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The Oceanfloor Puzzle of the Alpine-Carpathian Orogenic Belt

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Alps
Carpathians
Ophiolites
Ocean Floor
Isopic Zones

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Das Ozeanboden-Puzzle des alpin-karpatischen Gürtels

Zusammenfassung

In den Alpen und Karpaten treten mehrere Bereiche mit ozeanischer oder paraozeanischer Kruste auf. Sie unterscheiden sich voneinander in ihrem Entstehungsalter, ihrer tektonischen Position und ihrem Abstand von der Europäischen Platte. In einem Überblick wird gezeigt, dass gegenwärtig noch unüberbrückbare Diskrepanzen vorhanden sind, was ihre Anzahl, Position und laterale Fortsetzung betrifft. Das ist hauptsächlich durch die auf lange Distanzen hin fehlenden Aufschlüsse bedingt. Das hat zu sehr unterschiedlichen paläogeographischen Rekonstruktionen und Modellen des Alpen-Karpaten-Bogens geführt. Während über die verschiedenen kontinentalen Fragmente und Plattformen und ihre faziellen Charakteristiken weitgehende Übereinstimmung herrscht, wird die Südgrenze der Europäischen Platte entlang verschiedener Suturlinien gezogen.

Es lässt sich zeigen, dass während der Trias und des frühen Jura das Austroalpin und seine karpatischen Äquivalente den Südrand der Europäischen Platte gebildet und somit am Nordufer des Tethys-Ozeans gelegen haben. Erst später, vom mittleren Jura bis zur frühen Kreide, fand die Abtrennung des Austroalpinen und Liguro-Penninischen Raumes von Europa statt.

Abstract

In the Alps and Carpathians several oceanic/paraoceanic areas can be distinguished. They differ from their age of rifting, position and distance from the external European plate. In an overview is shown that great unbridgeable differences are existing concerning number, position and lateral continuation of the former ocean floors which is depending mainly on the discontinuity of the outcrops. This has led to very different paleogeographic reconstructions and models of the Alpine-Carpathian fold belt.

About the different continental platforms, their distribution and facies characteristics has been reached a high degree of consent, but the southern limit of the European plate is drawn along different suture lines. It is shown that during the Triassic the Austroalpine and inner Carpathian realms have formed the southernmost part of the European continent and therefore Tethys northern strand. Later a separation of the Austroalpine and Penninic domains from Europe took place during Jurassic and early Cretaceous times.

1. Introduction

During the last decades earth sciences not only accumulated a wealth of new geologic data on the Alpine-Carpathian folded belt but also developed a very high variety of interpretations. Noteworthy differences appeared for example in the way where the tectonic units of the Eastern Alps are extending eastwards, how and where the boundaries of the European plate can be drawn, how many terranes or microplates are situated north of the

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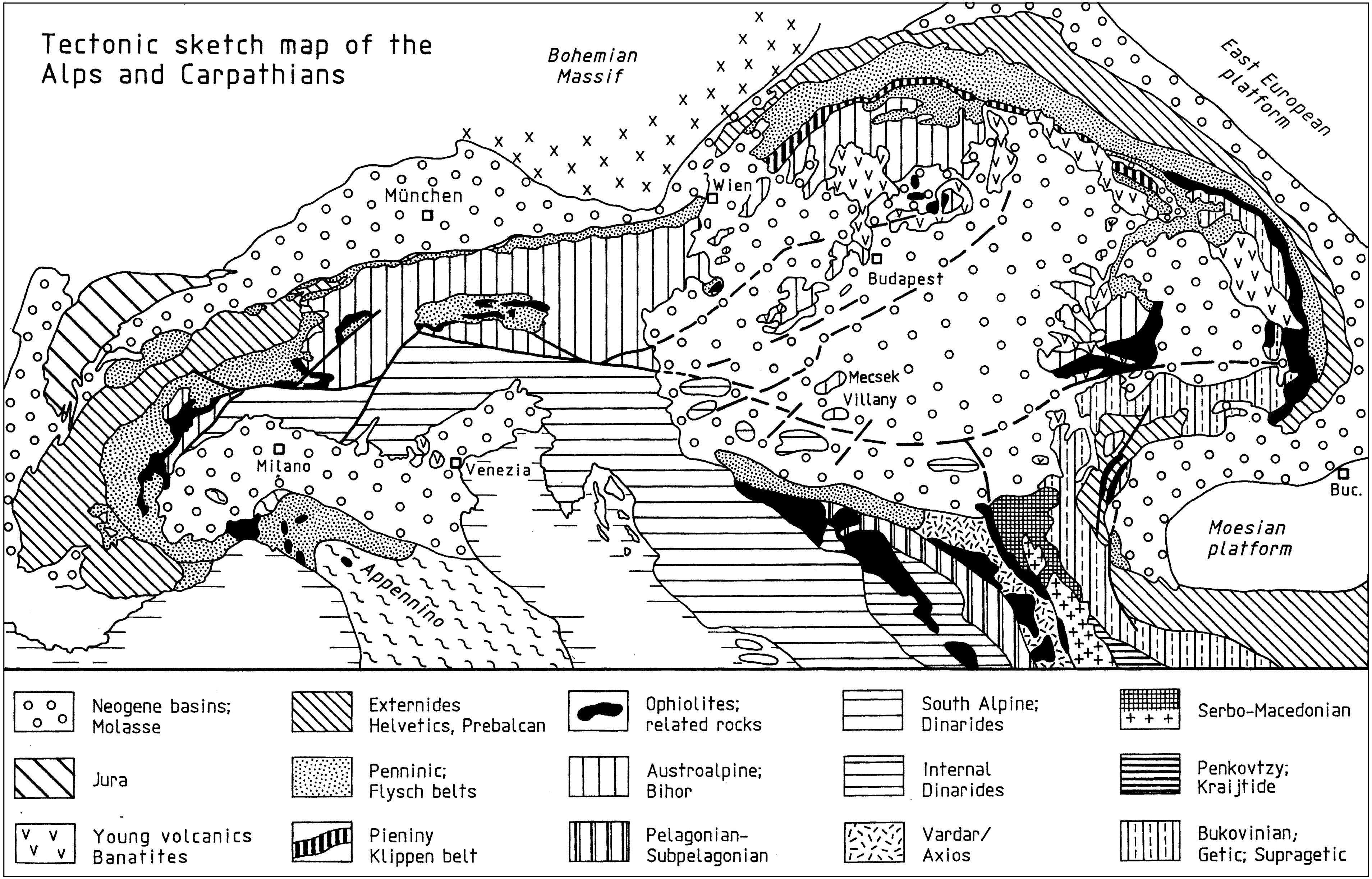


Text-Fig 1.
Tectonic sketch map of the Alps and Carpathians.

Gondwana margin and how many oceanic crust domains have been opened south of the European plate.

The aim of this paper is to summarize the main ideas which have been discussed so far in the literature to compare them and then to try to find some solutions or at least to suggest other possibilities of interpretation.

The following main features will be taken into consideration:

a) the oceanic crust bearing tectonic units and their correlation;
b) the main mesozoic isopic facies domains;
c) the problems of the plate boundaries between Africa und Europe.

2. Areas with an Oceanic Crust

A look into the literature of the last decade reveals some significant differences between the Western and Eastern Alps on one side and the West Carpathians and their continuation into the Romanian East and Southern Carpathians on the other.

Obviously there are some significant differences in the opinions about the number and prolongation of oceanic crust areas and suture zones in the Western and Eastern Alps on one side and the West Carpathians and Romanian East and Southern Carpathians on the other.

2.1. Western Alps East of the Rhine Valley

In the Franco-Swiss sector of the Western Alps two areas are known where an oceanic crust is very probable (North Penninic or Valais belt in the north) or ascertained (South Penninic or Piemontais belt in the south). But not all authors agree about the existence of two oceanic belts in the Swiss sector of the Alps. While a majority is favoring a solution with two oceans (e.g.TRÜMPY, 1988; FROITZHEIM et al., 1995), STAMPFLI (1994) is advocating the existence of a single Penninic ocean in the East. According to TRÜMPY (1988) and others the north Penninic Valais zone is widening eastwards and opening into a truely oceanic area and becomes the main Penninic ocean. Unfortunately east of the Lower Engadine window the continuation of the Penninic zone is covered by Austroalpine nappes and therefore an eastern continuation of the Valais zone into the Tauern window is highly controversial and cannot be proved by field observations. There is also no compelling reason why the Valais trough should open more to the East.

Several options are open for discussion to solving the problem of the prolongation of the Penninic domain to the East:

a) There is only one main Penninic ocean East of the Engadine window (model of STAMPFLI, 1994; EGGER, 1992) which continues eastwards into the Carpathians.
b) There are two Penninic oceanic areas in the West and only the north Penninic ocean continues eastwards into the Eastern Alps and Carpathians while the south Penninic Piemontais ocean disappears east of the Rhine valley (model TRÜMPY, 1992).
c) Two penninic oceans continue eastwards into the Carpathians.

An important role in the paleogeographic puzzle of the Penninic zones plays the Rhenodanubian flysch-zone. Its position, whether north Penninic or south Penninic in the Western Alps and in a single Penninic ocean east of the Rhine valley decides where to root the Penninic units north of the Austroalpine nappes in the Eastern Alps. The continuously outcropping Rhenodanubian flysch zone along the northern rim of the Calcareous Alps is indicating that at least during the whole Cretaceous a non-interrupted Penninic ocean must have existed.

KELT'S (1981) idea concerning a break-apart of the European continental crust at its southern rim into rhombe-shaped blocks or microcontinents along active transcurrent faults and a connection of the oceanic areas as pull-apart-like basins may explain not only the absence of an outcropping oceanic crust but also the present contact of very different tectonic units and microcontinents within this area and the discontinuity of outcrops.

According to TOLLMANN (1987) the eastern prolongation of the Valais realm is to be seen in the Ybbsitz Klippenzone, where the northern Penninic ocean is supposed to end. SCHNABEL (1992) however advocates an eastern continuation of the Valais belt into the St. Veit Klippenzone and thus to extend into the Pieniny Klippen belt.

Already this short summary of ideas about the eastern extension of the north Penninic Valais belt demonstrates very clearly that the eastern prolongation of the Valais realm through the Eastern Alps into the West Carpathians is still an open question with several possible solutions.

The south Penninic (i.e. more internal) Piemont domain is unanimously accepted as the main and most extended oceanic crust in the Alps although it is still under discussion of how many ophiolitic zones the penninic ocean consists (TRÜMPY, 1988) or if there have been real oceans at all (DESMONS, 1996).

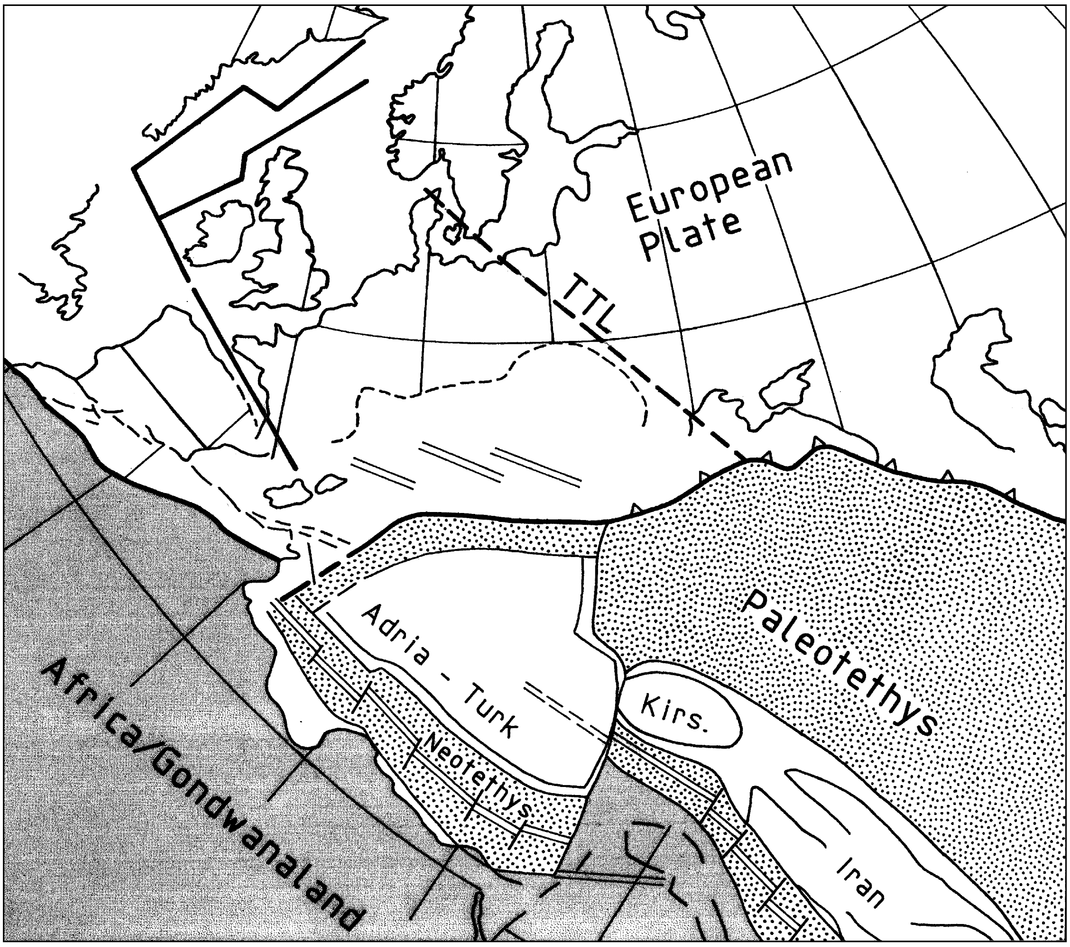
A sinistral movement between the European plate and the Southern Alps and the Austroalpine of a southern continent (SCHMID et al., 1989) provides a kinematic model for the opening of oceanic basins which are dissected by transform faults. The basins generated through this mechanism are not continuous though forming long chains of unconnected ocean floors. The eastward prolongation of the south Penninic Piemontais trough has been differently evaluated by various researchers. While TOLLMANN (1987) considers the Rechnitz window as the eastern end of the Piemontais SĂNDULESCU (1980a,1984) and DEBELMAS & SĂNDULESCU (1987) suggested a possible correlation with the Transylvanides of Romania.

In the West Carpathians BIRKENMAJER (1985, 1986) and BIRKENMAJER et al. (1990) distinguished three basins with oceanic floor: the Silesian, the Magura and the Pieniny (from N to S). The number has to be completed to the south by two additional oceanic realms, the Vahicum and Meliata areas. WIECZOREK (1995) has supposed that the opening of the Meliata ocean has reached the southwestern border of the European plate during Triassic while in the Middle Jurassic with the opening of the Vahicum ocean the border moved farther north.

Also BIRKENMAJER et al. (1990) considered the Pieniny Klippen belt as a branch of the Transylvanian ocean supposing the same Middle to Late Triassic age of rifting. The opening of the Magura oceanic basin is thought to be of Early Middle Jurassic age and that of the Silesian Basin to be of Late Jurassic to Early Cretaceous age.

This concept of three oceanic basins was doubted and contradicted by HOVORKA & SPIŠIAK (1989, 1993) who stated that with the Meliata group (including the Silica – Bükk terrane and Rudabanya units) only one area with true oceanic crust is existing in the Western Carpathians (Table 1). The volcanics which appear in other units are considered to be of intraplate character.

More or less similar to BIRKENMAJER's opinion the volcanics of the Silesian nappe were thought to be of Early Cretaceous age.



Text-Fig. 2.
Plate and microplate configuration at the boundary Paleozoic/Mesozoic in the circum Mediterranean area.
Redrawn and modified after STAMPFLI & PILLEVUIT (1993).

Table 1:
Comparison of the main ideas about the occurrences of oceanic crust in the Alps and Carpathians.

Western Alps STAMPFLI 1993	Swiss Alps TRÜMPY 1988,92	Eastern Alps TOLLMANN 1987,89	Eastern Alps HÄUSLER et al. 1993	West Carpathians BIRKENMAJER 1985	West Carpathians HOVORKA & ŠPI. 1989	Roman. Carpath. SĂNDULESCU 1984
Dauphine-Helvetic *continental*	Helvetic *continental*	Helvetic-Gresten *continental*	Gresten *continental*	Subsilesian-Skole *continental* Subsilesian Silesian *intraplate: E. Cretaceous*	Ždanice *continental* Silesian	Moldavides Marginal Dacides *continental*
Subbriançonnais *thinned continental*	North Penninic (Valaisan) *(incertain) oceanic*	Valaisan-Pienidic *oceanic* *L. Jurassic*	Flysch Zone *oceanic* *L- Jurassic* Klippen Zone Ultrapienidic Z.	Submagura Măgura basin *oceanic* *E-M Jurassic*	Măgura	Outer Dacides (Sinaia-Ceahlău) *J_2- Cretaceous ?*
Middle Penninic (Briançonnais) *continental*	Middle Penninic (Briançonnais) *continental*	Middle Penninic *continental*	Middle Penninic *continental*	Čzorstyn ridge *continental*	Čzorstyn ridge *continental*	Middle Dacides *continental*
Penninic (Liguro-Piemontais) *oceanic* *M-L Jurassic*	South Penninic (Piemontais) *oceanic* *M-L Jurassic*	South Penninic (Piemontais) *oceanic* *M-L Jurassic*	South Penninic *oceanic* *M-L Jurassic*	Pieniny Klippen *oceanic* *M-L Triassic* Exotic ridge arc	Kysuče-Pieniny *intraplate* *M-L Jurassic* Klape	Transylvanides *oceanic* *T ? + Jurassic*
—	—	Austroalpine *continental*	Austro-alpine *continental*	Manin High Tatric Subtatric *continental*	*continental*: Manin Tatric Fatric (Krîžna) Veporic Choč (Hronic)	Inner Dacides *continental*
—	—	Hallstatt-Meliata *oceanic* *M. Triassic*	—	—	*oceanic*: Strazov Silica Bükk Meliata Rudabanya *M-L Triassic*	—

continental crust — oceanic crust — thinned continental/paraoceanic crust — active continental margin units

SĂNDULESCU (1984) has correlated the Transylvanides with the Magura – Pieniny realm. He discussed four possibilities among which the Manin zone and the Exotic Ridge are thinned continental crust areas, while the other Pieninic zones have an oceanic basement or that the whole Pieninic realm has a thinned continental crust. The idea of a thinned continental crust would explain the existence of a transition toward the Transylvanian oceanic crust area to the north. Finally SĂNDULESCU (1984) supposes a correlation of the Transylvanides with some parts of the Magura unit and the whole Pieniny Klippen belt including the Vahicum (MAHEL', 1981).

Taking into account all these ideas concerning the oceanic areas of the West Carpathians it is of course very difficult to achieve a precise correlation of the Valais belt (considered to widen toward the East) as well as of the south Penninic (Piemontais) oceanic basin, or if there is a correlation possible at all.

2.3. Romanian Carpathians

If the northward prolongation of the Transylvanian oceanic basin is supposed to be situated north of the Exotic Ridge the question arises to which paleotectonic realm the units south of it are belonging to since the Tatrides are usually (except of TOLLMANN, 1987) correlated with the Austroalpine zone.

Further southeastward the Romanian Carpathians offer more data about oceanic and continental crust bearing units. An E–W section through the Eastern Carpathians displays a similar arrangement of paleotectonic units as it is known from the Eastern Alps (LUPU & ZACHER, 1996). The westernmost units, the Inner Dacides (SĂNDULESCU, 1984, 1989; DEBELMAS & SĂNDULESCU, 1987) show similar features like the Eastern Alps with continental basement, Mesozoic platform development and pre-Gosauan tectogenesis.

The Transylvanides, the next realm eastwards are considered (SĂNDULESCU, 1980b, 1984, 1989; DEBELMAS & SĂNDULESCU, 1987) as a segment of the main Tethyan branch, which is not only proved by the eastward obducted mid-Cretaceous nappes of the East Carpathians but also by the Western active continental margin, the South Apuseni Mountains, including connected marginal basins and volcanic arcs (CIOFLICA et al., 1980, 1981; LUPU, 1983, 1984). The tectonic history of the South Apusenids started in Middle Jurassic and was accomplished during the mid-Cretaceous and Laramian tectogeneses.

The opening of the Transylvanian oceanic basins was supposed to be of Middle Triassic age (SĂNDULESCU, 1975) although there is no certain proof for this idea. At this time probably only an initial splitting of the continental crust began. The start of the ocean floor formation at the Western active continental margin occurred most probably during Middle Jurassic and is therefore contemporaneous with other spreading events.

On the Eastern flank of the Transylvanian ocean the continental basement realm of the Middle Dacides, whose position correlates with the Briançonnais ridge separated the oceanic Transylvanides from the outer paraoceanic Sinaia – Ceahlau belt. This belt is known from the Ukrainian Carpathians in the north toward the south in the Romanian East Carpathians and in the South Carpathians. Its ophiolites s.l. display an intracontinental basalts character in the N (SĂNDULESCU & RUSSE-SĂNDULESCU, 1981) while in the South Carpathians their oceanic nature becomes evident.

The similarities between the position of the Sinaia – Ceahlau trough relative to the Transylvanides have led also to the idea of a correlation with the alpine north penninic Valais trough. DERCOURT et al. (1990) supposed that the Sinaia – Ceahlau area was probably a back-arc marginal basin between the East European continent and the Transylvanian oceanic basin which developed during the late Jurassic and late Cretaceous. But the westward subduction of the Transylvanian oceanic crust is not supporting this idea. If on the other hand, the Sinaia – Ceahlau ophiolites are considered to originate from a marginal basin or even an island arc (SAVU et al., 1994) then it is necessary that a former oceanic basin has existed to the East with an eastward subduction or an eastward subduction in the Transylvanian oceanic area, situated to the West.

A former oceanic basin situated east of the Sinaia – Ceahlau area is not known in the East Carpathians. But it can be supposed that the black shales (Silesian facies) of the Audia nappe might have been ophiolitic, marking an opening of the southern prolongation of the teschenites basement area of the Silesian unit. Since presently there are no data existing to prove this idea, we are in this respect in the field of speculations. This is also the case with a possible eastward subduction of the Transylvanian oceanic crust.

2.4. Carpathians and the Vardar/Axios Ocean

The last segment of the Alpine-Carpathian orogenic belt to be considered in this paper are the South Apuseni Mountains and their possible connections with the Vardar/Axios zone. That in the SW of the western tectonic units (LUPU, 1991) of the South Apuseni Mountains exists a prolongation to the Šumadija – inner Vardar/Axios zone which was first supposed by ANDJELKOVIC & LUPU (1967) has been confirmed in the meantime on both the Jugoslavian and Romanian sides of the border by deep drillings as well as by geophysical data.

One other problem to be discussed is whether the Vardar/Axios zone bifurcates or not. This will be discussed in the last chapter.

As a second problem in the nature of the Vardar/Axios zone s.l. BOILOT et al. (1977) it is emphasized that the northern prolongation of the Inner Vardar/Axios zone (= Šumadija zone in Yugoslavia) is derived from a former marginal basin (Peonias unit), while the true oceanic floor basin was situated more westward (Almopias unit). This idea, that the Inner Vardar/Axios zone is not a true oceanic area was afterwards supported by several authors (e.g. BÉBIEN et al., 1978; MLADENOVIC, 1995; ZACHARIADOU & DIMITRIADIS, 1995).

The southwestern prolongation of the South Apuseni Mountains into the Šumadija – Vardar zone rises the problem of a single or two oceanic areas starting from the Vardar zone until the Meliata zone beginning north of the Vardar/Axios zone and extending northward into the Meliata zone (ÁRKAI et al., 1995).

TOLLMANN (1990), KOVÁCS et al. (1989) and KOVÁCS (1995) optate for the idea of a single ocean but in a different way from KOZUR (1991). On our opinion the main difficulty is the southwards correlation of the Meliata zone. KOZUR separated the oceanic Transylvanides from their active continental margin (the South Apuseni Mountains) as a prolongation of the Meliata area and further to the south under the South Carpathians continental basement units, through the Strandja area and Eastern Balkans to the Pontides. This correlation which is hard to accept was also refused by KOVÁCS (1995).

Paleomagnetic researches (PATRASCU et al., 1994) evidenced a paleogene clockwise rotation of the Apuseni Mountains opposite to the Paleogene–Early Miocene counter clockwise rotation (MÁRTON & FODOR, 1995) of the north Pannonian – Alpine area. If we turn back the two mentioned areas, they must have had during the Triassic – Early Jurassic a face to face position. One unproved possibility is that also the Apuseni Mountains have been in a first stage submitted to a counter clockwise rotation and further to a clockwise one. In this case they probably have been initially situated in the prolongation of the Meliata area.

Another and on our opinion more plausible possibility is the existence of a former, second bifurcation of the Vardar zone situated northwards of the South Apuseni bifurcation. Thus, the similarity in the position of the South Penninic and Transylvanian oceanic troughs is preserved.

3. Extent and Prolongation of the Main Isopic Zones in the Alps and Carpathians

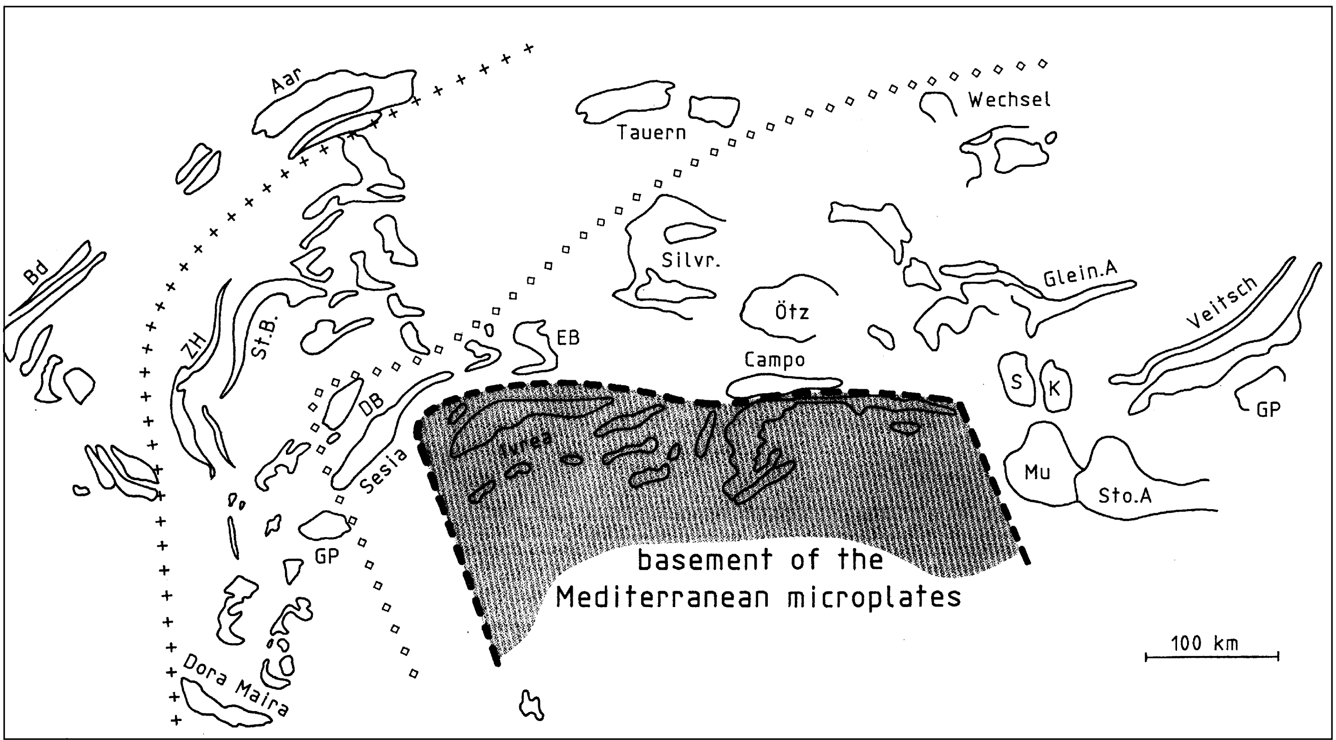
The tectonic units in the Alps and Carpathians have been defined by their tectonic boundaries, facial and stratigraphic development and the main stages of tectonic evolution. Similar criteria are used in the plate tectonic concept for defining the plates, microplates and exotic terranes. In the Alpine-Carpathian area the main domains which have to be taken into consideration are the European plate, the Apulian promontory and the African/West Gondwana plate itself. On this topic a great number of publications have been written so that in this paper we will stress only a very limited number of points.

Especially during Triassic time significant differences in the sedimentary cover of the two (or three) plates can be noted. While in the southern part of the European plate a relatively uniform sedimentary sequence in Ibero-Germanic facies extends over very large areas and even into NW Africa, the Adriatic plate and contiguous realms in the Mediterranean have developed huge shallow water carbonate platforms with internal deeper basins.

But within the Alpine-Carpathian area in the last years different interpretation concerning especially the stratigraphic sequence and facies have lead to divergent ideas about the affiliation to one or another block or microplate. The newest and in our opinion the most important example is the discussion about the possible correlation between the Eastern Alps – West Carpathians – North Apuseni Mountains and the Villany – Mecsek area.

Since PATRULIUS (1976), SĂNDULESCU (1972), BLEAHU (in MAHEL', 1974), who were the first to correlate these areas, several authors agreed generally with this idea (e.g. TOLLMANN, 1987; LUPU, 1984). But in the last years some new controversies arose concerning the correlations within this areas. Thus, while the correlations Eastern Alps – West-Carpathians are becoming more precise (HÄUSLER et al., 1993), there are also other opinions (MIŠIK et al., 1990) who dispute the northern prolongation of the Central West Carpathian facies belt into the North Apuseni Mountains and the Villany – Mecsek area. They presented arguments concerning the difference in the prealpine metamorphic basement which in our opinion as well as in many others is not providing significance in the later alpidic geotectonic framework.

KOVÁCS et al. (1989) remarked that the differences in long range facies relations, evidenced by MIŠIK et al. (1990) are normal in such a large area as between the Eastern Alps and the SW of Hungary. We also agree with KOVÁCS that the differences in thickness of various forma-



Fext-Fig. 3.
Southern boundary (thick dashed line) of the European plate (white) in Triassic times. According to their variscan deformation the Mediterranean microplates are not considered to be part of Africa/Gondwanaland.
Modified after RAUMER & NEUGEBAUER (1993).

tions are unsignificant. The existence of several facies in the North Apuseni Mountains which do not exist in the West Carpathians cannot be used as an argument for the impossibility of large scale correlations. There is to notice that in the East Carpathians in the crystalline basement nappes (Infrabucovinian, Subbucovinian and Bucovinian) which have a similar position as the (Briançonnais) Mid-Penninic as well as the Transylvanian nappes which can be correlated with the South Penninic area, there are East Alpine Triassic and Jurassic facies (e.g. Campil and Wetterstein Formation etc.).

Concerning the existence of a large area, represented by the Eastern Alps, West Carpathians, North Apuseni Mountains, Mecsek and Villary Mountains, which had a more or less common behaviour our opinion agrees in general with the ideas of SĂNDULESCU (1980a), DEBELMAS & SĂNDULESCU (1987), DERCOURT et al. (1990) and others. There is only the question left in the inner parts of the East Carpathians (Bucovinian nappes) where to join it or not in the case that the Transylvanian Tethys really opened during the Middle Triassic or later (SĂNDULESCU, 1980). If the spreading has started in the Middle Triassic then the Alpine facies in the East Carpathians would represent a coincidence with the similar facies in the North Dobrogea or even farther eastwards.

With one exception (NEUBAUER, 1994) most of the researchers consider the large area discussed above as a promontory of Africa (CHANNEL & HORVÁTH, 1976) or as an individual microplate named Apulia or Preapulia. The arguments used in favor of a particular facies and tectonic realm are predominantly seen in the same platform facies of the Triassic and the importance of the pre-Gosauan tectogenesis. In fact, the differences between the Triassic platform facies of the Apulian block and the European German facies are more or less the same as the differences with the African plate where also the Ibero-Germanic facies is well developed during the Triassic (especially Keuper) in the NW of the continent (ZAPPATERRA, 1990).

For a long time it has been known that the Carpathian facies of the germanic Keuper is extending into the Austroalpine domain (Keuper of the lower Austroalpine nappes) and that the Raibl Sandstones in the Calcareous Alps are an equivalent of the germanic Schilfsandstein formation. It means that during Triassic time the Apulian microplate was surrounded in the East, North and West by a belt in Ibero-Germanic facies.

4. The Plate Boundary between Europe and Africa

Within the plate tectonic framework of Europe the plate boundary between the African part of Gondwanaland and the European plate is still a discussed problem which has been disputed newly by NEUBAUER (1994). While CHANNEL & HORVÁTH (1976) considered the whole Austroalpine to West Carpathian area as a promontory of Africa, NEUBAUER has cast doubts upon the African origin of the Eastern Alps and Adriatic microplate.

The idea to interprete as an individualized microcontinent the area between Europe and Africa started with TOLLMANN's (1978) proposed "Kreios" plate, supposed to have extended from the Betic region in the West to the Zagros – Lut unit.

Later on, SĂNDULESCU (1984) and LUPU (1984) defined in a more restricted area than TOLLMANN's Kreios plate the Austro-Bihorean respectively Intratethyan microplate. SĂNDULESCU (1990) separated a Preapulian block delimited from Apulia by the South Pannonian suture. The Preapulian block shows in the authors idea a different facial evolution from the Apulian microplate area as well as from Europe.

An extremely complicated picture is offered by the Central Eastern Alps where the puzzle of different blocks/units situated between the Jura Mountains and Lombardia in the West and the Helvetics and the Eastern Alps in the East cannot be solved by the lateral displacement as supposed by DEBELMAS & SĂNDULESCU (1987). Therefore the initial terrane interpretation (TRÜMPY, 1992) or for instance the long displacement of the Briançonnais (STAMPFLI, 1993) from the Southwest tried to find new ways of explanation.

The problem is: what has happened between Africa and Europe? Starting with the Triassic until the end of the Cretaceous the main tectonic units of this area have been developed. First of all it is to notice that the separation of Europe from Africa/Gondwana took place during different times in different areas but also in different ways. Thus, although during the Triassic several rifts are known in the Eastern and Southern Alps (TOLLMANN, 1990) as well as in the North Apuseni Mountains (CIOFLICA et al.,1980) they did not evolve into a real oceanic crust. The areas which developed a widening oceanic crust were the Hallstatt – Meliata, probably the Transylvanides and the Vardar/Axios oceans, the latter becoming oceanic only in the early Jurassic. If we consider the Triassic opening as significant for the plate boundaries we have to accept that the whole Austroalpine area is belonging to the European plate and that the separation from Africa/Gondwana is made by the Hallstatt – Meliata oceanic belt (Triassic Tethys).

Later on, during the Jurassic, opened the Ligurian – Piemontesian (South Penninic) ocean – possibly in back-arc position to the earlier Hallstatt – Meliata ocean – which was before nearly unanimously accepted as the most important suture zone within the Alpine belt. During the late Jurassic/early Cretaceous in the Western Alps (FLORINETH & FROITZHEIM, 1994; FROITZHEIM et al., 1995) as well as in the East and South Carpathians a new opening of a para-oceanic to oceanic belt (Valais; Ceahlau) occurred. The polarity of closing was the same as the opening. The Meliata ocean closed during the late Jurassic and early Cretaceous while the south Penninic ocean has a closing interval which is commonly dated to be during late Cretaceous and Paleogene. The Valais ocean's closing time is dated to be of Paleogene age.

As a rule it can be supposed that the opening of the outer ocean (closer to Europe) began with the closure of the more internally (closer to Africa) situated ocean belt. In the Pieniny Klippen belt, which was considered by several geologists as a possible prolongation of the Piemontais oceanic area but seems to bear no real oceanic crust, tectonic deformation was of Cretaceous and early Miocene age. The subduction of the Transylvanian ocean began in the middle Jurassic and during the mid-Cretaceous and Laramian tectogenesis the main tectonic framework was achieved.

In the Vardar/Axios zone the subduction started in late Jurassic with the Eohellenic phase being followed by several others during Cretaceous and Paleogene. It seems rather acceptable that the area between the Africa/Gondwana plate in the South and the European plate (s.str.) bordered by the Valais – Ceahlau troughs can be considered as an individualized one which was successively separated from both plates.

NEUBAUER (1994) discussed the idea that the Eastern Alps and the Adriatic microplate are belonging to the African plate with arguments rather valuable to emphasize the complicated structure of this orogenic belt than to demonstrate this aim.

In the Romanian Carpathians the similar position of the Transsylvanides within the south Penninic belt gave rise to many authors to consider it as the boundary between Europe and Apulia.

If we agree with the significance of the Meliata oceanic opening and the European character of the Austroalpine area we have to accept also that the Transsylvanides which have on both sides continental basement units with Austroalpine (North Apuseni Mountains) or very similar (Central East Carpathians) Mesozoic facies belong to Europe, too.

In the southwestern prolongation of the South Apuseni Mountains, in the Šumadija – Vardar zone arises the problem of a single or two oceanic areas virgating from the Vardar/Axios zone southeast of Belgrade (ÁRKAI et al., 1995).

TOLLMANN (1990), KOVÁCS et al. (1989) and KOVÁCS (1995) advocated the idea of a single ocean in a different way from KOZUR (1991).

The southern prolongation of the Hallstatt – Meliata ocean raises one of the main paleotectonic problems of the central Tethys area. If the Meliata oceanic realm is considered to extend into the Transsylvanides for the reason that in both areas the oceanic opening happened during Triassic time, their relationships with the Austroalpine facies are more difficult to explain. While the Hallstatt – Meliata zone is situated at the southern rim of the Austroalpine realm, their possible prolongation into the Transsylvanides occupies a position between the North Apuseni Mountains with Austroalpine facies in the Mesozoic and the units close to the East European plate.

Even if a clockwise rotation of the whole Apuseni Mountains is taken into account (PATRASCU et al., 1994) then it is to notice that it took place not earlier than Eocene time. The similarities between the tectonic positions of the eastern units of the South Apuseni Mountains and the Transsylvanian nappes of the East Carpathians indicate a connection between these areas.

Thus it seems rather possible that the Transsylvanides have to be connected, as supposed by several authors (SĂNDULESCU, 1984; BIRKENMAJER et al., 1990) with the Penninic ocean. The connection problem between the Transsylvanides (including the South Apuseni Mountains as their active continental margin area) and the Inner Vardar – Šumadija zone does not seem to be simple too, for the South Transsylvanian fault is obliterating the Transsylvanian oceanic crust so that in the South Apuseni Mountains only active continental margin related units are appearing.

If the Šumadija – Inner Vardar zone is being considered as a former marginal basin then the problem arises where the oceanic crust is reappearing. The Transsylvanian oceanic crust reappears south of the South Transsylvanian fault which has the character of a transform fault which changes the polarity of the subduction from westward in the Transsylvanian area to eastward in the Vardar/Axios area. CANOVIC & KEMENCI (1988) assume a bifurcation of the Šumadija ophiolites near Belgrade with one branch extending towards the Northeast into the South Apuseni Mountains and the other branch towards the Northwest.

A different position concerning the southeastward continuation of the Hallstatt – Meliata ocean is advocated by KRÄUTNER (1996). He extends the Meliata ocean into the Pindos oceanic belt (sensu ROBERTSON et al., 1996).

If we suppose an unsharp boundary between Europe and Africa/Gondwana we must accept that similar to the South Penninic ocean or Meliata one, the Vardar ocean and the Pindos constituted only a couple like in the Alps or Carpathians.

Thus, the whole Dinaric area is also to be situated in this region between Europe and Africa. The north Pannonian, Tisia and other in the last years separated units developed almost probably as a consequence of the late Cretaceous–Pliocene extensional movements north of the Periadriatic – South Transsylvanian fault (RATSCHBACHER et al., 1991). The Quaternary age of these movements was recently documented by the age determination (SZAKACS & SEGEDI, 1996) of the shoshonites in the South Transsylvanian fault area.

5. Conclusions

In the Alpine-Carpathian mountain belt many different fragments of oceanic crust and ophiolites are existing. But their position within the edifice of nappes and facies realms is very controversially discussed in the literature. Depending on basal assumptions like the long extended continuity of ocean floors or if their occurrences are discontinuous like strings of pearls (DÜRR et al., 1993: 408) very different palinspastic reconstructions are resulting. One of the main problems concerning long range correlations is caused by the large overthrusts of the Austroalpine nappes and their western Carpathian equivalents over the penninic units. Thus the Tauern window is considered either as north Penninic (Valaisan) or as the continuation of the south Penninic Piemont trough. Mostly the Liguro-Piemontais is seen as the main continuous Penninic ocean, traceable from the Western Alps as far as into the Transsylvanian of the Romanian Carpathians.

In the morphologically lower mountain chain of the West Carpathians erosion has most probably not yet opened windows of the overthrust lower tectonic units or oceanic areas. Therefore it is not possible to decide whether the Penninic ocean floor bearing units are continuing eastwards. In the easternmost (south)-Penninic Rechnitz window no indication has been found that this oceanic area will end in the East already after a short distance. A high degree of consent is existing in the literature about the age of rifting, ocean floor generation and the closure of the deep sea areas floored by oceanic or paraoceanic crust. Also about the extent and characteristics of the main facial realms like Helvetic, Penninic, Austroalpine and Southalpine in the Alps and their equivalents in the Carpathians discussions have ceased and a general concept is mainly agreed upon. This is also the case with the importance of tectogenetic phases which are characteristic for distinct tectonic units but are not found in all parts of the isopic zones.

The question along which suture zone the boundary between the European plate and the contiguous African plate is to be drawn or if between the two large plates a number of smaller microplates have existed can be answered now. During Permo-Triassic the Hallstatt – Meliata ocean and its southern and western prolongation has been the main plate boundary between Europe and a number of Mediterranean continental microplates (TOLLMANN's former Kreios plate) which have been separated from Africa/West Gondwana by a southern branch of Paleotethys. Until early Jurassic time the Penninic as well as the Austroalpine realms and their Carpathian equivalents were part of southern Europe. A separation from Europe occurred with the opening of the Liguro – Penninic ocean (s) during Middle to Late Jurassic time (backarc spreading??). In the western Alps a second Penninic (Valaisan) ocean opened insignificantly later during Late Jurassic to Early Cretaceous.

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