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Miocene deposits of the Carpathian Foredeep (according to results of oil and gas prospecting)

The geology of the Miocene deposits in the central part of the Carpathian Foredeep is examined. The Neogene deposits from this area were subdivided into two units — the inner unit and the outer one. Between them the Zgłobice Unit was distinguished (J. Kotlarczyk, 1988), overthrusted onto the parautochthonous unit in the western part of the foredeep. The lithostratigraphic units of the Miocene formation, distinguished here, are correlatable with Miocene lithofacies from the northern margin of the Carpathian Foredeep. The problems of gas occurrences in the Miocene deposits of the autochthonous unit and sulphur findings in the Lower Badenian (Middle Miocene) series are discussed.

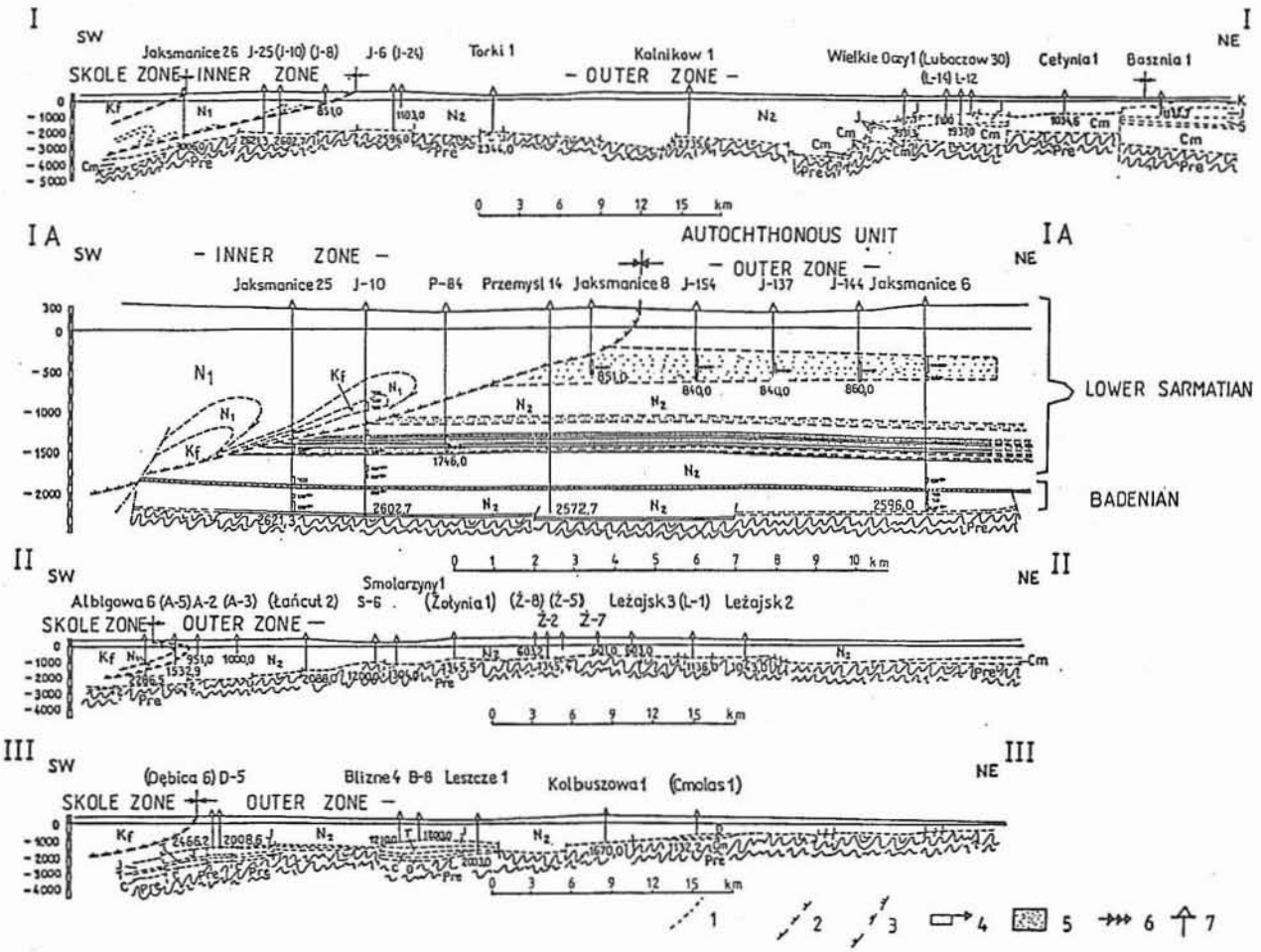
INTRODUCTION

The area, the Polish part of the Carpathian Foredeep is about 18 000 km^2, its northern boundary is delimited by the extent of the Miocene marine deposits and the southern one — by the Carpathian Overthrust. This large trough continues westward into the Czech area and to the east — into the Ukraine.

Geological research on the area of the Carpathian Foredeep started at the end of the last century and has during that time documented numerous natural gas traps, especially in the eastern part of the trough. The first discoveries of gas plays were in 1921–1924 (Daszewo, Opary) in the Ukraine. The findings of gas plays within the Miocene series in the Polish part of the foredeep took place in 1946 (Dębowiec Śląski), in 1948 (Wojsław near Mielec), in 1957 (Lubaczów) and in 1960 (Przemyśl) — Fig. 1. During 1946–1992 73 gas plays were discovered. 40 of them are still being exploited, 10 have been closed and 23 small ones are being saved as a reserve.

Fig. 1. Map of gas, oil and native sulphur deposits in the Carpathians and the Carpathian Foredeep
1 — oil field, 2 — natural gas field, 3 — oil well, 4 — gas well, 5 — uncommercial flows of oil, 6 — uncommercial flows of gas, 7 — oil shows, 8 — gas shows, 9 — the Stebnik Unit (the inner zone) with the Zgłobice Unit and the parautochthonous sediments, 10 — the Miocene deposits on the Carpathian Flysch, Pa — Palaeozoic, T — Triassic, J — Jurassic, K_1 — Lower Cretaceous, K_2 — Upper Cretaceous, M — Neogene deposits of the Carpathian Foredeep, KA — the Carpathian Flysch deposits, KJ — Pieniny Klippen Belt, TA — Tatra Mts.; I–I — III–III — lines of the geological sections of the Fig. 2

Mapa złóż gazu, ropy i siarki rodzimej w Karpatach i zapadlisku przedkarpackim
1 — złoże ropy, 2 — złoże gazu ziemnego, 3 — otwór naftowy, 4 — otwór eksploatacyjny gazowy, 5 — nieprzemysłowe wypływy ropy, 6 — nieprzemysłowe dopływy gazu, 7 — objawy występowania ropy, 8 — objawy występowania gazu, 9 — jednostka stebnicka (strefa wewnętrzna) wraz z jednostką Zgłobic i osadami parautochtonicznymi, 10 — osady miocenu na fliszu karpackim, Pa — paleozoik, T — trias, J — jura, K_1 — kreda dolna, K_2 — kreda górna, M — osady neogenu w zapadlisku przedkarpackim, KA — osady fliszu karpackiego, KJ — pieniński pas skałkowy, TA — Tatry; I–I — III–III — linie przekrojów geologicznych zamieszczonych na fig. 2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AUTOCHTHONOUS UNIT
INNER ZONE
OUTER ZONE
Jaksmanice 25
J-10
P-84
Przemysl 14
Jaksmanice 8
J-154
J-137
J-144
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LOWER SARMATIAN
BADENIAN
II
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(Żołynia 1)
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Kolbuszowa 1
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0 1 2 3 4 5 6 7 8 9 10 km
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Most of the gas plays occur within the Miocene sediments, but some of them are located also in the Mesozoic series. Single deposits were found in the Lower Palaeozoic sequence (in Cambrian, Ordovician, Devonian and Carboniferous rocks). During the period 1946–1990 about 75 mld m^3 of gas and 3.7 mln t of oil were extracted from the area of the foredeep. The largest gas plays are: Przemyśl – Jaksmanice, Lubaczów, Husów, Jarosław, Żołynia, Mirocin, Tarnów and Łąkta, the oil ones are: Grobla – Pławowice and Nosówka. The total area of all gas deposits is estimated at about 700 km^2 the average area of a single play is about 10.5 km^2. The average gas resources of one deposit are about 2.1 mld m^3 and 205 mln m^3 per 1 km^2 of the deposit area.

GENERAL CHARACTERISTICS OF THE MIOCENE DEPOSITS

The numerous explorations for hydrocarbons in the Carpathian Foredeep supplied a lot of new data on the geological structure of the trough and on its Miocene infill. The aim of this work is a synthesis of the actual knowledge on the geology of the Miocene formation in the northern and central parts of the foredeep. Sulphur mineralization, observed there in the evaporitic horizon, coexists with hydrocarbon deposits, which confirms the occurrence of all main factors, responsible for the generation of native sulphur deposits according to the model of bioepigenesis (comp. S. Pawłowski, 1968, 1970; S. Pawłowski *et al.*, 1985; M. Nieć, 1982; B. Kubica, 1992). These relations enabled the description of such mineralization and the prediction of the location of new native sulphur deposits in the central part of the foredeep, farther from its margins.

The Miocene structural complex is the most important one in the geological pattern of the Carpathian Foredeep. During the Palaeogene all this area was uplifted and intensely eroded. The Jurassic, Cretaceous and older deposits were removed from large areas. In the Neogene, simultaneously to the intensive folding of the Carpathians, the foreland trough was originated, later being flooded by the sea (J. Nowak, 1927; Z. Obuchowicz, 1966).

This transgression, started in the area of the Outer Carpathians in the Lower Badenian, later expanded up to the southern border of the Holy Cross Mts. (the meta-Carpathian Ridge — after J. Nowak, 1927), covering the whole area of the contemporary Carpathian Foredeep. The Badenian and Sarmatian deposits completely infilled the foredeep and their thickness is about 3 km near the Carpathians (Fig. 2).

Fig. 2. Schematic sections of the Carpathian Foredeep (for location see Fig. 1)
1 — faults, 2 — the overthrust of the Carpathian Flysch and the Stebnik Unit, 3 — the Stebnik Overthrust, 4 — brine and gas inflow, 5 — gas-bearing part of the deposit, 6 — gas inflow into the well, 7 — boreholes, Pre — Precambrian, Cm — Cambrian, S — Silurian, D — Devonian, C — Carboniferous, T — Triassic, J — Jurassic, K — Cretaceous, N_2 — the autochthonous Miocene deposits, N_1 — the Miocene deposits of the Stebnik Unit, K_f — the Carpathian Flysch deposits
Schematyczne przekroje przez zapadlisko przedkarpackie (lokalizacja na fig. 1)
1 — uskoki, 2 — nasunięcie fliszu karpackiego i jednostka stebnicka, 3 — nasunięcie stebnickie, 4 — dopływ solanki i ropy, 5 — gazonośna część złoża, 6 — dopływ gazu do otworu, 7 — otwory wiertnicze, Pre — prekambr, Cm — kambr, S — sylur, D — dewon, C — karbon, T — trias, J — jura, K — kreda, N_2 — osady miocenu autochtonicznego, N_1 — osady miocenu jednostki stebnickiej, K_f — osady fliszu karpackiego

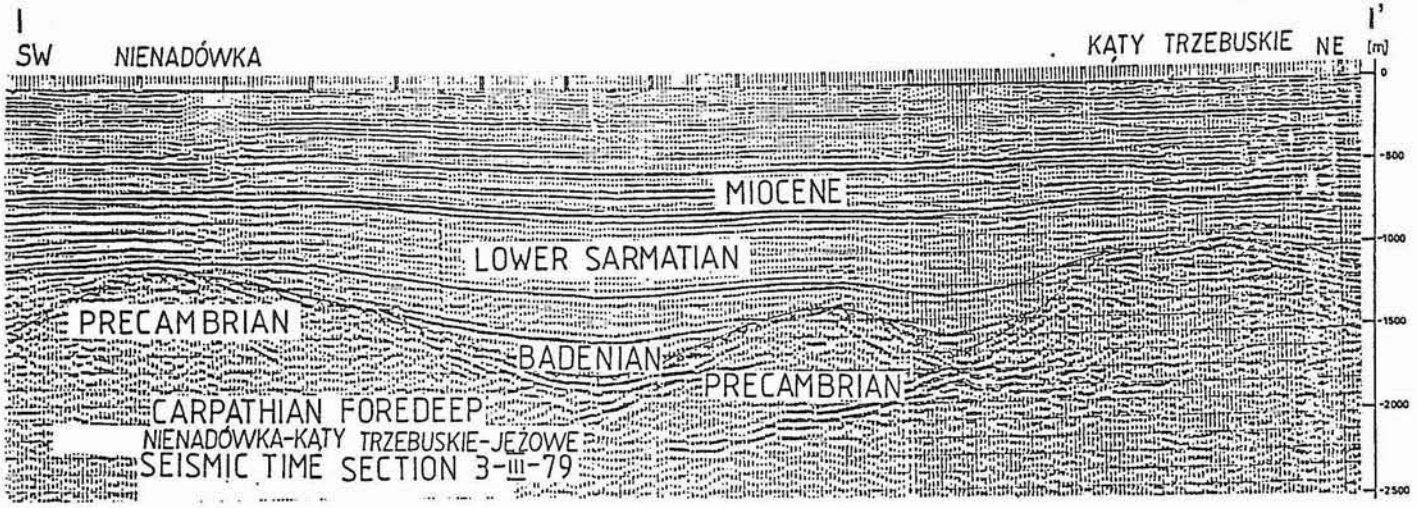


Fig. 3. Seismic-geological section from the central part of the Carpathian Foredeep (Nienadówka – Kąty Trzebuskie near Rzeszów); the palaeovalleys, infilled by the Badenian and Lower Sarmatian deposits, are very distinct (for location see Fig. 7)

Przekrój sejsmiczno-geologiczny przez centralną część zapadliska przedkarpackiego (Nienadówka –Kąty Trzebuskie koło Rzeszowa); widoczne paleodoliny, wypełnione osadami badenu i dolnego sarmatu (lokalizacja na fig. 7)

Two main units of the Miocene formation were distinguished there, based on their lithology and tectonics (M. Książkiewicz, 1972; R. Ney, 1968). They are as follows:

1. The outer unit (autochthonous one), located outside the arc of the Carpathian orogene and wedged toward the meta-Carpathian Ridge. The deposits, composing this unit, are generally undisturbed and slightly inclined (0–15°). They reflect the basement morphology and form several compaction structures (Figs. 2–4). These sediments were dated as Badenian-Sarmatian.

2. The inner unit (allochthonous one), situated before the Carpathians or under the Carpathian Overthrust. This unit consists of strongly folded Miocene deposits (the Eggenburgian-Badenian stages) — Fig. 2.

THE OUTER UNIT

The outer unit occupies the area between the Carpathian margin, the border of the Holy Cross Mts. and Roztocze to the north. It consists of the autochthonous Miocene deposits (Lower Badenian-Sarmatian in age) but in the Ukraine area its equivalent is the sediments of the Bilcze – Wolica zone. The Badenian stage is subdivided here into three lithostratigraphic substages: Opolian substage (Lower Badenian), Bochenian substage (evaporites of Lower Badenian) and the Grabovian substage (Upper Badenian). The Lower Badenian complex is composed of sandstones and siltstones in the lower part and of a sulphate-salt series at the top, containing sulphur-bearing deposits, well known from the native sulphur mines in Tarnobrzeg, Jeziórko and Basznia (Fig. 7). Sulphur mineralization in the anhydrite series in the discussed area was noticed also in many other boreholes (i.e. Gwoździec 1, Komorów 1 — A. Gąsiewicz, 1989) and sites (Posądza – Czarkowy — T. Osmólski, 1972). Carbonate-clastic deposits of barrier origin occur on the northern margin of the foredeep (G. Czapowski, 1984), dated as Upper Miocene. The Upper Badenian-Lower Sarmatian complex of this part of the foredeep consists of pelitic sediments, called the Krakowiec Clays, with frequent sandy interbeds of deltaic genesis. These clastics infilled palaeovalleys with a NW–SE orientation (P. Karnkowski, 1989, Fig. 4) and they are the main gas reservoir in the whole foredeep.

The area of the outer unit occurrence is subdivided into two zones:

— a sulphate zone, with a widespread series of sulphates (various types of gypsums and anhydrites), being a good reflexive horizon;

— a zone without sulphates, named "the Rzeszów island" (after R. Ney *et al.*, 1974), continuing from Rzeszów – Sędziszów up to Leżajsk. There the Upper Badenian deposits overlie the Precambrian basement (H. Jurkiewicz, P. Karnkowski, 1961). The Miocene deposits, covering the Carpathian Flysch of Badenian age, have another structural position. They are partly folded and exposed near Nowy Sącz, Iwkowa, Grudna Dolna, near Pilzno and Rzeszów. These sediments have been accumulated primarily on the flysch and were later moved together with it northward (S. Połtowicz, 1991*a, b*) — Figs. 1, 2.

During Badenian time the Carpathian margin was located southward from its recent position. After the Lower Sarmatian, the Lower Badenian deposits of the inner unit together with the Carpathian Flysch were finally displaced onto the area of the autochthonous Miocene sediments (outer unit).

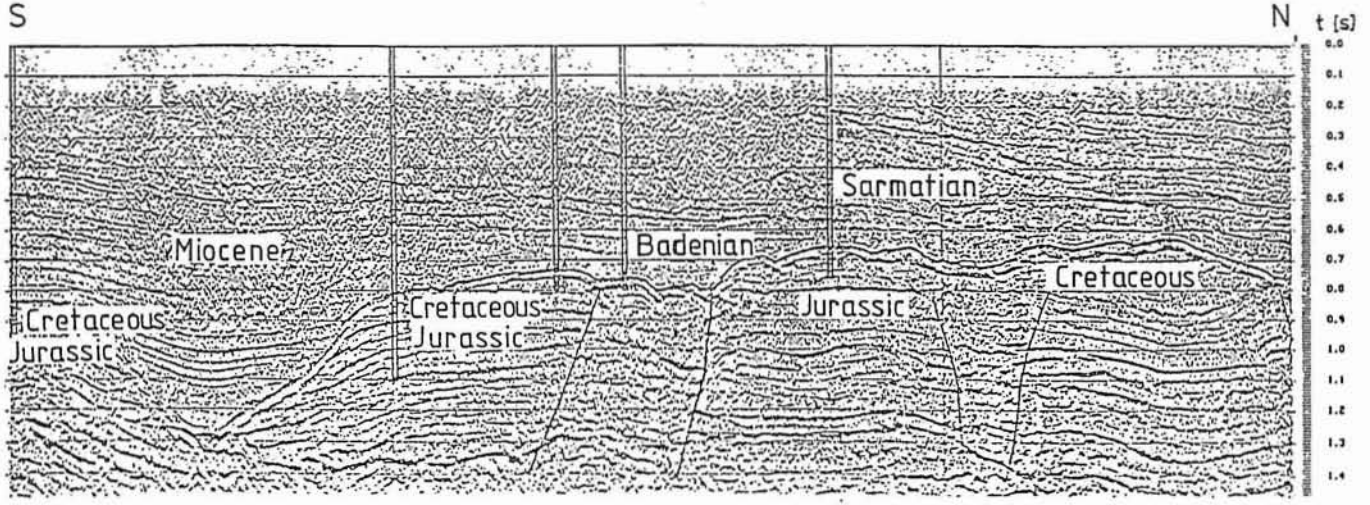


Fig. 4. Seismic-geological section from the Carpathian Foredeep, the Jastrząbka Stara near Tarnów; the deep palaeovalley, incised into the Cretaceous and Jurassic basement and infilled with the autochthonous Miocene sediments, is well indicated (after E. Jawor, 1983)

Przekrój sejsmiczno-geologiczny przez zapadlisko przedkarpackie z okolic Jarząbki Starej koło Tarnowa; widoczne głębokie paleodoliny, wycięte w podłożu kredowo-jurajskim i wypełnione osadami autochtonicznego miocenu (według E. Jawora, 1983)

THE INNER UNIT

The inner unit is subdivided into four subunits:

1. The peri-Carpathian salt-bearing formation.

2. The Stebnik Unit (= the Sambor Unit in the Ukraine), including conglomerates, sandy, shaly and evaporitic deposits of Eggenburgian-Badenian age. This unit is folded together with flysch sediments of the Skole Unit of the Carpathians and it is overthrusted onto the autochthonous Miocene series in the foredeep.

3. The Zgłobice Unit (J. Kotlarczyk, 1988), placed before the Carpathians (Zgłobice near Bochnia) and under their overthrust. This unit consists of folded evaporitic and clastic deposits of the Middle Badenian age and it was earlier included in the Stebnik Unit.

4. The unit of the Miocene parautochthonous deposits (Badenian-Sarmatian in age), occurring outside the Carpathian Overthrust and partly on the Carpathian Flysch (Fig. 5). The best data on it are from the Pilzno – Tarnów – Bochnia – Wieliczka region. This unit is removed from its primary position (S. Połtowicz, 1991*a*).

LITHOSTRATIGRAPHY OF THE AUTOCHTHONOUS MIOCENE COMPLEX

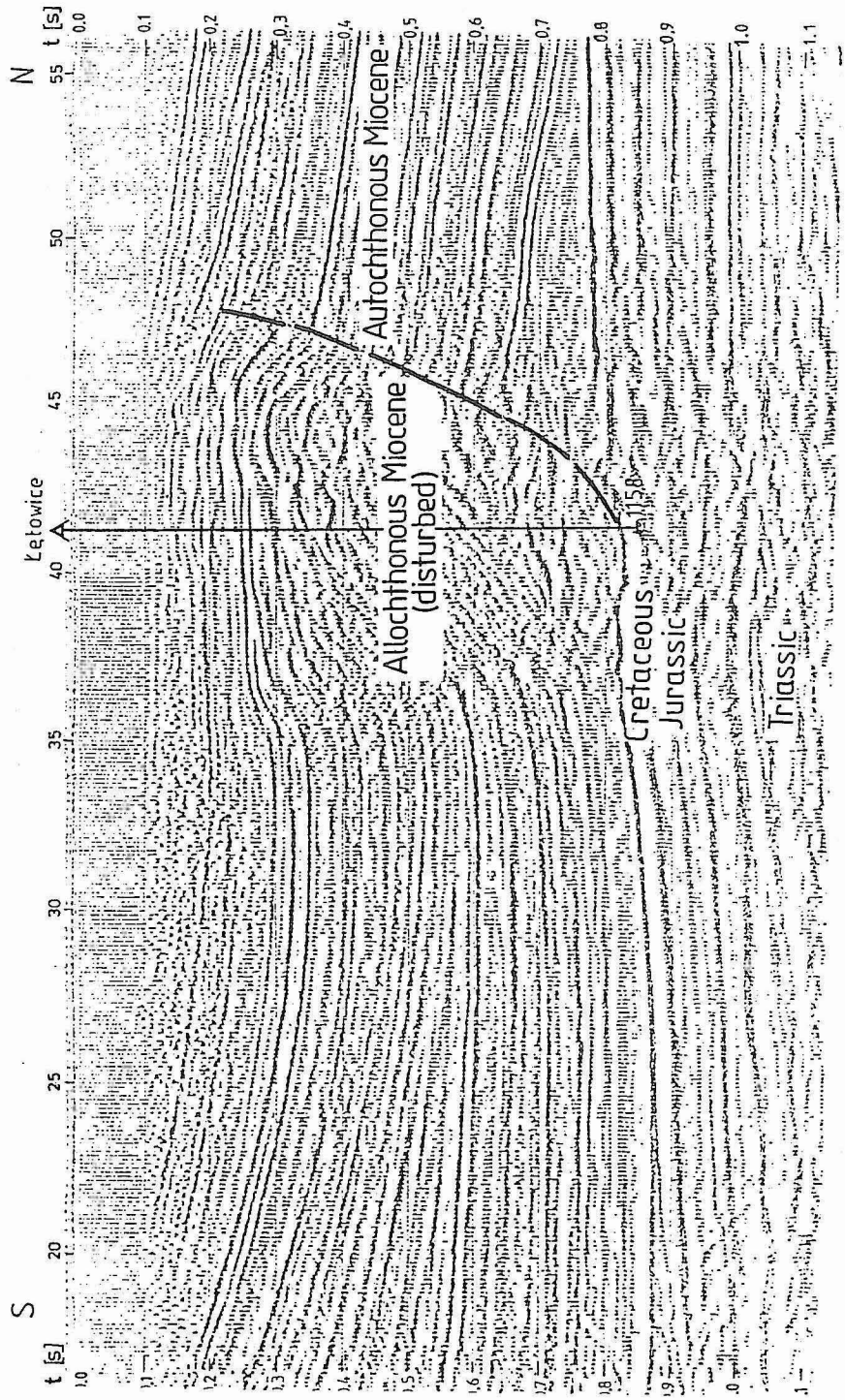
LOWER BADENIAN (OPOLIAN SUBSTAGE = MORAVIAN SUBSTAGE; A. PAPP *ET AL.*, 1978)

The lowermost part of the Lower Badenian series, named "the Baranów Beds" (S. Pawłowski *et al.*, 1985), consists of *Lithothamnium* limestones, siltstones, sandstones and sands. The limestone thickness, several tens of metres, declines southward. They outcrop on the southern border of the Holy Cross Mts. and in Roztocze and are found in some boreholes: Basznia 1, Cetynia 1, 2, 3 and near Lubaczów (where they overlie the Cambrian quartzitic sandstones). These limestones include the detritus of *Lithothamnium* reefs and clasts of detritic marls. Foraminifera specimens of the families Rotalidae and Globigerinoidae are frequent.

Near Lubaczów the shales, grey or green in colour, with intercalations of glauconitic marls, occur on *Lithothamnium* limestones. These series are overlain by medium-coarse-grained sandstones, with a glauconitic admixture, from 20 up to 70 m thick (borehole Lubaczów 5). Near Dąbrowa Tarnowska the sandy-marly shales are equivalent of the above mentioned psammites. The thickness of the whole Baranów Beds is estimated to be from several metres (boreholes: Mielec 6, Cetynia 1) up to 150 m the margin of the foredeep (B. Kubica, 1992; S. Pawłowski *et al.*, 1985). They contain abundant macro- and microfossils with the index form of this substage — *Amusium denudatum*.

MIDDLE BADENIAN (WIELICIAN SUBSTAGE; A. PAPP *ET AL.*, 1978)

The Baranów Beds are overlain by an evaporitic (= chemical deposits) horizon, being the last member of the transgressive-regressive depositional cycle of the Lower Badenian and this horizon is dated as Middle Badenian. These deposits are anhydrites and gypsum. Two kinds of gypsum were distinguished (A. Garlicki, 1979; B. Kubica, 1992) in the Tarnobrzeg area: a coarse crystalline gypsum and a massive, laminated and often brecciated


S
N
t [s]
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Łętowice
Autochthonous Miocene
Allochthonous Miocene
(disturbed)
Cretaceous
Jurassic
Triassic

one. The first gypsum type originated in shallow marine waters from highly concentrated sulphate brines, but the second one — commonly overlying the former gypsum type — accumulated in conditions of basin drying and changes of brine concentrations.

The anhydrites are 0–60 m thick. They are often of detritic type, with various stratification and common fractures and joints. They contain some gas reservoirs (in the borehole Lubaczów 2 a gas trap was found in anhydrites at a depth of 1007–1014 m) as well as frequent native sulphur concentrations, for instance the sites: Lubaczów, Basznia, Wojsław, Komarów, Gwoździec (S. Pawłowski *et al.*, 1965; B. Cisek *et al.*, 1983). The large native sulphur deposits originated due to reaction between hydrocarbons and sulphates and the activity of sulphur bacteria (S. Pawłowski *et al.*, 1965; M. Nieć, 1982).

The evaporitic series is the basic correlative horizon within the Miocene deposits of the outer unit and an index level for seismic studies. After some authors it is assumed to be the impermeable barrier for oil and gas plays which occur in the basement of the Miocene sequence of the foredeep.

Northward from Rzeszów the anhydrites are hitherto unknown. Some scientists suppose that at that time this area was an island, others that anhydrites have been completely eroded there after the Lower Badenian.

UPPER BADENIAN (KOSOVIAN SUBSTAGE; A. PAPP *ET AL.*, 1978)

The next depositional cycle started in the Upper Badenian with grey-green sandy shales, intercalated with sandstones. This series is 30–800 m thick and it contains a specific faunal assemblage with *Spirialis valvalina* Reuss (H. Jurkiewicz, P. Karnkowski, 1961). Due to frequent concentrations of *Spirialis* these deposits are called "the *Spirialis* Beds" and they are applied as another correlative horizon, widespread throughout the Miocene of the outer unit, both in Poland and the Ukraine. At the northern margin of the Carpathian Foredeep this series is correlated with the *Pecten-Spirialis* Beds (S. Pawłowski *et al.*, 1985).

The Upper Badenian deposits wedge out to the north, and at the northern boundary of the Miocene series in the foredeep Lower Sarmatian sediments overlie the Precambrian basement.

THE LOWER SARMATIAN

At that time the energy of the sedimentary environment had increased as well as basin bottom subsidence. The intensive river erosion supplied more clastic material to the basin. The Lower Sarmatian transgression was reflected by the overlapping of wedged lithostratigraphic units (Fig. 3), especially in the case of the lower horizons of the autochthonous Miocene (Figs. 3, 4).

Fig. 5. Seismic-geological profile from Wierzchosławice near Tarnów
Dashed line — the contact of the parautochthonous and autochthonous Miocene series
Profil sejsmiczno-geologiczny z Wierzchosławic koło Tarnowa
Linią przerywaną oznaczono kontakt utworów parautochtonicznego i autochtonicznego miocenu

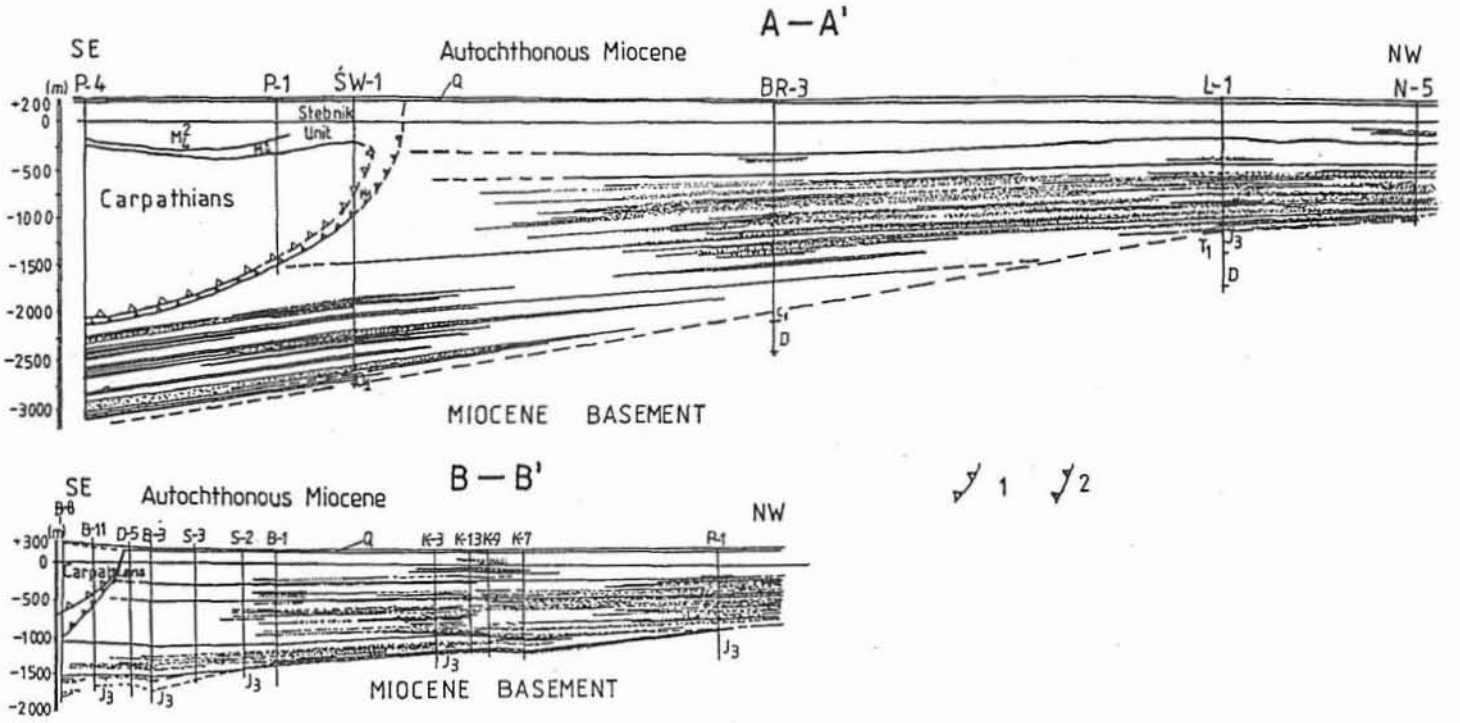

Fig. 6. Facies correlations in the sections from the Carpathian Foredeep (after A. Zubrzycki, 1986)

A–A' — the Rzeszów – Niwiska section, B–B' — the Brzezówka – Poręby section; dotted areas — the Miocene siliciclastics; blank areas — the Miocene pelites; D — Devonian, D_1 — Lower Devonian, C_1 — Lower Carboniferus, T_1 — Lower Triassic, J_3 —Upper Jurassic; 1 — boundary of the Carpathian Overthrust, 2 — boundary of the overthrust of the Stebnik Unit

Korelacje facjalne w przekrojach przez zapadlisko przedkarpackie (według A. Zubrzyckiego, 1986)

A–A' — przekrój Rzeszów – Niwiska, B–B' — przekrój Brzezówka – Poręby; obszary kropkowane — silikoklasty miocenu; obszary pozbawione szrafury — pelity miocenu; D — dewon, D_1 — dewon dolny, C_1 — karbon dolny, T_1 — trias dolny, J_3 — jura górna; 1 — granica nasunięcia karpackiego, 2 — granica nasunięcia jednostki stebnickiej

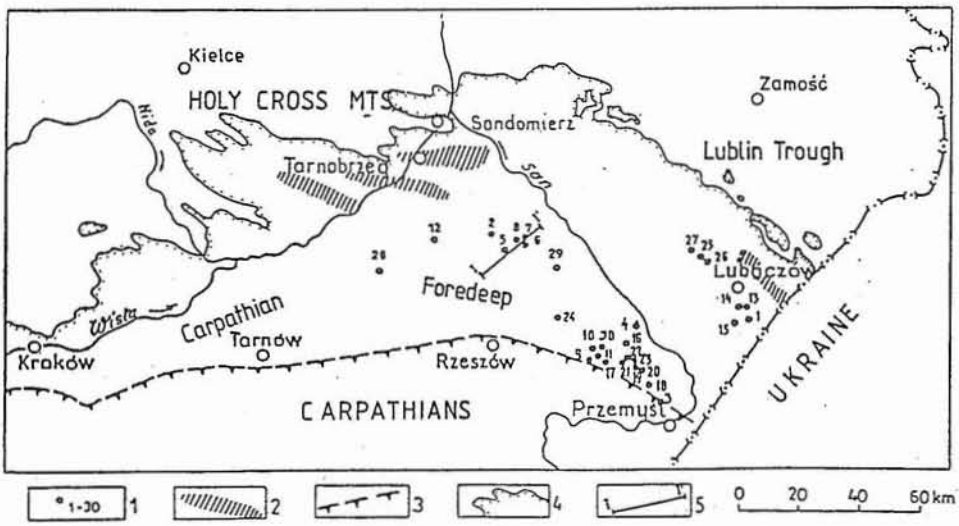

Fig. 7. Map of native sulphur occurrences in the Carpathian Foredeep
1 — deep oil boreholes with sulphur occurrences (*1* — Cetynia 1, *2* — Gwoździec 1, *3* — Jaksmanice 63, *4* — Jarosław 6, *5* — Kamień 1, *6* — Kamień 2, *7* — Kamień 4, *8* — Kamień 5, *9* — Kańczuga 2, *10* — Kańczuga 5, *11* — Kańczuga 17, *12* —Komorów 1, *13* — Lubaczów 2, *14* — Lubaczów 3, *15* — Łukawiec 1, *16* — Mirocin 40, *17* — Pruchnik 6, *18* — Przemyśl 148, *19* — Rokietnica 4, *20* — Rokietnica 6, *21* — Roźwienica 2, *22* — Roźwienica 3, *23* — Roźwienica 5, *24* — Smolarzyny 5, *25* — Uszkowce 14, *26* — Uszkowce 15, *27* — Uszkowce 16, *28* — Wojsław 10, *29* — Żołynia 23, *30* — Żurawiczki 1), 2 — area of native sulphur deposits (after S. Pawłowski *et al.*, 1979), 3 — the Carpathian margin, 4 — northern boundary of the Carpathian Foredeep, 5 — seismic section from Fig. 3
Schematyczna mapa występowania siarki na obszarze zapadliska przedkarpackiego
1 — głębokie otwory górnictwa naftowego (*1–30*), w których stwierdzono występowanie siarki, 2 — obszary występowania złóż siarki (według S. Pawłowskiego i in., 1979), 3 — brzeg Karpat, 4 — północna granica zapadliska przedkarpackiego, 5 — linia przekroju sejsmicznego z fig. 3

The clastic material was supplied to the sedimentary basin both from the uplifting Carpathians and from the meta-Carpathian Ridge. Near the Carpathian margin sandstones prevail as well as at the border of the Holy Cross Mts. (Fig.6).

Bottom turbidity currents carried sandy material along channels, the pattern of which was controlled by differentiated bottom morphology (Figs. 3, 4). The southward inclination of the Miocene basin bottom determined the transport direction of clastics, which — including fragments of eroded slopes of the Carpathians — were distributed along the palaeovalley system far to the south. The best example of such deposits is the polimictic conglomerate from Husów, occurring within the Sarmatian series eastward from Rzeszów. The carbonate clasts contain the Jurassic foraminifers: *Pseudocyclammina* cf. *sequana minor*, *Sprillina* sp., *Trocholina* sp. and the Cretaceous foraminifers — *Globotruncana* sp. div. (H. Jurkiewicz, 1991). These clasts were probably eroded from the Mesozoic cover of the Holy Cross Mts. and their surroundings, being denudated during the Tertiary.

The facies analysis and development of lithological traps within the Miocene deposits from the Pilzno – Rzeszów area was presented by A. Zubrzycki (1986). The sections

indicated that the distribution of sandy material is controlled from the south by the Carpathians and from the north — by the meta-Carpathian Ridge. The section centers are dominated by shales. Such a facies pattern documents the delivery from both directions to the basin during the Upper Badenian and Lower Sarmatian (Fig. 6).

The thickness of the Lower Sarmatian series is over 2 km. It contains thin interbeds of bentonites and it is partly deltaic in origin (E. Jawor, 1983; A. Zubrzycki, 1986).

NATIVE SULPHUR OCCURRENCE IN THE CENTRAL PART OF THE CARPATHIAN FOREDEEP

The first concentrations of native sulphur were observed in 1954 in the oil wells near Gwoździec and Komorów, located in the area of the southern continuation of sulphur deposits from the Tarnobrzeg region. In 1956–1957 sulphur traces were also found in the boreholes Lubaczów 2 and Mędrechów 1. Further explorations have documented native sulphur occurrences in the Badenian anhydrites in over 30 wells (Tab. 1), no new data can be expected from current drills (Fig. 7).

The Middle Badenian evaporites, found in the above mentioned boreholes, consist of anhydrites, limestones and marls with imprints and concentrations (nests, veins) of crystalline and amorphic sulphur, yellow, golden and brown-reddish in colour. These rocks have a hydrocarbon and hydrogen sulphide admixture and in some cases, i.e. Kańczuga, Przemyśl, Roźwienica, Żurawiczki — also oil traces. In many places the sulphur mineralization has penetrated deposits under the evaporites — into the siltstones and shales of the Baranów Beds.

The native sulphur occurrence in the Carpathian Foredeep is connected with the gypsum-anhydrite series. Local condensations of sulphur findings (Fig. 6) could be related to the hydrocarbon migration paths from the south-east. The drilling data indicated that sulphur concentrations occur mainly at the tops of anhydrite elevations, but were absent on their slopes. Such a location pattern could result from gas migration toward uplifted structures and its reactions with calcium sulphate. None of these sulphur findings are of economic value, they are only sulphur traces despite the positive geological circumstances such as the structural, palaeogeographic and hydrological pattern as well as the coexistence of gas and liquid hydrocarbons. The character of sulphur mineralization, sulphur content and features of sulphur-bearing rocks are unfavourable for the generation of economic sulphur deposits in this part of the Carpathian Foredeep.

Natural gas, occurring in the anhydrite series, contains an admixture of H_2S and CO_2 and it should be desulphured. Economic deposits of natural gas were found within this series and in the Baranów Beds near Cetynia, Lubaczów, Rokietnica, Roźwienica and Mirocin.

Table 1

List of boreholes with sulphur mineralization

Borehole name	Year of drill finish	Depth interval of anhydrites and limestones with sulphur [m]	Thickness of evaporites [m]	Sulphur content in core [%]
Cetynia 1	1958	967–997	30	15
Gwoździec 1	1954	581–592	11	25
Jaksmanice 63	1970	2293–2303	10	5
Jarosław 6	1962	1487–1498	11	5
Kamień 1	1966	727–747	20	15
Kamień 2	1966	825–846	21	10
Kamień 4	1966	823–835	12	10
Kamień 5	1966	767–791	24	30
Kańczuga 2	1960	1516–1530	14	40
Kańczuga 5	1961	1483–1493	11	20
Kańczuga 17	1964	1487–1502	5	10
Komorów 1	1954	751–772	21	30
Lubaczów 2	1957	999–1015	16	5
Lubaczów 3	1958	892–998	16	15
Łukawiec 1	1959	1472–1486	14	10
Mirocin 40	1980	1634–1655	16	15
Pruchnik 6	1981	1700–1708	8	5
Przemyśl 148	1972	2086–2098	12	10
Rokietnica 4	1963	1785–1812	27	15
Rokietnica 6	1965	1896–1910	14	5
Roźwienica 2	1978	1863–1870	7	5
Roźwienica 3	1982	1899–1909	10	10
Roźwienica 5	1982	1744–1763	19	20
Smolarzyny 5	1977	1180–1193	13	15
Uszkowce 14	1960	1275–1283	8	5
Uszkowce 15	1961	1347–1455	8	5
Uszkowce 16	1961	1309–1322	13	10
Wojsław 10	1962	698–708	10	15
Żołynia 23	1982	1042–1055	13	10
Żurawiczki 1	1966	1530–1538	8	8

SUMMARIZING

The geological structure of the Miocene sequence of the Carpathian Foredeep, especially of its central part, is now better recognized due to the application of new methods of investigation such as geophysical complex studies or sedimentological analysis. All the above presented data supplemented the former knowledge on the geological structure of the foredeep center. They indicate that the lithostratigraphic subdivision of the Miocene, established for the foredeep margin, could be applied also to its center. Some carbonate units are wedged out toward the basin center and sulphates are reduced and replaced by

chlorides. Geophysical investigations documented that the Miocene sequence infilled the bottom differentiated basin.

Traces of sulphur mineralization, mainly within the evaporitic series were found in many drills. Native sulphur findings are not of economic value, they occur irregularly and only locally are larger concentrations noticed.

Nevertheless, the synthesis of the geological structure of the whole Carpathian Foredeep, both in Poland and in the neighbouring countries, has not yet been examined. Such a situation influences the prospection of mineral resources. Despite discoveries of significant volumes of natural gas, oil, native sulphur, mineral waters and others, many geological problems are as yet unclear and only future investigations may solve them.

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UTWORY MIOCENU PRZEDGÓRZA KARPAT W ŚWIETLE POSZUKIWAŃ WĘGLOWODORÓW

Streszczenie

Przedgórze Karpat, zwane też zapadliskiem przedkarpackim, tworzy rów przedgórski wypełniony utworami miocenu, będącymi pozostałością morza Tetydy.

Po oligocenie, na skutek ruchów alpejskich, Karpaty fliszowe zaczęły się fałdować i stopniowo nasuwać na swoje przedpole. Tangencjalne naciski ruchów alpejskich skierowane z południa ku północy miały też daleki pozakarpacki zasięg na obszar Niżu Polskiego. W wyniku tych procesów doszło m.in. do wydźwignięcia *en bloc* obszaru Gór Świętokrzyskich, jak również do wypiętrzenia wału świętokrzysko-dobrudzkiego. Materiał do basenu mioceńskiego był dostarczany od strony Karpat oraz od strony wspomnianego wału metakarpackiego (J. Nowak, 1927). W miarę gromadzenia się osadów nastąpiło przemieszczenie się osi zapadliska ku północy.

Ze względu na rozwój litofacjalny osadów miocenu przedgórza i występujące w nim różnice tektoniczne, w ogólnym zarysie można wydzielić:

— utwory miocenu dolnego silnie sfałdowane (częściowo z fliszem karpackim i nasunięte na swoje przedpole), należące do tzw. strefy wewnętrznej;

— utwory miocenu autochtonicznego (dolny baden-dolny sarmat), leżące na północ od Karpat, zaliczane do tzw. strefy zewnętrznej.

W strefie wewnętrznej, w wyniku ostatnich badań, wydzielono:

— przykarpacką formację solonośną eggenburgu-ottnangu, sfałdowaną, otulającą częściowo fałdy fliszowe jednostki borysławsko-pokuckiej;

— jednostkę stebnicką (odpowiednik po stronie Karpat ukraińskich jednostki samborskiej), obejmującą utwory zlepieńcowo-piaszczyste, łupkowe i salinarne (eggenburg-baden), sfałdowaną z fliszem jednostki skolskiej Karpat i nasuniętą na utwory przedpola, zwłaszcza miocenu autochtonicznego;

— jednostkę Zgłobic wyróżnioną przez J. Kotlarczyka w 1985 r. (*fide* J. Kotlarczyk, 1988), zawierającą sfałdowane utwory okruchowe i salinarne badenu-sarmatu dolnego (zaliczaną dawniej do jednostki stebnickiej), występującą przed czołem Karpat (Zgłobice) i pod ich nasunięciem;

— jednostkę utworów miocenu parautochtonicznego badenu-sarmatu dolnego, występujacą przed nasunięciem i częściowo na fliszu Karpat, a lepiej poznaną zwłaszcza w rejonie Pilzna – Tarnowa – Bochni – Wieliczki i przesuniętą ze swojego pierwotnego położenia (S. Połtowicz, 1991*a*, *b*).

Strefa zewnętrzna rozciąga się od brzegu Karpat aż po obrzeżenie Gór Świętokrzyskich i Roztocze. Obejmuje ona utwory miocenu autochtonicznego dolnego badenu-dolnego sarmatu, będące odpowiednikiem po stronie ukraińskiej tzw. strefy Bilcz – Wolicy (fig. 1). Na obszarze tym w utworach badenu występują osady piaszczysto-mułowcowe, seria anhydrytowo-gipsowa i siarkonośna (znana z odkrytych złóż siarki m.in. w Tarnobrzegu, Jeziórku i Baszni). Osiarkowanie w tej strefie przedgórza stwierdzono również w wielu innych otworach, jak Gwoździec i Komorów (B. Cisek i in., 1983; A. Gąsiewicz, 1989) oraz Posądza – Czarkowy (T. Osmólski, 1972). W brzeżnych partiach górnego miocenu występują utwory węglanowe i piaszczyste typu barierowego (G. Czapowski, 1984). W utworach dolnego sarmatu notowane są głównie utwory ilasto-piaszczyste, często pochodzenia deltowego. Zaznaczają one paleodoliny przebiegające głównie z NW ku SE (P. Karnkowski, 1989). Utwory piaszczyste dolnego sarmatu są głównym zbiornikiem gazu ziemnego w zapadlisku przedkarpackim.

Oddzielne miejsce zajmują osady badeńskie leżące na fliszu karpackim (fig. 2). Są one częściowo sfałdowane i występują m.in. w rejonie Nowego Sącza, Iwkowej i Grudnej Dolnej; wraz z fliszem zostały one nasunięte ku północy (fig. 2).

W badenie brzeg Karpat znajdował się jeszcze kilkadziesiąt kilometrów na południe od jego dzisiejszego występowania. Ostatecznie utwory dolnego miocenu strefy wewnętrznej wraz z fliszem karpackim nasunęły się na swoje przedpole miocenu autochtonicznego po dolnym sarmacie.