Tectonic Evolution of the Tethyan Region

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TRIASSIC AND JURASSIC OCEANIC/PARAOCEANIC BELTS IN THE CARPATHIAN-PANNONIAN REGION AND ITS SURROUNDINGS

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ABSTRACT. Mafic/ultramafic rocks and associated oceanic/paraoceanic sediments of two ages occur in the Carpathian-Pannonian region. The older rocks indicate Middle Triassic rifting and spreading and occur in the Meliata unit of the Inner Carpathians, in the Transylvanides of the East Carpathians, and in the Vardar zone of the Dinarides and Hellenides. These localities can be united into a Middle Triassic-Late Jurassic Vardar ocean, forming the westernmost embayment of the Triassic Tethys ocean. The younger mafic/ultramafic rocks occur in the Penninic-Valais unit of the Alps, in the Pieniny Klippen Belt of the Carpathians, in the Bükk unit of the innermost West Carpathians, in the Mecsek unit of the Pannonian region, in the Mureş ophiolite belt of Apuseni Mts., in the Black flysch nappe of the East Carpathians and in the Severin nappe of the South Carpathians. These indicate rifting and/or spreading starting in late Early Jurassic. Most of these localities can be united in a Middle Jurassic-Early Cretaceous "Penninic" oceanic zone. Consequently, in the Carpathian-Pannonian-Dinaride region the Jurassic "Penninic ocean" lay to the north of the Triassic Vardar ocean. Its opening was most likely caused by the interaction of the opening of the Atlantic and back-arc basin formation connected with Vardar subduction.

1. INTRODUCTION

The Carpathian-Pannonian region is dissected by major fault systems /Fig. 1/ into distinct blocks of very different history. This area provides the key to trace the continuation of Alpine ophiolitic belts eastward towards the Dinaride-Hellenide system. In the Pannonian basin the

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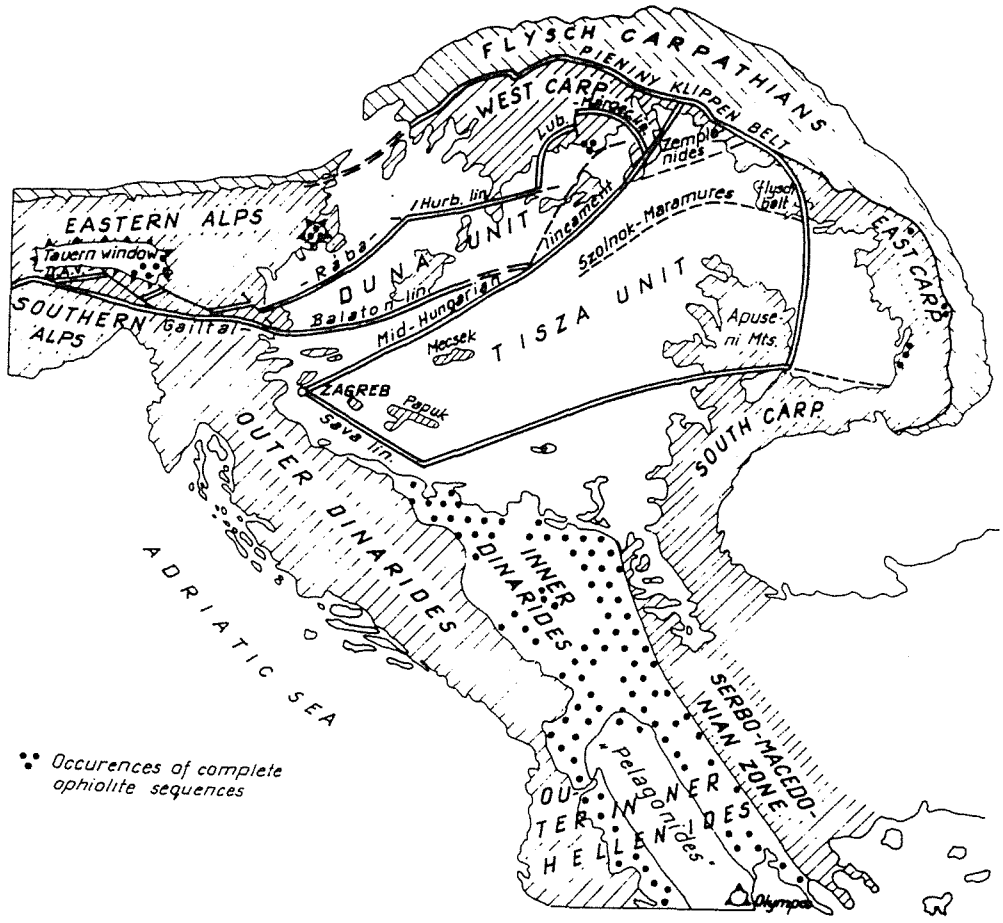

Fig. 1. Tectonic sketch of the pre-Neogene basement of the Pannonian basin. with occurrences of complete ophiolite sequences. The major tectonic lineaments are indicated. "Pelagonian zone" includes the Flamburion, Almopias and Kastoria nappes /Papanikolaou, 1984/. DAV = Defereggental-Anterselva-Valles Lineament; Lub.-Marg. = Lubeník-Margecany Lineament.

Triassic Vardar ocean, which opened to the SE and the Jurassic Penninic one, which opened to the W and was generated by the opening of the Atlantic /Frisch, 1977/ overlap each other. Their closure in the Late Jurassic /in the Vardar ocean/, and in the Middle-Late Cretaceous /in the "Penninic oceanic belt" sensu lato/ also overlap each other. Complete ophiolite sequences between the easternmost tectonic window of the Alps /the Kőszeg-Rechnitz window/ and the Vardar zone are only known in the Meliaticum of North Hungary and Southern Slovakia /Réti, in press; Hovorka et al., 1984/ and in the Transylvanides of the East Carpathians /Săndulescu et al., 1981; Săndulescu and Russo-Săndulescu, 1981/. All of these represent the Triassic Vardar ocean /Fig. 1/.

A large number of deep boreholes have proven the continuation of the nappe structure of the Apuseni Mts. in the basement of the Great Plain in Hungary /Balázs et al., 1985/. Major discontinuities dissect the territory of Hungary into fragments of quite different history and facies affinity. It is now evident, that the heterogenous block structure of the Pannonian basement /Fülöp and Dank, 1985/ is due to Late Jurassic to Early Miocene horizontal displacements. By taking into account the sharp facies differences among adjacent blocks and their facies relationships, the original palaeogeographic situation can be reconstructed approximately.

In this paper we used the map of Hungarian data /Fülöp and Dank, 1985/ in the reconstruction of the Vardar and Penninic oceanic systems. For the Romanian Carpathians the following papers were mostly used: Guidebooks of the 12th CBGA Congress, Bleahu /1976/, Cioflica et al. /1980/, Ianovici et al. /1976/, Săndulescu /1980/, Lupu /1984/; for the West Carpathians: Andrusov et al. /1973/ /with the exception of the South Gemeride area/, Andrusov /1975/, Birkenmajer /1963, 1985/, Mišík and Sýkora /1981/, Unrug /1984/; for the Dinarides: Karamata et al./1980/, Pamić /1983/ among others.

2. MIDDLE TRIASSIC-JURASSIC OCEANS /VARDAR SYSTEM/ /Fig.2/

The Vardar oceanic system formed the northwesternmost embayment of the Triassic Tethys ocean /Şengör, 1984/. Rifting, as evidenced by red, pelagic, Hallstatt-type limestones and some volcanic rocks, started in the Late Scythian in the Hellenides /Jacobshagen, 1972/. It became gradually younger towards the NW, but not younger than Middle Anisian /Kovács, 1985/. The ophiolites are distributed in two belts /Vardar and Subpelagonian belts/. However, it is now accepted by most authors that all these

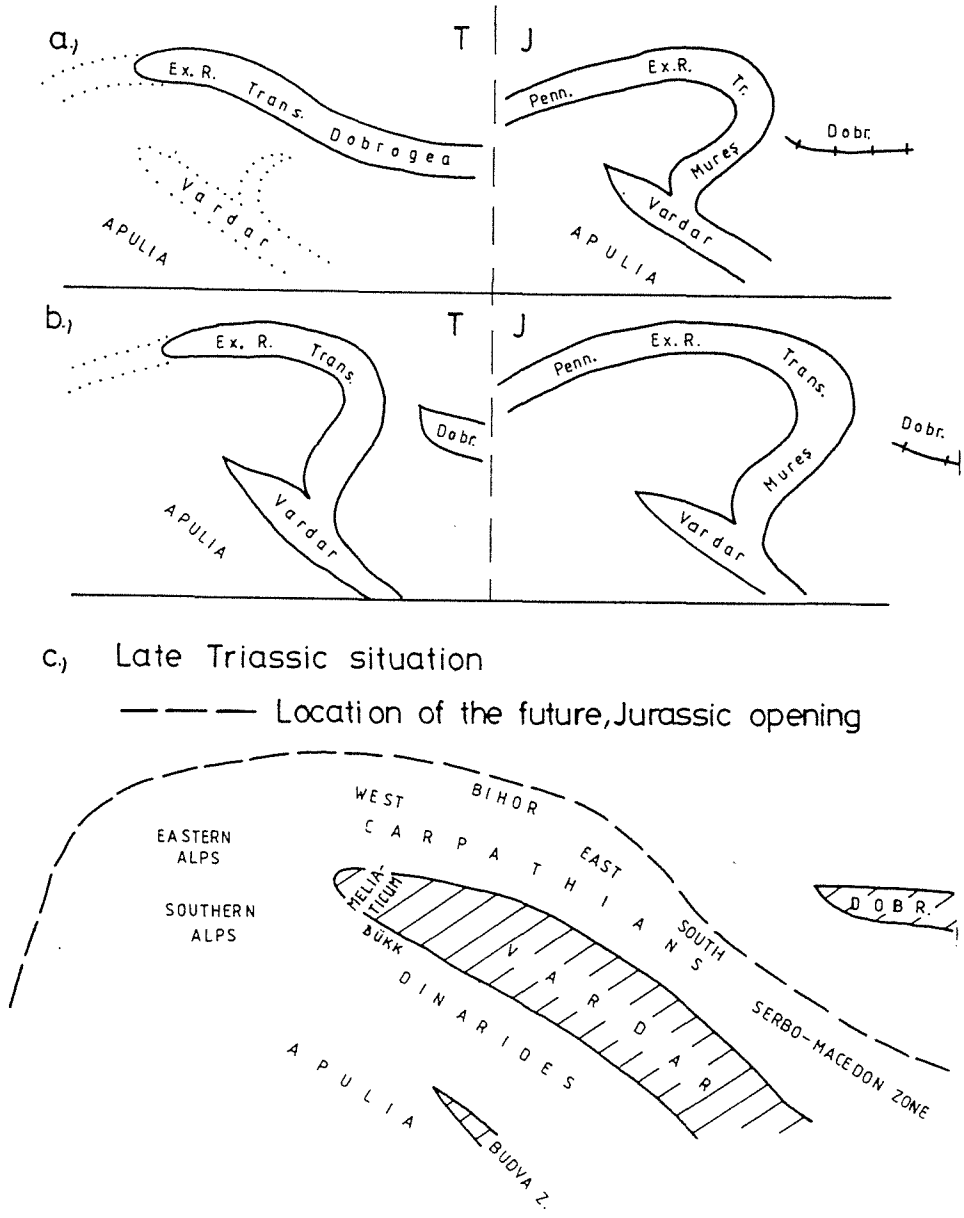

Fig. 2. Review of concepts on the connections of oceanic zones in the Carpathian-Pannonian region. a/ Single Triassic ocean, developing into single Jurassic ocean after Late Triassic closure of Dobrudja /Herz and Savu, 1974; Kozur, 1979/. b/ Single Tethys ocean: Triassic rifting in the east, Jurassic rifting in the west. Dobrudja is inde-

ophiolites /at least in Greece/ originated from the Vardar zone proper, while the western belt constitutes a large ophiolite nappe only /Papanikolaou, 1984/. Sedimentation continued in pelagic, deep-water carbonate and radiolarite facies during the rest of the Triassic.

The Transylvanides of the East Carpathians originally belonged to this oceanic embayment /Săndulescu, 1980/ as did the Meliaticum and related deep-water Triassic formations in North Hungary and Southern Slovakia /Kovács, 1985; Réti, in press/ and the Pieniny Exotic Cordillera /Kázmér and Kovács, in preparation/. Their present isolated position is due to later oblique-slip and rotational movements of different blocks in the basement of the Pannonian basin.

In North Hungary and Southern Slovakia small tectonic units bear Triassic deep-water formations and mafic/ultramafic rocks. These are bordered to the west, north and east along major faults by Central West Carpathian units featuring pre-Alpine crystalline basement and Triassic shallow marine cover. To the south lies the Bükk unit, also featuring shelf-type Triassic formations, here of Dinaric character. The existence of a southwestern Triassic seaway connecting the Bükkium with the Dinarides, reviewed by Kovács /1982/ has been disproven. Drillings along its supposed location between the Balaton and Mid-Hungarian lineaments yielded shallow marine Triassic rocks related rather to the Transdanubian Midmountains in Hungary and the region of the Sava folds in Yugoslavia, both forming the northern border of the postulated seaway, than to the Bükk unit /Brezsnyánszky and Haas, 1985; Kázmér, 1986/. The isolated position of the Triassic deep-water rocks

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Fig. 2. /Continued/ -pendent of this system /Săndulescu, 1980, 1983, 1984; Lupu, 1984/. c/ The model discussed in this paper: the Triassic Vardar rifting and the Jurassic Penninic rifting are two superimposed steps in Western Tethyan evolution. The Vardar ocean has been opened in Middle Triassic, containing the Meliata zone of Northern Hungary and Southern Slovakia and the Vardar zone in Yugoslavia and Greece. The surrounding Carpathian, Alpine and Dinaric units are arranged according to the Norian facies reconstruction of Kovács /1982/. The Eastern Alpine - Carpathian - - Serbo-Macedonian region form a single unit adjoining Europe and forming the northern margin of the Tethys. Dobrudja formed a separate extensional basin with thinned continental crust and mafic volcanism. Ex. R. = Pieniny Exotic Ridge; Trans. = Transylvanides; Penn. = Penninic; Dobr. = Dobrudja.

and associated mafic/ultramafic formations is interpreted by large-scale strike-slip faulting connected with the eastward continental escape of the Bakony unit /Transdanubian Midmountains/ /Kázmér, 1984/. This Palaeogene displacement removed the North Hungarian-Southern Slovakian Triassic deep-water formations from their original position at the NW termination of the Vardar zone /Kovács, 1985/. Palaeogeographic evidences of these displacements are discussed by Kázmér and Kovács /1985/ and Kovács /1985/. The North Alpine deep-water Triassic Hallstatt facies belt /Salzberg facies/ /Plöchunger, 1976/ formed only an extension of the Vardar ocean on thinned continental crust.

Pelagic Triassic rocks, mafic and ultramafic magmatic rocks and glaucophane are known in Albian-Maastrichtian conglomerates in the Pieniny Klippen Belt and south of it. These are derived from the hypothetical Pieniny Exotic Ridge /Mišík et al., 1977; Mišík and Sýkora, 1981/. However, because the first sign of their presence are the pebbles in Albian conglomerates, there is no evidence for the pre-Albian history of the Exotic Ridge. Mišík et al. /1977/ supposed the existence of another Triassic oceanic trench north of the nearshore sediments of the autochthonous High Tatric Triassic cover. Due to the shortcomings of this model we propose an alternative one /Kázmér and Kovács, in preparation/. We suggest that the Pieniny Exotic Ridge was part of the northern margin of the Vardar ocean. Following the Late Jurassic final closing of Vardar, fragmentation and horizontal motions brought it to the neighbourhood of the Pieniny Klippen Belt before Albian time.

Closure of the Vardar ocean started in the Early or Middle Jurassic, as witnessed by the olistostromes in the "diabase-chert formation" of the Inner Dinarides and by the 170-160 m.y. radiometric age of the emplaced ophiolite bodies /Karamata and Lovrić, 1978/. Collision occurred by the end of the Jurassic /"Eohellenic phase" of Jacobshagen et al., 1976/, and is marked by the appearance of shallow-water carbonates in the Inner Dinarides, Transylvanides and Inner West Carpathians. The northwesternmost manifestation of this tectonic activity was the emplacement of Hallstatt nappes over the marginal Dachstein platform in the Northern Limestone Alps /Plöchinger, 1976/.

The Jurassic subduction of the Vardar ocean s. str. formed several marginal seas along its margins /Fig. 3/. At its westernmost end the Bükk unit of northern Hungary /now displaced by subsequent strike-slip faulting/ contains Jurassic tholeiitic basalts and gabbros indicating the opening of a marginal sea /Balla et al., 1983/.

The Mureş zone was another marginal sea /South Apuseni Mts./; its opening began in the Callovian, forming two marginal seas and an island arc /Lupu, 1983/. This zone

occupied the whole southern margin of Tisza unit, from Apuseni Mts. in Romania /Lupu, 1983/ to Vojvodina in Yugoslavia /Čanović and Kemenci, 1975/.

The marginal sea of the Sumadija zone opened in Late Jurassic time producing mafic/ultramafic magmatic rocks. Based on stratigraphy and petrography a direct connection to the Mures zone is outlined by Andelković and Lupu /1967/.

3. JURASSIC-CRETACEOUS OCEANS /PENNINIC SYSTEM/ /Figs. 3-4/

The opening of the Jurassic-Early Cretaceous Tethys was initiated by the opening of the Atlantic /Frisch, 1977/. The earliest /Middle Jurassic: Trümpy, 1985/ oceanic zone of the Piemont region extended to the east not farther than the presen-day Rechnitz-Kőszeg window /Koller and Pahr, 1980/. The Brianconnais ridge separating it from the Valais zone did not extend even as far as to the Engadin window /Oberhauser, pers. comm., 1985/, so the separation of the two oceanic belts is problematic. The Valais zone is mostly of paraoceanic character. It is connected to the Outer Carpathians and, farther east, to the Outer Dacides /until the Niš-Trojan unit/, where, with the exception of the Severin nappe, no ultramafic rocks are known. The mafic rocks are usually associated with black shales /schistes lustrés facies: Isler and Pantic, 1981/.

In the Carpathian-Pannonian region the situation is more problematic. While detailed interpretations exist for individual oceanic or paraoceanic zones, their connections to one another have not been established.

Possible connections between the oceans of the Alps and the West Carpathians are given by Birkenmajer /1977/. More recently he introduced an interpretation with three oceans /Birkenmajer, 1985/. Evidence for the northern Silesian ocean is based on the presence of alkali mafic rocks /teschenites/. In the middle ocean, the Magura basin, no mafic rocks are known /except some cineritic tuff intercalations at Piana Botizei, Romania/. Evidence for the southernmost ocean of the Pieniny Exotic Ridge is based on exotic pebbles; however, the autochthonous position of the source rocks /Mišík et al., 1977/ is highly disputable /Kázmér and Kovács, in preparation/.

Deep-water sediments of Middle Jurassic age and younger, including radiolarites, are known in the Pieniny Klippen Belt /Birkenmajer, 1977/. Their similarity with the Mecsek unit of the Pannonian region has been recognized by Birkenmajer /pers. comm., 1983/ and by Kázmér et al. /1984/.

No volcanism is known in the Pieniny Klippen Belt but in the Mecsek unit a large volume of alkaline basalts

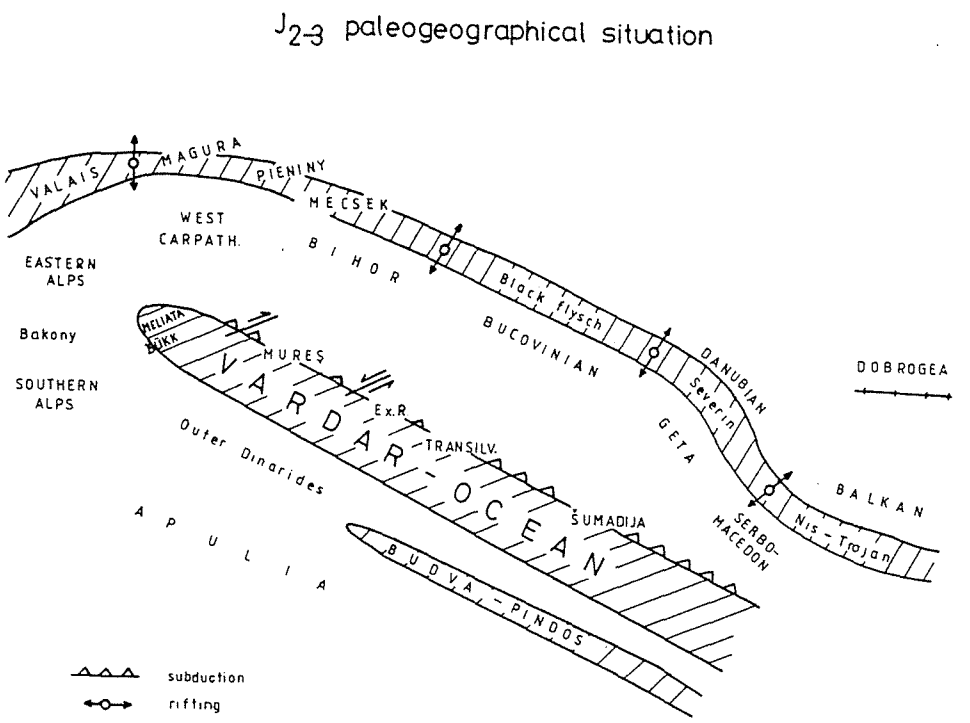

Fig. 3. Middle to Late Jurassic palaeogeographical situation. The Vardar ocean began to subduct below its northern margin during the Jurassic. Contemporaneously began the Penninic rifting of the Valais-Magura-Pieniny--Mecsek-Black flysch-Severin-Niš-Trojan zone, producing troughs either with oceanic or with thinned continental crust. The Eastern Alps - Carpathians /including Bihor, Bucovinian, Geta/ and Serbo-Macedonian units of normal continental crust formed a continuous zone between the two oceanic zones

are known in Hungary /Juhász and Vass, 1974/ and in the Soviet Union /Dolenko et al., 1980/. These are interpreted as products of continental rifting /Bilik, 1983/. The volcanism began not later than Oxfordian time /Főzy et al., 1985/ and culminated in Valanginian time /Bilik, 1974/.

The Black flysch nappe in Maramureş /East Carpathians/ contains Tithonian basaltic volcanics interpreted as products of intracontinental rifting /Russo-Săndulescu and Bratosin, 1985/. The East Carpathians contain a Tithonian-Barremian flysch, the Sinaia beds in the Ciuc digitation of the Ceahlau nappe /Săndulescu et al., 1981/; although no mafic rocks are present, this might be considered as direct continuation of the South Carpathian, ophiolite-bearing Sinaia Flysch of the Severin nappe /Săndulescu, 1980/.

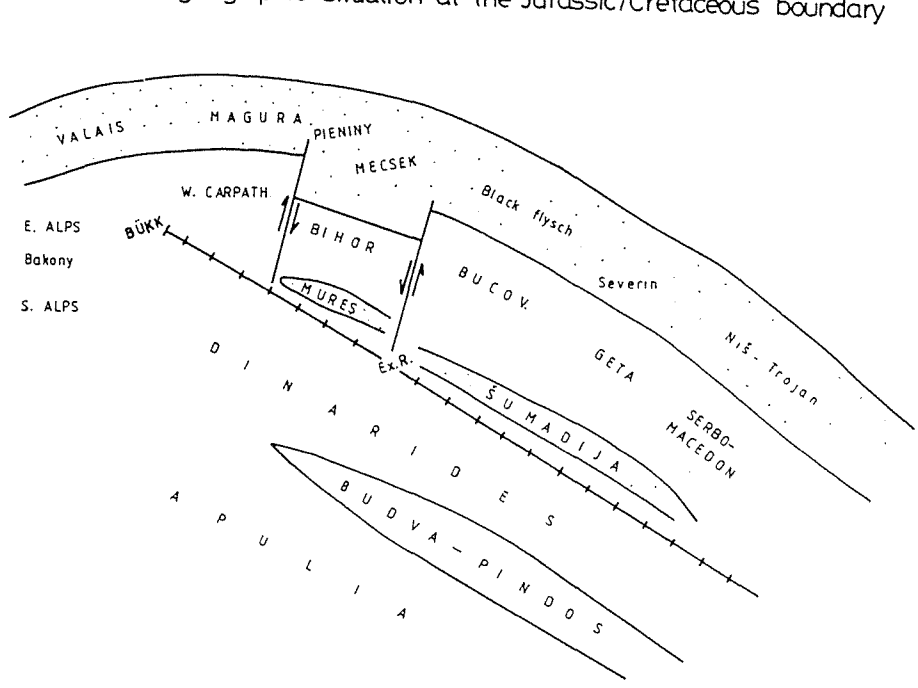

Fig. 4. Palaeogeographic situation at the Jurassic/Cretaceous boundary. The Vardar ocean had been closed during latest Jurassic, forming the marginal basins of Bükk /its dimensions are not known/, Mureș and Šumadija. The Pennic oceanic/paraoceanic zone from Valais to Niš-Trojan has reached considerable extension. The Eastern Alpine - Serbo -Macedonian continent is dissected by strike-slip faults.

The Severin nappe contains a complete pre-Late Tithonian ophiolitic suite of ocean-floor origin /Cioflica et al., 1981; Savu, 1985/. A continuation of this unit is found in Yugoslavia: the Kiloma basalts in schistes lustrés are of Late Jurassic/?/-Early Cretaceous age TGrubic and Ercegovac, 1983/.

A possible continuation of the Severin ocean to the southeast might be the Niš-Trojan trough, which is an extensional basin containing thick Tithonian-Berriasian flysch sediments /Hsü et al., 1977; Nachev in Adamia, 1984/. No mafic volcanic rocks of this age are known in Bulgaria.

In summary, we think that the oceanic/paraoceanic belt from the Valais zone through the Magura/Pieniny, Mecsek, Black flysch, Ceahlau and Severin zone to the Nis--Trojan unit was not a continuous ocean. It was rather a chain of extensional basins, partly underlain by oceanic

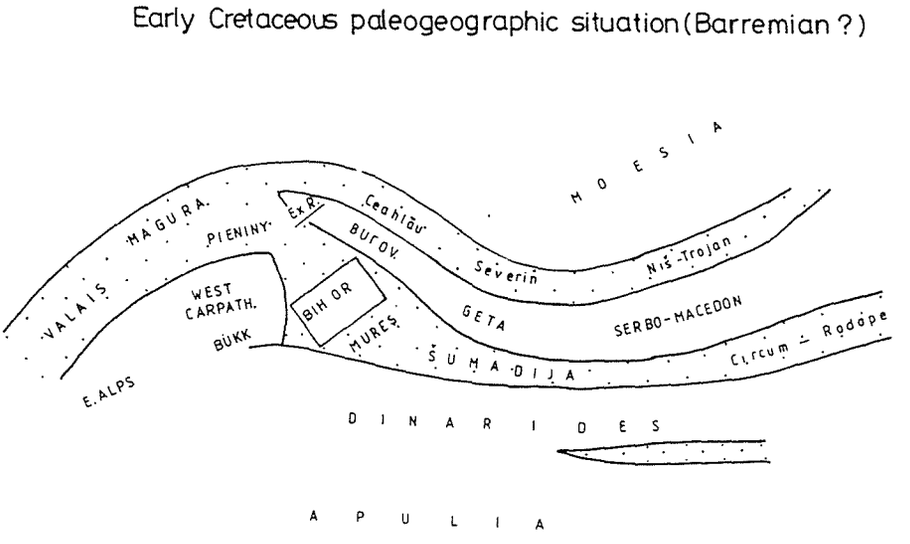

Fig. 5. Early Cretaceous /Barremian?/ palaeogeographic situation. The former East Alpine - Serbo-Macedonian continent, dissected by strike-slip faults, has suffered considerable displacements. The promontory of the Pieniny Exotic Ridge /showing Transylvanian, i.e. Vardar characters/ is being introduced between the Pieniny basins and the Central West Carpathians.

crust /Valais, Severin/ and partly by thinned continental crust /Magura-Pieniny, Mecsek, Black flysch, Ceahlău, Niš--Trojan/. These basins were separated and/or connected by transform faults similar to those outlined by Weissert and Bernoulli /1985/ in the Swiss Alps. However, these formed an oceanic/paraoceanic belt /the Penninic ocean s.l./ independent from the Vardar ocean and its marginal seas. These basins are similar in their age of opening: Late Jurassic to Earliest Cretaceous, and their age of closure: Middle to Late Cretaceous. During the beginning of this interval the Vardar ocean was being closed.

4. EMPLACEMENT OF THE PIENINY EXOTIC RIDGE /Figs. 5-6/

This problem is reviewed here only briefly; a detailed discussion will be published elsewhere.

The palaeogeographical model outlined in this paper offers an explanation for the origin of Transylvanide /i.e. Vardar/ type exotic pebbles /ophiolitic rocks, Triassic deep-water carbonates, glaucophane bearing rocks, etc./ in the Albian and younger flysch deposits of the Pieniny

Middle Cretaceous (Albian) paleogeographic situation

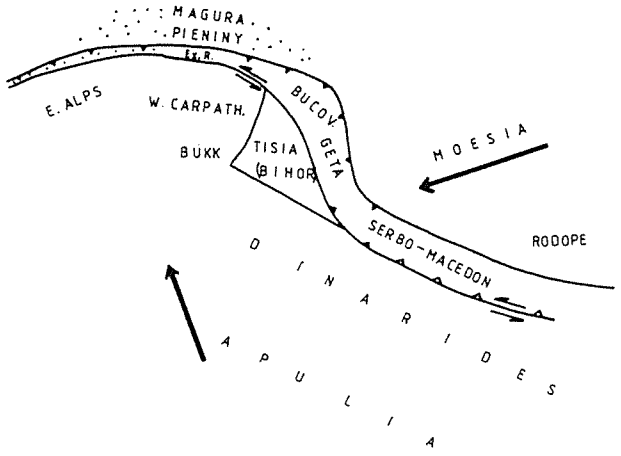

Fig. 6. Middle Cretaceous /Albian/ palaeogeographic situation. The Mureș - Sumadija zone and the Penninic zones from Magura to Niš-Trojan have been closed due to NW motion of Apulia and W motion of Moesia. Sedimentation in the East Alpine and Carpathian flysch region continues. The Pieniny Exotic Ridge /Ex. R./ occupied its presen position between the Pieniny sedimentary basins and the central West Carpathians.

Klippen Belt and external Central West Carpathian units.

By the closure of the Vardar ocean at the end of the Jurassic the East Alpine - Serbo-Macedonian microcontinent was fragmented by transverse faults. These were formed contemporaneously with the formation of the marginal seas. The most important ones bordered the Bihor unit /Fig. 4/ to the east and west, and separated it from the adjacent units. The Bihor unit /Mecsek, Villány and Apuseni Mts./ suffered considerable counterclockwise rotation during Early Cretaceous time /Márton, 1985/. Its immediate eastern neighbour, containing the remnants of the closed Vardar ocean passed the Bihor unit to the north /Fig. 5/ and began to shed detritus in Albian time into the Pieniny basins and into the basins of the external Central West Carpathians. This hypothesis /Kázmér and Kovács, in preparation/ resolves the contradiction of the occurrence of Vardar-type /internal/ detritus in the external zones of the West Carpathians.

5. CONCLUSIONS

1/ The westernmost termination of the Tethys consisted of: a/ the Vardar zone, which opened in the Middle Triassic, and closed in the Late Jurassic, and its marginal seas: the Bükk, Mures and Sumadija zones, which opened in the Jurassic and closed in the Middle Cretaceous, b/ and the Penninic zone, including the Valais, Magura, Pieniny, Mecsek, Black flysch, Ceahlău, Severin and Niš--Trojan zones, which opened in the Late Jurassic-Early Cretaceous, and closed in the Middle Cretaceous or later.

2/ The tectonic units from the Eastern Alps through West Carpathians, Bihor, East Carpathians, South Carpathians to Serbo-Macedonian unit formed a continuous unit corresponding to the northern margin of the Vardar ocean until Early-Middle Jurassic time. By Late Jurassic--Early Cretaceous time Penninic rifting formed a microcontinent or peninsula /this is supported by palaeobiogeographic data of Vörös, 1977/.

3/ The breakup of this microcontinent by strike-slip faults during Early Cretaceous finally resulted in the emplacement of the promontory of the internal Pieniny Exotic Ridge in between the external units of the West Carpathians.

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