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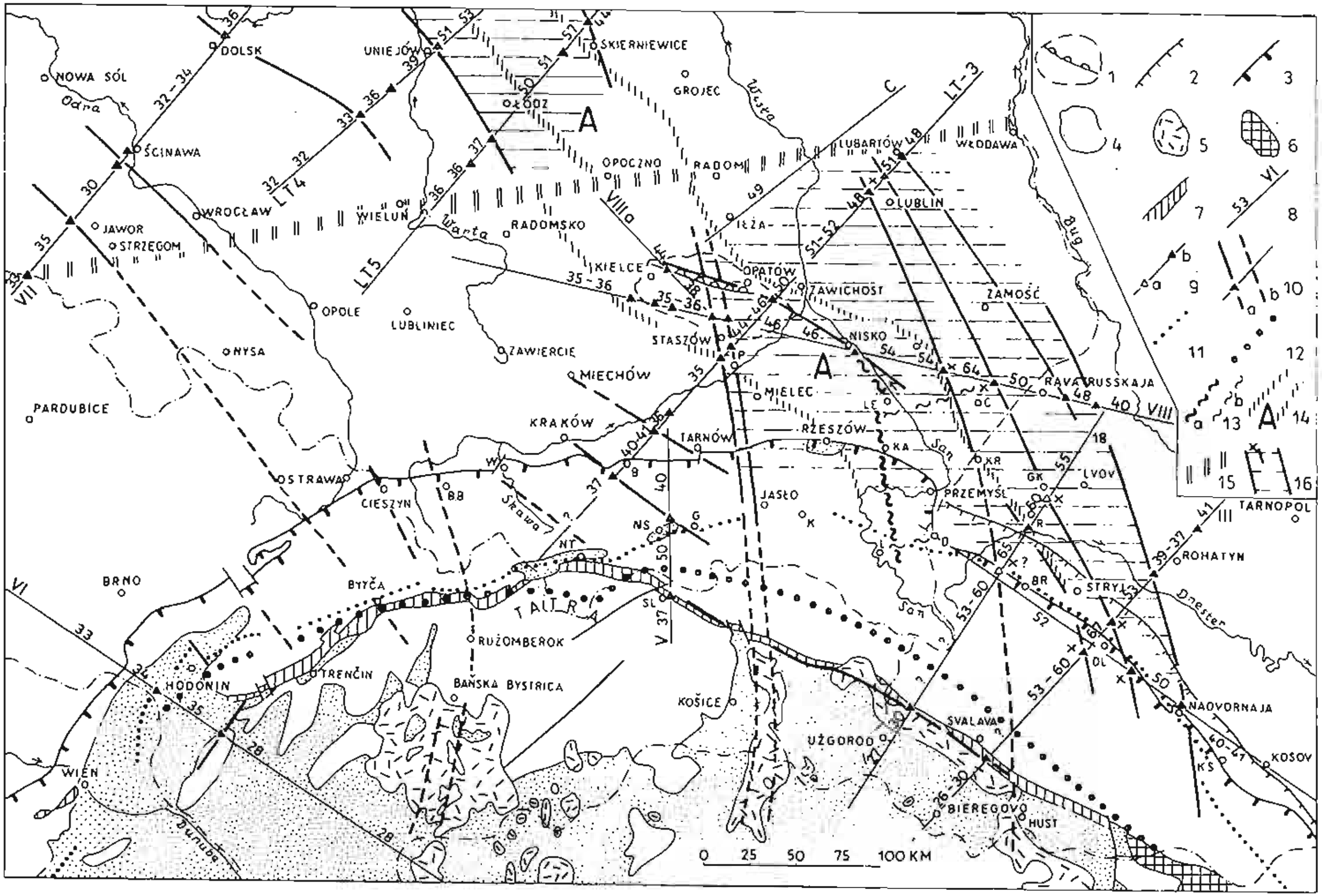
Some problems of a geodynamic model of the Northern Carpathians

Modified picture of the Earth's crust structure in the Northern Carpathians and their foreland (Fig. 1) is discussed. Karlovy Vary – Radom – Chernigov deep fracture is implied, being introduced as a northern boundary of the Meta-Carpathian range. This fracture cuts both Paleozoic and pre-Vendian (East European) platforms as far as Dnepr-Donetz aulacogen (Fig. 2). According to author's new analysis the western extremity of the Skole flysch near Brzesko is connected with the southern extension of western slope of the Mid-Polish aulacogen. Since Campanian mobile San massif (southern part of the Mid-Polish anticlinorium) was a source area for submarine slumpings and olistolites in the Skole flysch of Przemyśl region. Thrust directions of the Carpathian flysch masses are discussed.

The most northern part of the European Alpides, situated in Poland, represents a transitional zone between West Carpathians oriented SW – NE and East Carpathians oriented NW – SE. The Central and West European Paleozoic and partly also the East European pre-Vendian platforms (bordering along Teisseyre-Tornquist line) constitute the foreland for the Northern Carpathians. The vicinity between the boundary zone of both platforms and transitional zone of two distinct Carpathian orogen segments simplifies a quest for common paleogeographic and structural traites of geosyncline and its foreland. This is the searching for the principles of the palinspastic reconstruction of the Carpathians and for understanding the present structure of this orogen.

Present paper deals with problems of the Earth's crust structure in the northern part of the Carpathian chain and in their foreland basing mainly on the published results of the deep seismic soundings (V.B. Sollogub et al., 1978, 1980; A. Guterch et al., 1983). The problems of geological boundary between West and East Carpathians as well as paleogeographic and structural relations of the Carpathian geosyncline and foreland platform with reference to the papers by W. Pożaryski and K. Żytko (1981), and K. Żytko (1984) are analysed. Much attention has been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paid to the connection between the structural frames of Polish and Ukrainian Carpathian basement.

The author refers to the role of Africa in the origin of European Alpides. The information about a pattern of Alpine compression in the Carpathians and their foreland in terms of plate tectonics were mainly taken from the paper by J.F. Dewey et al. (1973).

EARTH'S CRUST IN THE NORTHERN CARPATHIANS AND THEIR FORELAND

Results of investigation of the Earth's crust in Central and East Europe, published in many papers, are presented synthetically (V.B. Sollogub et al., 1978, 1980). Several zones of changes of the Moho discontinuity depth, qualified as the deep fractures have been discovered by the deep seismic soundings (DSS). Some of those zones have a distinct connection with boundaries of suprastructure elements thus helping to establish their directions. They split the crust into separate blocks. Certainly there exist also the crustal fractures without changes of the Moho discontinuity depth.

A net of DSS profiles is widely spaced. There are still problems with selection of fracture's directions as well as in some cases with determination of their angle of projection on the surface. The young thrusts of flysch masses in the Carpathians mask the basement fractures. Due to the above reasons the sketch of crust in the Northern Carpathians and their foreland (Fig. 1) contains many obscure points. Fractures have been divided into probable and conjectural ones. This sketch is connected with the picture of the Moho discontinuity (level) which is accepted for the area of Poland by A. Guterch (1977) and for the NE Carpathians and their foreland by V.B. Sollogub et al. (*vide* V.B. Sollogub et al., 1978, Fig. 152; 1980, Fig. 87). However, it is also based on the new materials (A. Guterch et al., 1983) as well as on an additional analysis of the author. The tectonic map of the Carpa-

Fig. 1. Sketch of the Earth's crust fractures in the Northern Carpathians and in their foreland

Szkic rozłamów skorupy w Karpatach północnych i na ich przedpolu

1 – Holy Cross Mts; 2 – margin of folded molasses of inner foredeep (Stebnik-Sambor unit); 3 – margin of overthrusted Carpathian flysch; 4 – Neogene postorogenic depressions; 5 – Late Alpine volcanic rocks; 6 – crystalline – Mesozoic zone of the East Carpathians; 7 – Pieniny Klippen Belt; 8 – deep seismic sounding (DSS) profiles and depth of the Moho discontinuity in km; 9 – Moho flexures (a) and faetures (b) localized by DSS – vertical projection; 10 – crustal fractures (a – probable, b – conjectural); 11 – axial zone of regional negative anomaly (Carpathians only); 12 – zone of changes of geoeleetric vectors of induction (Wiese's vectors); 13 – western boundary (a) and discontinuity zone (b) of the magnetic anomaly belt related to the Gothian socle (in San river – basin only); 14 – boundaries of the Mid-Polish anticlinorium; 15 – line of hypothetical Karlovy Vary – Radom – Chernigov crustal fracture; 16 – area of thick Earth's crust (x – x zone of additional thickening). BB – Bielsko, W – Wadowice, NT – Nowy Targ, B – Bochnia, NS – Nowy Sącz, G – Grybów, SL – Stara Lubovna, P – Połaniec, K – Krosno, LE – Leżajsk, KA – Kańczuga, L – Lesko, D – Dobromil, C – Cieszanów, KR – Krakowiec, GK – Gorodok, R – Rudki, BR – Borislav, DL – Dolina, KS – Kosmacz

1 – Góry Świętokrzyskie; 2 – brzeg sfałdowanych molas wewnętrznego zapadliska (jednostka Stebnik-Sambor); 3 – brzeg nasuniętego fliszu; 4 – neogeńskie depresje postorogeniczne; 5 – młodoalpejskie wulkanity; 6 – strefa krystaliczno-mezozoiczna Karpat Wschodnich; 7 – pieniński pas skałkowy; 8 – profile głębokich sondowań sejsmicznych (GSS) i głębokość granicy Moho w km; 9 – zlokalizowane metodą GSS fleksury (a) i rozłamy (b) granicy Moho (rzut pionowy); 10 – rozłamy skorupy (a – prawdopodobne, b – domniemane); 11 – strefa osiowa regionalnej ujemnej anomalii grawimetrycznej Karpat; 12 – strefa zmian geoelektrycznych wektorów indukcji Wiese'go; 13 – zachodnia granica (a) i strefy nieciągłości (b) pasa anomalii magnetycznej wiązanej z blokami podłoża o gotyjskiej konsolidacji (tylko w dorzeczu Sanu); 14 – granice antyklinorium środkowopolskiego; 15 – hipotetyczny rozłam skorupy Karlove Vary – Radom – Czernichów; 16 – obszar grubej skorupy Ziemi (x – x strefa dodatkowego zgrubienia)

thians and their foreland (M. Maheł ed., 1973) has been mainly used for the references to the suprastructure phenomena. The author does not approach neither a problem of indistinct or double nature of the Moho discontinuity in some areas, discussed by geophysicists (*vide* V.B. Sollogub et al., 1980) nor of the age of this level. It results from the work of A. Guterch, V.B. Sollogub and coauthors that in a relief of the Moho level in Poland the direction NW – SE predominates whereas in the foreland of East European platform in the region of Lublin – Lvov – Nadvornaja the direction NNW – SSE is distinctly marked. It seems that the last one is also present further to the west (Fig. 1).

MAIN FRACTURES OF THE SUDETES MTS AND THEIR CONTINUATION IN THE CARPATHIANS

Thin block of the crust (about 30 km thick) has been discovered on the profile VII (A. Guterch et al. *vide* V.B. Sollogub et al., 1978, Fig. 60). In the suprastructure this block corresponds with the Fore-Sudetic block. On its both sides the Moho level occurs several km deeper. Presumably on the profile VII there is a connection between the Moho fractures bordering the block mentioned above and the Tertiary Marginal Sudetic fault in the region of Jawor as well as with system of Laramian faults of Middle Odra in the area of Ścinawa NW from Wrocław. Those faults belong to the main fractures of suprastructure of NW – SE direction (L. Sawicki, 1966; J. Oberc *vide* M. Książkiewicz et al., 1977). Due to this connection and to the gravimetric direction of the „Sudetic anticlinorium" (Zielona Góra – Kraków – Użgorod) traced by V. Scheffer (1960) one could assume a continuation of the Moho fractures south-east-wards beneath the Carpathians.

The line of disturbances of Sudetic Marginal fault continues south-eastwards from the crossing with profile VII in the area of Jawor. In the Silesian-Moravian

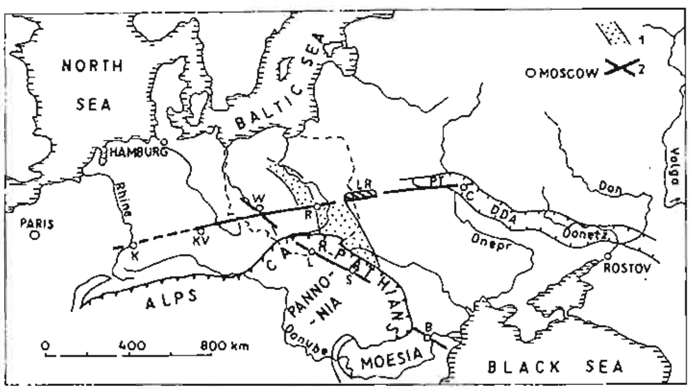

Fig. 2. Sketch of selected features of the Earth's crust in the Carpathian region
Szkic wybranych elementów skorupy rejonu Karpat

1 – area of thick Easth's crust in the border zone between Paleozoic and pre-Vendian (East European) platforms; 2 – selected deep fractures; LR – Łuków – Ratno horst, PT – Prypyat trough, DDA – Dnepr-Donetz aulaeogen, K – Karlsruhe, KV – Karlovy Vary, R – Radom, C – Chernigov, W – Wrocław, L – Stara Lubovna, S – Svalava, B – Braila

1 – obszar grubej skorupy w granicznej strefie platform paleozoicznej i prewendyjskiej (wschodnioeuropejskiej); 2 – wybrane ważne rozłamy; R – horst Łuków (Sławatycze) – Ratno, PT – rów Prypeci, DDA – dnieprowsko-doniecki aulakogen

Beskidy Mts in the extension of this line the Silesian unit disappears from the surface and it probably becomes reduced. Further south-eastwards it changes the structure of inner zone of the Magura nappe (eastern ending of the Bile Karpaty unit) and the width of the Pieniny Klippen Belt near Bytča. In the Inner Carpathians there is the fault of Valča (M. Mahel, 1974, Fig. 2), which continues towards Banska Bystrica. It is possible that those important phenomena constitute together the fracture of Jawor-Bytča marking a boundary of separate blocks of the crust.

The system of Middle Odra faults is a part of Odra–Dobrogea fracture/lineament (B. Beranek, A. Dudek *vide* V.B. Sollogub et al., 1980) but the continuity of this fracture is not well documented. It is marked by discontinuity zones of Moho level on the following profiles: VII(Ścinawa-Prochowice NW from Wrocław), V (Stara Lubovna), 18 (Perechin near Użgorod), III (Svalava) and II (Braila). It could be considered as a boundary of blocks with thick crust from the NE side and relatively thin crust from the SW side. Alpine evolution gave this fracture a different character and throw in the Carpathian section (Fig. 1, 2). The structural disturbances of flysch along the Wadowice–Krościenko line (the line of Skawa – M. Książkiewicz et al., 1977, p. 579, 598), the structure of eastern segment of Pieniny Klippen Belt (SE from Nowy Targ), the Neogene volcanites (mainly andesites) of the Pieniny and Eastern Carpathians and probably also the seismic zone of Vrancea seem to have genetic connection with such interpreted fracture of Wrocław–Braila[1].

Along the Carpathian segment of the thin „Fore-Sudetic" block of crust, limited by the fractures of Jawor–Bytča and Wrocław–Stara Lubovna there extends the West Carpathian gravity minimum of the Tatra Mts region (Fig. 1, see also V. Scheffer, 1960). On this block there are the main masses of the Silesian unit (reconstructed sequence of Cretaceous-Paleogene flysch up to 5000 m thickness) with basic rocks (teschenites) in the Lower Cretaceous flysch. A problem of the overthrust directions of these masses will be considered later in this paper.

Allochtonous masses of the Carpathian units overlying the block described above, are cut by structural disturbances along the Bielsko–Zazriva–Rużomberok line of NNW–SSE direction. These phenomena, particularly Z-shaped bend of Zazriva in the Pieniny Klippen Belt and the western boundary of the Lower Tatra massif as well as the distribution of volcanic centres in the SSE extension of this line point to the existence of a deep fracture of the crust. M. Mahel (1974) includes the Zazriva bend into the system of the Inner-Carpathian faults of Zazriva–Revuca oriented NNE–SSW, running in the direction of Budapest.

The less intensive disturbances but similar to those along the Bielsko–Zazriva line appear in the flysch of outer Carpathians along the Olza river line, between Cieszyn and Jablonkov.

FRACTURES IN THE AREA OF KRAKÓW–TARNÓW

On the profile LT-3 between fractures in the vicinity of Bochnia and Borzęcin (between 76 and 108 km of the profile) as well as on the profile V northwards from the fracture near Nowy Sącz the crust is about 40 km thick (Fig. 1). The fracture

[1] This fracture has been described as the Odra–Dobrogea lineament (*vide* B. Beranek, A. Dudek, *l.c.*). Some part of this line has been connected with the peri-Pieninian lineament. On the profile III this fracture is defined as the Transcarpathian one. The name Odra has been also used for describing a completely different line "Odra–Kaukaz" forming the boundary of East–European platform (V. B. Sollogub et al., 1980, Fig. 85, 126, 127) therefore the term Wroclaw–Braila is used in the present paper.

of Kraków – Grybów passing the area of Bochnia forms the south-western boundary of this block of the crust. Between Nowy Sącz and Grybów in the area of this fracture the axial zone of a gravity minimum is displaced. It was already noted by J. Uchman (*vide* V.B. Sollogub et al., 1978, Fig. 64) however he assumed more meridional direction of the fracture.

In the blocks of the crust bordering along Kraków – Grybów fracture a pivotal configuration of the Moho level is marked; it comes down from 37 km in the marginal part of Carpathians, south from Kraków (LT-3 profile) to about 50 km south from Nowy Sącz (V profile) as it approaches the axial part of the gravity minimum. On the NE side of Kraków – Grybów fracture the Moho level occurs at a depth of 40 km on both profiles.

NE from the Borzęcin – Tarnów fracture found on the LT-3 profile, the crust is a few km thinner. In the extension of this fracture in the Eastern Carpathians there is an axial zone of the regional gravity minimum, but the mutual relation of those linear phenomena is not certain.

FRACTURE ZONES BETWEEN THE PALEOZOIC AND EAST EUROPEAN PLATFORMS

The investigations by DSS method, carried out by A. Guterch et al. (A. Guterch, 1977; V.B. Sollogub et al., 1978, 1980) on the Northern Carpathians foreland showed the presence of three areas differing in thickness of the crust. In the western area belonging to the Paleozoic platform the crust in most cases is 32 – 37 km thick. In the eastern area belonging to the East-European platform the thickness of the crust amounts to 40 – 41 km. Both areas are separated by a depressed zone in the Moho level with the crust more than 50 km thick. K. Żytko (1981*a*) included to this zone the „hanging" block of the crust of 44 – 46 km thick found by the profiles LT-3 and VIII in the eastern part of the Holy Cross Mts. This quite a thick block became thinner by a few km as a result of an erosion after the late Cretaceous uplift of the Mid-Polish anticlinorium (J. Kutek, J. Głazek, 1972). Therefore it should be included into the areas of Moho trough.

In this approach the Staszów – Połaniec fracture (more precisely the zone of fractures) of NNW – SSE direction, revealed by the profiles LT-3 (160 – 170 km) and VIII (160 – 175 km), constitutes the border between the area of thin crust of the Paleozoic platform and the „hanging" block of the Moho trough. To the south the extension of the Staszów – Połaniec fracture cuts the margin of the Carpathians between Pilzno and Dębica and runs towards Jasło. This fracture is marked there by the zone of quick decline to the east of the intensity of negative gravity anomaly of the West Carpathians. The structural disturbances of the flysch on the Wisłoka line and farther south in the Slovakia, the occurence of Neogene volcanics of Slanske Pohorie to the E from Prešov-Košice (*vide* M. Mahel ed., 1973) are probably connected with this fracture, although the Carpathian part of this lineament may be younger.

An important fracture extending from the Opatówka valley to Nisko has been localized by the DSS method on the profiles LT-3 and VIII. It has a throw of several km. The fracture near Kielce on the profile VIIIa (A. Guterch et al., 1976) has similar throw but on a higher hipsometric plan. One can see the connection between this fracture and the Łysogóry overthrust as the big differences in the evolution of both northern and southern parts of the Holy Cross Mts during the Paleozoic. The DSS data point out that Staszów – Jasło fracture continues to the north, crosses with the Kielce – Nisko fracture and is responsible for the difference of the Moho hipsometric plan in the area of the Kielce fracture (38/44 km) and Opatówka valley (44–46/50 km) as well as for the difference of the depth in Łysogóry (44 km) and on the profile C (49 km).

The Velikije Mosty–Nadvornaja fracture forms the eastern border of the Moho trough. From the east of Rava Russkaja region (profile VIII) it runs to SSE between Żuravno and Rohatyn (III); in the region of Nadvornaja (Dobromil–Kosov–Krasnoilsk profile) it goes as far as the margin of the overthrusted Carpathians (*vide* V.B. Sologub et al., 1978, Fig. 150, 151; 1980, Fig. 23, 80).

The Staszów–Jasło and Velikije Mosty–Nadvornaja fractures delimit the Moho trough of about 200 km wide and of NNW–SSE direction which obliquely crosses the Carpathian margin. In the area of the extension of its borders the disturbances of the course of the negative gravity anomaly of Jasło–Krosno and Kosmach region are marked (W. Pożaryski, K. Żytko, 1981). The course of southern part of the East Carpathians may be connected with continuation of the eastern boundary of this trough (Fig. 2).

Within the area of the Moho trough there is an anomalous zone of additional thickening of the crust to 60–65 km (Fig 1). It has been localized on the profiles LT-3 and VIII. This zone runs from Lublin towards Cieszanów. The block of the crust of a similar thickness (65 km) has been ascertained on the profile 18 (*vide* V.V. Glushko, S.S. Kruglov, 1979, Fig. 3) between the margin of the Carpathians and Krakowiec–Rudki fault in the suprastructure. This block – the structural extension of the eastern part of the Mid-Polish anticlinorium (post-Variscan San massif built of the Proterozoic – Early Paleozoic rocks) sank a few km in the Late Miocene (the SE extension of the Krukienice depression – V.N. Utrobin et al., 1974). An effect of this movement could be the differentiation of the crust (the blocks 65 and 60 km) between the margin of the Carpathians and Gorodok on the profile 18. It is possible that the fracture existed there, having a reflection in the Krakowiec–Rudki suprastructural fault which arose in the extension of the Kielce–Nisko fracture, though contrary to the West, the southern block is lowered south from Rudki.

North-west of Dolina on the Dobromil–Kosov–Krasnoilsk profile (V.B. Sollogub et al., 1978, Fig. 151) the Moho discontinuity occurs at a depth of 52 km. This points out that on the profile 18 rather only block of Rudki corresponds with the anomalous zone of Lublin–Cieszanów. In spite of this pattern the western fracture of the anomalous zone has been drawn westwards from Borislav towards the bend of Neogene volcanite belt near Hust (Fig. 1).

One should say that Soviet authors (*vide* V.V. Glushko, S.S. Kruglov, 1979) assume a dip towards NE of the deep fractures on the profile 18. Intensive, vertical movements of the reverse displacements, for example the upward Laramian and downward Miocene, took place several times in the zone of Krakowiec and Gorodok faults, bordering the San massif and furthermore there is exact superposition of faults pattern in the suprastructure and the Moho fractures. In this situation it is probable that the fractures existing there are vertical.

Following the pattern of faults of suprastructure (V.N. Utrobin et al., 1974) one could observe the Rudki block through the area of Stryj and identify it in the profile III DSS (V.B. Sollogub et al., 1978, Fig. 150). This block is 67 km thick there, bordered by deep fractures in the region of Dolina and Zawadka. The Rudki – Stryj block is on the profile III about 22 km wide and it has a thick cover of platform Jurassic and Cretaceous deposits overlying the Early Paleozoic sediments. The molasses of Sambor unit, rooted under the flysch of the Borislav–Pokutie unit, are overthrusted on this block.

The zone of anomalously thick crust of Lublin – Cieszanów is in line with Rudki – Stryj block. This zone also appears as a gap in the Moho registration between Dolina and Niebylov on the Dobromil – Kosov – Krasnoilsk profile, mentioned above. Farther to SSE it plunges beneath the Carpathians. The thickened crust in the area of Dolina on the profile III has therefore no connection with an evolution of the Carpathians as it assumed by W.J. Sikora (1976), but it is related to the old plan of the platform which is mainly directed NNW – SSE. A picture of such a trough in the Moho level entering the area of Alpides was accepted by V. B. Sollogub et al. (1978, Fig. 152; 1980, Fig. 87). They accept its extension in the Rhodope massif. Taking into consideration the westward shift of this massif together with the Moesia in the Upper Cretaceous (K. Żytko, 1984) a relict of trough's extension could be present in the Outer Dinarides (J. Bragaševič, B. Andrič *vide* V.B. Sollogub et al., 1978).

FRACTURES OF THE EARTH'S CRUST OF THE CARPATHIANS BASEMENT

The fractures, presented above, extending from the platform to the area of the Carpathians (Fig. 1) are mainly based on the DSS data. The Wrocław – Braila fracture, coinciding with the considerable part of the Pieniny Klippen Belt is the most important for the Carpathian tectogenesis. The fracture (28/35 km) on the profile VI has the similar position in the structure of the Western Carpathians. It occurs in the basement of the Inner Carpathians and is connected with the seismic line going from Myjava to SW (A. Zatopek et al. *vide* V.B. Sollogub et al., 1978). Some authors connected this fracture with the boundary between Outer and Inner Carpathians.

An important information results also from other geophysical study. At the San river basin in both regions – the Carpathians and its foreland (Fig. 1) in a picture of the vertical component of magnetic field the margin of Gothian basement is visible in a form of a strong regional gradient (W. Pożaryski *vide* M. Książkiewicz et al., 1977, p. 67 – 77). From Olszanica near Lesko to Żołynia near Leżajsk this boundary, led along the western range of gradient zone, is of NNW – SSE direction. To the south it crosses the axis of the gravity depression of the Eastern Carpathians. The northern extension of this boundary to the NW runs along the valley of San to Nisko and further to NNW. Analysis of the detailed data compiled by M. Karaczun et al. allows to state a transversal field discontinuity of Lesko – Liskowate – Chyrov near Dobromil and Żołynia – Narol near Cieszanów. The western boundary of the gradient zone as well as both transversal discontinuities could be considered as the fractures of the suprastructure reaching down to the deep crust.

An analysis of the Lesko – Chyrov discontinuity indicates the westward shift or the uplift of the southern block of basement or at least more shallow position of Gothian magnetic rocks of this block. However, in the region of Lesko a displacement of a deep magnetotelluric boundary of reverse sign has been stated (J. Święcicka-Pawliszyn, J. Pawliszyn, 1978). According to the unpublished data of W. Bachan the zone of displacement (9/15 km) can be of NNW – SSE strike. It is possible that the western boundary of Mid – Polish anticlinorium, in other words of the San massif (Fig. 1) reaches the region of Lesko under the flysch. This boundary could be of similar character as the eastern one (the Krakowiec fault); thick, Late Paleozoic-Mesozoic platform deposits of the Miechów synclinorium extension can have tectonic lateral contact with the rocks of the San massif. In such an approach, magnetotelluric horizon would be connected with the top of the Proterozoic-Early Paleozoic rock complex.

Considering the regional picture of the gravity field (*vide* M. Książkiewicz, 1956; V. Scheffer, 1960) as well as later more precise data one could mark an axis of the Western Carpathian depression along Hodonin – Jasło line (Fig. 1). It is possible that a small fracture of the crust is connected with this zone (DSS results on the profile VI – A. Zatopek et al. *vide* V.B. Sollogub et all., 1978). Magnetic discontinuity line of Żołynia – Narol mentioned earlier can be considered as the extension of this fracture, if the block of thick crust with this magnetic line is shifted northwards.

The fracture qualified as the peri-Carpathian is also accepted by many authors in the axial zone of the East Carpathians gravity depression (Fig. 1). This fracture is possibly displaced at the boundary of the Moho trough and the East-European platform in the area of Kosmach. Genetic connection between the structural zone marked by the axis of depression in the Moho trough and the Borzęcin – Tarnów fracture on the Paleozoic platform is probable.

Though regional, gravity depressions and the fractures connected with them are important for the understanding of the Carpathian tectogenesis, nevertheless this paper does not deal with this problems. The similarity of the magnetic features of the deep basement east of Lesko (magnetic gradient zone) on both sides of the axis of the East Carpathian gravity minimum should be emphasized by now. Similarly, an existence of the geophysical features of the Bohemian Massif SE from the West Carpathians gravity depression is announced by Z. Roth (1980). However he pointed to the traces of „Neo-Alpine tectonization" in the SE zone.

Geoelectric study (J. Jankowski et al., 1977) discovered in the basement of the Carpathians a zone of changes of geoelectric vectors of induction (Wiese's vectors) which extends as an arc from the Vienna basin along the Pieniny Klippen Belt, mainly on the northern side of it as far as the crystalline Mesozoic zone of the Eastern Carpathians (Fig. 1). A localization of this zone on the sections where it occurs in the area of the Outer Carpathians, points to its probable origin. One can connect its extent with a suture in the basement which is possibly a fossil trace of the earlier main cordillera (Silesian) dividing the flysch basin of the Northern Carpathians into the southern Dukla – Magura part and the northern Silesian – Skole part in the Upper Cretaceous and partly in the Paleogene (*vide* M. Książkiewicz, 1962). It indicates the northwestward displacement of the section Trenčin – Stara Lubovna of the Pieniny Klippen Belt over the deep basement.

BOUNDARY BETWEEN THE META-CARPATHIAN RANGE AND THE AREA OF NORTHERN POLAND

The belt of thick Earth's crust (the Moho trough) cutting diagonally the area of Poland has been initialy interpreted as the marginal zone of the pre-Vendian, East-European platform (A. Guterch, 1977). Then this belt has been regarded as a boundary zone between the Paleozoic platform of Central Europe and East-European platform (J. Znosko, 1979; W. Pożaryski, W. Brochwicz-Lewiński, 1979; A. Guterch et al., 1983).

V.B. Sollogub and coauthors consider the Lublin – Lvov part of the discussed belt as one of the submeridional, Early Proterozoic thickenings of the Earth's crust characteristic of the Ukrainian shield as well as of Voronezh massif of the East-European platform (V.B. Sollogub et al., 1978, Fig. 112; 1980, Fig. 18, 84).

Indeed the margin of the East-European platform south of Radom, investigated by the magnetic survey (A. Dąbrowski, K. Karaczun *vide* M. Książkiewicz et al., 1977, Fig. 10; A. Dąbrowski et al., 1981) occurs within the belt of thick crust. On the other hand in Central Poland (the region of Bydgoszcz – Łódź) between the profiles LT-2 and LT-5 the Moho trough (55 – 70 km wide) occurs west from the boundary of the platform marked by the same method (*vide* R. Dadlez, 1982, Fig. 2). In this situation, Dadlez's question (*l.c.*) – is the connection between Central Poland and Lublin parts of the thick crust's belt direct or are they the separate structures – is still actual.

Modification, proposed in the present paper, of the western boundary of the Moho trough in the southern Poland in comparison with the Guterch's picture (A. Guterch, 1977) as well as the pictures of published profiles LT-4 and LT-5 (A. Guterch et al., 1983) indicate the structural discontinuity of this trough in the Radom region and also different width and direction of both its segments – NW – SE – to the north and NNW – SSE to the south (Fig. 1, 2). In this approach the Płock – Łódź transversal fracture assumed by A. Guterch et al. (1983) is omitted. From the area of Płock the eastern boundary of the trough has been actually led towards the Skierniewice fracture in accordance with the magnetic data.

The line of discontinuity of the belt of thick crust is (in author's opinion) distinctly marked in the geological evolution and in the present structure of the Poland's area. Without going into details attention should be paid to the dextral displacement along the line (the Late Paleozoic – Mesozoic pattern) of the axes and frames of the North Sudetic synclinorium in relation to the Intra Sudetic (= South Sudetic) as well as of the Mogilno – Łódź trough (synclinorium) in relation to the Miechów trough (cf. J. Oberc and W. Pożaryski *vide* M. Książkiewicz et al., 1977). Both displacements are of similar order. Variscan granitoid intrusions of Karkonosze and Strzegom – Sobótka in the Sudetes presumably preferred the zone of this old line of the Earth's crust discontinuity. The big Ohře trough with intensive volcanism in the Bohemian Massif (the region of Karlovy Vary) as well as the small but distinct Bełchatów trough south from Łódź occur on this line in the Neogene pattern.

The fact that the Ohře trough is connected with the former crustal suture (V. Zoubek, M. Malkovsky, 1974) as well as an importance of changes occuring on the discussed line show that the marked discontinuity of the crust at Radom area can also have its extension in the East-European platform.

It follows from the International Tectonical Map of Europe (N.S. Szatskij et al., 1962) that the relationship between discussed discontinuity and the southern boundary of both the Łuków (Sławatycze) – Ratno horst and the Upper Paleozoic Prypyat trough is very probable. Dnepr – Donetz aulacogen is the continuation of the latter after a change of direction for NWW – SEE near Chernigov (*vide* V.B. Sollogub et al., 1978, p. 158 – 169). It results from the above that the Karlovy Vary – Radom – Chernigov crust fracture cuts both the Paleozoic platform of Central Europe and the East European. The western extension of this fracture towards Karlsruhe could also be considered (*vide* S. Mueller, L. Rybach, 1974).

Discussed fracture dividing the area of Poland along the line directed WSW – ENE at the Variscan pattern was probable dextral wrench fault. The movement along this compensating fracture took place as the result of the opening of Dnepr – Donetz aulacogen (rift) if the idea of such an opening is right (A.V. Chekunov *vide* V.B. Sollogub et al., 1980, Fig. 124). The posthumous traces of such a dextral Early Devonian movement (20 – 30 km) are seen in the Mesozoic pattern of the Sudetes and Mogilno – Łódź – Miechów synclinorium.

The picture of the Moho trough's discontinuity in the area of Radom indicates however the sinistral displacement of the elements of a deep crustal pattern (Fig. 1). There is an indication for the earlier pre-Variscan origin of this discontinuity. An influence of the fracture connected with this discontinuity is pronounced in the picture of Orsha – Volhyn aulacogen in the Proterozoic Polesie series east from Włodawa (*vide* M. Książkiewicz et al., 1977, Fig. 15; R.G. Garecki et al., 1981). While analysing the presented considerations and the picture of the crust – the Early Paleozoic, large scale strike-slip movements along SW margin of the East-European platform, in Poland recently discussed (W. Brochwicz-Lewiński et al., 1981), are not very probable.

On the Carpathian foreland the Karlovy Vary – Radom – Chernigov fracture could be admitted as the northern boundary of the meta-Carpathian range (J. Nowak, 1927) which is interpreted as the uplifted area occuring between the Carpathian geosyncline and the epicontinental Middle European Basin in the Alpine cycle.

The extreme north-western extent of the marine Miocene found in the area of Otmuchów – Nysa on the Sudetes foreland (S. Dyjor et al., 1978), in the Połaniec depression (W. Pożaryski *vide* M. Książkiewicz et al., 1977, p. 445 – 448) and near Opatów in the vicinity of the Holy Cross Mts recur to the direction of the Karlovy Vary – Radom line and not to the Wisła (Vistula) line. The fracture along the Wisła valley (A. Guterch, 1977), connected with W. Teisseyre's Kraków (Kurdwanów) – Zawichost line is not justifiable in the light of DSS data (Fig. 1).

BOUNDARIES OF THE WESTERN, MIDDLE AND EASTERN FLYSCH CARPATHIANS

K. Tołwiński (1921, 1956) distinguished in the area of the Northern Carpathians the following segments: Silesian (SW – NE, WSW – ENE), Tatric (W – E) and Carpathian, more precisely East – Carpathian (NW – SE). The segment of Tatric direction has been later distinguished as the Middle Carpathians however it is often joined together as the Western Carpathians, with the segment of the Silesian direction. The boundary between Tatric and East Carpathian directions had been led by K. Tołwiński from the Dunajec – Poprad interfluve in the Pieniny through the area of Nowy Sącz, between Jasło and Krosno and farther along the Wisłok valley towards Rzeszów (Fig. 1). The zone of mixed directions exists by this line just as it does near the boundary of the Silesian and Tatric directions which is led north from the Soła valley near Bielsko through Koszarawa to the valley of Upper Skawa.

The sectors directed SW – NE, W – E, and NW – SE are also distinguished in the Inner Carpathians (M. Mahel, 1974). The tectonic maps of the northern zone of the Slovakian Inner Carpathians (M. Mahel, 1973 ed., 1974) indicate an existence of only two main systems. Distinct structural elements of the West Carpathian system, oriented WSW – ENE and SW – NE, meet at an angle of about 90 – 120° with the elements of East Carpathian system directed WNW – ESE and NW – SE in the Poprad depression (Stara Lubovna area – Fig. 1) filled in with the Central Carpathian Paleogene flysch. It results from this pattern that north from the Pieniny Klippen Belt both in the Carpathians and in their foredeep the extensions of longitudinal dislocations of both structural systems should exist in the basement and in the flysch.

They continue indeed, particularly in the extension of both main linear segments of the Pieniny Klippen Belt. The disturbances of flysch determined as the

Skawa line/dislocation (M. Książkiewicz et al., 1977, p. 598) are of NW trend. They occur on the line of Wadowice – Rabka – Nowy Targ. The possibility of the connection of those disturbances with the Middle Odra fracture zone has been already noted.

The structural factors controlling an existence of the gravity depression running farther to ENE into the Outer Carpathians and shallowing on the Nowy Targ – Nowy Sącz – Grybów line occur in the NE extension of the Pieniny Klippen Belt of the Western Carpathians in the basement plan. The Neogene postorogenic depressions of Orava and Nowy Sącz are connected with this line as well as the Rzeszów depression in its extension. Farther to ENE in the foredeep (the area of Kańczuga – Przeworsk) the change of Tatric direction (W – E) into the East Carpathian one (NW – SE) is marked in the thickness distribution of the autochtonous Miocene deposits. This was already noted by K. Tołwiński (1956) as the Przeworsk dislocation. A connection between this line and the zone of mentioned magnetic discontinuity of Żołynia – Narol could be considered.

Presented lines of Wadowice – Nowy Targ and Krościenko – Jasło – Rzeszów could be treated as the Tołwiński's modified boundaries between three main regions of different structural trends in the Northern Carpathians. This is also probable that on the ruptures of the basement along those lines there was the compensation of movement (in relation to the platform) of the basement blocks of the Western and Eastern Carpathians plunging independently under the allochtonous masses during various stages of tectogenesis.

PROBLEM OF THE OVERTHRUST'S DIRECTION OF THE FLYSCH MASSES

The Miocene deposits, mainly Badenian, have been found in the profiles of many drillings under the overthrusted flysch (Cretaceous-Paleogene) in the belt of 20 – 30 km south from the Carpathian margin west from the Przemyśl meridian (S. Wdowiarz, 1976, 1983). They evidence the minimal Badenian-Early Sarmatian overthrust. Full Neogene overthrust is obviously bigger. The front of flysch should be moved back at least to the line of the negative, gravity anomaly as it is accepted by many geologist.

There exists a problem in which direction the allochtonous flysch masses of the Northern Carpathians should be moved back in order to reconstruct their primary position in the geosyncline in comparison to the structures of the platform. There is also a problem of underthrusting and shortening time of the Western and Eastern Carpathian basements and thereby of the age of the compensating basement's ruptures mentioned above. The starting point for the analysis of those phenomena is the different position of an axis of regional gravity depressions in comparison to the outer margin of orogene in the Western and Eastern Carpathians (Fig. 1). The above questions can be answered by using an interaction of Europe and Africa plates which was caused by their movements in various phases of diachronous opening of the Atlantic (J.F. Dewey et al., 1973). J.F. Dewey (1982) took the same way while reconstructing the evolution of the British Isles in the Mesozoic and Cenozoic times.

B.C. Burchfiel (1980) has noted a minor correspondence between the post-Jurassic movements deduced solely from geology in the East-European Alpine system and the movements of two major plates. However, omitting the changes

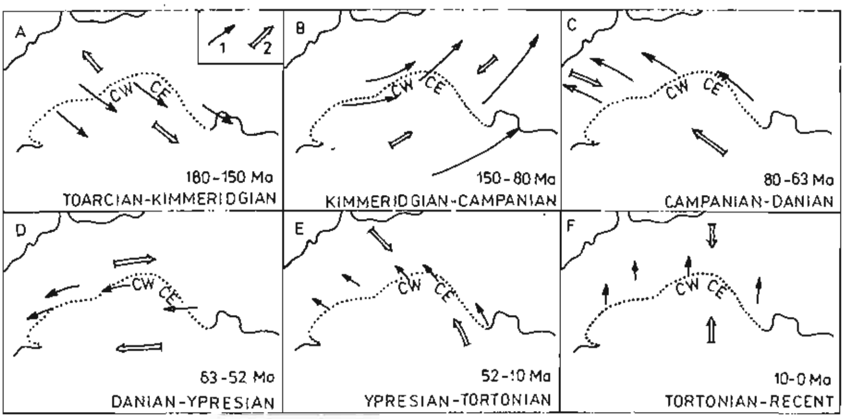

Fig. 3. Regional effects of the interaction of both European and African plates in Carpathian region
Regionalne efekty wzajemnego oddziaływania płyt europejskiej i afrykańskiej w rejonie Karpat

1 – vectors of Africa path relative to Europe (after J.F. Dewey et al., 1973; time modified after J.F. Devey, 1982); 2 – probable regional effects of the interaction of major plates in contact zone of the Northern Carpathians and European platform; CW – West Carpathians; CE – East Carpathians

1 – wektory przesunięcia Afryki względem Europy (według J.F. Deweya et al., 1973; czas zmodyfikowany według J.F. Deweya, 1982); 2 – przypuszczalne efekty wzajemnego oddziaływania głównych płyt w strefie kontaktu Karpat północnych z platformą europejską; CW – Karpaty Zachodnie, CE – Karpaty Wschodnie

occuring inside the Alpine-Mediterranean belt of microplates dividing the major plates, one should consider the time and directions of regional stress in the area of the contact of the Northern Carpathians with European platform.

It results *a priori* from the picture presented in Fig. 3 that in the area of the Northern Carpathians after the Jurassic stage of extension (A) since the Late Jurassic till Campanian the compression acted as a result of Africa's movement towards NE in relation to Europe (B). In the Late Senonian (C) and in Eocene–Early Miocene (E) the compression in the area of the Carpathians has been caused by the NW movement of Africa. The interruption in the convergence of both major plates marked in the Paleocene caused a strike slip as the main effect of the movement (D). Since the Late Miocene the convergence was along the N–S line (F).

Tectogenesis of the northern part of the Flysch Carpathians has begun in their inner part (the Magura zone) as an expansion of the synsedimentary folds in the Early Eocene[2] (K. Żytko, 1977, 1981*b*). The compression's wave gradually migrated outwards, a major paroxysm of movements taking place in the Early Miocene (M. Książkiewicz et al., 1977, p. 603–604). With reference to the regional picture of compressive stress presented above one could assume that the beginning of the overthrust of flysch masses was connected with the change of Africa movement in the Ypresian (Fig. 3 D, E). Till the Middle Miocene the overthrusts were directed NW. As a result of above phenomena there is bigger overthrust of the flysch masses on the platform in the Western Carpathians in comparison with the Eastern ones. This overthrust is implied by the position of the gravity anomalies and the position of the zone of changes of geoelectric vectors of induction in the orogen (Fig. 1).

[2] T. Pescatore and A. Ślączka (1984), incorrectly reffering to the paper of K. Żytko (1977), have assumed the lack of synsedimentary folds before the Oligocene. It has become an argument for the acceptance of the continental collision in the Carpathians at the turn of the Eocene and Oligocene.

In the final stage of tectogenesis the flysch masses overthrusted north. The unpublished study by N. Oszczypko and K. Żytko indicates the gradual rotation of an axis of the Northern Carpathians foredeep from WSW – ENE direction during the Carpathian – Lower Badenian through WNW – ESE in the Middle and Upper Badenian to NW – SE direction in the Lower Sarmatian. This phenomenon as well as the eastward migration of folding movements at the margin of the Polish Carpathians during the Badenian-Sarmatian (M. Książkiewicz et al., 1977, p. 604) have probably the connection with the mentioned change of the regional compression's direction in the Late Miocene (Fig. 3 EF).

The regional compression towards NE, NW and N activated various crustal fractures of the Carpathians and their foreland in the various stages of tectogenesis (Fig. 1).

PROBLEMS OF THE CONNECTION BETWEEN THE NORTHERN CARPATHIAN GEOSYNCLINE AND THE FORELAND

REMARKS ON THE MARGINAL ZONE OF THE FLYSCH GEOSYNCLINE

An important and long known feature of the northern segment of the Flysch Carpathians is an *en echelon* approach of the Stebnik-Sambor (Early Miocene molasses), Borislav-Pokutie (Late Cretaceous – Early Miocene flysch and Early Miocene molasses) and Skole (Cretaceous – Early Miocene flysch) units to the outer margin of the chain. The Skole unit terminates in Pleśna folds south from Brzesko – Tarnów and it has not been found in the Western Carpathians well recognized by drillings. It is probable that the extension of the Skole zone is represented by the Frydek type deposits of the Subsilesian unit found near Bielsko (J. Liszkowa, W. Nowak, 1960). The Pisarzowice Beds (Cenomanian-Turonian) occuring in the profile of the Subsilesian unit underlying the Frydek Marls are similar to the Upper Cretaceous flysch of the Skole unit. In such an approach, more shallow zone of the Frydek Marls sedimentation in the area of the Silesian-Moravian Carpathians would be considered as the extension of the sedimentary area of the Skole succesion in the Upper Cretaceous. The Paleogene „outer flysch" of Wadowice area included by M. Książkiewicz to the Subsilesian unit (M. Książkiewicz et al., 1977, p. 568), but having a succesion of sandy Middle Eocene (differing from a typical one) could be also considered as an equivalent of the Skole unit's deposits. The Krosno Beds with tuffite intercalations occuring east from Wadowice (Radziszów) are traditionally included to the Silesian unit (M. Książkiewicz et al., 1962). According to the radiometric investigations these deposits are of the Early Miocene age (Ch. Naeser *vide* T. Wieser, 1979). Such a young tuffites from the Krosno Beds are only known from the Skole unit.

The connection of the Skole unit with the Subsilesian – Frydek one of the Western Carpathians and possibly with the „outer flysch" solves only a part of problem. The western extent of the flysch of the Borislav – Pokutie outer unit is also not clear. Total width of three digitations recorded in the drillings of the Borislav area amounts to 20 km. Regarding the presumable full width of those elements and probable presence of deeper digitation, the Soviet geologist estimate the width of the area where the Borislav – Pokutie unit of Dobromil region was formed as about 60 km (W.W. Glushko, S.S. Kruglov et al., 1977, Fig. 30 – 33). S. Wdowiarz

(1983) assumed about 40 km of width in the Dnester – Prut river-basin with trend to northwestward reduction.

Studies in Tarnów – Wojnicz area (L. Koszarski, 1961; M. Książkiewicz ed., 1962) and in the Carpathians of Przemyśl region (J. Kotlarczyk, 1978) showed a rapid reduction of thickness of the Upper Cretaceous of the Skole unit to the north, towards the margin of the unit. This indicates the morphological separateness of the Skole flysch trough from the extension of the Borislav – Pokutie area i.e. outer trough. Distribution of the Eocene and Lower Oligocene deposits (Hieroglyphic Beds, Kliwa Sandstones) gives evidence (M. Książkiewicz ed., 1962) of an existence, also in the Paleogene, of the axial zone of the flysch trough in the inner part of the Skole unit. The presence of the Kliwa Sandstones in the marginal zone of the Skole unit near Przemyśl (M. Książkiewicz *l.c.*) indicates a possible existence there of the Borislav – Pokutie flysch trough in the Oligocene.

S. Dżułyński et all. (1979) paid attention to unique accumulation of olistolites, submarine slumps and pebbly mudstones amongst the flysch sediments of the Skole unit, particularly in the Przemyśl area. They are present in the Upper Campanian – Maestrichtian (e.g. the Jurassic olistolites of Kruhel), Paleocene (Babica Clays), Upper Eocene (Popiele Beds) and Lower Miocene sediments (diatomites at the top of the Krosno Beds). They point to the proximity (since the Campanian) of a shallow zone and occasionally of a cliff north from the Polish part of the Skole basin as it was assumed earlier (M. Książkiewicz ed., 1962). The beginning of this input in the Campanian could be connected with the mentioned change of regional compressive stress direction (Fig. 3 B, C).

The blocks or lenses of the Baculites Marls of epicontinental character occur in the slumped material among the Upper Senonian flysch in the marginal zone of the Skole unit. They occur in the belt south from Ropczyce – Rzeszów – Przemyśl – Dobromil as far as Dnester valley and they contain the Upper Campanian – Maestrichtian fauna (S. Geroch et al., 1979). The marls of the platform type, different from the Węglówka Marls have accumulated outwards from the sedimentary zone of the Skole flysch of the mentioned belt. Thus the existence, west from the Przemyśl – Kruhel meridian, of an extension of the Borislav – Pokutie part of the flysch basin in the Upper Senonian and also later is problematic. In this situation one should refer to the analysis carried out recently, of the connection between the Carpathian geosyncline and the platform structures (W. Pożaryski, K. Żytko, 1981; K. Żytko, 1984).

MODIFIED CONCEPTION OF THE CONNECTION BETWEEN THE MID-POLISH AULACOGEN AND THE CARPATHIAN GEOSYNCLINE

Analysing the connection between aulacogen and the Carpathians W. Pożaryski and K. Żytko (1981) have assumed the Shevchenkovo zone south from Stryj with unusually great thickness of the Cretaceous deposits (more than 4000 m) and the Paleogene of the Skole unit to be the extension of the platform linear zone of increased subsidence. This zone entered obliquely the area of the geosyncline. They also paid attention to the existence of another similar zone of the great thickness of the Skole Upper Cretaceous (up to 3000 m). It occured farther west in the area of Szufnarowa SW from Rzeszów and was not connected with the extension of aulacogene. The Szufnarowa and Shevchenkovo zones (secondary depresions) are separated by the Przemyśl – Cisowa – Brzegi Dolne zone with a thinner flysch sequence (Upper Cretaceous – Paleocene 1000 – 1200 m) and a great amount of siliceous and fucoides marls in the Upper Cretaceous sequence (J. Kotlarczyk, 1978).

New analysis indicates that all these three zones, marked in the longitudinal profile of the Upper Cretaceous Skole trough, could have connection with the aulacogen's extension in the geosyncline. The replacement, noted in the preceding chapter, of the Upper Cretaceous Skole flysch by the less thick Frydek Marls formed in the more shallow sea west from Szufnarowa could be connected with the extension of the western slope of aulacogen into the geosyncline.

The zone of Cisowa i.e. the zone of relatively thin flysch, rich in marls may have formed in the extension of the San massif. The submarine slumpings and olistolites which appeared in the Skole flysch of Cisowa zone particularly in the Przemyśl region in the Campanian – Maestrichtian, could derive from the tectonic active Mid-Polish anticlinorium i.e. the then uplifting San massif. The Baculites Marls from Węgierka could have been derived from the cover of this massif which is devoid of the Mesozoic sediments.

The Santonian – Campanian sandstones from Żuravno, developed in the profile of the platform Cretaceous of SW part of Lvov synclinorium (S.J. Pasternak et al., 1968; V.S. Burov, J.M. Sandler, V.A. Szakin *vide* V.V. Glushko, S.S. Kruglov et all., 1971), have a great importance for an understanding of the connection between geosyncline and platform. Their thickness diminishes to NE and they laterally pass into marls. They constitute a clastic wedge probably penetrating from the geosyncline into the platform in the NE secondary depression of the aulacogen (the extension of the Shevchenkovo zone). Some workers accepted the connection of the Żuravno Sandstones with the Stryj Beds (Skole – Skiba succesion) of the geosyncline (S.J. Pasternak et al., 1968, p. 74). However, the sedimentological study of this problem is necessary.

One could assume that the flysch of the Skole succesion of the Przemyśl area (Cisowa zone) rich in olistolites with participation of the Baculites Marls has been formed in the relatively ~~more~~ shallow sea on the San massif extension. NE from this uplift there was secondary depression the axis of which was also crossing obliquely the plan of the Carpathian geosyncline. From the downwarped part of the Skole zone i.e. Shevchenkovo zone through the shallowing Borislav – Pokutie zone this depression could continue on the platform NE from the uplifting massif. The Żuravno Sandstones and earlier the Lower Cretaceous sediments of Basznia – Javorov – Paryshche belt (V.S. Burov, J.M. Sandler, V.A. Szakin *vide* V.V. Glushko, S.S. Kruglov et al., 1971) have been formed in this secondary depression. It results from this pattern that the Borislav – Pokutie flysch zone, at least in the Campanian – Paleogene plan, had to turn into the zone of more shallow, non-flysch sediments because on its extension to the west there is an uplift marked out by the San massif on the platform and by ubiquitous presence of the Baculites Marls in the Skole allochton. The flysch zone of the western (Szufnarowa) depression was shallowing in a similar way westwards in the extension of the western slope of aulacogen; the flysch passed there into the grey marls of the Frydek type.

The sediments of the platform Lower Cretaceous, preserved on both sides of the San massif (Stasiówka near Dębica, Basznia near Lubaczów – J. Kutek, J. Głazek, 1972, Fig. 3B) precisely mark the minimal width of the aulacogen deviating NW from the geosynclinal trough of the Western and Eastern Carpathians (K. Żytko, 1984).

All the northern part of the Upper Cretaceous flysch of the Skole – Borislav – Pokutie trench, with marked the influence of the axial massif, is the extension of the aulacogen in the geosyncline. If the assumed system existed then it accounts for the rapid westward disappearance of the flysch facies of the Borislav – Pokutie unit.

OVERTHRUSTS OF THE NORTHERN CARPATHIANS DURING THE TERTIARY TIME

R. Unrug (1979) carrying out the palinspatic reconstruction of the Carpathians has assumed the Neogene northeastward overthrusts and additional clockwise rotation of the Western Carpathians. Also S. Wdowiarz (1983) has accepted (which is seen from the position of Szufnarowa and Brzegi Dolne boreholes in the map) the overthrust to N in the Western and to NE in the Eastern Carpathians. However, the outer position of the negative gravity anomaly of the Eastern Carpathians which is doubtless connected with the Carpathian structure does not point to a distant overthrust to NE (Fig. 1).

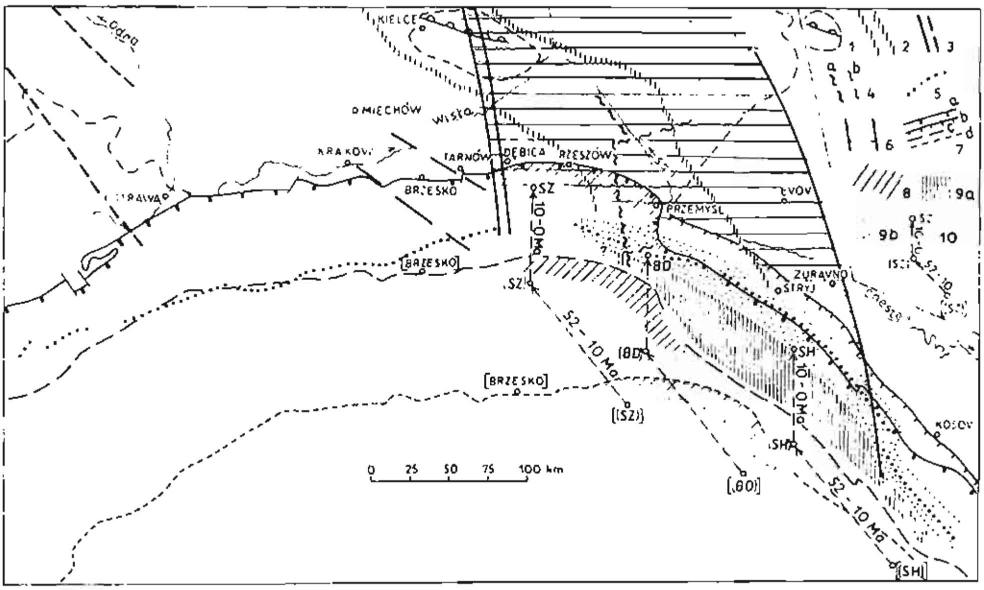

Fig. 4. Test of the palinspastic reconstruction of the Carpathian flysch front in the post-Paleocene time
Próba palinspastycznej rekonstrukcji czoła mas fliszowych Karpat po paleocenie

1–6 – autochthonous elements: 1 – Holy Cross Mts, 2 – boundaries of the Mid-Polish anticlinorium, 3 – crustal fractures (a – probable, b – conjectural), 4 – western boundary (a) and discontinuity zones (b) of the magnetic anomaly belt related to the Gothian socle (in San river-basin only), 5 – axial zone of regional negative gravity anomaly (Carpathians only), 6 – area of thick Earth's crust: 7–10 allochthonous elements: 7 – present margins of Carpathian flysch (a) and folded Stebnik-Sambor molasses (b), approximate position of the flysch front (without Borislav-Pokutie flysch) in the Middle Miocene (c) and Early Eocene (d) times, 8 – zone with numerous olistolits in Skole flysch, 9 – approximate position of Borislav-Pokutie flysch (a) and Stebnik-Sambor molasses (b) in the Middle Miocene time, 10 – displacements of the positions of the characteristic thickness zones of the Skole flysch (thick flysch: SZ – Szufnarowa, SH – Shevchenkovo: thin flysch: BD – Brzegi Dolne)

1–6 – elementy autochtoniczne: 1 – Góry Świętokrzyskie, 2 – granice antyklinorium środkowopolskiego, 3 – rozłamy skorupy (a – prawdopodobne, b – domniemane), 4 – zachodnia granica (a) i strefy nieciągłości (b) pasa anomalii magnetycznej związanej z blokami podłoża o gotyjskiej konsolidacji (tylko w dorzeczu Sanu), 5 – strefa osiowa regionalnej ujemnej anomalii grawimetrycznej Karpat, 6 – obszar grubej skorupy Ziemi: 7–10 elementy zmienne: 7 – współczesne granice karpackiego fliszu (a) i sfałdowanych molas jednostki stebnicko-samborskiej (b), przybliżona pozycja czoła mas fliszowych (bez fliszu jednostki borysławsko-pokuckiej) w środkowym miocenie (c) i wczesnym eocenie (d), 8 – strefa fliszu z licznymi olistolitami, 9 – przybliżona pozycja fliszu strefy borysławsko-pokuckiej (a) i molas strefy stebnicko-samborskiej (b) w środkowym miocenie, 10 – zmiany pozycji charakterystycznych profili fliszu skolskiego (gruby flisz: SZ – Szufnarowa, SH – Szevczenkovo; cienki flisz: BD – Brzegi Dolne)

M. Książkiewicz (1956) assumed the depression of the subcrustal material below the mountains as an explanation of the regional gravity anomaly. According to some authors (G. Bojdys et al., 1983) a gravity low of the Carpathians is related to a horizontal density gradient beneath the Moho level and deep location of the latter. However, another analysis of the regional anomaly of the Carpathians, in different parts of the chain, indicates that the source of anomaly is at a depth of 8 – 10 km (Č.Tomek et al., 1979; A. Kozera *vide* S. Młynarski et al., 1982).

The displacement of the compressional wave during Tertiary time on the outside of the geosyncline, as well as the connection of this phenomenon with decollement of the allochthon from the basement (K. Żytko, 1977, 1981*b*), makes it possible to connect the source of anomaly with Early Miocene molasses as it was already assumed (K. Żytko, 1965). The proximity of the endings of both anomalies: that of the Western Carpathians in the area of Grybów – Jasło (Fig. 1) with that of the Eastern Carpathians in the area of Krosno point to their similar origin despite of their discontinuity. In this situation one should commence the palinspatic reconstruction from the removal of the allochton flysch from both zones of anomalies.

Using the picture of the regional field of compressive stress (Fig. 3F) the front offlysch masses has been removed straight southward at a distance of about 60 km (minimum value) in order to restore the situation in the Miocene time before huge Badenian rotation of the axis of the Northern Carpathians Foredeep (Fig. 4). Long-lasting, continuous change of foredeep pattern took place before the re-orientation of major plate motions (10 Ma). Those phenomena are presumably mutually connected.

Earlier, before the last stage of compression, 52 – 10 Ma ago, as a result of anticlockwise rotation of Africa the compression had been directed mainly to NW (Fig. 3E). The synsedimentary folds of WSW – ENE strike can be observed in the Eocene deposits of the Magura unit in the western part of the Polish Carpathians; however, the synsedimentary folds in the Oligocene – Early Miocene flysch of NW – SE strike also exist in the Carpathian area, for example in San river-basin (K. Żytko, 1977). The components of movement to N and NE were also strong at that time.

The anomalous Shenchenkovo zone of the Upper Cretaceous flysch of the Skole-Skiba unit appeared as an extension of the axis of the Mid-Polish anticlinorium (the San massif) before the last stage of motion, 10 Ma ago (Fig. 4). In order to obtain the paleogeographical connection, discussed in the present paper, between the anticlinorium and the shallow zone of Cisowa – Brzegi Dolne one should displace the flysch masses far to SE. The 100 km displacement (Fig. 4) results in an approximate coincidence of the Mesozoic pattern of the platform with the geosynclinal deposits in accordance with the modified conception. This distance of 100 km is also the dimension of the Carpathian anticlockwise forward – thrusting to NW in relation to the front of the Alps (Fig. 2). Apart from the regional field of compression the rigid Moesian microplate which was shifted to W at the end of Cretaceous (*vide* K. Żytko, 1984) played also its role in a displacement of the Carpathians, together with Pannonia, to NW.

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REFERENCES

BOJDYS G., LEMBERGER M., WOŹNICKI J., ZIĘTEK J. (1983) – Budowa litosfery na profilu Kraków – Zakopane w świetle wyników modelowania grawimetrycznego. Kwart. Geol., **27**, p. 605 – 616, nr 3.

BROCHWICZ-LEWIŃSKI W., POŻARYSKI W., TOMCZYK H. (1981) – Mouvements coulissant de grande ampleur au Paléozoique inférieur le long de la marge sud-ouest de la plate-forme Est--Européenne. C.R. Acad. Sc. Paris, **293**, ser. 2.

BURCHFIEL B.C. (1980) – Eastern European Alpine system and the Carpathian orocline as an example of collision tectonics. Tectonophysics, **63**, p. 31 – 61.

DADLEZ R. (1982) – Tektonika permo-mezozoiku a głębokie rozłamy strefy Teisseyre'a-Tornquista na terenie Polski. Kwart. Geol., **26**, p. 271 – 282, nr 2.

DĄBROWSKI A., KARACZUN K., KARACZUN M. (1981) – Południowo-zachodni brzeg platformy wschodnioeuropejskiej w Polsce w świetle wyników badań magnetycznych. Prz. Geol., **29**, p. 415 – 419, nr 8.

DEWEY F.J. (1982) – Plate tectonics and the evolution of the British Isles. J. Geol. Soc. London, **139**, p. 371 – 412.

DEWEY F.J., PITMAN W.C. III, RYAN W.B.F., BONNIN J. (1973) – Plate tectonics and the evolution of the Alpine system. Bull. Geol. Soc. America., **84**, p. 3137 – 3180.

DYJOR S., DENDEWICZ A., GRODZICKI A., SADOWSKA A. (1978) – Neogeńska i staroplejstoceńska sedymentacja w obrębie stref zapadliskowych rowów Paczkowa i Kędzierzyna. Geol. Sudetica, **13**, p. 31 – 65, nr 1.

DŻUŁYŃSKI S., KOTLARCZYK J., NEY R. (1979) – Podmorskie ruchy masowe w basenie skolskim. Sekcja Sedyment. PTG, Oddział Karpacki IG, IGSM AGH. Tow. Przyj. Nauk w Przemyślu, Mat. Teren. Konf. Nauk. w Przemyślu, p. 17 – 27.

GEROCH S., KRYSOWSKA-IWASZKIEWICZ M., MICHALIK M., PROCHAZKA K., RADOMSKI A., RADWAŃSKI Z., UNRUG Z., UNRUG R., WIECZOREK J. (1979) – Sedymentacja margli z Węgierki. Rocz. Pol. Tow. Geol., **49**, p. 105 – 133, z. 1/2.

GUTERCH A. (1977) – Structure and physical properties of the Earth's crust in Poland in the light of new data of DSS. Publ. Inst. Geoph. PAN, nr A4 (115), p. 347 – 357.

GUTERCH A., KOWALSKI T.J., MATERZOK R., PAJCHEL J., PERCHUĆ E. (1976) – O głębokiej strukturze ze skorupy ziemskiej w rejonie Gór Świętokrzyskich. Przew. 48 Zjazdu Pol. Tow. Geol., p. 52 – 58.

GUTERCH A., MATERZOK R., GRAD M., TOPORKIEWICZ S. (1983) – Badania metodą głębokich sondowań sejsmicznych. W: Budowa geologiczna niecki warszawskiej (płockiej) i jej podłoża. Pr. Inst. Geol., **103**, p. 46 – 50.

JANKOWSKI J., PETR V., PEĆOVA J., PRAUS O. (1977) – The Carpathian geoelectric anomaly and its relation to independent geophysical information. Acta Geol. Ac. Sci Hung., **21**, p. 337 – 349.

KOTLARCZYK J. (1978) – Stratygrafia formacji z Ropianki (fm), czyli warstw inoceramowych w jednostce skolskiej Karpat fliszowych. Pr. Geol. Komis. Nauk Geol. PAN Krak., **108**, p. 81.

KOSZARSKI L. (1961) – Nowe dane o rozwoju serii skolskiej na S od Tarnowa i Wojnicza. Kwart. Geol., **5**, p. 994 – 995, nr 4.

KSIĄŻKIEWICZ M. (1956) – Geology of the Northern Carpathians. Geol. Rundsch., **45**, p. 369 – 411, z. 2.

KSIĄŻKIEWICZ M. ed. (1962) – Atlas Geologiczny Polski. Zagadnienia stratygraficzno-facjalne. Z. 13. Kreda i starszy trzeciorzęd w polskich Karpatach zewnętrznych. Inst. Geol. Warszawa.

KSIĄŻKIEWICZ M., OBERC J., POŻARYSKI W. (1977) – Geology of Poland. 4. Tectonics, p. 618. Inst. Geol. Warszawa.

KUTEK J., GŁAZEK J. (1972) – The Holy Cross area, Central Poland, in the Alpine cycle. Acta Geol. Pol., **22**, p. 603 – 653, nr 4.

LISZKOWA J., NOWAK W. (1960) – Seria podśląska w Karpatach Bielskich (frydecka seria podśląska). Kwart. Geol., **4**, p. 510–529, nr 2.

MAHEL M. ed. (1973) – Tectonic Map of the Carpathian – Balkan mountain system and adjacent areas. Carpatho-Balkan Association. Geol. Inst. Dionyz Štur. Bratislava.

MAHEL M. (1974) – The Inner West Carpathians. In: Mahel M. (ed.) – Tectonics of the Carpathian – Balkan regions. Carpatho-Balkan Association. p. 91–133. Geol. Inst. Dionyz Štur. Bratislava.

MŁYNARSKI S., BACHAN W., DĄBROWSKA B., JANKOWSKI H., KANIEWSKA E., KARACZUN K., KOZERA A., MAREK S., SKORUPA J., ŻELICHOWSKI A.M., ŻYTKO K. (1982) – Interpretacja geofizyczno-geologiczna wyników badań wzdłuż profilów Lubin–Prabuty, Przedbórz–Żebrak, Baligród–Dubienka. Biul. Inst. Geol. **333**, p. 5–60.

MUELLER S., RYBACH L. (1974) – Crustal dynamics in the Central Part of the Rhinegraben. In: Illies J.H., Fuchs K. (eds.) – Approaches to Taphrogenesis. p. 379–388. Stuttgart.

NOWAK J. (1927) – Zarys geologii Polski. II Zjazd Stow. Geogr. p. 5–160. Kraków.

PESCATORE T., ŚLĄCZKA A. (1984) – Evolution models of two flysch basins: the Northern Carpathians and Southern Apennines. Tectonophysics, **106**, p. 49–70.

POŻARYSKI W., BROCHWICZ-LEWIŃSKI W. (1979) – On the Polish trough. Geologie en Mijnbow., **57**, p. 545–557.

POŻARYSKI W., ŻYTKO K. (1981) – On the Mid-Polish Aulacogen and the Carpathian Geosyncline. Bull. Acad. Pol. Sci., Sér. Sc. Terre. **28**, p. 303–316, nr 4.

ROTH Z. (1980) – Zapadni Karpaty – tercierni struktura stredni Evropy. UUG. Praha.

SAWICKI L. ed. (1966) – Geological Map of the Lower Silesian Region. 1:200 000. Inst. Geol. Warszawa.

SCHEFFER V. (1960) – Some contributions to the geophysical knowledge of the Carpathians Basins. Acta Techn. Ac. Sci. Hung., **30**, p. 423–461.

SIKORA W.J. (1976) – On lineaments found in the Carpathians. Rocz. Pol. Tow. Geol., **46**, p. 3–37, z. 1–2.

ŚWIĘCICKA-PAWLISZYN J., PAWLISZYN J. (1978) – Zastosowanie badań magnetotellurycznych do rozpoznawania złożonych struktur geologicznych. Geofiz. Stos., **2**, p. 16–25.

TOŁWIŃSKI K. (1921) – Dyslokacje poprzeczne oraz kierunki tektoniczne w Karpatach polskich. Pr. Geogr., **6**, p. 27–63. Lwów–Warszawa.

TOŁWIŃSKI K. (1956) – Główne elementy tektoniczne Karpat z uwzględnieniem górotworu Salidów. Acta Geol. Pol., **6**, p. 75–226, nr 2.

TOMEK Č., ŠVANCARA J., BUDIK L. (1979) – The depth and the origin of the Carpathian gravity low. Earth Planet. Sci. Lett., **44**, p. 39–42.

UNRUG R. (1979) – Palinspatic reconstruction of the Carpathian arc before the Neogene tectogenesis. Rocz. Pol. Tow. Geol., **49**, p. 3–21, z. 1/2.

WDOWIARZ S. (1976) – O stosunku Karpat do zapadliska przedkarpackiego w Polsce. Prz. Geol., **24**, p. 350–357, nr 6.

WDOWIARZ S. (1983) – Zagadnienie południowo-wschodniego przedłużenia aulakogenu środkowopolskiego w geosynklinie karpackiej. Prz. Geol., **31**, p. 15–21, nr 1.

WIESER T. (1979) – Korelacja horyzontów tufowych warstw krośnieńskich na podstawie cech mineralogicznych i wieku bezwzględnego. Kwart. Geol., **23**, p. 930, nr 4.

ZNOSKO J. (1979) – The Teisseyre-Tornquist tectonic zone: some interpretative implications of recent geological and geophysical investigations. Acta Geol. Pol., **29**, p. 365–382, nr 4.

ZOUBEK V., MALKOVSKY M. (1974) – The Czechoslovakian Part of the Bohemian Massif. In: Mahel M. (ed.) – Tectonics of the Carpathian-Balkan regions. Carpatho-Balkan Association, p. 407–414. Geol. Inst. of Dionyz Štur. Bratislava.

ŻYTKO K. (1965) – Sur le rapport de la formation du pétrole et l'orogenèse des Karpates. Carpatho-Balkan Geol. Assoc. VII Congress. Sofia. Reports, part IV, p. 75–81.

ŻYTKO K. (1977) – Uwagi o paleogeńskich ruchach tektonicznych w Karpatach zewnętrznych. Kwart. Geol., **21**, p. 938–940, nr 4.

ŻYTKO K. (1981*a*) – Bloki i rozłamy skorupy ziemskiej na przedpolu Karpat. Kwart. Geol., 25, p. 428–429, nr 2.

ŻYTKO K. (1981*b*) – Orogenic polarity of Carpathian flysch in Tertiary time. Carpatho-Balkan Geol. Assoc. XII Congress. Bucharest. Abstracts, p. 153–155.

ŻYTKO K. (1984) – The Atlantic, the Indian Ocean and main linear fracture zones of the post-Variscan Europe. Rocz. Pol. Tow. Geol., 52, p. 3–38, z. 1/4.

ГАРЕЦКИЙ Р.Г., ЗИНОВЕНКО Г.В., ВИШНЯКОВ И.Б., ГЛУШКО В.В., ПОМЯНОВСКАЯ Г.М., ХИЖНЯКОВ А.В. (1981) — Балтийско-приднестровская система перикратонных опусканий. В: Геология запада Восточно Европейской платформы, с. 44—61. Наука и Техника. Минск.

ГЛУШКО В.В., КРУГЛОВ С.С. и др. (1971) — Геологическое строение и горючие ископаемые Украинских Карпат. Тр. Укр. НИГРИ, вып. 25, с. 392.

ГЛУШКО В.В., КРУГЛОВ С.С. и др. (1977) — Обоснование направлений поисков нефти и газа в глубоко залегающих горизонтах Украинских Карпат. Тр. Укр. НИГРИ, с. 175. Наукова Думка.

ГЛУШКО В.В., КРУГЛОВ С.С. (1979) — Главнейшие особенности тектоники и развития Украинских Карпат. ВИЭМС. Обзор, с. 54. Москва.

ПАСТЕРНАК С.И., ГАВРИЛИШИН В.И., ГИНДА В.А., КОЦЮБИНЬСКИЙ С.П., СЕНЬКОВСКИЙ Ю.М. (1968) — Стратиграфия и фауна крейдових видкладив заходу Украини. Наукова Думка.

СОЛЛОГУБ В.Б., ГУТЕРХ А., ПРОСЕН Д. и др. (1978) — Строение земной коры и верхней мантии Центральной и Восточной Европы. Наукова Думка.

СОЛЛОГУБ В.Б., ГУТЕРХ А., ПРОСЕН Д. и др. (1980) — Структура земной коры Центральной и Восточной Европы по данным геофизических исследований. Наукова Думка.

УТРОБИН В.Н., ВИШНЯКОВ И.Б., КАРПЕНЧУК Ю.Р. (1974) — Тектоника внешней зоны Предкарпатского прогиба в свете новых материалов сейсморазведки и бурения. В: Новые данные по геологии и нефтегазоносности УССР. Тр. Укр. НИГРИ, 9, с. 36—43.

ШАТСКИЙ Н.С. и др. (1962) — Международная тектоническая карта Европы. 1:2 500 000. Межд. Геол. Конгресс. Москва.

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НЕКОТОРЫЕ ПРОБЛЕМЫ ГЕОДИНАМИЧЕСКОЙ МОДЕЛИ СЕВЕРНЫХ КАРПАТ

Резюме

Статья посвящена обсуждению картины разломов, секущих линию нарушений Мохо в Северных Карпатах и на их форланде (фиг. 1), установленных главным образом методами глубокого сейсмического зондирования (ГСЗ). Возможно, что западной границей пояса мощной земной коры (ров Мохо), проходящего на пограничье палеозойской и Восточно-Европейской платформ, является разлом Сташув—Поланец—Ясло, ориентированный в ССЗ—ЮЮВ направлении. На его продолжении располагается цепь третичных вулканитов Сланского погорья к востоку от Кошиц.

По данным ГСЗ в районе Радома обнаруживается нарушение упомянутого пояса мощной земной коры. С этими нарушениями связана важная линия структурных изменений в варис-

цийско-мезозойском плане (декстральное смещение оси и границ Северо и Внутрисудетского синклинория, а также Могильненско-Лодзинского и Меховского синклинориев и гранитоидные варисцийские массивы Карконоше и Стжегом). Принимается за факт существование разлома Карловы Вары—Радом—Чернигов (фиг. 2), являющегося северной границей метакарпатского вала. Это сдвиго-сброс, компенсирующий варисцийское раскрытие Днепровско-Донецкого авлакогена. Синистральный сдвиг пояса мощной земной коры в зоне нарушений Радома свидетельствует о изменении направления движений вдоль разлома за время его существования и, возможно, протерозойское заложение этого линеамента.

Система трещин, приуроченных к осевой зоне гравиметрических депрессий Восточных и Западных Карпат, связано, вероятно, с разломами на платформе, сигнализированными ГСЗ (район Тарнув—Краков) и магнитометрией (район Жолыня—Цешанув).

Зона смены направлений геоэлектрических векторов индукции приурочена, вероятно, к шраму в фундаменте, оставшемуся от силезской кордильеры флишевых Карпат, активной в верхнем мелу и нижнем палеогене. Разлом, выявленный магнитотеллурическим методом в районе Леска, может определять собой западную границу продолжения массива Сана в основании флиша.

Исходя из иного расположения осевых зон гравиметрических депрессий по отношению к краю Западных и Восточных Карпат и из миграции орогенных процессов в третичное время в сторону внешних участков геосинклинали, образование депрессии считают следствием раннемиоценовых тектонических движений. Указывается на возможность связи олистолитов во флише в районе Пшемысля с процессом поднятия Среднепольского антиклинория (массива Сана), начиная с кампана. Верхнемеловой флиш скольской преемственности между Бжеском и Бельском, переходил в маломощные мергелистые породы фридецкой преемственности. Это изменение, вероятно, обусловлено протяженностью на юг западного склона Среднепольского авлакогена.

Автор обращается к изменениям в региональном поле компрессии в районе Карпат, обусловленных движениями африканской плиты по отношению к европейской (фиг. 3). В конечной фазе орогена, начиная с бадена, флишевая масса Северных Карпат сдвигалась к северу. Раньше, между нижним эоценом и баденом, намечался нажим в сторону СЗ (фиг. 3, 4). Этот нажим способствовал выдвижению края Карпат из фронта Альп (фиг. 2). При этом свою роль сыграла стабильная микроплита Моэзии, сдвинутая в конце мела на запад.

Kazimierz ŻYTKO

NIEKTÓRE PROBLEMY GEODYNAMICZNEGO MODELU KARPAT PÓŁNOCNYCH

Streszczenie

W pracy dyskutowany jest obraz rozłamów przecinających nieciągłość Moho w Karpatach północnych i na ich przedpolu (fig. 1), stwierdzonych głównie metodą głębokich sondowań sejsmicznych (GSS). Jest możliwe, że zachodnią granicę pasa grubej skorupy Ziemi (rowu Moho), znajdującego się w strefie granicznej platform paleozoicznej i wschodnioeuropejskiej, stanowi rozłam Staszów—Połaniec—Jasło o kierunku NNW—SSE. Na jego przedłużeniu znajduje się pasmo trzeciorzędowych wulkanitów Slanskiego Pohoria na E od Koszyc.

Z analizy danych GSS wynika nieciągłość w rejonie Radomia w przebiegu wspomnianego pasa grubej skorupy. Z tą nieciągłością związana jest ważna linia zmian strukturalnych w planie późnowaryscyj-

sko-mezozoicznym (dekstralne przesunięcie osi i ram synklinorium północno- i wewnątrzsudeckiego oraz synklinorium mogileńsko-łódzkiego i miechowskiego, a także waryscyjskie granitoidowe masywy Karkonoszy i Strzegomia). Przyjęto istnienie rozłamu skorupy Karlove Vary – Radom – Czernichów (fig. 2) stanowiącego północną granicę wału metakarpackiego. Jest to uskok przesuwczy kompensujący waryscyjskie otwarcie aulakogenu dnieprowsko-donieckiego. Sinistralne rozsunięcie pasa grubej skorupy w strefie nieciągłości Radomia wskazuje na zmiany kierunku ruchu wzdłuż rozłamu w ciągu jego historii i przypuszczalnie proterozoiczne założenie tego lineamentu.

Układ pęknięć związanych z osiowymi strefami depresji grawimetrycznych Wschodnich i Zachodnich Karpat ma przypuszczalnie związek z rozłamami na platformie wyznaczonymi z danych GSS (rejon Tarnowa – Krakowa) i magnetometrii (rejon Żołyni – Cieszanowa). Strefa zmian kierunku geoelektrycznych wektorów indukcji wiąże się przypuszczalnie z blizną podłoża po śląskiej kordylierze Karpat fliszowych aktywnej w kredzie górnej i starszym paleogenie. Wyznaczony magnetotellurycznie rozłam w rejonie Leska może wiązać się z zachodnią granicą przedłużenia masywu Sanu w podłożu fliszu.

Wychodząc z odmiennego układu osiowych stref depresji grawimetrycznych w stosunku do brzegu Zachodnich i Wschodnich Karpat oraz z migracji zjawisk orogenicznych w trzeciorzędzie ku zewnętrznym strefom geosynkliny, powiązano depresje z wczesnomioceńskimi zjawiskami tektonicznymi. Wskazano możliwość związku olistolitów we fliszu rejonu Przemyśla z wypiętrzeniem antyklinorium środkowopolskiego (masywu Sanu) począwszy od kampanu. Górnokredowy flisz sukcesji skolskiej przechodził między Brzeskiem a Bielskiem w margliste utwory sukcesji frydeckiej o małej miąższości. Zmiana ta związana była przypuszczalnie z przedłużeniem ku południowi zachodniego skłonu aulakogenu środkowopolskiego.

Nawiązano do zmian w regionalnym polu kompresji w rejonie Karpat wywołanych ruchami płyty afrykańskiej w stosunku do europejskiej (fig. 3). W końcowej fazie orogenezy, od badenu, masy fliszowe Karpat północnych przesuwały się ku północy. Wcześniej, między dolnym eocenem i badenem zaznaczał się nacisk ku NW (fig. 3, 4). Wiąże się z tym wysunięcie brzegu Karpat w stosunku do czoła Alp (fig. 2). Odegrała tu rolę sztywna mikropłyta Moezji przesunięta z końcem kredy ku zachodowi.