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PARTICULARITIES OF ALPIDE SEGMENTS; TECTONOTYPES, ARCS, AND DIFFERENT FLYSCH BASINS IN THE WESTERN CARPATHIANS

MICHAL MAHEĽ

Dionýz Štúr Institute of Geology, Mlynská dolina 1, 817 04 Bratislava, Czecho-Slovakia

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Abstract: 1. Tectonic units of the Western Carpathians are not the same as Eastern Alpine ones, but some of them are their analogues.
2. The completeness of the Western Carpathian Alpide segment is manifested in:
six tectonotypes – genetically different groups of nappes; three geotectonically different types of flysch basins; at least six types of molasse basins; four areas of neovolcanic sequences in various positions.
3. The formation of the Carpathian arc is an example of multistage genesis, beginning with smaller Mesoalpine arcs – the predecessors of core mountains – accompanied by intramontane depresions (transtensional and tensional).
4. Thus, the Western Carpathians represent an etalon of the orogen, displaying a whole series of specific features.

Key words: tectonic units, tectonotypes, flysch basins, arc and paleoarcs, Western Carpathians.

In the present time, when models are made with a global approach, the particularities of individual Alpide segments have been neglected. Thus, some fundamental features typical of the European Alpides, such as structural complicatedness, as well as heterogeneity of crust in the course of its development – the foundation of particularities of individual Alpide segments – are often neglected. However, the European Alpides are virtually a complex of specificities, characteristic of each segment, due to dissection of crust already in pre-Mesozoic periods (Maheľ, 1973).

The number of allochthonous units essentially increased, but their structural and genetic differences slipped away from attention. The original meaning of the term "nappe" gradually loses its importance in the Alpides.

The substance of specific features in individual Alpide segments

In spite of the uniform development trend of the Alpides, each segment has a whole series of specificities, particular tectonic units and paleotectonic elements. The Western Carpathians, in spite of lithotypes and tectonic units corresponding to the Eastern Alps, or even connected with them, essentially differ from the Eastern Alps not only in Neoalpine depressions and neovolcanics, but also in their morphostructural plan.

The differences of segements are based in a long history of evolution reaching back to the pre-Alpine period with unequal stabilization of the crust and its subsequent dissection. The following phenomena could not have been accidental:

– deeper-water formations of the Triassic in the Alpides are in located zones of less marked Hercynian stabilization (Inner Dinarides, southern units of the Western Carpathians);

– Jurassic troughs formed on „heavier" continental crust, whereas intrageosynclinal ridges on strips of „lighter" crust with granitoid massifs.

The specifities of individual segments are to a considerable extent also *inherited* (Maheľ, 1978, 1981b).

The differences in crust dissection are distinctly displayed in the segmentation of the Alpides. The Western Carpathians are instructive also from this point of view (Fig. 2):

a) Morphostructurally are the Western Carpathians *separated from the Eastern Alps* by a Neogene transversal fault gap – the Vienna Basin, connected by horizontal strike-slip faults (Roth, 1977; Tollmann, 1975, 1976; Maheľ, 1973, 1983a; Wessely, 1975). The principal tectonic zones (Wienerwald-Carpathian Flysch, Penninicum-Vahicum+Klippen Belt, Unterostalpin-Tatricum, Oberostalpin-higher nappes of the Western Carpathians, the so-called "Subtatric" ones) are obviously more or less related to each other. Each pair, however, represents only *analogues, having their own sets of tectonic units* and different contents, the differences having been caused partly by different intensity of tectonogenesis, but also by previous development of the units. The similarity is evident in the transitional zone in the south-western part of the Western Carpathians – the so-called Devín subsegment (Maheľ, 1983a), or in the easternmost corner of the Eastern Alps which displays so-called "Carpathian influences" (Tollmann, 1975). The substance of differences between the Eastern Alps and the Western Carpathians should be searched for in a deeper, old phenomenon, such as the complicated transversal eastern margin of the Bohemian Massif.

This so-called spur of the Bohemian Massif is manifested as a marked thickness change of the authochthonous Mesozoic, and probably it was playing a significant role in the formation of the Paleoalpine nappe structure.

There is basically an arc, along which the following units have been formed:

– due to transpression – a zone of upright coulisses (of immature klippen style) of the Frankenfels-Lunz frontal system (including the SW part of the Manín Nappe), of the southwestern Klippen Belt promontory and of the back part of the Magura or Laab Nappe;

– due to subsequent transtension – a pull-apart type basin (the Vienna Basin).

b) Quite different type of segmentation is represented by the eastern corner of the Western Carpathians, their *connection with the Eastern Carpathians*. Both segments are connected into a common arc by the huge Neoalpine Flysch Belt, with some units running through (Silesian), others wedging out at length and coulisse-like replaced. The characteristic features and marked differences in the Western Carpathian and Eastern Carpathian structure are displayed in their central zones where they coulisse-like substitute each other (Maheľ, 1983b). The Paleoalpides of these two regions are of essentially different structure, in spite of several sets of similar tectonofacies of Mesozoic and Paleozoic sequences. They belong to different blocks of continental crust separated by an oceanic trough; however, this is not the Transylvanian-Pieninic (Sandulescu, 1973), but the Vahicum trough, situated south of the Pienides, at the northern margin of the Central Carpathian block. Vahicum is linked with the Transylvanian oceanic trough in the eastern part, at the southern margin of the Eastern Carpathian block. Thus, the Pienides are not an analogue of the Transylvanicum, but the shelf margin of the European platform, separated at the beginning of the Jurassic, changed into a dissected submarine island zone (Maheľ, 1981). Structurally the Pienides are an appendix of the Vahicum, which is a continuation, but only in the form of an analogue, of the Penninicum, as well as of the Transylvanicum. The Pienides themselves are a specific unit of the Western Carpathians. From this point of view, the whole region of the Eastern Slovak lowland (including the transversal Szolnok trough) should be considered a part of Western, and not of the Eastern Carpathians.

c) The classification of an essential part of the Ukrainian Centralides with the Western Carpathians increases the urgency to solve the problems of their *relation to the Apuseni Mts*. These, equally as the Western Carpathians, have a Paleoalpine structural plan. According to this criterion Sandulescu (1973) classified them with the Western Carpathians and called them "Western Dacides". However, a whole group of tectonofacies – tectonogroups (mainly the Austroalpine type of Triassic, as well as several Paleozoic sequences in the Codru and Moma Nappe system) resemble the Choč and higher nappes in the Western Carpathians; the Muresh zone is analogous to the Perivahicum, not only as far as the type of flysch ("carbonate") is concerned, but also due to its many similar lithotypes. There are, however, many differences between the Central Carpathians and the Apuseni Mts., not only concerning the Bihor Mts., the lithology displaying a number of specificities (Mišík, 1988), with a most distinct affinity to the Southern Carpathians.The Apuseni Mts. have a characteristic structural and morphostructural plan, as well as their own tectonic units. Differences in the structure and development of the Apuseni Mts. and the Western Carpathians are even greater than those between the Western Carpathians and Eastern Alps. Thus, the Apuseni Mts. are not representing a part of the Western Carpathians, but an independent segment of the Alpides, most markedly affected by rotation, as a consequence of which the innermost part, the Bihor Mts., are in northern position.

Equally like the Tisia units, the units of the Apuseni Mts., especially those of Bihor Mts., attain great thicknesses, incomparable with those of the Western Carpathian units. Bihor and Tisia Mts. formed on a block of different crust quality, of aulacogene type.

The affinity of the Bihor Mts. – known already for some time – mainly to the Villany Mts., as well as other Tisia units, and the Austroalpine character of the Codru and Moma units indicate the „transitional" character of the Apuseni Mts. between the Carpathians and Tisia. The Apuseni Mts. are obviously a segment connecting the „massif" with the Carpathians.

The importance of the specificities of individual segments lies also in the fact that some phenomena are *more marked* in one segment than in others. The recognition of these Alpide features in the compilation of the Tectonic Map of KBGA regions (Maheľ, 1973) stimulated a change in our views on some Western Carpathian features, e. g. the extent of Early Paleoalpine (Neokimmerian) and Mesoalpine folding, the existence of a trough with oceanic-type crust – the Vahicum, several types of troughs, ridges, basins, mostly flysch.

Each segment of the Alpides, and especially the Western Carpathians, has some characteristic features which predetermine it for the study of *the substance of some phenomena*. In the Western Carpathians they are:

– the Klippen Belt – unique tectonic „melange", as well as the suture at the boundary of megablock, a *transpression zone;* this is a unit with a lot of problems to be solved;

– geotectonically different *three types of flysch basins*, formed under different geodynamic conditions, on a different type of crust – they provide a possibility to learn more about the geodynamic importance of flysch;

– the Križna Nappe – in its complexity a *prototype* of a large group *of fold nappes*, reflecting the heterogeneity of the crust in the Alpide Centralides;

– not less than *6 tectonotypes* of allochthons – a possibility of genetic classification of nappes;

– *Neoalpine arc* types, accompanied on the inside by paleoarcs with transversally oriented folds and fault gaps, and on their back part partly also by synclinores and shear zones;

– *geotectonic complexity*, with all fundamental zones from the foredeep through the Externide Flysch Belt – Klippen Belt – Centralide core mountain belt – inner zone (internides) to the hinterland – Tisia; each one underwent different development, has different structure, type of crust. This provides a possibility to design the prototype of an Alpide geodynamic model;

– *a large number* of inner *Tertiary basins* formed in several stages, as well as *four neovolcanic regions* in different geotectonic positions, making it possible to understand the processes which formed the morphostructural plan of the Carpathians, as well as the role of an older structural plan.

Tectonotypes

The dissection of the Alpides and of the Western Carpathian segment is reflected in the large number of nappes arranged into several genetically different groups – tectonotypes. Each group of nappes is a reflection of different crust quality, it is a different genetic type, formed in different structural conditions. The way to the clarification of problems of crustal shortening processes will obviously start at the knowledge of differences in the structural plan, in the degree and type of deformation (Maheľ, 1982).

In the Western Carpathians there are at least 6 tectonotypes (Fig. 1):

1. *Neoalpine nappes* of the Flysch Belt (Beskydicum) – nappes of *fold and thrust type*, mostly passive, with distinct listric planes, not displaying any intensive inner reworking, with distinct manifestations of unidirectional upthrusts, with older members situated in the frontal part and younger ones mainly in the rear part of the nappes (Fig. 1, I). The foreland was playing an especially active role in the formation of the Flysch Belt nappes as a movable „undercarriage". The nappes are genetically closed by continental block collision – the foreland with the Central Carpathian block. This tectonotype has its origin in the flysch geosyncline with its own trend of development. It is genetically related to marginal parts of the platform capable of extension, or basification, enabling thus the forming of deep troughs as well as cordilleras.

2. A system of heterogeneous tectonic units of the Klippen Belt, with a unified, specific tectonic style – *the mature klippen style*, following the boundary of the Central and Outer Carpathian blocks in the *foreland of a subducted oceanic trough – the Vahicum*. Enormous crumbling, a significant role of steep north-and south-vergent upthrust, often fan-like distribution, *coulisse structure* – these are the fundamental features of the Klippen Belt tectonic style, which is considered to be related with the Savian–Early Styrian *transpression along a deep fault*.

In the Neoalpine plan of the Carpathians the Klippen Belt is the inner margin, partly the back part of the Flysch Belt nappe root zone – the zone with most marked manifestation of south-vergent upthrusts – structural elements of the inner wing of the Neoalpine fan (Fig. 1, II). The Klippen Belt represents in the Mesoalpine structural plan:
– with its fundamental Pienide-Oravicum units – a ramp weakly tectonically affected, with slight recrystallization of rocks and good preservation of macro-as well as microfauna and a prevalence of buckle-folds formed by sliding movement with restricted plastic flow;
– with the flysch units of the Perivahicum (Klape nappes);
– an accretion wedge;
– with the frontal part of Central Carpathians (Manín Nappe).

3. The Central Carpathian – Centralide tectonotype represents a complex of *Late Paleoalpine (post-Cenomanian) nappes*. They differ from all other tectonotypes by *fold nappes*, by abundant recumbent folds, digitations, by distinct plastic-flow tectonics, in near-surface as well as socle nappes. Undular movement is evident; it has been caused by the subduction of oceanic crust of the Vahicum – the continuation of the Penninicum in the Western Carpathians (Maheľ, 1981, 1986). The genetic relationship of nappes to heterogeneities of the crust is evident. The complexity of this Centralide tectonotype is manifested by (Fig. 1, III):
– rooted nappes of the ramp – Tatricum;
– the extensive near-surface Krížna Nappe – formed from

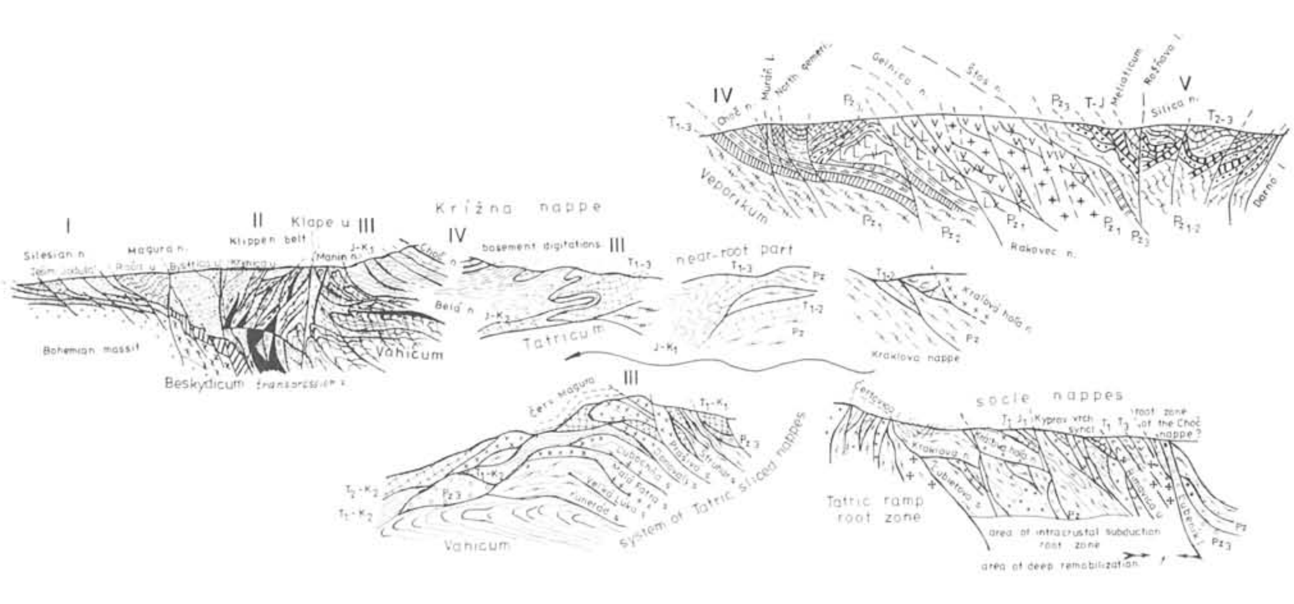

Fig. 1. Tectonotypes of the Western Carpathians – M. Maheľ, 1990.
Explanations: I – Neoalpine nappes of "fold and thrusts" type – created underthrust of fore-land; II – the coulisse – like transpression zone – Klippen Belt; III – Paleoalpine fold nappes generated by subduction of oceanic crust: Krížna fold Nappe with Tatric ramp-nappes and system of Vahicum fold nappes; IV – carried Paleoalpine nappes – Choč and higher Nappes; in the rear part filling of synclinores; V – system of two-stage tectonic units: formed by Neokimmerian subduction of the Meliaticum to the north and by Cretaceous compression wave from S to N.

a trough, linked with a tongue-shaped Krakľová socle nappe without Hercynian granitoids;
– a socle granitoid nappe (Kráľová hoľa Nappe) and a shear (root) zone with Alpine granitoids.

a) *Tatricum* – is a system of laterally alternating nappe slices reflecting the differences in crust thickness of individual regions. Characteristic are *recumbent folds*, not only in the Mesozoic envelope, but also in crystalline complexes (analogically as in the Unterostalpin); in most of them the granitoid bodies are predominant. The most topical questions appearing in their study are those of Prealpine thrust shortentings, of Hercynian nappes as well as of their influence on the development of the Alpine geosyncline. The character of the root zone of nappes is indicated in the southern part of the Tatricum, mainly in the Nízke Tatry Mts., by marked slaty structure as well as an enxtraordinarily large negative gravimetric anomaly signalizing the presence of granitoid bodies (Šefara et al., 1989).

b) *The Krížna Nappe* is structurally a group of nappes formed by paleogeographically different sequences. The fundamental Zliechov Nappe is derived from a narrow trough with attenuated continental crust, and the subordinate Vysoká, Manín, Belá and Havran nappes are of slope type.

Digitations and recumbent folds in the frontal as well as rear part of the nappe which are a result of wave movement, recorded the process of subduction (of Vahicum) accompanied by sinking of oceanic crust, as well as by the formation of a deep-water flysch foredeep, starting in the Lower Albian.

The Krížna Nappe was formed by the process of *multiple shortening* of the original home area, affected in its rear part by Lower Cretaceous, in the trunk part by post-Cenomanian and in the front part by post-Upper Creataceous overthrusting. The northernmost part, the Manín Nappe, which is to the greatest extent incorporated into the Klippen Belt, was as a separate nappe formed in the of Upper Cretaceous movements (Maheľ, 1982).

c) The rear part of the Krížna Nappe, affected by metamorphism, is linked with the socle nappes, i. e. the Krakľová and Kráľova hoľa Nappes, consisting of Veporic crystalline complexes accompanied by metamorphosed Mesozoic envelope. The hinterland is formed by the slaty-structured Rimavica zone, with apophyses of Alpine granites.

4. *Paleoalpine near-surface shear* „carried" nappes (Fig. 1, IV) – the Choč, Strážov, Muráň, Besník Nappe – their skeleton being formed by Triassic complexes of the Oberostalpin type, predominantly composed of carbonates, shallow-marine ones as well as of basin type; in the „home" areas there are *tongue-shaped socle nappes* aligned into a slate belt, with Alpine granites – the Gemericum. The difference from the Eastern Alps is the distribution and tectonic style of analogous, mainly pre-Carboniferous complexes. The thick rear fundament of the Melaphyre „series" (a specific Western Carpathian sequence) shows greater structural independence from the Choč Nappe (when compared with the analogous Lunz Nappe). Whilst in the Eastern Alps the Grauwacken-zone is in a marked nappe position, the essential southern part of Gemericum has slaty structure, partly with fan cleavage, accompanied by *Paleoalpine granites;* it is oviously rooted.

5. *The Late Kimmerian–Early Paleoalpine* tectonotype of the *Internides* – tectonic units of the Slovak Karst: fan-like distributed nappes dissected into (Fig. 1, V):
– the Silica Nappé of active carbonate dissected shelf type, with an affinity of the southernmost Oberostalpin;
– Meliaticum – a system of slices characterized by an „incomplete ophiolite complex" (Hovorka, 1984), or ophiolite melange (Mello and Reichwalder, 1982), affected by metamorphism (blue schists).

The basement of Meliaticum is composed of the Štós formation, genetically closely related to the Szendrö and Upponyi Paleozoic thrusted over Gemericum. Structural independence of the Štós Nappe is masked by its incorporation, together with Gemericum, into a uniform shear zone (slate belt), with fan-like schistosity.

Tectonic „mixing" and especially the superposition of Silicicum as a nappe (Kozur and Mock, 1970) is a result of Neokimmerian submergence of Meliaticum, its subduction towards the north followed by Cretaceous tectonogenesis, with predominantly north-vergent fold upthrusts and nappe slices, and incorporation of Meliata slices into the Silica structural elements.

At its inner margin this internide tectonotype displays a south-vergent imbricate zone of transpressive character, as a part of a fan connecting it with the Bükkicum.

The above described tectonotype represents the rear part of the north-vergent Carpathian system, the source area of a deep wave which gradually trasferred the compression process in the direction towards the North European platform.

6. *Bükkicum* – is the representative of the southern wing of the Western Carpathian system. Moreover, its specificity is enhanced by:
– the Paleozoic as well as the Triassic (with more abundant volcanic rocks) of Dinaride type;
– more extensive effects of weaker metamorphism;
– the presence of the Szarvaskö complex (Balla et al., 1980), with volcanics and ultarabasics of crustal origin, derivatives of the upper mantle connected by a rift (Kubovics, 1984), accompanied by olisthostromes.

The paleotectonic relationship of the Bükkicum and Meliaticum can be deduced from the manifestations of *riftogenesis and Neokimmerian tectonogenesis,* as well as from coincidences in the tectonic style with the Silica Nappe, such as *fold structures* of more regional extent truncated by upthrusts. More distinct strike-slip faults at the northern margin of Bükkicum are partly pre-Paleogene, partly genetically related to the formation of an arc structure throug which the Bükk Mts. are morphostructurally more closely incorporated into the Western Carpathian system (Balla, 1987).

In the presented classification of Western Carpathian nappe groups the Mecsek and Villany Mts. – *Tisia units* – cannot be omitted. Their Mesozoic sequences essentially display the same trend of development as the Paleoalpine units of the Alpides. They, however, differ mainly in a much greater thickness, practically of all stratigraphic members, in lesser variability of facies, as well as in that they are contrasting. They obviously formed on aulacogene-type crust, with different dynamics, which experienced intensive subsidence and weaker Alpine reworking, probably with week detachment – *intracrustal allochthon.*

The structural relatedness of the Bihor Mts., similarly as of Tisia „strange" but with nappes of Austroalpine type (Moma, Codru), to heterogeneities of the crust (one of the fundamental features of the European Alpides) is an evidence of their (as well as the Villany Mts. and Mecsek Mts.) genetic bond with the Carpahians. However, the position of the Mecsek and Villany block can be explained in a „modern way" by the existence of a far-reaching strike-slip fault (Wein, 1978; Kovács, 1980) as well as exotic terranes.

However, strike-slip faults, complementing the kinetic pattern of the Alpides, should be considered to have occurred especially:

– at the opening of oceanic troughs and rifts;
– during the formation of transpression structures and partly of transtension structural elements, as well as;
– in the generation of arcs and segmentation.

Each of the mentioned groups of nappes formed in different geodynamic conditions:

– nappes in the Flysch Belt, of fold and thrust type, at the collision of continental blocks;
– the system of coulisses, slices and small nappes of the Klippen Belt as an accretion wedge formed due to fading-away compression of the Centralides and subsequent transpression related to the formation of the outer Carpathian arc;
– nappes of the Centralides – predominantly fold nappes as a consequence of the subduction of oceanic (Vahicum) crust;
– shear-carried nappes of Gemericum (and higher Subtatric nappes) – a result of compression and accompanying sudden uplift of dissected continental crust;
– the fan of Internide nappes formed as a consequence of an interaction of continental and suboceanic to oceanic crust, in rifts controlled by global factors, which induced deep wave movement in the asthenosphere.

The problem of terranes: the tectonotypes, manifested in a complex of facial, magmatic and metamorphic developments, as well as in the regime of deformations, are in the first place a tectonic category. They consist most often of several tectonogroups – groups of tectonofacies, reflecting the paleogeographic conditions and partly also material tectonics (Maheľ, 1973; Maheľ et al., 1974).

The approach based on the paleotectonic character of tectono-stratigraphic successions is very frequently applied in Anglo-Saxon literature. However, the development of the European Alpides is incomparably more extensive in time as well as in space in comparison with the Appalachians or Cordilleras. The majority of terranes in the Carpathian-Balkan regions is a complex of genetically related tectonogroups. A part of the terranes coincides with our tectonotypes – a complex of tectonic units formed roughly in the same time range, under equal kinematic conditions, due to same dynamic factors.

The knowledge of the genesis of tectonotypes and their role in the structure of the individual Alpide segments moreover makes it possible to recognize the specific features of individual segments, as well as to make a genetic classification of the nappes. This task is very topical at the present, when there are practically no autochthonous units in the Alpine system and the nappe concept distinguishes units which are morphostructurally and genetically quite different.

Shear zones, their relation to the arc

The more extensive Early Styrian strike-slip fault at the margins of the Klippen Belt was in the last time considered to be related to the formation of the Carpathian arc (Birkenmajer, 1985). However, phenomena such as crumbling, segmentation on a small scale, imbricate and coulisse structure – classified as mature klippen tectonic style – have also been put into relation with this process (Maheľ, 1963, 1989).

Analogous, however, more limited phenomena, mostly the coulisse structure, in places also local manifestations of the klippen style, are observed also in the Central Carpathians (Fig. 2), mainly at the outer side of the semi-arc formed by the Ďumbier and Volovec „massifs".

These manifestations, obviously of Mesoalpine movements, are accompanying:

– dissected foredeeps, formed by extension of the crust, filled by Central Carpathian flysch (Lutettian–Lower Oligocene), in the foreland of arcs;
– elongated synclinores in Mesozoic units, with fan-like distribution of upthrusts and manifestations of coulisse structure, as well as structures converging into narrow gorges (Maheľ, 1964, 1967, 1986);
– shear zones of slate-belt type, with deep-reaching upthrusts in hinterland of arcs in pre-Mesozoic complexes (Rozložník, 1965);
– a system of transversal fold structures, as well as transversal fault zones accompanied by strike-slip faults (Párnica, Štítnik, Hornád faults), which show in the blocks structure already in the process of dissection of the Central Carpathian flysch basins.

The arc (semi-arc) shape is in some places more, elsewhere less apparent also in other core mountain ranges, as well as in the Gerecse Mts. (including the Komárno block) and it is especially marked in the Bükk Mts.. The formation of these inner arcs is a consequence of compression in W–E WNW–ESE and ENE–WSW directions (Balla, 1987). Its results are: – manifestations of the superimposed immature klippen style, e. g. in the Vysoká unit of the Malé Karpaty Mts.;

– „missing" or „squeezing out" of whole sequences in the envelope units, e. g. in the SW part of the Malá Fatra Mts., as well as in other core mountains, and manifestations of strike-slip faults, frequent at the boundary of the crystalline core and Mesozoic „envelope" units. Greater strike-slip faults at the northern margin of the Bükk Mts. are considered to be related to the approachment of the African and North European plate (Balla, 1984). Strike-slip faults are accompanied by transtension during the Paleogene, with the foundation of several deep basins, including the North Hungarian-Southern Slovak basin.

The Neoalpine morphostructural plan of the Central and partly Inner Carpathians with core mountains and accompanying intramontane basins is a specific feature, typical of the Western Carpathians. Its fundamental are:

– the inner arcs accompanied by manifestations of transpression and transtension phenomena (discussed above), partly perhaps of cylindrical type (sensu Grecula and Roth, 1979);
– the block structure with manifestations of faults, in several directions: in the western block NW–SE and NNE–SSW to NNW–SSE, in the central block mainly N–S and NE–SW, in the eastern block NW–SE and NNE–SSW, their leading role alternating in the course of development;
– the gradually more and more distinct Carpathian arc, with a gradual rebuilding of the structural plan in four stages (equally as in other Alpide segments, Maheľ, 1973), accompanied by displacement of the force fields (compressional and transpressional changing into transtensional and tensional)

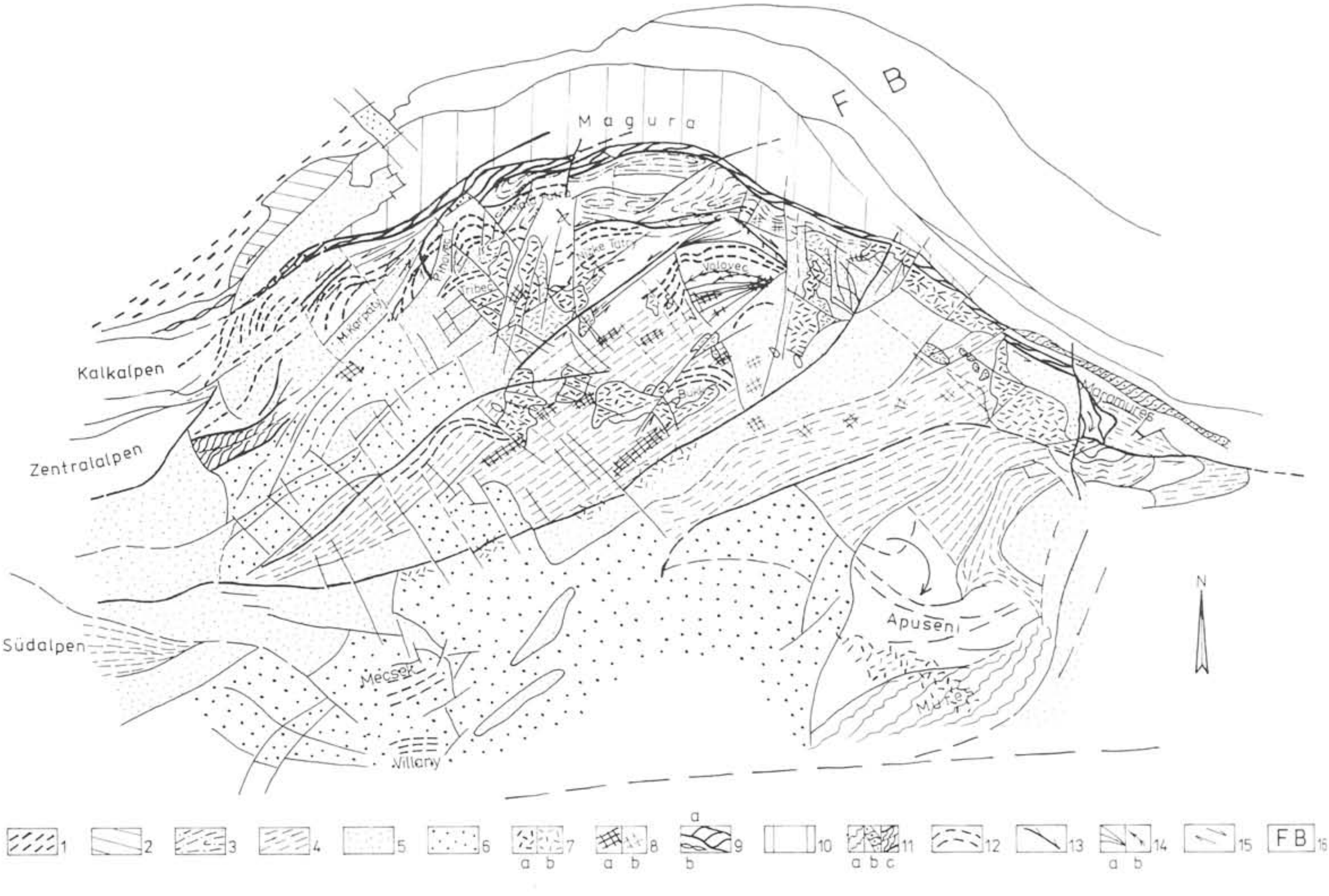

Fig. 2. Sketch-map of arcs and basin types in the Western Carpathians – M. Maheľ, 1990.
Explanations: 1 – foredeep; 2 – Ždanice–Waschberg flyschoid; 3 – basins of post-tectonic flysch; 4 – back-deep; 5 – Miocene basins; 6 – Pannonian basin; 7 – a) neovolcanics (Badenian–Sarmatian), and b) areas of pyroclasts; 8 – "heavy" bodies a) mentioned ophiolitic, b) ophiolitoid zones; 9 – a) Klippen Belt with coulisse-like structure, b) ultrahelvetic klippen; 10 – Magura Nappe; 11 – ophiolite zone: a) Mures, b) Ceahlau, c) Penninic; 12 – arcs; 13 – faults accompanied by coulisses; 14 – knots of synclinores; 15 – strike-slip faults.

Three geotectonic types of flysch basins

The abundance and variety of flysch facies in different stages of development, their presence in tectonic zones from the externide to internide ones, is most characteristic of the Alpides. It is a reflection of higher dynamics of the crust, of its variability in individual stages of development. As in other Alpide segments, in the Western Carpathians there are also flysch lithotypes:

– genetically linked with riftogenesis in the Triassic of the Meliaticum and with paleogeographical changes in the Choč Nappe (Lunz Beds);

– with rebuilding of paleotectonic plans at the beginning of the Dogger ("Posidonia and Supraposidonia" beds in the Pienides) and towards the Lower Cretaceous (Poruba Formation in the Krížna Nappe and Tatric units).

A specific feature of the Western Carpathians is, however, the presence of tectonic units, even their whole groups (tectonotypes), consisting of flysch complexes. The presence of a vast Flysch Belt, with a whole series of tectonic units, the great extent and variety of intrageosynclinal flysch sequences in the Perivahicum (Periklippen zone) and the considerable extent of the late-tectonic (Central Carpathian) flysch are proofs of the presence of geotectonically different flysch basin types. Their relationships in time and space allow to understand the causes of the differences, as well as the deeper significance of flysch complexes in the development of the orogen.

a) The *Outer Flysch Carpathians*, with complexes up to 10 km thick, having a stratigraphic span of Upper Tithonian to Eggenburgian (110 m. y.), are characterized by a prevalence of *siliceous greywacke material*, with lower contents of detritus originating in intrageosynclinal sources, further by a considerable stability of lithotypes (mainly in longitudal direction), by a high portion of coarse (sandstone) flysch, besides flysch s. s. and subflysch.

Limiting lithotypes, which separate the fundamental development stages of the flysch geosynclines, such as variegated claystones, Jaslo clays, Menilite Beds, are characterized by stability practically along the whole geosyncline. The individual tectonic (nappe) units display differences in the distribution of fundamental lithofacies in time. Direct influence of platform on the composition of flysch is restricted to the outer margin of the basin (Roth, 1980). This type of flysch is bound to activated margin of platform foreland, gradually incorporated into the geosynclinal system. Geotectonically there is a complicated system of basins formed by interaction of the craton with the system of active Alpide blocks, with a considerable role of collision. The genetic relationship to the platform margin is evidenced also by the fact that the platform margin does not display any significant signs of plastic flow, as well as by „thrusts and folds“ genetically related to collision.

b) *„Carbonate“ flysch*, up to 2000 m thick (Lower Albian-Middle Paleocene, 60 m. y.) is characterized by a high content of carbonate detritus from intrageosynclinal sources (Marschalko, 1979, 1986) and abundant representation of marlstones or sandy marls (spherosiderite and inoceramus marls, of couche-rouge type), as well as by wildflysch-type conglomerates with exotics, the presence of organogenic layers (orbitolite sandstones, rudist and orbitoid limestones), with frequent planktonic and agglutinated foraminifers (Salaj, 1988; Salaj et al., 1987). Because of its facial variability, horizontal and vertical, we classified it as a heterogeneous type (Mahel', 1973, 1974). The numerous exotics, including those of volcanics and Alpine granites, and the presence of chromium spinels indicate its genetic relationship with obducted margins of ophiolite – Vahicum, subducted below Tatricum before the onset of flysch sedimentation – an analogue of the Penninicum. Structurally, this type of flysch complexes forms mostly the tectonically complicated system of the Klape Nappe and the upper stage of the Manín Nappe – the units of Perivahicum incorporated into the Klippen Belt, and in part the frontal elements of the Central Carpathian nappes.

This type of flysch resembles flysches of the central zones in the Dinarides and Hellenides, as well as flysch of Muresh in the Alps – mainly the Verspala flysch and the Rand-Cenoman, partly also the Gosau-type flysch basins genetically related to the subduction of oceanic crust.

c) The Central Carpathian *late-tectonic flysch*, its original thickness sporadically reaching 3000–4000 m (Middle Eocene–Lower Oligocene, 12 m. y.), with a prevalence of quartz detritus; the stability and lithotypes resemble those of the Outer Carpathian flysch. It differs however in its more frequent marginal facies derived from local sources (Marschalko, 1976), moreover, there are differences in thickness of some lithotypes in partial basins, and it was less tectonically affected. In many points it resembles the Majevica flysch, but also flysch-filings of early inner depressions of the Balkans – basins of late rejuvenation which preceded the disintegration of crust typical of the subsequent molasse stage.

Conclusions

1. The European Alpides are a complex of specific features characteristic for each segment; they are a result of *dissection of the crust* already in pre-Mesozoic periods (Mahel', 1973). Some particularities in the structure of individual segments are to a considerable extent inherited (Mahel', 1978, 1983).

The differences in crust dissection are distinctly displayed in the *segmentation* of Alpides. The Western Carpathians are instructive also from this viewpoint. In the Alps and Carpathians, tectonic units of higher order are linked with each other, however, they are only *analogues*, having their own set of tectonic units and displaying differences in the content and structure. Another type of segmentation is represented by the Western and Eastern Carpathians, connected into a common arc by the Neoalpine Flysch Belt. Their Centralides belonged to different, coulisse-like emplaced blocks of continental crust, separated by a connecting oceanic trough – Transylvanian-Vahicum (Mahel', 1981). The other block is represented by the northern Apuseni Mts., with some units analogous to the Western Carpathian ones, connecting the Tisia with the Carpathians.

Each segment of the Alpides, and especially the Western Carpathians, has characteristic features which allow to explain the substance of some phenomena.

2. The dissection of the Alpides and of the Western Carpathian segment is reflected in a number of nappes arranged into several genetically different groups – *tectonotypes* (Mahel', 1987). In the Western Carpathias there are at least 6 tectonotypes, with differences in their structural plan, in the degree and type of deformation, which will enable to solve the problems concerning shortening of the crust (Mahel', 1982).

The explanation of the genesis of the tectonotypes may become a significant step towards a genetic classification of the nappes.

3. The formation of the Western Carpathian arc was a multistage process, occurring in the Mesoalpine and Neoalpine times. With the formation of older *Mesoalpine arcs* (in the Internides and Centralides) are genetically connected the basins of the Central Carpathian flysch (in its foreland), synclinores and coulisse structure, as well as the formation of transversal fault zones accompanied by narrow fold structures and strike-slip faults. The formation of the Neoalpine arc is most markedly characterized by inner depressions, which are a result of crust disintegration preceded by the formation of inner arcs – the foundations of later core mountains or horst megaanticlines.

4. *Three geotectonical types of flysch basins* formed under different geodynamic conditions on different types of crust provide the possibility to learn more about the geodynamics of flysch formation. They are:

– thick complexes of greywacke flysch in the Carpathian Flysch Belt bound to the platform margin, incorporated into the "geosynclinal" system. The "strange" (predominantly quartzy) detritus has been several times redeposited, with no marked differences along the Flysch Belt, in the Alps and the Carpathians, regardless of the change in the foreland structure;

– sequences of "carbonate" flysch of Perivahicum, with detrital rocks derived from Carpathian sources (equally as the majority of flysch sequences in other Alpide segments); they are more closely paleotectonically related to flysch lithotypes of the Pienides, as well as to the subduction of Vahicum;

– post-tectonic flysch, the predecessor of molasse basin fillings in the Centralides, genetically related to the formation of the Carpathian arc. The essential part of detrital flysch rocks is derived from an unknown source, different from the Flysch Belt.

5. Thirty years ago, owing to many coincidences in the stratigraphy and tectonic structure, the Western Carpathians appeared in many regards as an appendix of the Alps, or the "Alps in small". With a more profound knowledge of the specifities in their development and structure we feel justified to present the Western Carpathians as a model segment of the European Alpides, specific not only in their Neoalpine morphostructural plan, but also in the completeness of stratigraphical-paleotectonic units – tectonogroups, tectonotypes (terranes).

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