MICHAL MAHEĽ*

TECTONIC MAP OF THE CARPATHO-BALCANIC AND ADJACENT REGIONS

Abstract: The map under preparation includes the regions of the Carpathians, Balkan, Hungarian Lowland, great part of the Dinarides, the East Alps and the extensive foreland of the Alpides.

The aim of the map is to present the fundamental features of the structure of the Alpine system as well as the differences in the structure of the individual segments.

The fundamental principle of the map is the degree of deformation. In the Young Alpine complexes 19 groups of units were distinguished according to the age of origin and degree of deformation.

Marking out of tectonogroups nearer determines the content of the tectonic units, contributes to further structural division and determination of the paleotectonic type of structures.

The present tectonic map 1 : 1 000 000 was worked out within the work of the Tectonic Commission of the Carpatho-Balkanic Association, a wide collective of geologists from Austria, Bulgaria, the German Democratic Republic, Federal Republic Germany, Yugoslavia, Hungary, Poland, Roumania, the Soviet Union and Czechoslovakia.

I am going to mention at least those who mostly participated in the elaboration of the map: Beck-Mannagetta, Pray (Austria); Bončev (Bulgaria); Watznauer (German Democratic Republic); Gaertner (Federal Republic Germany); Sikošek, Dimitrijević, Grubić (Yugoslavia); Balogh, Körrössy (Hungary); Wdowiarz, Znosko, Sikora (Poland); Codarcea, Dumtrescu, Sandulescu (Roumania); Vjalov, Gluško, Dolenko (USSR-Ukraine); Zoubek, Leško, Roth, Matkovský, Maheľ (ČSSR). M. Maheľ managed the work; he worked out the principles of the legend, worked up the uniform legend of the whole map after many sessions and several proposals (treated at 10 meetings of the Tectonic Commission of the KBA in the years 1962—1968) and carried out the editorship of the worked out map in the sense of the uniform legend by editorial groups of the participating states. The cartographic works at the compiling original were carried out by members of the Cartography Department of the Dionýz Štúr Institute in Bratislava under the leadership of R. Púchy, who also cooperated with the editor in chief in compiling of several proposals of the legend.

The topographic base of the map was made and delivered by the Institute of Cartography and Geodesy in Prague.

The map under preparation includes the region of the Carpathians in its whole extent, the region of the Balkan Hungarian Lowland, wide part of the Dinarides, the East Alps and the extensive fore-land of the Alpine-Carpathian system including the Bohemian Massif. It is compiled with the aim to show the fundamental features of the structure of the Alpine system and also not only the common features but also the differences in the structure of the individual segments. Presenting the fore-land we intended to show the relations between the Alpides and the fore-land and to indicate

* Prof. RNDr. M. Maheľ, Dr. Sc., Dionýz Štúr Institut of Geology, Bratislava, Mlynská dolina 1.

the differences in the structure. The above mentioned aims directed our endeavour to compile the map, to a considerable degree a structural-tectonic one but with historic-evolutionary aspect. In this way with the applied principles we were based on the tectonic map of Europe compiled under the leadership of B o g d a n o v and S a t s k y. It concerns the evolutionary cycles, structural stages and formations. It was however necessary to work out and adapt the content of these fundamental principles if we wanted to express the complexity of the structure with a plenty of tectonic units and also their genetic relation to the fundamental paleotectonic (geotectonic) zones.

We distinguished in our map coloured complexes formed during the following cycles: Paleo-Pre-Baikalian (reddishviolet), Neo-Pre-Baikalian (slightly reddish-violet) Baikalian (brick-red), Hercynian (brown) and Alpine. Distinguishing of the Hercynian complexes by colour into Old Hercynian (brown sepia) and Young Hercynian (light-brown) but also three fundamental groups of colours for the Alpine complexes: green for the internide-Old Alpine units, orange for Young Alpine units-externides and yellow for depressions resembles, when also in a schematic way only, the structural stages of the tectonic map of Europe. We also applied the plan of deformation of the complexes as the fundamental principle of the map and expressed it with colours. The structural stages in our conception — it is more suitable to speak about the stages of deformation — have however a more distinct structural accent (more or less in the sense applied in the tectonic map of Roumania 1 : 1 000 000) (D u m i t r e s c u et al.).

In the division the Pre-Paleozoic complexes we distinguished two regions of the Alpides: the western: Alpine—West Carpathian and eastern: the East and South Carpathians, Serbo—Macedonian Massif and Rhodopes. In the western region division of Pre-Paleozoic units is only carried out according to the degree of metamorphosis into two Pre-Alpine types (meso —kata and epi — meso) and the third type represents the crystalline of zones of Alpine re-working.

In the eastern region the Pre-Paleozoic complexes are also distinguished by colour into Paleo-Pre-Baikalian, Neo-Pre-Baikalian and Baikalian ones. To the Paleo-Pre-Baikalian ones with marking of meso-katametamorphism the oldest complexes of the Rhodopes, Balkan, Serbo-Macedonian Massif, in the South Carpathians —the Lotarian complexes, are ranged. As Neo-Pre-Baikalian we ranged the Late Assyntian complex of gneisses in the Rhodopes and Pelagonic Massif and the Alutian in the South Carpathians. The Baikalian complexes include: the spilite-keratophyre series of the Rhodopes, Srednogorje and Balkan, the Vlasin-Asogov-Complex or the Riffeo-Cambrian complex of the Krajstides and Serbo-Macedonian Massif, ophiolite formation of the South Carpathians. In the Roumanian Carpathians the Baikalian-Hercynian complex is distinguished as particular complex. In accordance with necessary distinguishing of Pre-Paleozoic metamorphites also the granitoids, synorogenic and postorogenic are distinguished with particular, usual symbols.

As Old Hercynian units are considered those formed by the Bretonian to Asturian folding. The individual zones especially differ in the degree of Alpine re-working and also in the portion and type of volcanites.

With great embarrassment we performed demarcation of Young Hercynian units formed by Saalian and Pfalzian folding. The Young Paleozoic complexes are the most frequent part of the younger, Alpine units, they are also related to them in some geotectonic zones and also in whole regions — the Alpine geosynclinal cycle already commenced with them. Taking into consideration the difference in intensity and geotectonic significance of the Late Alpine folding in the individual regions we ranged

a part of the Young Paleozoic complexes as Young Hercynian molasses in our map (displaying paleogeographical and tectonic discordance with the younger complexes — Balkan, Centrocarpathicum, South Carpathians). In these regions the Alpine geosyncline commenced as late as with the Triassic or Jurassic (South Carpathians). In places, where the Permian molasse passes into the Lower Triassic without distinct discordance and the Permian complexes are a part of the Alpine unit we marked them also in colour as Alpine (Austroalpinicum). The Young Hercynian units form in their terminal stage the foundation of the Alpine geosyncline, and that in the Dinarides, Bück and South Gemeride unit, in this case we ranged not only the Permian, predominantly of marine development, but also the Carboniferous to the Alpine complexes.

The scale of colours of the Alpine cycle is quite variable in our map (5 types of green colour, 5 of orange, 3 of transitional colour between orange and green and 5 of yellow). Working it out we were based on some characteristic features of the Alpides.

We consider as characteristic features of the Alpides:

1. The intensity of the individual phases of folding was not equal everywhere; it was changing from zone to zone and from segment to segment. In some segments there is a more in other ones less distinct succession of formation of the units in time from the internal towards the external part.

2. The individual segments differ in number, the age of tectonic units and structures, intensity and general plan of deformation and naturally also in the stratigraphic range of the tectonic units.

Stressing the time of origin of the units as the fundamental principle of division, we distinguished:

1. Neocimeric units (Strandža-Sakar-Zone).

2. Early Cretaceous units especially originated in the time of the Austrian and Subhercynian phase of folding: Drauzone, Unterostalpin, Penninicum, units of the Central Carpathians, Codru-Moma, the atochthon of Bihor, Meczek, Vilany.

3. Early Cretaceous units, the second time affected by intense folding in the periode of the Laramide or Ilyrian folding, e. g. the internal units of the Dinarides, the nappes of the Northern Calc Alps: Ceahlau-, Bukovina- and Transsylvanian nappe of the East Alps, the Getic nappe, Danubicum, Severin-nappe of the South Carpathians; the southern units of the South Carpathians (Stara Planina, Miroč, the Krajstides), Srednogorje in the Balkan.

4. Units folded twice, in Early Alpine time and at the end of the Eocene: Zukali and Budva, the Klippen Belt of the West Carpathians, Balkanides.

5. Young Cretaceous to Old Paleogene units-Upper Cretaceous complexes, partly folded together with the older units, formed as early as during the Old Cretaceous folding: upper Cretaceous complexes in the inner zones of the Dinarides, of South Carpathians, in the Mureš Zone and Upper Cretaceous complexes in the Northern Calc Alps.

Slight reach of folding was in the Hungarian Midmountains.

All the above mentioned groups of units represent the i n t e r n i d e s. The younger complexes superimposed on them are late-tectonic to post-tectonic.

6. In the innermost zones the Upper Cretaceous is of early post-tectonic character: the Gosau type of the Central Alps and Apusins, early molasse of the Serbo-Macedonian Massif and southern zones of the West Carpathians.

7. Another group marked with colour is represented by Paleogene late-tectonic complexes situated in the outer zones of the internides: the Trans-Carpathian and Central Carpathian Elysch, Majevica, early molasse in the Vardar Zone.

8. A particular position show the Old Paleogene units, originated in the time of the Pyreneic and Ilyrian phases. They link up the externides with the internides. They are as follows: the Krš Zone in the Dinairdes, younger complexes of the Zukali and Pieninic Klippen Belt in the Carpathians. An analogous function displays the Ludokamčija Zone of the Balkan. The units and structures in the Balkanides representing in their position the zone of externides correspond to this folding in age.

We divided the units of the externides into three groups, using shades of orange colour:

9. Units formed in the time of the Ilyrian and Savian phase, nappes of the Flysch Zone together with the Helveticum of the East Alps, the Magura nappe of the West Carpathians and the South-Jonian Zone in the Dinarides.

10. Units especially formed during the Early Styrian phase: Silesian, Dukla, Pre-Magura, Curbicortale, Čierna hora-Audia.

11. Units especially formed during the Late Styrian phase: Skole-Tarkau, Unite marginale, Ždánice, Pouzdřany unit.

It is necessary to point at the difficulties in division and ranging of some tectonic units, especially in the Flysch Zone of the West Carpathians. All the units of the Flysch Zone were also affected by folding in the time of the later phases. The affects of the earlier phases are frequently masked and it is not easy to determine their share in formation of the units.

The youngest units of the externides are represented by the for-deep divided into:

12. The older — inner fore-deep, late-tectonic and

13. the outer, post-tectonic fore-deep.

14.—18. We mark out the basins with shades of yellow colour, according to the age of origin. They rarely originated as early as in the Paleogene, more frequently they are Post-Savian, very frequently Post-Early Styrian and also Post-Late Styrian. Largely represented are also Post-Moldavian (Intra-Sarmatian) basins.

Using colours for distinguishing of complexes of different tectonic deformation as the fundamental principle we distinguished by colour certain regions, large zones and some units. This however does not provide by far for sufficient base for marking a total amount of the tectonic units. This method makes possible to show only one aspect of tectonics — the age of folding and differentiation of the units according to the age of formation. Another aspect of tectonics, not less important, is however the tectonic style — being very variable in the Alpides, dependent upon spatial position of the units, intensity of folding and especially upon the material content of the units. Though the structural symbols — thrust lines, axes of anticlines and synclines etc. — contribute to marking of the tectonic style: the presented map abounds in them sufficiently (marked with black colour). We consider as the most favourable way of marking the structural elements however the marking out of the content of units, in this way our map represents an uncommon type of the tectonic map.

To a limited degree — for marking out of the geotectonic type — the fundamental formations are also applied in the mentioned map of Europe. In this direction however we apply the fundamental formations (flysch, carbonate, molasse, aspide) more thoroughly at Pre-Mesozoic complexes only.

In younger complexes we followed the problem of application of the marking of the content to a much larger degree, in the first place for structural-tectonic aims. For this purpose it was necessary in the first place to perform more detailed division of the content and its tectonic classification. The subformations in the sense of Soviet geologists and the tectofacies in the sense of K r u m b e i n, S l o s s came into

consideration. In both cases the danger arose that the result would be a map of the fundamental facies or some combined tectonic-paleogeographic map. After various working over we chose categories in many points approaching the subformations (in some also overlapping with them), to a much larger degree we however took into consideration tectonic aspects in division and classification. Placing just the structural requirements on the first place and that before the paleotectonic ones we distinguished complexes that seem to be therefore suitable to be termed t e c t o n o g r o u p s (= groups of tectonic importance).

The tectonogroups represent paragenetic sets of facies of certain stage or period of development, closer determining not only the paleotectonic type of the environment of sedimentation but also the tectonic style of the structural elements with regard to their share in formation of tectonic units. They are consequently complexes, in which the character of the tectonic conditions under which they originated is reflected, forming in its content of material the base for formation of the tectonic elements.

For the individual stages of development certain types of tectonogroups are characteristic. In the commencing stage of the Alpine geosyncline two of them are manifested especially distinctly: the shallow-water (detritic-marlstone-volcanogenic) and molassoid one. The former is characteristic of the inner zones of the Dinarides, Bück and South Gemeride unit; in the Dinarides linking of the Alpine structures with the Hercynian is evident. The commencement of the geosynclinal development may be considered as early as in the Carboniferous. Though the molassoid tectonogroup (partly the volcanogenic) represents dying away of the Hercynian cycle, but at the same time it also represents the commencement, foundation of the Alpine geosyncline and its volcanism is frequently mixed (subsequent — initial). This is distinctly manifested in the structural plan of the West Carpathians (also in the Apusins) — as the partial unit of the Melaphyre Formation.

The period of the Middle and Upper Triassic is very differentiated in the Alpides. It is distinctly manifested in structure especially in the inner zones — where evidently the axis of the geosyncline was situated in that period, partly in the Jurassic. On the basis of the differences in volcanism, variety of facies and thickness and consequently also variety of structure we distinguished these tectonogroups: Dinaride type, transitional Dinaride-Austride type, Austride type, Central Alpine (Unterostalpin), Bukovina- and Balkanic type.

The types of the mentioned tectonogroups in time succession reflect the changes of paleogeographical picture. In the commencing stages of the geosyncline, in the Triassic, the facial sets more distinctly show zonation, distinguishing of tectonogroups is therefore also of more distinct paleotectonic character. The commencing subformations of the more northern zones — internides, as the quartzite and carbonate ones, are not manifested as particular tectonogroups. Though the Triassic is present there, the most significant part of the tectonic units (dominating rôle) is represented by the Jurassic and even by the Lower Cretaceous. Many Jurassic, Cretaceous as well as Triassic facies are calcareous. They are however other types formed under different paleotectonic regimen and mostly otherwise manifested in structure. They are distinctly differentiated, representing particular tectonogroups: trough-tectonogroup, with marlstones prevailing, frequently accompanied by small cordilieras; cordiliera-tectonogroup with variety of shallow-water facies; in the East and South Carpathians the calcareous-neritic tectonogroup is spread with predominance of thick limestones of the Stramberk type (frequently without accompanying Triassic or Lower Jurassic: Trascau, Geticum); marlstone-calcareous tectonogroup with abundant bathyal facies (western part of the

Danubicum); in the Balkan the latter laterally passes into the calcareous-terrigenous tectonogroup with predominance of detritic facies in higher parts (Lower Cretaceous); terrigenous-limestone type in the Meesek with thick detritic facies (Keuper, Gresten Beds); limestone-dolomite type of the Velki Krs with abundant dolomite layers mainly in the Jurassic and Cretaceous; heterogeneous with variable facies; the Pieninic Klippen Belt, Kotlan Zone in the Balkan. Special type of tectonogroups are the Zukali and Budva Zone.

In places already in the Tithonian, mostly in the Cretaceous and Paleogene, the flysch facies occupy a significant portion in the structure of the Alpides, with particularities not only in the development but also in the tectonic style. Since complexes mostly originated in genetic connection with tectonic movements are concerned, their variety and variability in time and content and also the differences in significance of structure, especially distinct in the internides, are understandable. In our map we distinguished these tectonogroups; flysch s. s.; sandstone flysch; limestone flysch; limestone-detritic flysch; wild flysch; heterogeneous flysch partly volcanogene and flyschoid types; pelitic complexes with flysch facies; marlstone-limestone-detritic-volcanogene (Timok-Srednogorje); marlstone-limestone (Kučaj Zone) and limestones accompanied by flysch facies. Owing to such a division very distinct differences become evident in the individual segments and also in some zones.

In the flysch tectonogroups also changes in time succession in the individual segments are especially very interesting to study. In the map we distinguish the following tectonogroups with density of hachures: with the character of early flysch- — I_3^t — K_1; culmination flysch — K_2—Pg_2 (mostly in the time between two foldings) and terminal flysch Pg_3 — connected with the folding of the later period.

The division of the tectonogroups of the latest stages of the molasse corresponds to the type of basins. The geotectonic type is indicated in our map with colour and partly with the type of points: red in fore-deeps, green in intermontane basins, grey in inner basins; in superposed basins the points are coarse. From tectonic point of view it is important to indicate the duration of sedimentation in some basins — we perform it with symbols, marking commencement and termination of the sedimentation (e. g. N_1—N_3). The morphology of the basement of the basins and the thickness of the basin filling are marked with isohypses and the type of basement with coloured interrupted lines (only in large basins).

Applying the tectonogroups we pursued the following aims:

a) To reach graphically that the individual tectonic units marked with equal colour (i. e. formed in the time of the same folding) should be more distinct visually.

b) To mark out the partial structures of some units more distinctly.

c) To distinguish important partial units different in the content.

d) To point differences in the units indicated with equal fundamental colour (of the same age) but with different content, development and tectonic style, e. g. the Choč and Krížna-unit; Danubicum and Geticum; Audia and Curbicortale etc.

e) To point at accordance in the content in units of various segments, different in colour (since they were affected by different folding). They are from the same paleotectonic (geotectonic) zone, of equal development, with equal content and frequently also equal tectonic style, e. g. the nappes of the Northern Calc Alps — southern nappes of the Carpathians — Codru-Moma in the Apusins.

f) To mark out the common features and also the differences in the individual regions of the Alpides more distinctly.

g) To indicate the type of the geosyncline and its individual parts.

The greatest advantage of application of tectonogroups indicated with grey screens (in combination with the degrees of tectonic deformation — indicated with colours) is that we succeeded in marking out the tectonic units of higher and lower order in the map by means of them. For this purpose to a large degree we also applied the fundamental four directions of screen (vertical, horizontal, right diagonal, left diagonal) and that to distinguish units of the same age and analogous content. Besides that we marked the tectonic units with initials.

In order to stress some units or zones, particularly conspicuous tectonically: the Klippen Belt, Vardar Zone, Helvetides, Krajstides we applied hachures of blue colour. We applied violet hachure to indicate belonging to some nappe of the Mesozoic and Pre-Mesozoic complexes, e. g. the Getic nappe.

For marking of magmatites we applied symbols currently used in tectonic maps, e. g. in the tectonic map of Czechoslovakia: In intrusive volcanites (a) post-orogenic and (b) syn-orogenic we distinguished (by colour of the corresponding symbols — crosses) Pre-Baikalian, Baikalian, Hercynian, Old Alpine, Young Alpine ones and of uncertain age.

Closing I would stress that we intended by application of the mentioned approaches to ezpress the tectonic units and structures and to emphasize the common features as well as particularities of the structure of the individual segments and units.

Review by O. F u s á n.