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The Przemyśl sigmoid and possibilities of hydrocarbon exploration

Piotr KARNKOWSKI

Polskie Górnictwo Naftowe i Gazownictwo S.A., 03-301 Warszawa, ul. Jagiellońska 76

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The Flysch Carpathians drastically bend from the southeastern to southern direction in the Przemyśl region, and then at Dobromil take the southeastern direction again (Fig. 1). This sharp bend is called the Przemyśl sigmoid and results from the topography of deep Precambrian basement (J. Kuśmierek, R. Ney, 1988). A fold-block structure of the basement has recently been examined by seismic survey and boreholes (Figs. 2–5). The consolidated basement rises from the east towards north-west from a depth of 10 000–12 000 m south of Dolina, up to about 3000 m in the vicinity of Przemyśl and 600 m near Leżajsk. Its southern flank plunges to the south in a stepwise arrangement. The basement blocks are the obstacle to the thrusting Carpathian orogen which accomodated against the shape of the basement. The marginal Carpathians along with the Borislav–Pokutse unit and the Lower Miocene deposits form a common orogen extending from Borislav towards both the east and west (K. Tołwiński, 1937). Possibilities of western extension of the unit into the area of Poland in the vicinity of Przemyśl and some aspects of the occurrence of Miocene deposits and, perhaps, deep folds south of Przemyśl, are discussed here. These problems are related to hydrocarbon accumulation.

INTRODUCTION

The Flysch Carpathians drastically bend from the south-eastern to southern direction in the Przemyśl region. Thirty kilometres farther south, in the Dobromil–Strzelbice region, they take the south-eastern direction again (Fig. 1a). Near Przemyśl, this sharp bend of the Carpathians edge in a shape of the inverted "S" is called the Przemyśl sigmoid (J. Kotlarczyk, 1988; J. Kuśmierek, R. Ney, 1988; R. Ney, 1968). Its shape results from a deep geological structure of the basement. The evidence is derived from deep boreholes and seismic investigations, carried out in both Poland and Ukraine. These show that there is the Upper Precambrian basement of block structure and a very diversified relief underlying the Carpathians in this region.

DEEP BASEMENT OF THE MARGINAL FLYSCH CARPATHIANS

The consolidated basement rises generally from the territory of Ukraine towards Poland from a depth of about 10 000–12 000 m at the borehole Szewczenkowo 1 (7521 m deep), south of Stryj, up to around 3000 m in the vicinity of Przemyśl (Fig. 1), rising farther off towards Leżajsk up to a depth of about 600 m.

Top of the basement exhibits a diversified relief. It is cut by a series of major transversal and longitudinal faults reflected in the basement of the marginal part of the Skole unit (Figs. 2, 3). This unit along with the folded Lower Miocene deposits of Stebnik, borders the edge of the Małopolska Massif which is a slope of the East-European Platform or a separate crustal fracture.

The consolidated Precambrian basement uplifts stepwise towards the north (Fig. 3) and was the obstacle to the thrusting Carpathian orogen. In the eastern part of the area the marginal Carpathians has leant against a deep step of the basement, as high as a few thousand metres, which acted as a rigid massif

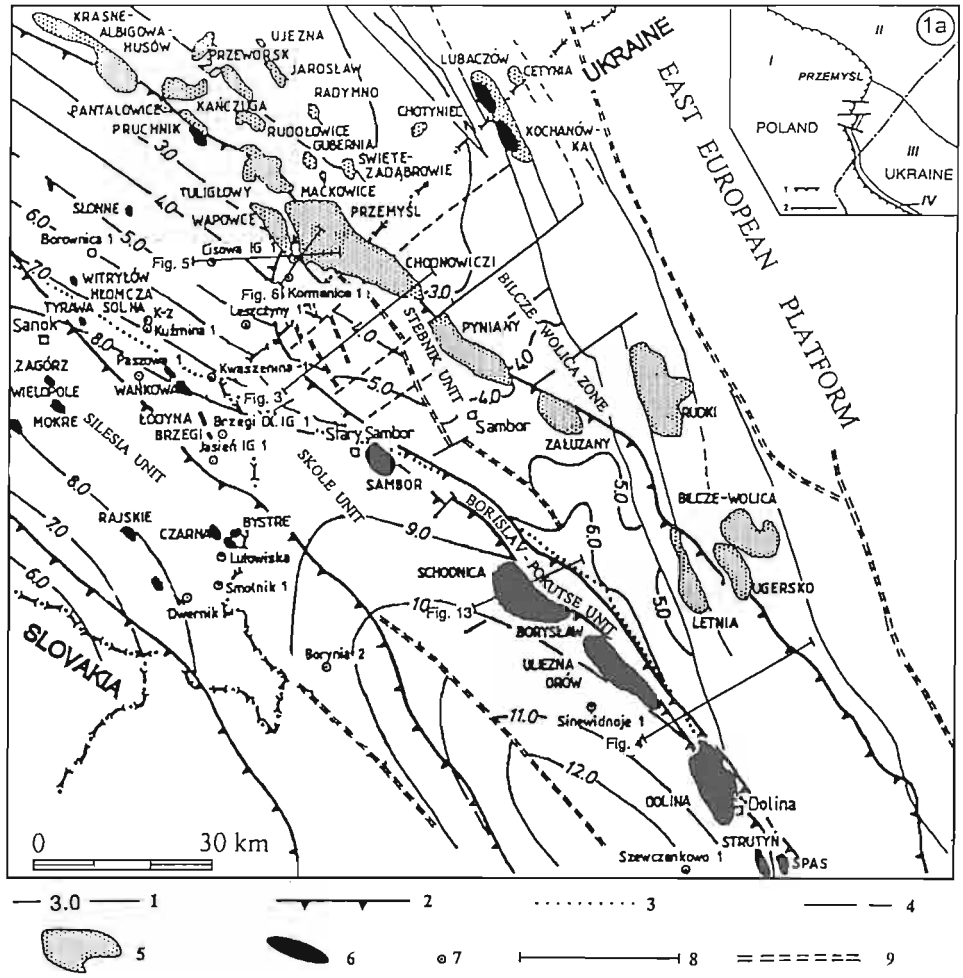

Fig. 1. Simplified geological sketch of the consolidated basement in the eastern part of the Flysch Carpathians, oil and gas occurrence

1 — top of basement in km; 2 — nappe front; 3 — axis of negative gravity anomaly; 4 — faults; 5 — gas fields; 6 — oil fields; 7 — boreholes; 8 — location of geological cross-sections shown in Figs. 3–6 and 13; 9 — deep crustal fractures

Uproszczony szkic geologiczny skonsolidowanego podłoża wschodniej części Karpat fliszowych oraz występowanie złóż ropy i gazu

1 — izohipsy utworów fliszowych jednostki stebnickiej (samborskiej) i miocenu; 2 — nasunięcia; 3 — oś regionalnego minimum siły ciężkości; 4 — dyslokacje; 5 — złoża gazu ziemnego; 6 — złoża ropy naftowej; 7 — głębokie otwory wiertnicze; 8 — lokalizacja przekrojów geologicznych przedstawionych na fig. 3–6 i 13; 9 — głębokie rozłamy skorupowe

Fig. 1a. Tectonic sketch of the Przemyśl vicinities

I — the Carpathians (Inoceramian unit); II — autochthonous Miocene unit; III — inner zone Miocene (Stebnik unit); IV — peri-Carpathian saliferous formation; 1 — Carpathian overthrust front; 2 — Stebnik unit overthrust front

Szkic tektoniczny okolic Przemyśla

I — Karpaty (jednostka inoceramowa); II — jednostka miocenu autochtonicznego; III — miocen strefy wewnętrznej (jednostka stebnicka); IV — przykarpacka jednostka solonośna; 1 — granica nasunięcia Karpat; 2 — granica nasunięcia jednostki stebnickiej

preventing them from farther northwards movement (Fig. 4). In the western part, where a gradient of the basement uplift is low, the Carpathian front could reach farther to the north (Fig. 5). This is the origin of the Przemyśl sigmoid.

The transversal Dniestr fault was the one that influenced the above mentioned variety — the fault runs not far to the east of the border of Poland. There are a few such faults in Ukraine. It may be inferred that they also influenced the shape of the orographic edge of the Przemyśl Carpathians. It is reflected in the trend of the Borislav–Pokutse unit which forms, together with the flysch, a common tectogen of the marginal Carpathians, fitting itself into a general tectonic frame (J. Kuśmierek, R. Ney, 1988).

In the region of the Przemyśl sigmoid the following units can be distinguished on the basis of lithology and tectonic style within the Miocene deposits: (1) the Stebnik unit, distinguished by K. Tołwiński (1937), also called the inner unit, and (2) the autochthonous Miocene unit, also called the outer unit. J. Kotlarczyk (1988) distinguished the Zgłobice unit between the autochthonous Miocene and Stebnik Miocene deposits.

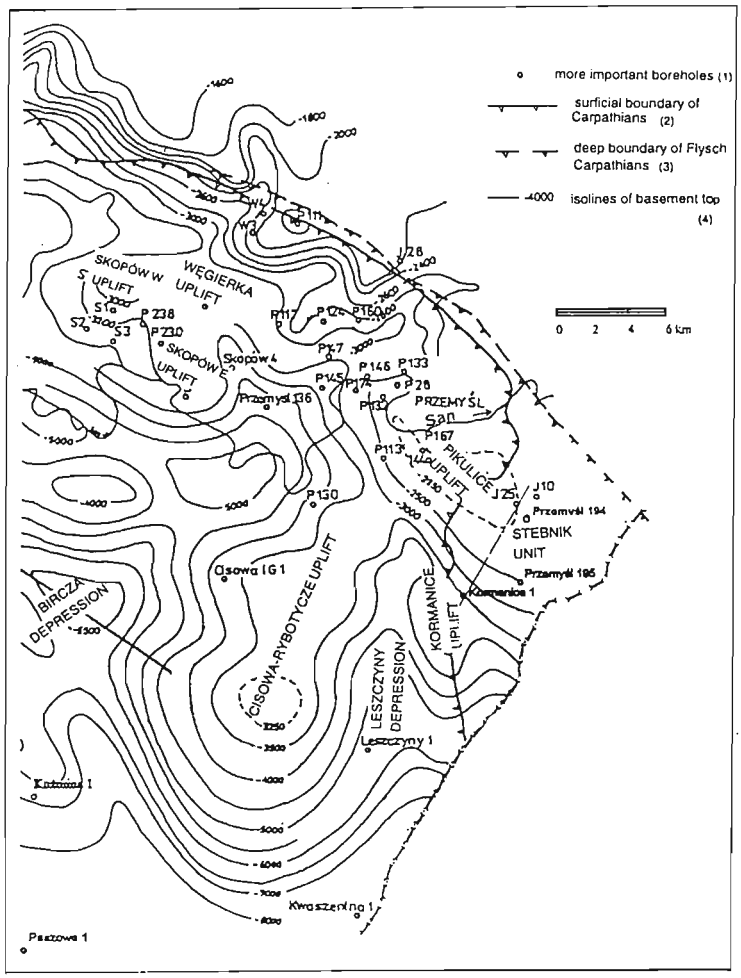

Fig. 2. Top of Precambrian basement after B. Jabłońska (unpublished work)

Szkic strukturalny stropu podłoża prekambryjskiego według B. Jabłońskiej (praca niepublikowana)

1 — ważniejsze otwory wiertnicze; 2 — powierzchniowa granica zasięgu Karpat; 3 — wgłębna granica zasięgu Karpat fliszowych; 4 — izohipsy stropu powierzchni podkenozoicznej

Within the lower part of the Stebnik unit, the peri-Carpathian saliferous formation, partly wrapping up the deep folds, has also been separated (M. Książkiewicz, 1972; R. Ney, 1968; J. Kotlarczyk, 1988; J. Kruczek, 1995).

Borehole data show that the Carpathian flysch along with the folded Miocene deposits of the Stebnik (Sambor) unit rest upon the folded Upper Precambrian phyllites (Fig. 5, 6). Farther east of the Stryj region, the Carpathian flysch overlies Mesozoic deposits, mainly epicratonic Jurassic and Cretaceous which are covered by the younger unfolded Neogene. Below the Jurassic there are Palaeozoic deposits. Such a geological structure has been recognized by Ukrainian geologists through boreholes and seismic data on the Łopuszna structure in the region of the Bukovina Carpathians. Cenomanian sandy deposits as well as Jurassic carbonates have been encountered within this structure under the Carpathian overthrust (Fig. 7). Those rocks have yielded oil outflow of 300 t/day from a depth of 4200–4250 m (D. D. Fedorishin, 1995).

West of the Przemyśl region the Carpathians rest upon the folded Upper Precambrian basement of a

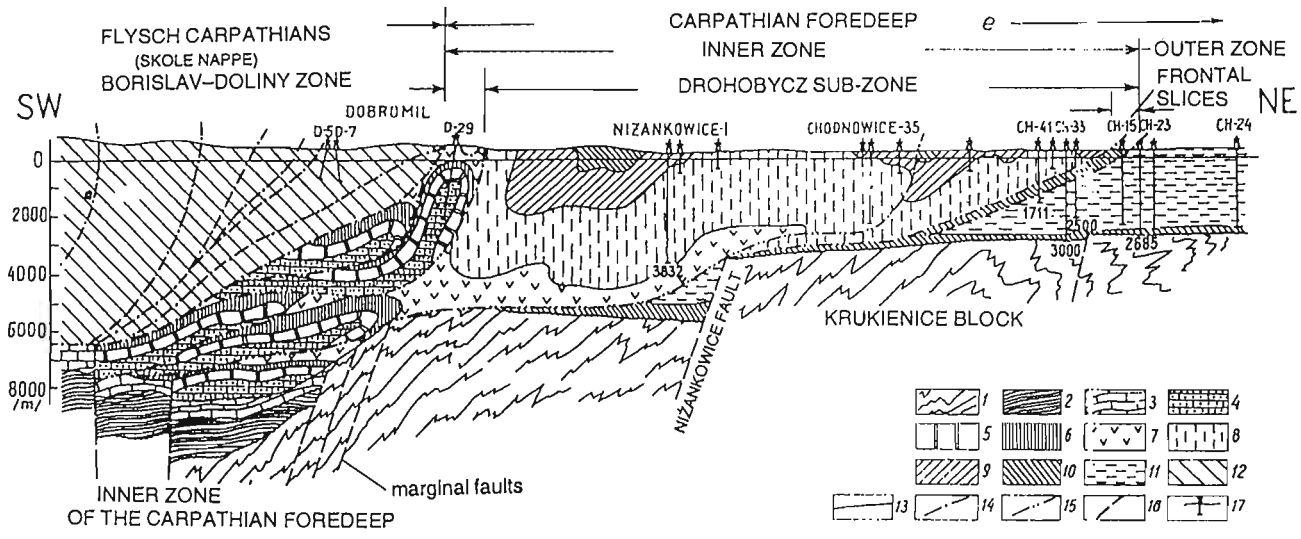

Fig. 3. Geological cross-section along Dobromil–Niżankowice–Chodnowice line in the region of the Przemyśl sigmoid (after O. S. Vjalov, 1965)

1 — Precambrian, 2 — Palaeozoic, 3 — Jurassic, 4–6 — Carpathian flysch (4 — Cretaceous, 5 — Palaeocene, 6 — Oligocene), 7–11 — Miocene deposits (7 — Worotyszcze series, 8 — Stebnik series, 9 — Balice series, 10 — Badenian, 11 — Sarmatian), 12 — Cretaceous-Oligocene Carpathian flysch, inseparable, 13 — stratigraphic unconformities, 14, 15 — overthrust fronts (14 — of the folded Carpathians, 15 — of the outer foredeep zone), 16 — faults in basement, 17 — boreholes

Przekrój geologiczny w rejonie sigmoidy przemyskiej na profilu Dobromil–Niżankowice–Chodnowice według O. S. Wjałowa (1965)

1 — prekambr, 2 — paleozoik, 3 — jura, 4–6 — flisz karpacki (4 — kreda, 5 — paleocen, 6 — oligocen), 7–11 — miocen (7 — seria worotyszczeńska, 8 — seria stebnicka, 9 — seria balicka, 10 — baden, 11 — sarmat), 12 — flisz karpacki kredowo-oligoceński, nierozdzielony, 13 — niezgodności stratygraficzne, 14, 15 — linie nasunięć (14 — Karpat sfałdowanych, 15 — strefy wewnętrznej zapadliska przedkarpackiego), 16 — uskoki w podłożu, 17 — otwory wiertnicze

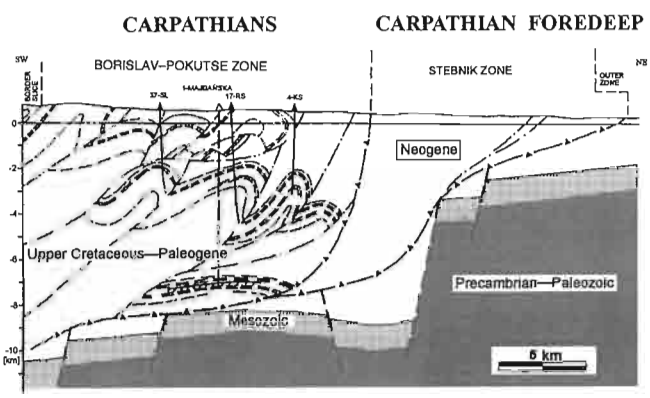

Fig. 4. Geological cross-section across the Flysch Carpathians and its foreland in the vicinity of Majdan (Ukraine) after M. J. Vul and O. O. Maksimova (1995) (simplified and modified)

Przekrój geologiczny przez Karpaty fliszowe i Przedgórze Karpat w okolicy Majdanu (Ukraina) według M. J. Wula i O. O. Maksimowej (1995) (uproszczony i zmodyfikowany)

diversified top relief, covered by the autochthonous Miocene deposits. Farther still towards Tarnów, younger and younger deposits appear: Devonian, Carboniferous and Mesozoic in age. Gas accumulations have been found within them (e.g. in borehole Zalesie 8, Devonian), oil within the Visean carbonates of Nosówka, oil and gas within the Upper Jurassic carbonates (Dębica, Tarnów, Bochnia and Dąbrowa Tarnowska region) and oil within the Cenomanian sandy series of Grobla (E. Jawor, 1983).

During the Palaeogene the Małopolska Massif area was intensely eroded. The erosion removed much of the Mesozoic and Palaeozoic and uncovered over a vast area even Upper Precambrian deposits. A very diversified palaeorelief was formed at that time, as reported for example north of Rzeszów where morphological gradients exceed 1000 m. Part of the eroded material was shed into the evolving Carpathian flysch basin. The northwest-to-southeast-running transportation paths (E. Jawor, 1983; P. Karnkowski, 1978, 1992) can be seen as palaeovalleys at the surface of sub-Miocene deposits of the Carpathian foreland (Fig. 8). The development of the palaeovalleys might have commenced as early as during the Palaeocene. They can be distinguished in the following regions: Szczurowa–Wojnicz, Tarnów, Pogórska Wola (Figs. 8, 9), Nisko–Kolbuszowa–Rzeszów (Fig. 10), Leżajsk–Przeworsk–Przemyśl and elsewhere. Some of them extend for below the present Carpathian overthrust. The palaeovalleys prove that the material supply must have been very intensive, taking into account the deep erosion confirmed by seismic data and boreholes. In the Neogene they were filled in with sandy-clayey sediments. At that time the material was transported into the Carpathian Foredeep from both the south and north (S. Połtowicz, 1990, 1991). In the Ukrainian Carpathians the deep palaeovalleys also occur (V. V. Glushko, 1977). They trend NW–SE and are filled in with Palaeogene strata.

The thrusting movements of the Carpathians migrated during the Miocene towards the north and east (W. Żuchiewicz, 1995). The oblique collision against the East-European Craton caused the rotation of the latter and its plunge under the Carpathians. The Małopolska Massif along with its cover were subjected to anticlockwise rotation. This might have caused the directions of palaeovalleys to turn from NW–SE to NWW–SEE, especially within the Neogene deposits (E. Jawor, 1983). From the Lower Cretaceous untill the end of the Miocene, i.e. during the development of the Carpathian flysch and the Neogene Carpathian Foredeep, rifting processes took place on the East-European Platform.

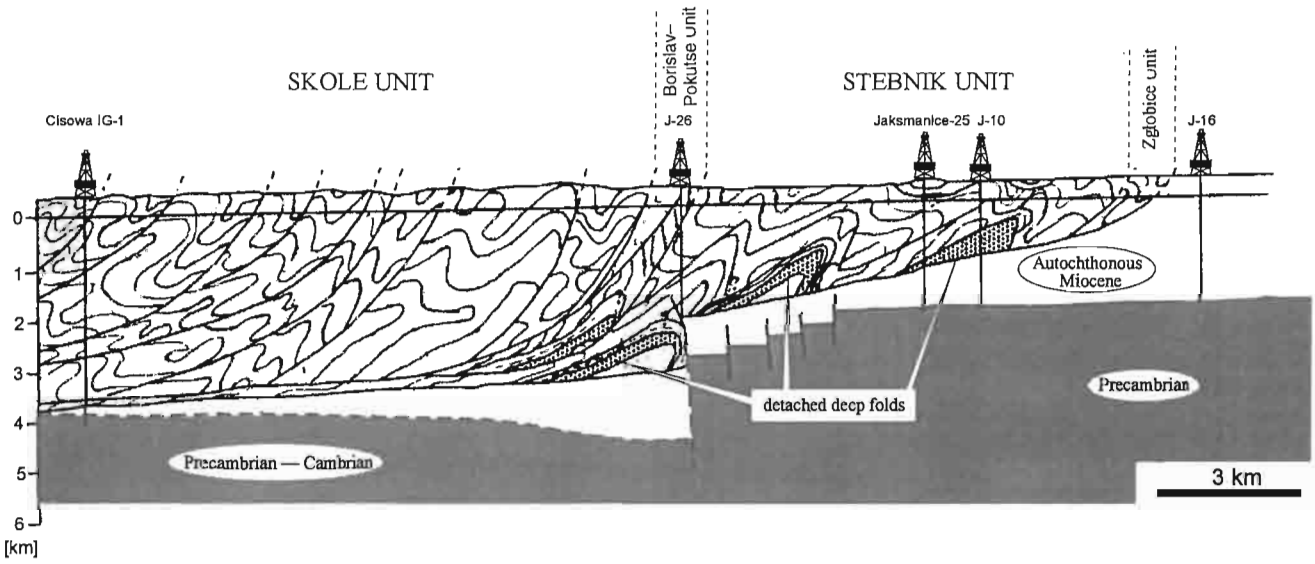

Fig. 5. Schematic cross-section across the Carpathians south of Przemyśl (partly after R. Ney, 1968)

Schematyczny i hipotetyczny przekrój przez region karpacki na S od Przemyśla (częściowo według R. Neya, 1968)

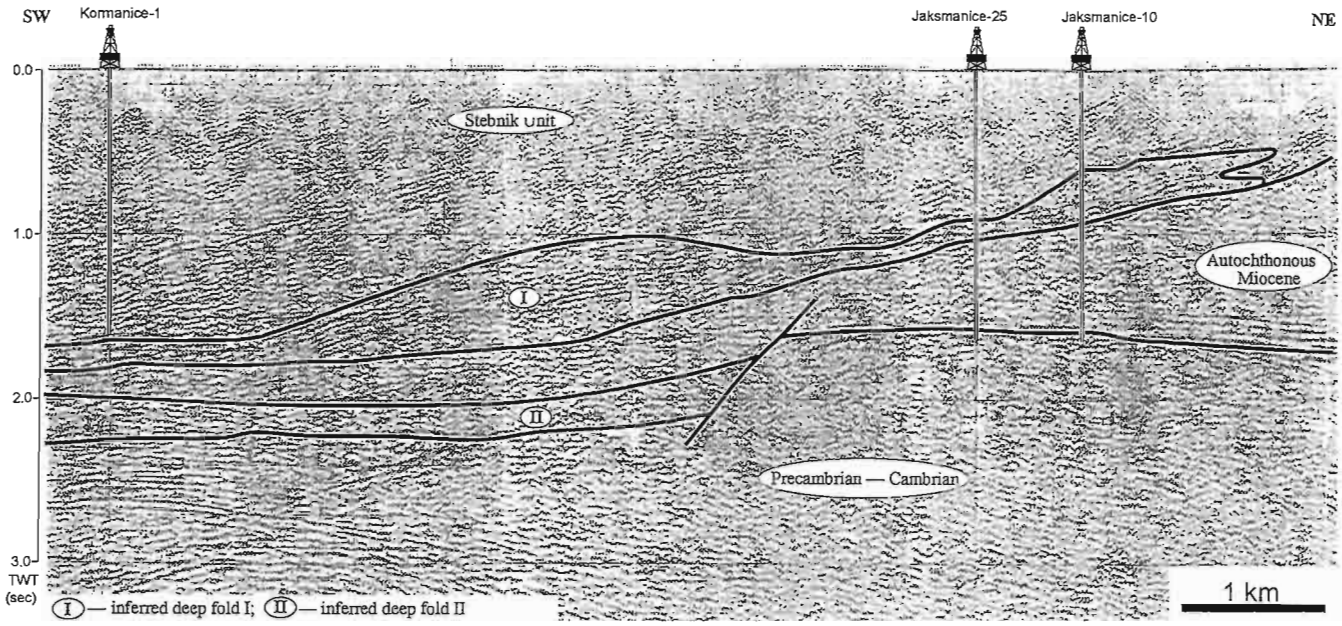

Fig. 6. Seismic time section 2-13-94 south of Przemyśl after "The Geophysical Enterprise", Kraków

Sejsmiczny przekrój czasowy 2-13-94 w rejonie na S od Przemyśla według „Geofizyki" Kraków
I — przypuszczalne elementy faldów wgłębnych I; II — przypuszczalne elementy faldów wgłębnych II

THE CARPATHIAN FLYSCH BASIN AND ITS FOREDEEP

The accumulation of flysch deposits, i.e. sandstones, siltstones, shales and occasionally carbonates, was a rhythmical and very intensive process during the Cretaceous and Neogene times all over the Carpathian basin. Clastic material was transported largely from the Małopolska Massif which was subjected to continued erosion at that time. Most of the Mesozoic and Palaeozoic deposits were removed from the massif at that time, causing the Upper Precambrian rocks to have been exposed. The flysch deposits are about 9–11 km thick in the deepest parts of the basin (M. Książkiewicz, 1972; V. V. Glushko, 1968; P. Karnkowski, 1992, 1993).

At the Palaeogene/Neogene boundary the main geosynclinal phase came to its end and the folding processes of the Flysch Carpathians began. The Carpathian Foredeep started to develop between the Carpathian front emerging from the south and the Carpathian foreland extending in the north (E. Głowacki *et al.*, 1966; R. Ney, 1968). The development of the inner zone (the Stebnik zone) of the Carpathian Foredeep commenced with the post-Oligocene uplifting movements.

The oldest Miocene deposits are predominantly clays with salts and anhydrite terminating the flysch sedimentary cycle. The deposits are called the peri-Carpathian saliferous formation (J. Garlicki, 1973; J. Kotlarczyk, 1988) which is the continuation of the Polanica (Krosno) Beds sedimentation and rests unconformably upon the flysch. Discordant position indicates that the flysch was not uniformly uplifted over the whole area after the Oligocene. Depositional conditions within the Stebnik zone significantly changed after the peri-Carpathian saliferous formation had been deposited. Coarse-grained fluvial material was transported into the basin from both the Carpathians and its foreland (Fig. 11). Conglomerates and sandstones of considerable thickness (up to about 2500 m), intercalated with shales and claystones, were deposited. South-east of Przemyśl, at Dubnik and Nowe Sady, the conglomerates are largely composed of exotic material derived from both the Carpathian foreland and the Carpathian flysch (R. Ney, 1968; J. Kotlarczyk, 1988).

In Ukraine within conglomerates of the River Tyśmienica profile at Borislav and Dubnik fragments of Upper Precambrian phyllites, quartzites and sandstones (presumably of Cambrian age), Jurassic dolomites and limestones and even boulders, reaching 1 m in diameter, have been found. Hornstones and fragments of menilite shales as well as sandstones of the Carpathian flysch have also been noted. The material transported into the Neogene basin testifies to its rapid deepening, but first of all to erosion of a high cliff that bordered the basin (Fig. 11).

During the deposition of the Stebnik, Balice and Halicz Beds, there were variable sedimentary conditions. Beside shales, siltstones and sandstones, which are the most common deposits, conglomerates were periodically deposited. They largely occur within the lowest beds of the Stebnik unit. Depositional processes and the development of the inner zone of the foredeep is shown in Figure 12. It is evident that the Lower Miocene sea, during its first development phase, occupied mainly the marginal zone of the Skole unit flysch, already

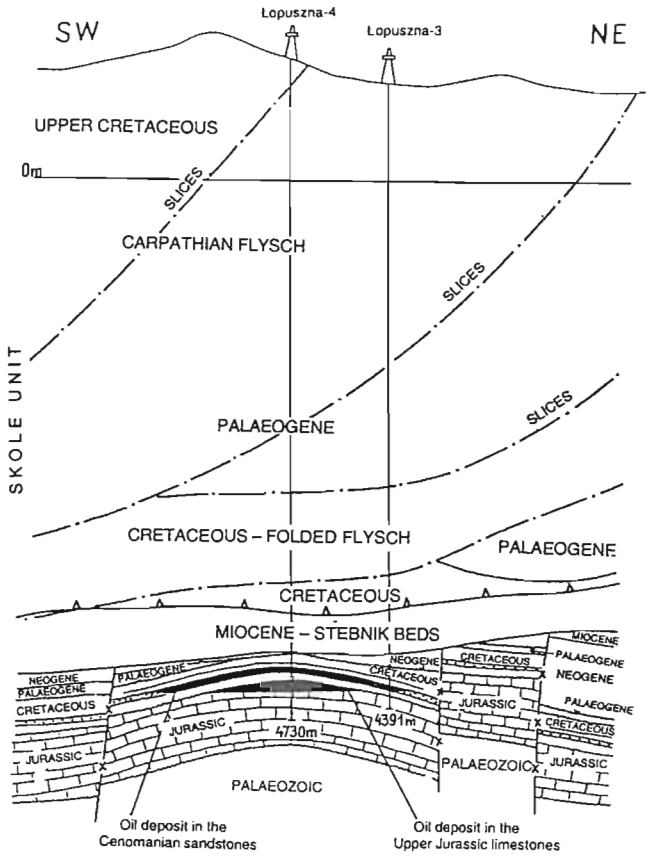

Fig. 7. Geological cross-section across the Łopuszna structure (Ukraine, the Bukovina Carpathians) after M. D. Buderkiewicz *et al.* (unpublished work)

Przekrój geologiczny przez strukturę Łopusznej (Ukraina, Karpaty Bukowińskie) według M. D. Buderkiewicza i in. (praca niepublikowana)

folded in part (Fig. 12a). The peri-Carpathian saliferous formation originated in lagoonal and semi-lagoonal conditions. During the following phase of the basin development further deepening and a gradual shift of the basin towards the north took place (Fig. 12b).

While the inner zone foredeep started to form, the outer zone was subjected to a partial uplift (Figs. 12c). Some uplifting movements occurred after the Lower Stebnik Beds had been deposited or even earlier. They affected the outermost parts extending at the Carpathian front (Fig. 12d). After the Lower Sarmatian, the inner zone was folded and thrusted over its forefield, i.e. upon the autochthonous Miocene. The Carpathian flysch that underlay the Miocene was also refolded and displaced northwards (Fig. 12e).

Suitable conditions for salt formation were within the peri-Carpathian saliferous formation, at the boundary of the Lower and Upper Stebnik Beds (Kałusz salts) and at the top of the Stebnik and Balice Beds (J. Garlicki, 1973). Evaporites, including rock salt, have also been found in the Lower Badenian (B. Cisek, J. Czernicki, 1972).

Depositional conditions within the Neogene foredeep rapidly altered; conglomerates, sandstones, clays and evaporites were deposited. Considering these, four sedimentary cycles are distinguishable in the Neogene basin (E. Głowacki *et al.*, 1966). Cycle I is the peri-Carpathian saliferous formation consisting of clay, gypsum and rock salt. Farther east it locally joins the Polanice Beds which terminate the Carpathian flysch sedimentation. Cycle II begins with the Słoboda conglomerates (of Dubnik). It is largely composed of the material originating from the Carpathian foreland and terminates in the Kałusz salts. They subdivide the Stebnik Beds into the lower and upper parts. Cycle III starts with the Upper Stebnik Beds (conglomerates, sandstones, clays) and ends in chemical deposits at the top of the Balice Beds (Lower Bade-

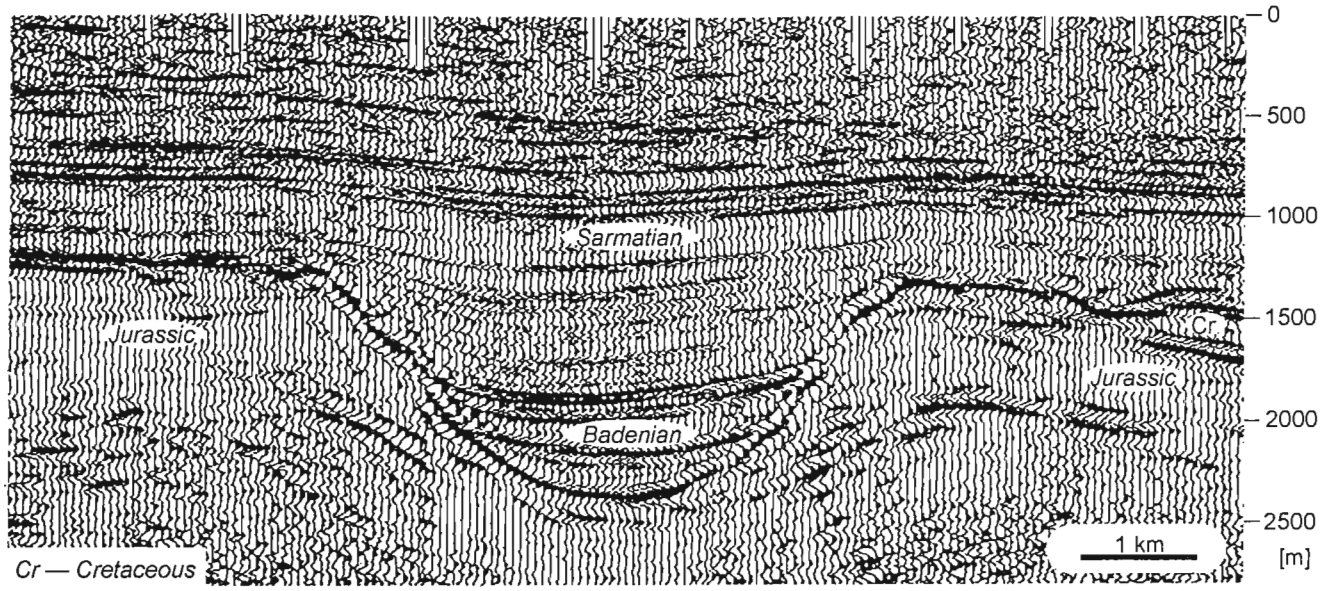

Fig. 8. Seismic section 3D in the Pogórska Wola region east of Tarnów after "The Geophysical Enterprise", Kraków

Profil sejsmiczny 3D w rejonie Pogórskiej Woli na wschód od Tarnowa według „Geofizyki" Kraków

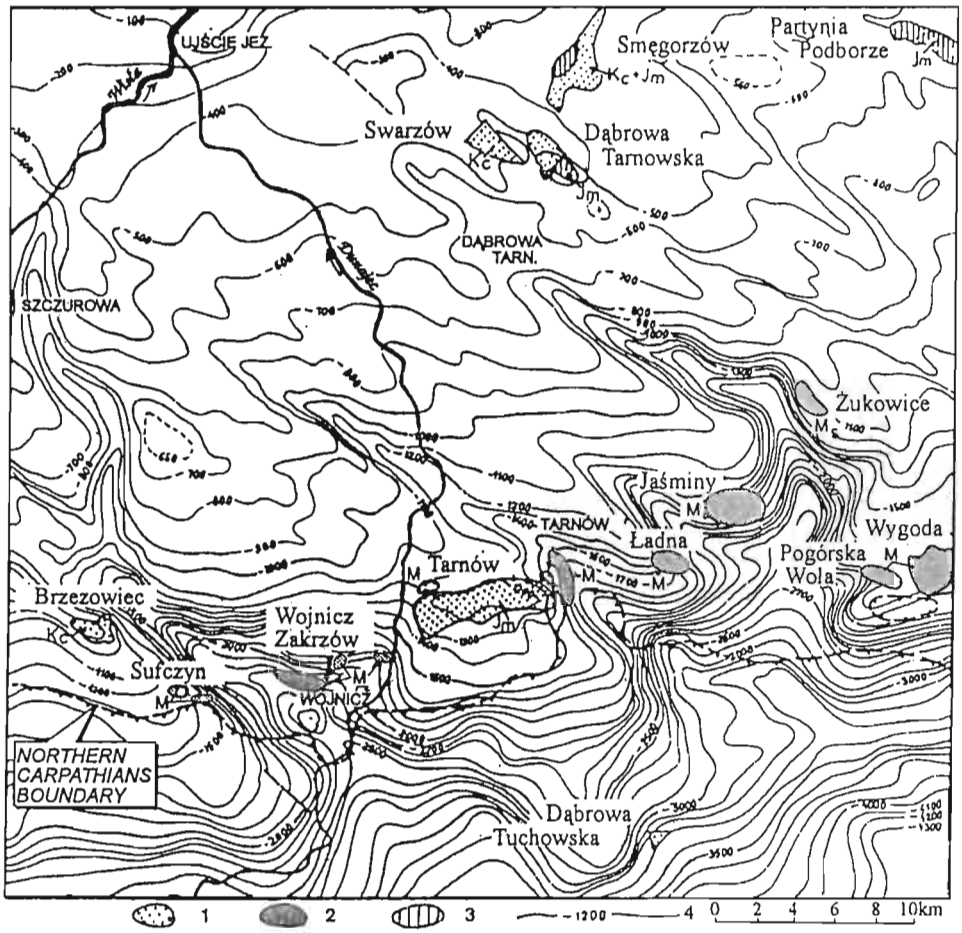

Fig. 9. Palaeovalleys in sub-Miocene surface of the Carpathian foreland, Tarnów region
1 — gas reservoir in Cenomanian deposits (Kc); 2 — gas reservoir in Miocene deposits (M); 3 — gas reservoir in Jurassic deposits (Jm); 4 — isohypses of base of the Miocene

Paleodoliny na podmioceńskiej powierzchni Przedgórza Karpat w rejonie Tarnowa
Złoża gazu w utworach: 1 — cenomanu (Kc), 2 — miocenu (M), 3 — jury (Jm); 4 — izobaty spągu miocenu

nian). Within the outer unit an evaporitic layer (anhydrite series with rock salt intercalations) was forming at that time (J. Garlicki, 1973; R. Ney, 1968; B. Cisek, J. Czernicki, 1972). Cycle IV begins with a clayey-sandy series. No saliferous deposits have been found within this cycle as yet. Studies of sedimentation ciclicity in the Neogene basin of the Carpathian Foredeep are faced with difficulties due to strong deformations of strata. Therefore the problem requires farther investigations.

Three tectonic units can be distinguished within the Carpathian Foredeep which extends from the Dolina and Borislav region towards the border of Poland: (1) the Borislav–Pokutse unit, (2) the Stebnik (Sambor) unit and (3) the autochthonous Miocene unit also called the Bilcze–Wolica unit (J. Kotlarczyk, 1988; S. Wdowiarz, S. Jucha, 1982).

The first one consists of a series of anticlinal folds thrusted one over another (Fig. 5). They are built of Cretaceous-Palaeogene flysch deposits overlain by variegated and saliferous Miocene sediments. Much of southwestern part of the zone is covered by the overthrusted flysch. The Borislav–Pokutse unit is thrusted over the inner zone (the Stebnik zone), built of variegated Stebnik deposits. Flysch deposits, in the form of detached blocks, have been recognized in the boreholes Jaksmanice 10 and 25 within this unit (Figs. 5, 6). They consist of menilite shales and Eocene beds similar to the series occurring within deep folds of Borislav–Dolina (J. J. Zieliński, 1963), 550 and 250 m thick, respectively. The origin of the detached blocks has not been determined yet. Oil accumulation occurs within these deposits in the Borislav region.

The Stebnik unit is, in turn, thrusted over the autochthonous Miocene zone of Badenian-Sarmatian age. This unit differs from the previous one in relatively low tectonic involvement.

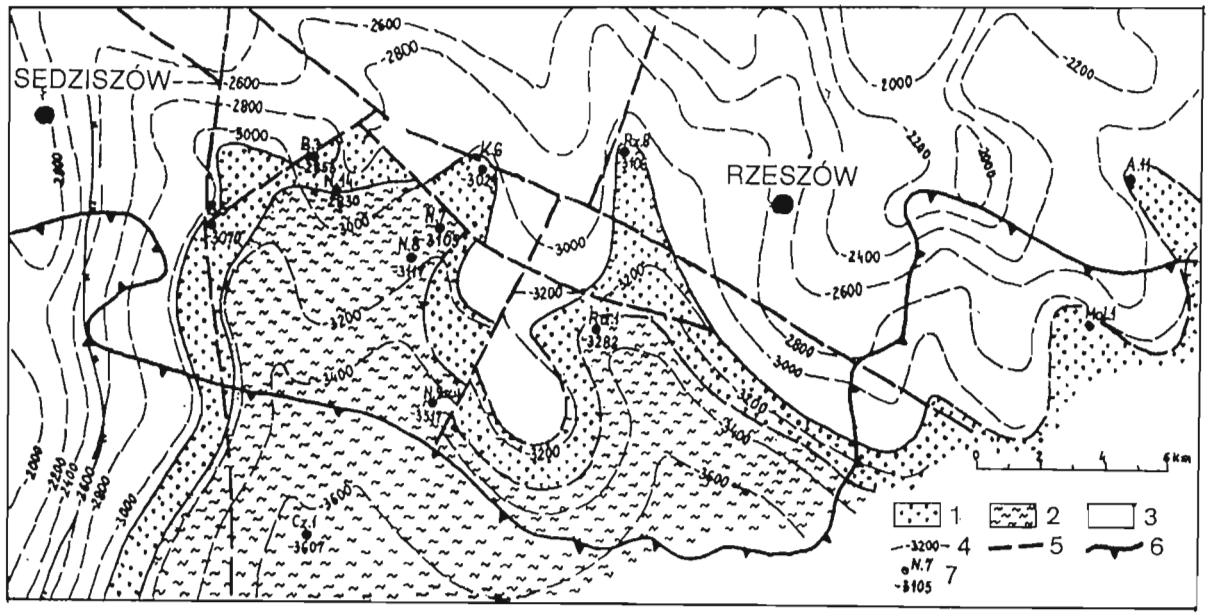

Fig. 10. Geological-structural map of the Lower Badenian base after W. Moryc (1995)
1 — Palaeogene conglomerates (Racławówka Formation); 2 — Palaeogene sandstones and siltstones (Czudec Formation); 3 — basement (Mesozoic-Palaeozoic-Precambrian); 4 — isolines of the Lower Badenian base; 5 — faults; 6 — Carpathian front; 7 — boreholes with Palaeogene deposits

Mapa geologiczno-strukturalna spągu badenu dolnego według W. Moryca (1995)
1 — utwory zlepieńcowe paleogenu formacji Racławówki; 2 — utwory mułowcowo-piaskowcowe paleogenu formacji z Czudca; 3 — podłoże mezozoiczno-paleozoiczno-prekambryjskie; 4 — izohipsy spągu badenu dolnego; 5 — uskoki; 6 — linia nasunięcia Karpat; 7 — otwory wiertnicze, w których stwierdzono utwory paleogenu

EXPLORATION PROSPECTS

According to R. Ney (1968), possibilities of hydrocarbon exploration in the Polish part of the Carpathian Foredeep between the state border and the site where the Stebnik unit plunges under the Skole nappe (Fig. 1) are slightly different from those in Ukraine. The difference is that in Poland there are deep folds within the lower part of the Stebnik unit or beneath it (Figs. 3, 5, 6).

The opinion that the deep folds of Borislav–Dolina type (Fig. 13) extend into the territory of Poland was especially expressed by K. Tołwiński (1937, 1957). He has written: "...Continuity of deep elements outside the East Carpathians margin has been documentary evidenced; it has also been realized that they extend under the Carpathians west of Przemyśl. The Przemyśl Carpathians thrust over a huge regional depression and cover the Borislav element, extending farther west." This opinion was also shared by J. J. Zieliński (1963), R. Ney (1968), S. Wdowiarz, S. Jucha (1981), J. Kruczek (1995), Z. R. Olewicz (1975) and others. M. Książkiewicz (1972) considered the narrow Lower Miocene saliferous for-

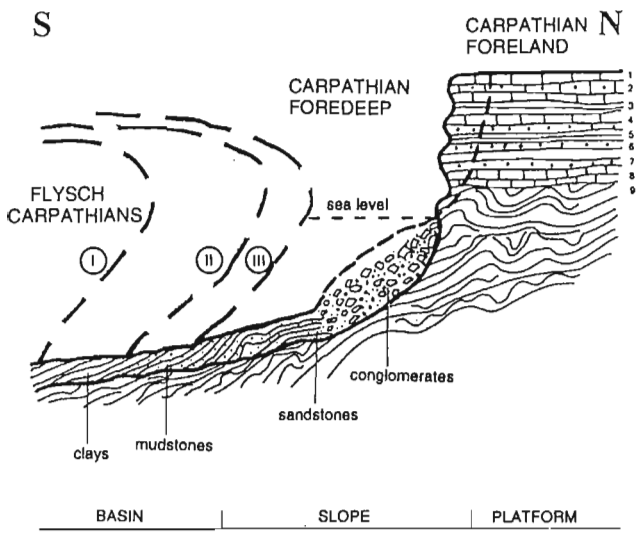

Fig. 11. Hypothetical northern cliff of the Carpathian Foredeep in the eastern part of the Przemyśl sigmoid
I–III — phases of Carpathian thrusting; 1 — Cretaceous (limestones, sandstones); 2 — Jurassic (limestones); 3 — Triassic (sandstones, shales); 4 — Carboniferous (siltstones, limestones); 5 — Devonian (dolomites, sandstones); 6 — Silurian (shales); 7 — Ordovician (limestones); 8 — Cambrian (sandstones, quartzites); 9 — Upper Precambrian (phyllites)

Hipotetyczny północny klif zapadliska przedkarpackiego we wschodniej części sigmoidy przemyskiej
I–III — etapy nasuwania się Karpat; 1 — kreda (wapienie, piaskowce); 2 — jura (wapienie); 3 — trias (łupki, piaskowce); 4 — karbon (mułowce, wapienie); 5 — dewon (dolomity, piaskowce); 6 — sylur (łupki); 7 — ordowik (wapienie); 8 — kambr (piaskowce, kwarcyty); 9 — górny prekambr (fyllity)

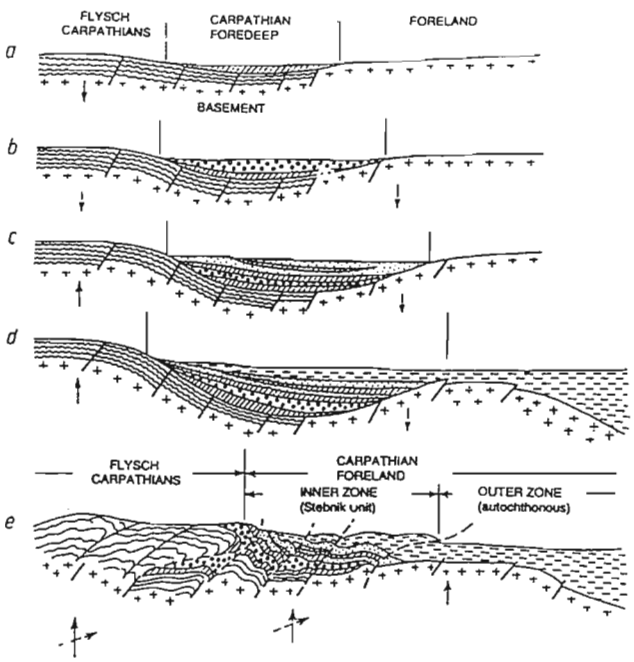

Fig. 12. Presumable scheme of development of the Carpathian Foredeep during the Eggenburgian (a), Ottnangian (b), Karpatian (c), Badenian (d) and Sarmatian (e)

Przypuszczalny schemat rozwoju zapadliska przedkarpackiego w: eggenburgu (a), ottnangu (b), karpacie (c), badenie (d) i sarmacie (e)

mation zone stretching along the Przemyśl sigmoid to be an immediate northwestern extension of the Borislav–Pokutse unit. J. J. Zieliński (1963) and P. Karnkowski (1993, 1995) also accepted the conception to be likely. At the surface, in the vicinity of Borislav, the zone is about 17 km in width, while at the border of Poland it is supposed to be of 5–7 km. In the Borislav–Pokutse zone, of 3100 square km, potential resources are estimated by M. J. Vul and O. O. Maksimova (1995) to be of 510 mln t of theoretical standard fuel. The zone has yielded 90 mln t of oil and over 50 bln m^3 of gas, i.e. about 140 mln t of theoretical standard fuel. The area located south of the borehole Jaksmanice 26, between the boreholes Kormanice 1 and Leszczyny 1, seems to be a zone of interest (Fig. 2). The two latter boreholes have not been completed due to technical difficulties. In the boreholes Dobromil–Strzelbice 22 and 23, situated 22 km east of the Poland/Ukraine border (Fig. 3), the deep folds unit has been encountered at depths of 4000 and 4700 m, respectively. Taking into account the evidence that the folds rise north-west of the two boreholes above mentioned, they are expected to occur slightly shallower in the vicinity of Przemyśl.

Somewhat different, more meridional trend of the deep folds in the area of the Polish Carpathians has been defined by S. Wdowiarz, S. Jucha (1981, 1982), S. Jucha (1989), K. Żytko (1982) and J. Kruczek (1995). It is likely that the deep fold unit branches into two parts. The first one runs towards Ustrzyki Dolne–Jasień (K. Żytko, 1982), and the other farther to the north, i.e. towards Przemyśl. According to Z. R. Olewicz (1975), the deep folds run in between, near Bircza (Borownica borehole project). These very difficult problems which have recently been solved by means of seismic survey

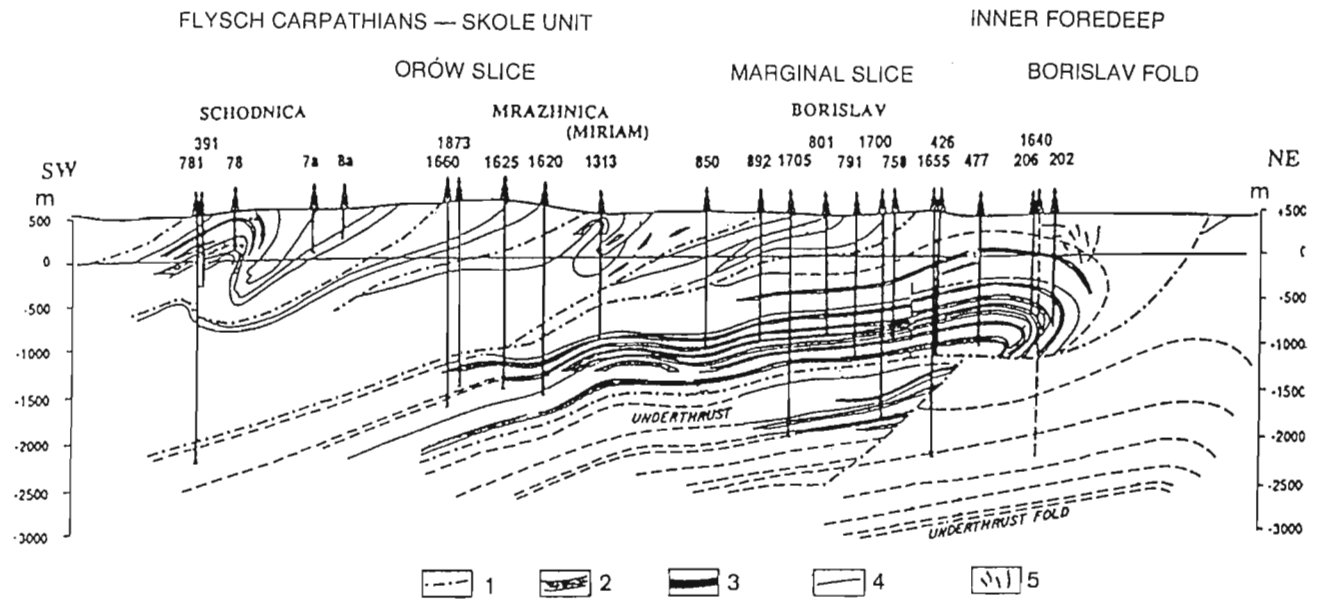

Fig. 13. Geological cross-section across Schodnica–Borislav reservoir after G. N. Dolenko *et al.* (1965)
1 — thrust faults; 2 — oil; 3 — gas; 4 — unconformities; 5 — ozocerite

Przekrój geologiczny przez złoża Schodnica–Borysław według G. N. Dolenki i in. (1965)
1 — uskoki nasuwcze; 2 — ropa; 3 — gaz; 4 — niezgodności; 5 — ozokeryty

can be explained soon. It seems, however, that the thrusting movements caused a northward shift of deep elements. It corresponds with K. Tołwiński's (1937, 1957), M. Książkiewicz's (1972), J. J. Zieliński's (1963) and others' opinion.

In the region of the Przemyśl sigmoid between the eastern border of Poland and the site where the Stebnik unit plunges under the Carpathian flysch and farther off in the direction of Skopowo, there is a special chance to recognize the autochthonous Miocene with regard to gas accumulation. Miocene deposits of considerable thickness may occur here since there is a huge depression south of Kniażyce fault, filled in with Miocene rocks. It is evidenced by initial seismic survey. Deep folds can also exist here.

One of the biggest gas fields in Poland has been discovered in the vicinity of Przemyśl. It is about 170 square km and its reserves are around 75 bln m^3, out of which about 50 bln m^3 has already been extracted. The gas accumulations occur in the autochthonous Miocene sandy deposits, north of the Carpathian margin and under the overthrust (Fig. 1). The deposits are separated from one another by faults and exist within 23 produtive horizons at depths of 600–2600 m. The Miocene deposits in which gas accumulations occur, gradually plunge under the Skole unit flysch.

The Miocene zone underlying the Carpathian overthrust has been penetrated in more detail by seismic survey and boreholes down to a depth of 3000 m, whereas the southern part of the Carpathians is known relatively poorly. Many problems still remain to be solved. First of all hydrocarbon prospects of the autochthonous Miocene deposits and, perhaps, possibilities of deep folds occurrence have to be solved.

Geophysical studies show that there is a high negative gravity anomaly south of Przemyśl between the boreholes Kormanice 1 and Leszczyny 1. It extends farther west. The results of the seismic section 2-13-94 (Fig. 6) running across the zone, suggest possibilities of the fully developed autochthonous Miocene and, perhaps, the Borislav–Pokutse unit as well. The studies of the problem should contribute to explain not only a complicated geological structure but also to bring substantial economic results: hydrocarbon accumulations discoveries.

Translated by Krzysztof Leszczyński

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SIGMOIDA PRZEMYSKA A MOŻLIWOŚCI POSZUKIWAŃ WĘGLOWODORÓW

Streszczenie

W rejonie Przemyśla Karpaty fliszowe ulegają gwałtownemu załamaniu z kierunku SE ku S, by znów od Dobromila przyjąć poprzedni kierunek południowo-wschodni. To nagłe załamanie noszące nazwę sigmoidy przemyskiej uzależnione jest od wgłębnego ukształtowania prekambryjskiego podłoża (J. Kuśmierek, R. Ney, 1988).

Pracami sejsmicznymi i wierceniami zbadano w ostatnich latach fałdowo-blokową budowę tego podłoża (fig. 2–5). Skonsolidowane podłoże podnosi się od strony wschodniej ku północnemu zachodowi od głębokości około 10 000–12 000 m w rejonie na S od Doliny do około 3000 m w okolicy Przemyśla i 600 m w okolicy Leżajska. Południowe skrzydło tegoż fundamentu zapada schodowo ku południowi. Te bloki podłoża tworzą zaporę dla nasuwającego się orogenu karpackiego, który przyjął wymuszoną formę od podłoża.

Brzeżne Karpaty, wraz z jednostką borysławsko-pokucką i utworami miocenu dolnego, tworzą wspólny orogen — kontynuując się od Borysławia zarówno na E, jak też W (K. Tołwiński, 1937). Omówiono także możliwości występowania zachodniego przedłużenia tej jednostki na obszar Polski w okolicy Przemyśla oraz aspekty występowania utworów miocenu, a być może i fałdów wgłębnych na S od Przemyśla, z czym wiąże się akumulacja węglowodorów.