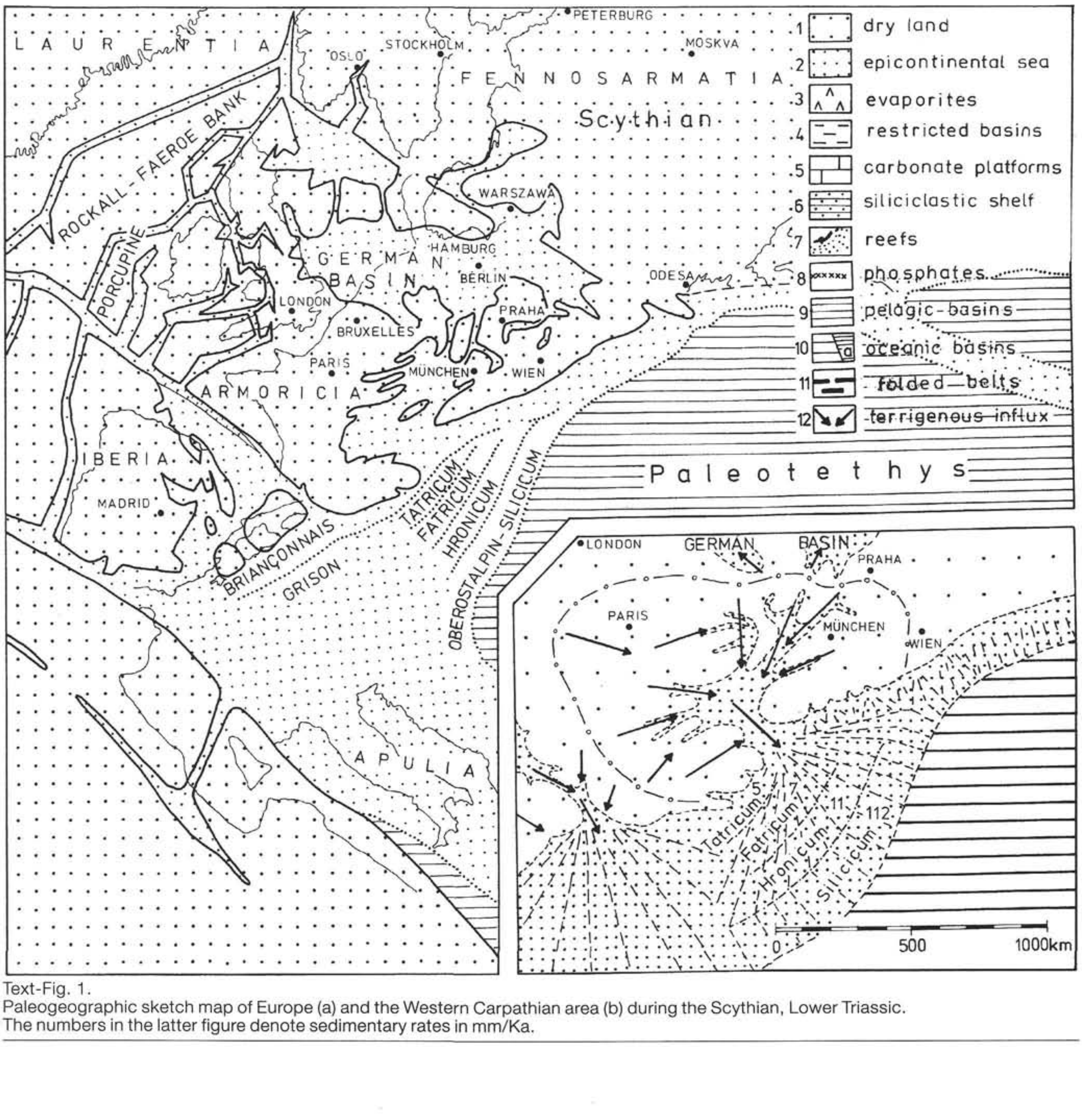
2. Paleogeographic Setting of the Western Carpathians at the Beginning of the Triassic

During the Triassic evolution, the Alpine-Carpathian units were derived from the margin of the North European shelf (KOVÁCS, 1980; TRICART, 1984; BRANDNER, 1984; MICHALÍK & MIŠÍK, 1987; MICHALÍK, 1992; etc.). The Triassic sedimentation on the shelves of the Mediterranean Tethys is characterized by the deposition of a thick pile of neritic carbonates. However, only terrigenous rocks deposited during several (Scythian, Carnian, Rhaetian) humide climatic events can serve as an indicator of the paleogeographic connections between individual paleogeographical domains. Considerable lateral dispersion and a great volume of these sediments in the Alpine-Carpathian region were traditionally interpreted by the direct transport from the extensive source areas in the "Vindelician Land", assumed to be located towards the north (RONIEWICZ, 1966). The zonality of Triassic sediments both in the Outer and the Central Western Carpathians denotes the increasing marine influence in a southern direction in both segments. This fact proves their independent position during the Eoalpine evolution, controlled by a left lateral strike slip between the Outer and the Central Carpathians (MARSCHALKO, 1986) that has been active during a great part of the Mesozoic era. Considering this, the assumed early Mesozoic position of the Central Carpathian blocks was to the southwest of the neighbouring Bohemian Massif (MICHALÍK, 1992). The Outer Carpathians represented the eastward continuation of this shelf, that rimmed the easternmost part of Paleoeurope at the south (Text-Fig. 1). In such a model, southward transport of clastics would continue from Palaeoeurope along the western slopes of the Bohemian Massif; terrigenous deposits could thus reach directly the Alpine-Carpathian area of the Paleoeuropean shelf (Text-Fig. 1).

The volume of Scythian clastics deposited in the Alpine-Carpathian area (Text-Fig. 1) is about 75.000–100.000 km^3. This material must have been derived from 250.000–400.000 km^3 of eroded granitoid rocks. The calculated source area of these clastics must attain not less than 750.000 km^2, the erosional rate being 150 to 200 mm per



Text-Fig. 1.
Paleogeographic sketch map of Europe (a) and the Western Carpathian area (b) during the Scythian, Lower Triassic.
The numbers in the latter figure denote sedimentary rates in mm/Ka.

thousand years. MICHALÍK (1993) estimated the whole Carpathian shelf subsidence at that time as 5 to 20 mm/Ka, while the subsidence rate of its southern border as ten times higher.

3. Begin of the Triassic Carbonate Platforms

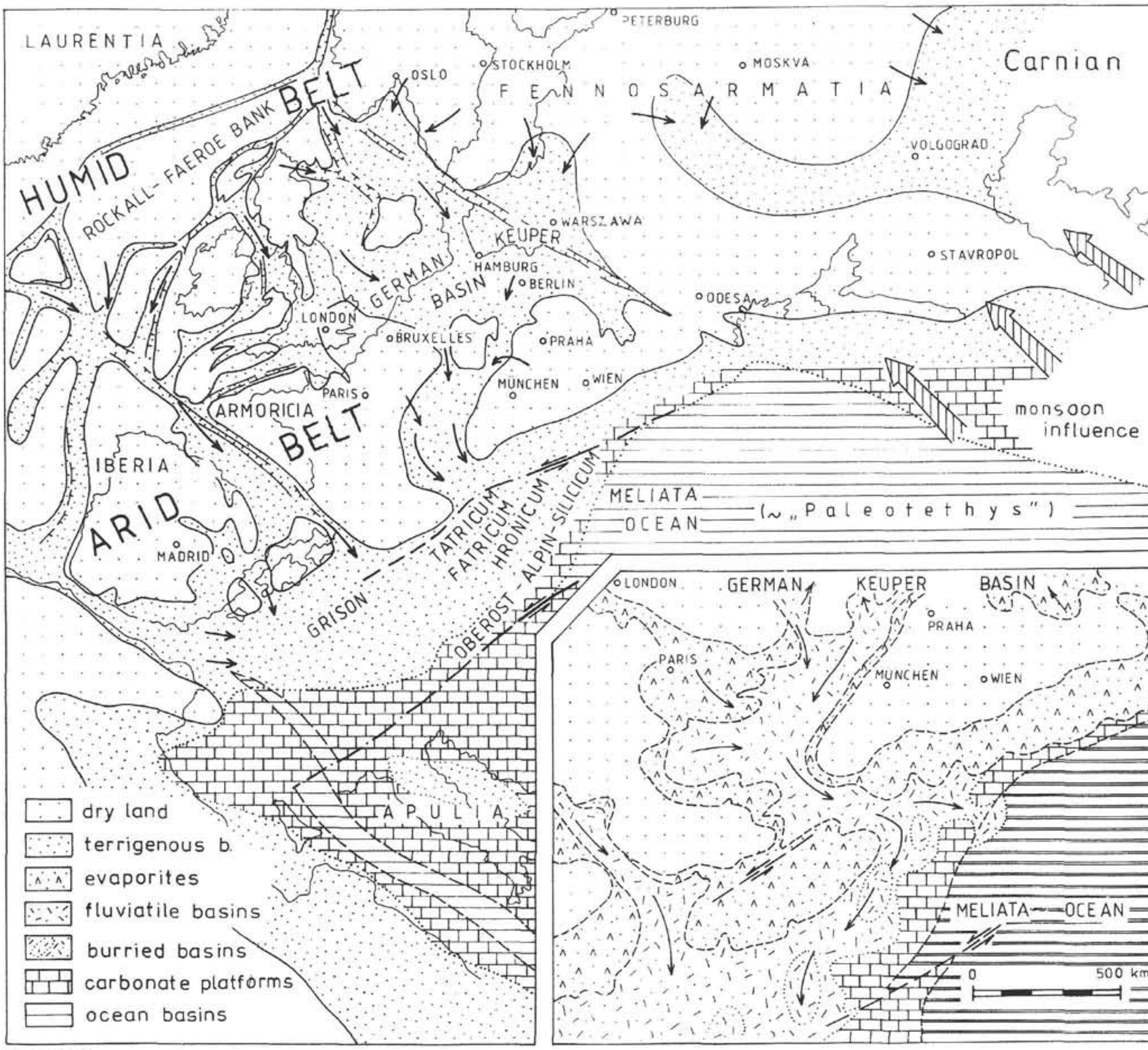
During the Anisian, the low-diversified southeastern Palaeoeuropean shelf reached a width of several hundred kilometers. An extremely shallow sedimentation regime (Gutenstein, Annaberg, Vysoký Formations) prevailed on this uniform carbonate ramp. Consequently, bioherms developed at its seaward border (in the Steinalm Fm.), heralding a change from a ramp to carbonate platform morphology. To the east, this shelf has bordered a deep oceanic basin (Meliata Unit).

The stabilization of the marine influence caused a gradual change in the sediment composition. Carbonates and evaporites became dominant during the Spathian/Anisian boundary time interval, when terrigenous support ceased and *monoclinal carbonate ramps started to grow. Strong* restriction of sea water circulation between the extremely shallow seas and the ocean limited environmental dynamics and caused hyper-salinity and low oxygen regime.

During the Anisian, the sedimentary rate in the northern nearshore zones attained 20 to 39 mm per thousand years, while 40 to 100 mm/Ka of carbonate sedimented in the southern zones (Oberostalpin – Silicicum, cf. Text-Fig. 1) at the same time (MICHALÍK, 1993). The different subsidence has also been caused by compaction of the underlying clayey (Permian and Scythian) sediments in the southern zones (about hundred meters loss of thickness during Anisian, cf. PERRIER & QUIBLIER, 1984). Eustatic processes were responsible for another hundred meters of the sea level rise. Thus, the remaining two hundred meters have been compensated by tectonic subsidence (at a rate of about 40 mm per thousand years).

4. Indications of Ladinian Extensional Tectonics

A new sedimentary *"mega-cycle"* started with the "Reiflinger Wende" (BRANDNER, 1984), when the Anisian carbo-



Text-Fig. 2.
Paleogeographic sketch map of Europe (a) and the Western Carpathian area (b) during the early Carnian time.

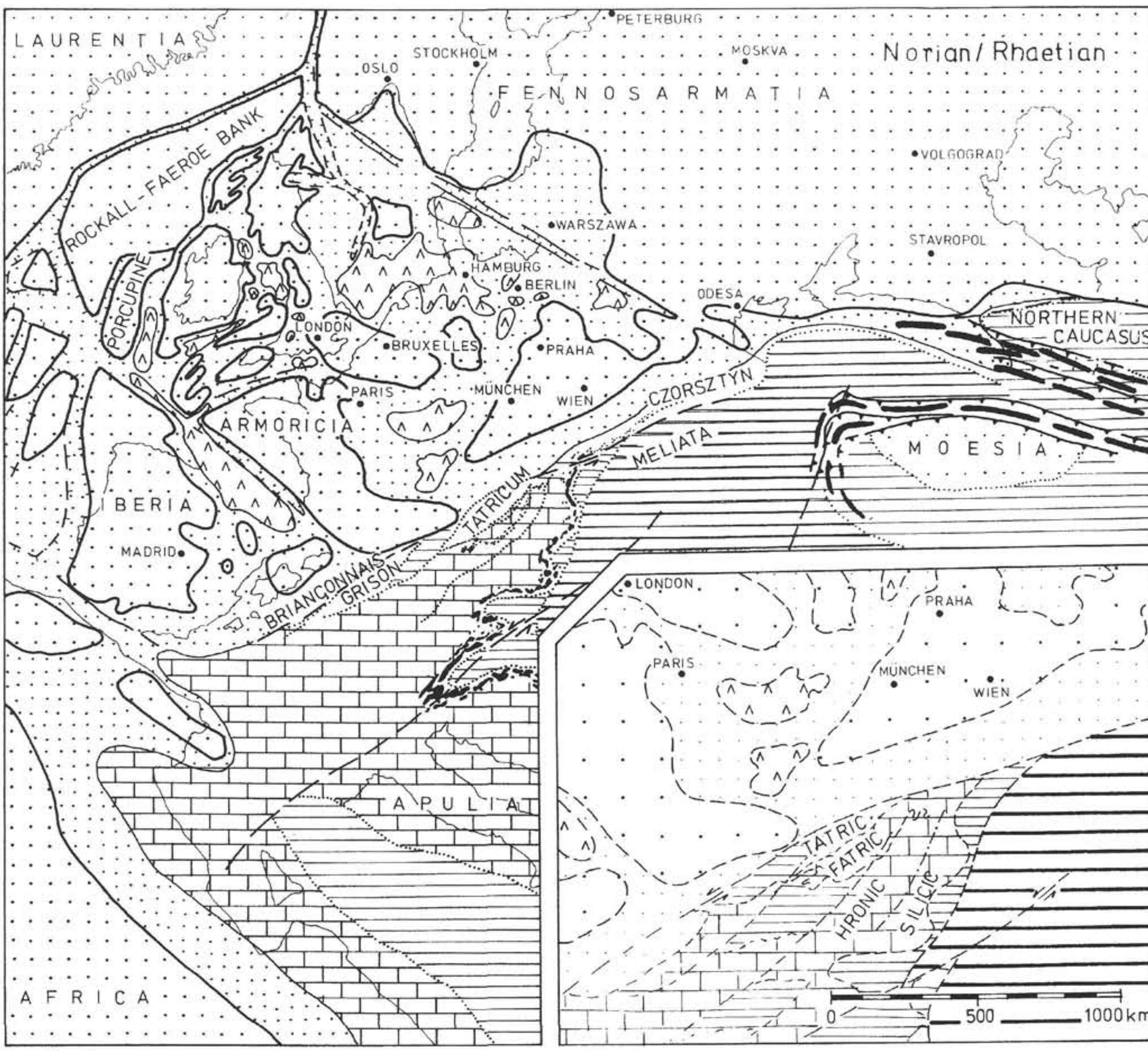
nate platforms started to differentiate. Initiation of a convergence of Palaeo-Tethyan margins during Ladinian caused a reorganization of the palaeogeography of the Western Carpathian area. The separation of the Alpine-Carpathian shelf fragment from the stable Palaeoeurope (as well as the separation of the Apulian shelf from Africa) and its east-southeast movement produced local rifts. Sedimentation rates in the rift zones attained relatively high values (400 mm/Ka). A few of them were accompanied also by volcanism (BRANDNER, 1984). Such a rift zone, associated with lateral transtension could be supposed between Northern and Southern Alps.

During the Late Pelsonian, traces of an accelerated mobility of the substratum have been recorded in carbonate platform sediments in the Western Carpathians. In the Fatric Zone, the Vysoký Limestone of the Malé Karpaty Mountains contains intercalations with sigmoidally bent structures of assumed tsunamic origin, indicating occasional earthquake activity along arising fault zones (MICHALÍK et al., 1992).

In the Hronic Zone, a more than one hundred meters thick body of carbonate megabreccia lies above the Pelsonian Gutenstein dolomites (MICHALÍK, 1979). The matrix of the breccia consists of fine cryptocystalline dolomicrite. Angular to subangular clasts attain 0,5 to 6 meters in diameter. They consist of dark mudstone, laminite and dolomitized pseudosparite and bituminous dolomicrite. This complex probably originated by slumping of little consolidated sediments into an arising depression along a tensional fault zone.

The sequence of dark bituminous limestone of the Zámostie Formation (KOCHANOVÁ & MICHALÍK, 1986) with a rich silicified fauna of Pelsonian/Illyrian age originated in semirestricted lagoonal depressions of small pull-apart basin type. The faunal association consists of neritic herbivorous gastropods, dentaliids, brachiopods and bivalves, accompanied by foraminifers, condontophorids and echinoderms. Their share depends on the distance from the open sea connection. The fauna of bars is poorer, consisting of pectenid bivalves and infaunal burrows.

While the transgression in the extra-Tethyan region continued, the sedimentation on the Tethyan shelves (with the exception of the Hallstatt area along its border) had a gene-



Text-Fig. 3.
Paleogeographic sketch map of Europe (a) and the Western Carpathian area (b) during the Triassic/Jurassic boundary interval.
Symbols as in Text-Fig. 1.

rally regressive character. The Ladinian and Lower Carnian carbonate platforms formed a wide belt, rimming the shelves. Biohermal carbonates accumulated along the border of these platforms and also along the rim of intraplatforms depressions.

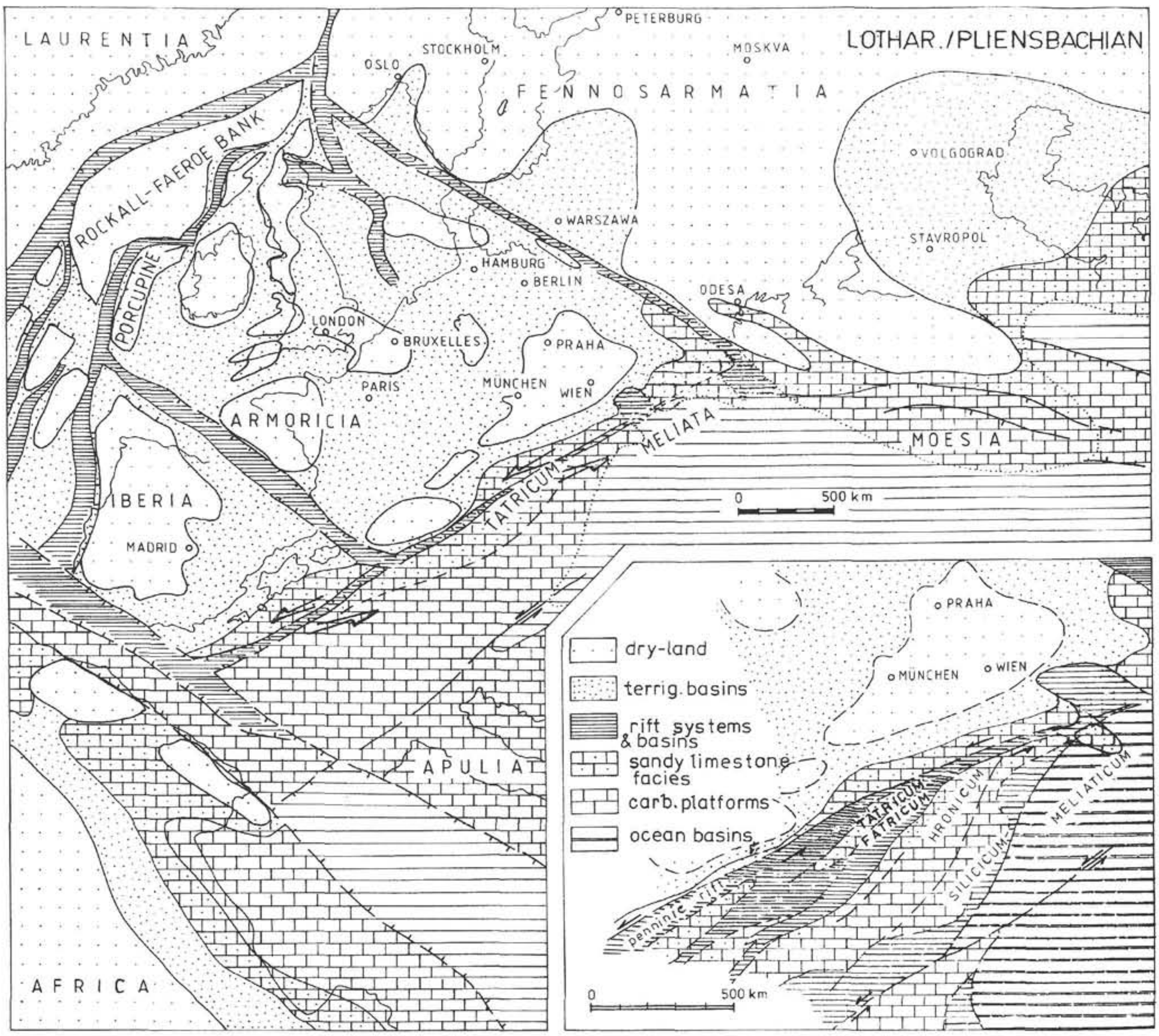
Eastward movement of the Apulian block caused tensional stress in the Alpine-Carpathian microcontinent. Intraplatform basins originated in a wide, shallow-marine carbonate platform system. The basins produced Reifling-, Buchenstein-, or Hallstatt Limestone Formations.

The transition between the platform carbonates and the superposed basins is usually sharp. Sometimes, it is accompanied by submarine volcanic products. The sedimentary rate of these structures was ten- to fifty times higher (500 to 700 mm/Ka) than those in the basins (4 to 14 mm/Ka, cf. MASARYK et al., 1993).

By such a way the bathymetry of these basins increased to thousand meters since the early Carnian. BECHSTÄDT et al. (1978) supposed open marine connections enabling passage for upwelling currents, bringing psychrosphaeric ostracods, radiolarians and other deep marine microfauna.

The Partnach marls and the siliceous Göstling Limestone were deposited in the deepest part of these basins. A substantial part of the bottom was covered by the "Knollenkalk" of a cherty Reifling Limestone facies (MASARYK et al., 1993). The slopes were characterized by the "Bankkalk" facies, with occasional calciturbidite intercalations (MICHALÍK et al., 1993). Progradation of the carbonate platforms caused gradual filling up of smaller basins by carbonate platform debris since the beginning of the Carnian.

During the Julian stage the arid climate in the northern hemisphere probably became more humid (VISSCHER & VAN DER ZWAAN, 1981). Large amounts of terrigenous sediments transported from the continent into the sea filled the remaining intraplatform depressions (Text-Fig. 2). The Reingraben-, or the Lunz Beds, up to 600 m thick have been deposited during 1 or 2 million years with a sedimentary rate of up to 500 mm/Ka!). VISSCHER & VAN DER ZWAAN (l.c.) interpreted the "Lunz event" by comparing it with the formation of a "Nile delta in a Carnian Sahara". HODYCH & DUNNING (1992) related the Julian humid or even glacial (SEFFINGA, 1988) event with a giant meteoritic impact in Labrador.



Text-Fig. 4.
Paleogeographic sketch map of Europe (a) and the Western Carpathian area (b) during the Early Jurassic time.
Symbols as in Text-Fig. 1.

However, the Middle Triassic intraplatform basins in the Alpine-Carpathian microcontinent filled by terrigeneous deposits were *covered* by *shallow water Hauptdolomit and* never renewed again.

5. Eo-Cimmerian Paleoenvironmental Changes

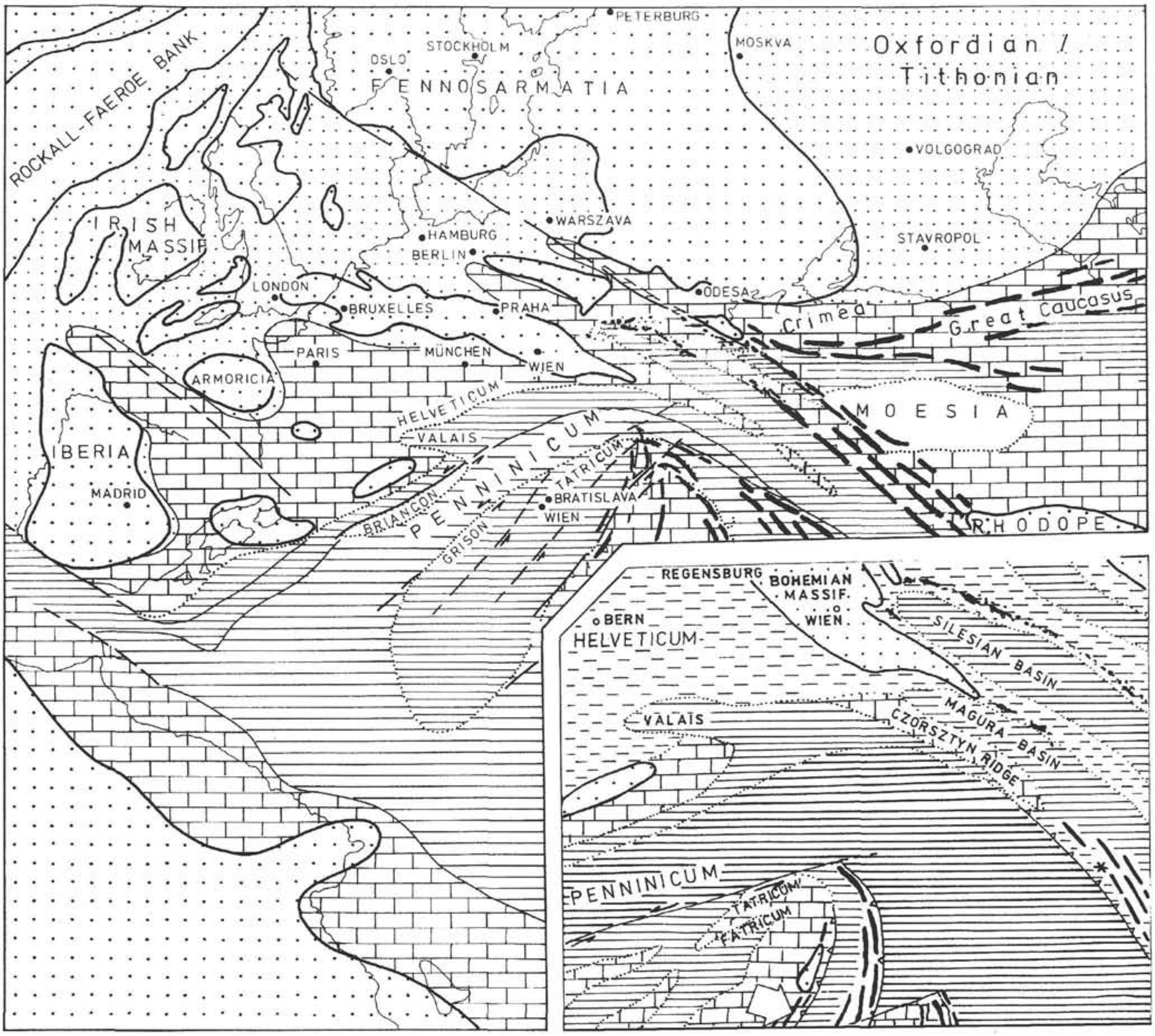
BOCCALETTI et al. (1984) suggested the opening of the Piedmont–Ligurian Ocean taking place along a megashear zone between the Teisseyre – Tornquist Line and the South Atlas during the Mesozoic evolution of the Neo-Europe. This motion resulted in the Eo-Cimmerian shortening of the Palaeotethys oceanic bottom. The direction of synsedimentary faults in the Fatric (MICHALÍK, 1978) was parallel with the "megashear" system (Text-Fig. 3). The motions connected with SENGÖR's *(1985) model of the fan-like closure of the* Palaeotethys resulted in the substitution of carbonates by the Carpathian Keuper sedimentation in the Alpine-Carpathian area (MICHALÍK & KOVÁČS, 1982).

In the Fatric Zone an isolated shallow basin formed that could be connected with the less restricted Alpine Kössen Formation (MICHALÍK, 1980; GOLEBIOWSKI, 1990).

The Fatra Formation basin was inhabited by a rich but monotypic fauna. The composition of faunal associations was directed by the physical properties of their restricted environment. The sedimentary record of the Fatra Formation denotes the cyclic character of environmental changes such as climate, basin dynamics and paleotectonics.

The paleogeographic pattern of the Mediterranean has changed abruptly during the T/J boundary (MICHALÍK et al., 1991b). The causes were both of paleodynamic and climatic character. Great amounts of fresh water supplied from the continents changed both the lithology of adjacent marine sediments and their fauna (MICHALÍK et al., l.c.). A left lateral strike slip fault separated the Alpine-Carpathian shelf fragment from the European shelf (Text-Fig. 4). The former shelf *fragment became an independent microplate* (VÖRÖS, 1984) enclosed by oceanic crust.

At this time, crustal stretching caused gradual subsidence of basins also in the West Carpathian area (MAHEL',



Text-Fig. 5.
Paleogeographic sketch map of Europe (a) and the Western Carpathian area (b) during the Late Jurassic time.
Symbols as in Text-Figure 1.

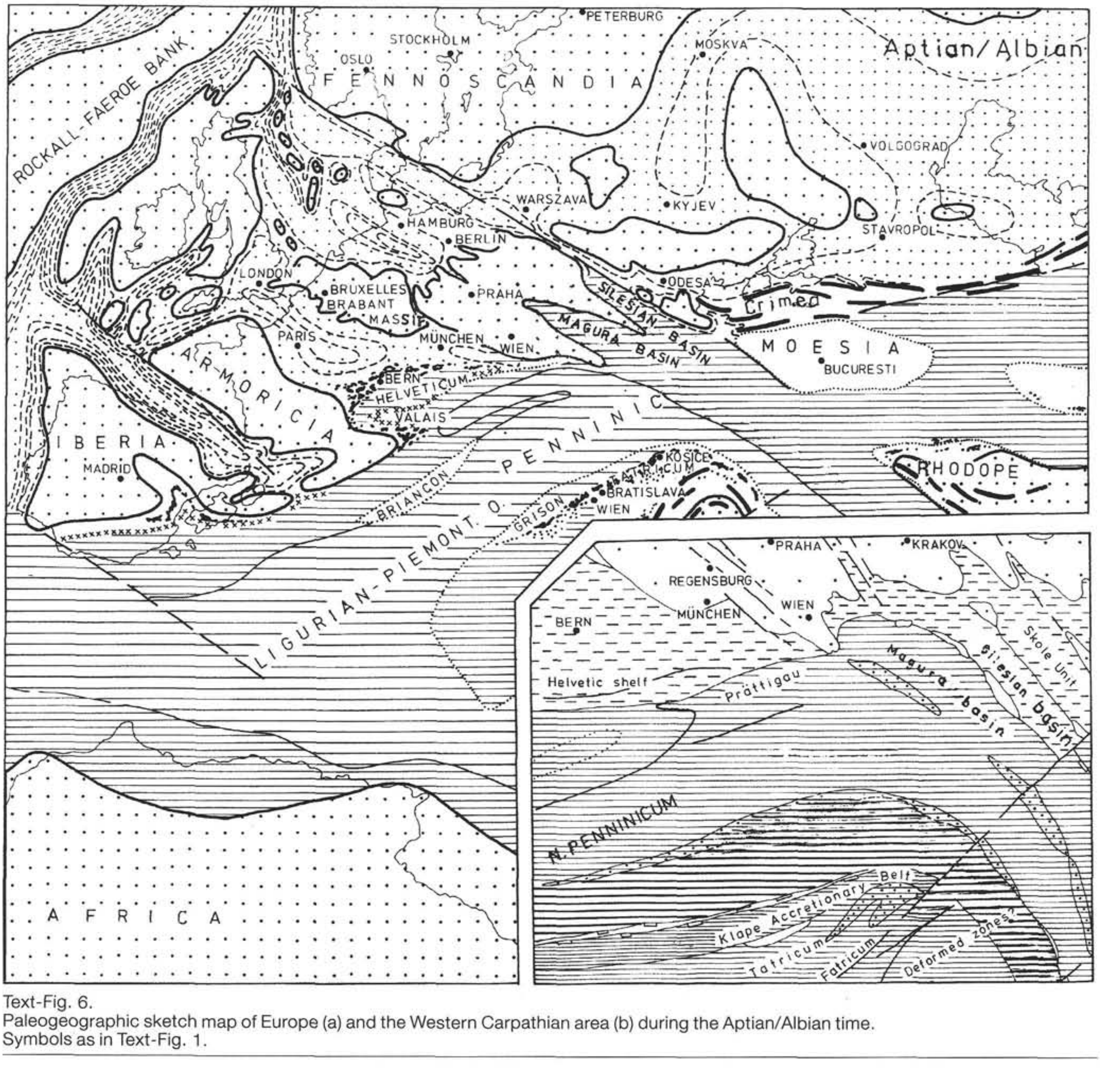
1979, 1980), the bottom of which sometimes subsided below the CCD.

Several types of continental margins can be recognized in the Mediterranean area during the Early Jurassic. A passive, Atlantic-type margin has developed in the West Alpine sector (TRICART, 1984). At the southern edge of the Palaeoeuropean craton the margin was of Californian type (KELTS, 1981). The southwestern edge of the East European Plate, where Palaeotethyan oceanic crust was subducted is a less typical collisional margin (MICHALÍK & MIŠÍK, 1987). Oceanic spreading during Jurassic in the Ligurian and later also in the "Californian" South Penninic sector (Text-Fig. 5) has lead to the creation of a new oceanic basin. This basin may have reached a width of almost a thousand kilometers.

The Eo-Cimmerian deformations expressively affected the regions of the Kopet-Dagh, Caucasus, Crimea and Dobrudja (SENGÖR et al., 1985). The separation of Triassic sequences is a striking feature not only in these folded areas, but also of the Outer Carpathian sequences including the Western Carpathian Klippen Belt. The central Carpathian Triassic carbonate sequences are terminated by the Late Triassic regression. The contact with the overlying Jurassic sequence is mostly erosional. In the Tatric Units (particularly in the Malé Karpaty Mts, (cf. PLAŠIENKA et al., 1991, or MICHALÍK et al., 1993) only erosional remnants of the Triassic sequence are preserved. Even this fact indicates a considerable rebuilding of the sedimentary area, where indications point towards block-breakage.

6. Neo-Cimmerian Paleogeographic and Paleotectonic Changes

Eastward movement of the Alpine-Carpathian shelf fragment and Apulia as well as their convergence with the Rhodope – Serbian – Marmarosh microcontinent resulted in a Neo-Cimmerian collision and reactivated the transverse troughs in cratonic Europe (Teisseyre – Tornquist Trough, Pyrenean Trough, Text-Fig. 3). The principal Neo-Cimmerian front was meridionally passing from the Taurides through the Hellenides and the Balkanides to Crimea. However, traces of slight Neo-Cimmerian deformations



Text-Fig. 6.
Paleogeographic sketch map of Europe (a) and the Western Carpathian area (b) during the Aptian/Albian time.
Symbols as in Text-Fig. 1.

have been recognized also in the Western Carpathians by MICHALÍK (1991) and in the Eastern Alps by TOLLMANN (1987).

Neo-Cimmerian deformations of the Carpathian shelf caused the extinction of Tithonian reefs, the origin of olistostromes in basins and the condensation of sedimentation in the Outer Carpathians, the origin of breccias in basins of the Central Carpathians (MICHALÍK et al., 1991, 1993) and probable a tectonic shortening in the innermost Carpathian zones (Text-Fig. 5). Analyses of tectonic structures in the Gemeric Units (GRECULA, 1982) indicate an expressive shortening of this area during the Neo-Cimmerian tectonic movements. Even the frequently discussed Silica gravity nappe system overlying the Meliata Unit could be well ascribed to these movements. It could be equivalent to the Hallstatt gravity nappe that slided during this period. These and other scarcely studied phenomena should be explained by a detailed stratigraphical and structural study.

7. Eo-Alpine Paleogeographic and Paleotectonic Changes

During the Early Cretaceous, the direction of the movement of the African plate and adjacent Mediterranean microcontinents changed to the north (KELTS, 1981; TRICART, 1984; etc.). The effects of tectonic rearrangement are noticeable during the Valanginian and Hauterivian evident by the deposition of the Rossfeldschichten in Alps (FAUPL & POBER, 1991) and the formation of tensional faults and Strážovce turbidites in the central Carpathians, cf. REHAKOVÁ & MICHALÍK in print). The deposition of a Barremian wildflysch in the Romanian Eastern Carpathians, chromium spinel rich Barremian limestone pebbles in the Mid-Cretaceous Upohlav Conglomerate, rich clastics in the Klippen Belt (MIŠÍK et al., 1981) or spinel-free turbidites of the Solirov Formation in the Tatric (JABLONSKÝ et al., 1993) proved the continuing dynamics of the substrate. The Barremian, Aptian and early Albian paleogeographic differentiation of the basin floors resulted from regional tension, accompanied by local basic volcanics, in the Alpine-Carpathian segment influenced the sea current direction and directed the growth of "Urgonian" carbonate platforms (Text-Fig. 6). During the middle Albian the collapse of the basinal bottom caused a complete substitution of the carbonate sedimentation by a terrigeneous depositional regime (SENKOVSKY, 1978).

The late Cenomanian/Turonian compressive movements affected not only a wide zone along the Palaeoeuropean Craton, but also several zones in its interior (ZIEGLER, 1980, 1982). These movements formed the nappe structure of the central Carpathians and the former prae-Styrian Alps (MAHEL', 1979, 1980). The Senonian rejuvenation of tectonic movements caused a rising of the central West Carpathian mountains and exposed them to tropical weathering. The vanishing Penninic oceanic basin (MAHEL' 1981) and frontal depressions in the foreland of nappe units have been the deposition places of thick accretionary prisms of wildflysch ("Klape Unit"). The main depocenters at this time were situated in the Outer Carpathians. Tectonic activity in this belt is recorded by the thick sequence of diastrophic sediments. Several thousand meters of flysch were deposited in subsided basins of this area until the Paleogene.

8. Conclusions

The Western Carpathians consist of two different parts. The outer West Carpathian area remained located between the Bohemian Massif and the mouth of the Polish trough. This segment has been affected by a Jurassic–early Cretaceous crustal shear. Subsequently, this area has been deformed and shortened during the Paleoalpine convergence and the Neoalpine collision with the the Central West Carpathian microcontinent.

The Central Western Carpathians together with the Austroalpine units represented a former part of the Paleoeuropean shelf. The Ladinian basins originated by tensional stress during strike-slip movements in this desintegrating shelf, followed by different sedimentary rates in the basins and along their borders. Tectonic movements ceased in the late Ladinian, allowing prograding reefs to fill considerable parts of intra-shelf depressions. The remnants of the depressions have been completely filled by rapid terrigenous influx during the Julian substage. The actual depth of these vanished basins could be determined to be in a range of a thickness of 1000 to 1200 meters.

During the early Jurassic this microcontinental block, located formerly to the SW of the Bohemian Massif, has been separated from this original place by a progressively widening Penninic trough. The central Western Carpathian block moved to the south-east since the Jurassic until the mid Cretaceous. Finally, northward movement of the African plate caused the Paleoalpine compression and the Neogene collision of this segment with its Outer Carpathian foreland.

The subsidence rate of these basins during orogenic "phases" was rather low, usually followed by a high sedimentary rate. Eo-Cimmerian movements in the Western Carpathians had mostly extensional effects. Compressional tectonics is indicated along the southern border of the Outer and Central Carpathians. Neo-Cimmerian movements in the Outer and the Central Carpathians were mostly extensional. However, the Inner Carpathians (= southern border in the contact with the former Meliata Ocean) were intensively deformed and uplifted. The Meliata Ocean was totally consumed. The "Proto-Silica" Nappe, similar to the Hallstatt Nappe of the Eastern Alps originated at this time.

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