Mineralia Slovaca, 47 (2015), 223 – 230
Web ISSN 1338-3523, ISSN 0369-2086

Hydrocarbon potential of pre-Neogene units of the Western Carpathians in Slovakia

JÁN MILIČKA[1] and MIROSLAV PERESZLÉNYI[2]

[1]Comenius University, Faculty of Natural Sciences, Dept. Geochemistry, Ilkovičova 6, Mlynská dolina, SK-842 15 Bratislava 4, Slovakia; milicka@fns.uniba.sk
[2]PC&G, Comenius University, Faculty of Natural Sciences, Ilkovičova 6, Mlynská dolina, 842 15 Bratislava 4, Slovakia; pereszlenyi@pcg.sk

(Received 30. 9. 2015, accepted for publishing 23. 11. 2015)

Abstract

Within the complex evaluation of the hydrocarbon potential in the Western Carpathians in Slovakia the pre-Neogene units are discussed in this paper. Hydrocarbon potential assessment is based mainly on the Rock-Eval pyrolysis and vitrinite reflectance in respect to actual geological conditions. The results show that besides the Neogene basins the most prospective regions for the hydrocarbon accumulations discoveries are the Flysch Belt and some areas of the Central Carpathian Paleogene Basin. The hydrocarbon potential of the Western Carpathians geological units in Slovakia older than Late Cretaceous is practically exhausted.

Key words: hydrocarbon potential, kerogen thermal maturity, vitrinite reflectance, pre-Neogene units, Western Carpathians, Slovakia

Introduction

The most explored and actually also the most prospective regions for hydrocarbon exploration in Slovakia are the Neogene basins – the Vienna-, Danube- and East Slovakian basins. Consequently the new organic geochemical methods were applied mainly to these areas (Franců et al., 1989, 1990, 1996; Milička et al., 1994, 1996) (Fig. 1). Nevertheless the first discoveries and oil production are dated to the second half of the 19th and the beginning of the 20th centuries in the western and eastern part of the Flysch Belt, besides Slovakia actually including the Czech Republic in the western part and Poland and Ukraine in the eastern part of Slovakia.

Within the systematic hydrocarbon potential assessment of the entire Western Carpathians in Slovakia there were studied practically all geological units excepting the basements of the core mountains (Pereszlényi et al., 1996). Mainly well cores, but also samples from outcrops with sufficient organic mater content were analysed. The Rock-Eval pyrolysis offered the knowledge about the kerogen type and the hydrocarbon potential; the vitrinite reflectance measurements revealed the thermal maturity rank of plant derived organic matter particles. Based on results obtained from these methods, selected samples mainly from the Flysch Belt and Central Carpathian Paleogene basin were analysed using GC and GC-MS (e.g. Milička and Macek, 2012, 2013). The essential method used in the study of the hydrocarbon potential of mainly the pre-Tertiary sediments was the vitrinite reflectance measurement. Together with the knowledge of actual depth position and geothermal conditions it allowed to confirm or rather exclude the active hydrocarbon generation from examined sediments on the present.

Methods and results

Thermal maturity of sedimentary organic matter based on vitrinite reflectance

Organic matter (OM) in sediments occurs in accumulated form (coal) or is dispersed (kerogen) and is very sensitive to changes of thermal conditions. Therefore it belongs to one of the most important indicators of the sediments thermal alterations. Thermal maturity state of organic matter or coalification rank depends mainly on maximal reached rock temperature (e.g. Teichmüller, 1986; Durand et al., 1986).

Vitrinite is one of the maceral groups derived from the terrestrial plants (Stach et al., 1975) and occurs in two basic forms – structural telinite and structureless collinite. Vitrinite is most concentrated in humic coals, less in shales (potential HC source rocks) and is practically absent in carbonates and sandstones except the macroscopic coalified debris. Its occurrence is limited to the sediments of post-Ordovician age (Katz et al., 1988). Initial conversion of plant tissues begins after the burial to various depths depending on geothermal gradient. The changes are of physical and chemical nature and include for example the increase of structure carbon ordering and the reduction of volatile components. Further burial of vitrinite causes additional structural ordering that results in increased reflectance.

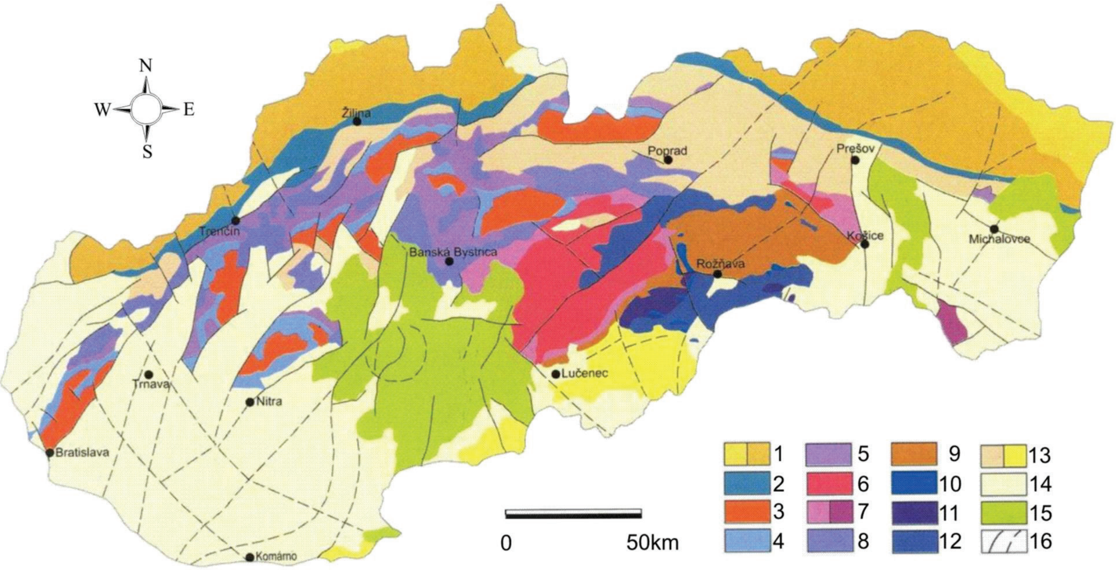

Fig. 1. Tectonic scheme of the Slovak part of the Western Carpathians according to Biely et al. (1996). 1 – Flysch Belt (Krosno/Magura zone); 2 – Pieniny Klippen Belt; 3 – Tatricum basement; 4 – Tatricum cover units; 5 – Fatricum (Krížna nappe); 6 – Veporicum basement; 7 – Veporicum and Zemplinicum cover units; 8 – Hronicum (Choč nappe); 9 – Gemericum; 10 – Meliaticum; 11 – Turnaicum; 12 – Silicicum; 13 – Inner Carpathian/Buda Paleogene; 14 – Neogene basins; 15 – Neogene volcanics; 16 – main faults.

The reflectance increase is an irreversible process and continues with increasing burial and heating eventually until metamorphosis. The vitrinite reflectance measurement is one of important methods used in evaluation of sedimentary plant derived organic matter thermal alteration.

Vitrinite reflectance was measured in Czech Geological Survey Prague, branch Brno on Leitz Wetzlar MPV 2 microphotometer under following conditions: monochromatic light (λ = 546 nm), circular micro-photometric field (r = 1 mm) and Leitz calibration standards (Ro values of 1.24 and 5.42 %). Measurements were carried out in oil immersion on polished sections from the well cores and the surface outcrops and statistically evaluated. The result is the mean vitrinite reflectance (Ro) measured in non-polarized light and maximal/minimal (Rmax/Rmin) reflectance measured in polarized light. The results are presented graphically in Figs. 2 and 3. Vitrinite reflectance measurements of individual well cores and outcrops samples from investigated regions with statistical evaluation and geological data

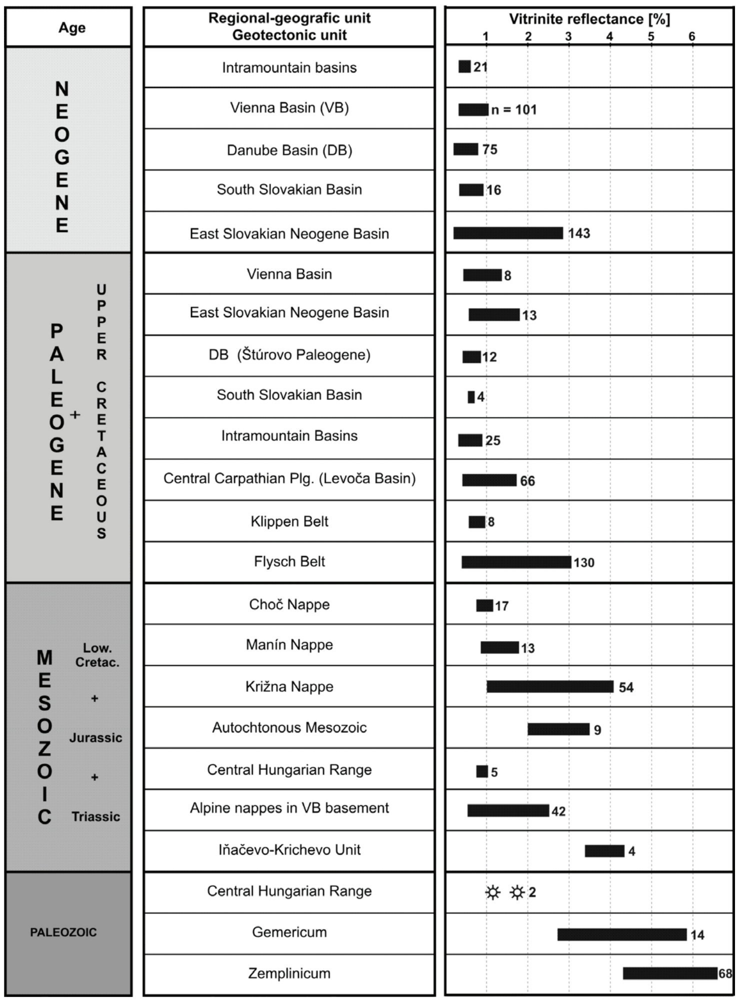

Fig. 2. Thermal maturity rank of sedimentary organic mater in regional-geographic and geological units without reference to the depth; n – number of measurements. Soták et al. (1995) published the occurrence of anisotropic organic matter in Zbudza 1 well in the northern part of the East Slovakian Neogene Basin. Presented values of vitrinite reflectance measured in polarized light (Rmax = 5.75 %; Rmin = 3.37 %) may correspond to the Mesozoic of Iňačovce-Kričevo unit in Fig. 2, however the authors (l. c. 1995) introduce the Eocene age of this sequence.

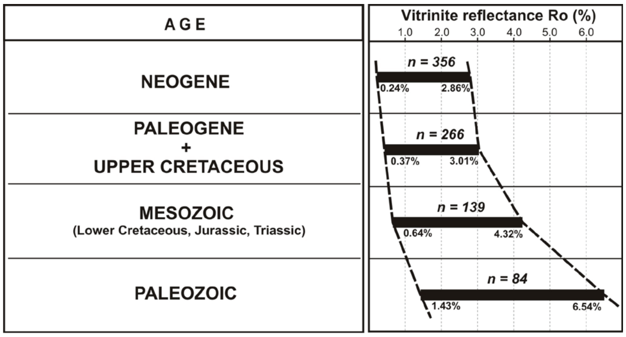

Fig. 3. Thermal maturity rank of sedimentary organic matter in individual stratigraphic units in Slovakian Western Carpathians; n – number of measurements.

are published in numerous reports, most consistently in Pereszlényi et al. (1996). Vitrinite reflectance data from the Vienna- and East Slovakian basins are partly taken from Francŭ (1986), as well as Chmelík and Müller (1987).

Hydrocarbon potential based on Rock-Eval pyrolysis

Sufficient organic matter content (TOC) dispersed in sediments is one of the key preconditions for potential hydrocarbon generation if other geochemical conditions are fulfilled. Minimal content of 0.5 weight % TOC is frequently referred for shales as potential source rocks.

Hydrocarbon potential is the amount of hydrocarbons that yields a source rock in the case of favorable generation conditions. Rock-Eval pyrolysis is used as one of the most efficient standard method for rapid evaluation of hydrocarbon potential and kerogen type. Principles, apparatus and interpretation of measured and calculated parameters are presented e.g. in Espitalié et al. (1985, 1986a, b); Peters (1986); Horsfield (1984) and Strnad et al. (1981).

Direct measurements were carried out in the Czech Geological Survey Prague, branch Brno on Rock-Eval I and V pyrolysers and they offered following parameters: S1 – amount of free hydrocarbons (HC) in one gram of rock [mg/g]; S2 – amount of HC bound in kerogen (residual HC potential [mg/g] and Tmax – the maximal pyrolysis temperature [°C]. From these there were calculated the parameters HI – hydrogen index [mg HC/g TOC] that expressed the relative amount of hydrogen; PI – production index expressing the relative amount of free HC to the total HC amount in the rock or top the initial HC source potential; GP – genetic potential, i.e. the total amount of hydrocarbons generated from kerogen during a sufficient time interval under adequate temperature; TR – transformation index that indicates the relation of generated hydrocarbon to the genetic potential.

Interpretation of genetic potential is documented summarily by TOC, S2 and HI average values in investigated geological units in Tabs. 1 and 2. Detailed analyses of individual well cores and outcrops samples from investigated regions are published in numerous reports, most consistently in Pereszlényi et al. (1996). In the case of hydrogen index (HI) there are presented also the maximal reached values

Tab. 1
Selected parameters of Rock-Eval pyrolysis for dispersed organic matter

	Dispersed organic matter			
	TOC [%]	S2 [mg/g]	HI [mg/g] average	HI [mg/g] max
Neogene	0.50–2.50	0.18–4.80	~250	410
Paleogene and LC	0.28–11.50	0.12–50.4	~90	555–667
Mesozoic (EC, J, T)	0.48–1.17	0.12–1.78	~65	–
Paleozoic	0.10–1.35	0	0	–

Note: TOC – total organic carbon; S2 – amount of fixes hydrocarbons; HI – relative amount of hydrogen; LC – Late Cretaceous; EC – Early Cretaceous; J – Jurassic; T – Triassic.

Tab. 2
Selected parameters of the Rock-Eval pyrolysis for coaly organic matter (maximal values)

	Coaly organic matter	
	TOC [%]	S2 [mg/g]
Neogene	76	87
Paleogene	18	42
Mesozoic	59	238
Paleozoic	55	0.0X

Note: Legend is the same as in Tab. 1

that indicate considerable better kerogen type with higher hydrocarbon potential for given sedimentary sequences.

Discussion

Paleozoic and Mesozoic sediments of the Central Western Carpathians

The hydrocarbon potential of Paleozoic and Mesozoic units of the Inner Western Carpathians that formed during the Hercynian and Paleoalpine orogeny is actually exhausted. The Early Paleozoic sequences of Tatric, Veporic and Gemeric units are affected by various grade of metamorphism and both Late Paleozoic and Mesozoic rocks of Tatric, Veporic, Gemeric, Hronic, Meliatic, Turnaic, Silicic, Zemplinic and Iňačovce-Kričevo units (Fig. 1) do not fulfill the criteria for the source rocks considering mainly their thermal metamorphism and actual depth position. These are either anchimetamorphosed or their hydrocarbon potential has been most probably exhausted already in their deposition basins before the Late Cretaceous period.

This is supported by maximal pyrolytic temperature and by free and fixed hydrocarbons content, but mainly by vitrinite reflectance data, measured on outcrops and well cores from deep wells, penetrating the basement of Tertiary basins (Pereszlényi et al., 1996). Only the sediments of the south-eastern part of the Vienna Basin basement that belong to the Northern Calcareous Alps comprise the potential hydrocarbon source rocks. The thermal maturation trend of sedimentary organic matter in individual regional-geographic and geotectonic units is documented in Fig. 2. These trends are created using more than 840 vitrinite reflectance measurements and do not reflect the exact depths in this case. The increasing global kerogen maturation trend from Neogene to Paleozoic sediments is shown in Fig. 3.

Metamorphic discordance between Tertiary to Late Cretaceous sediments and Mesozoic to Paleozoic carbonate sequences is indicated in depth profiles by distinct vitrinite reflectance discontinuities (examples are presented in Figs. 4 and 5). Some of Paleozoic sediments are even rich in organic carbon content e.g. some Permian and Carboniferous samples of Zemplinic unit, though their thermal maturity (Fig. 3) corresponds to anthracitic and graphitic stages, indicated by anisotropic organic matter (Milička et al., 1991; Janočko et al., 2006). The exhausted hydrocarbon potential is confirmed also by the negligible content of free and fixed hydrocarbons (Tabs. 1 and 2) and of extractible organic matter.

The Klippen Belt (Jurassic and Early Cretaceous) and peri-Klippen (Late Cretaceous and Paleogene) sequences

The origin, migration and accumulation of hydrocarbons in the Pieniny Klippen Belt can be actually assessed only roughly due to its complicated geological evolution and the low prospecting level. Characteristic feature of the Klippen Belt is represented by the intensive deformed Jurassic and Early Cretaceous mostly carbonate sediments that built klippes chaotically distributed in the Late Cretaceous and Paleogene, prevailingly clayey-sandy sediments. Jurassic and Early Cretaceous sediments contain thermally high altered organic matter without any hydrocarbon potential.

The total organic content depth distribution in the Hanušovce-1 well has indicated as the potential source rocks in the Klippen Belt the Late Cretaceous and Paleogene shales (TOC up to 0.82 %) in depth interval of 1 400 – 3 000 m. The Rock-Eval pyrolysis data indicate plant derived kerogen (type III) with entire genetic potential maximally up to 0.85 mgHC/g in the rock. Vitrinite reflectance of 0.6 to 0.7 % in interval 690 – 1 990 m indicates the passive (relict) maturation stage of the Late Cretaceous-Paleogene sequence in this well.

The Inner Carpathian Late Cretaceous formations are preserved only in small remnants and their HC potential is practically negligible (Janočko et al., 2006). On the other hand, the few data from the pre-Tertiary basement of the Vienna Basin (e.g. Gajary-125, Studienka-83 and Závod-68 wells) indicate potentially fair source rocks also from the viewpoint of an active hydrocarbon generation in convenient geological positions regarding their thermal maturity. Vitrinite reflectance data of 1.14–1.35 % correspond to the depth range of 3 944–4 842 m.

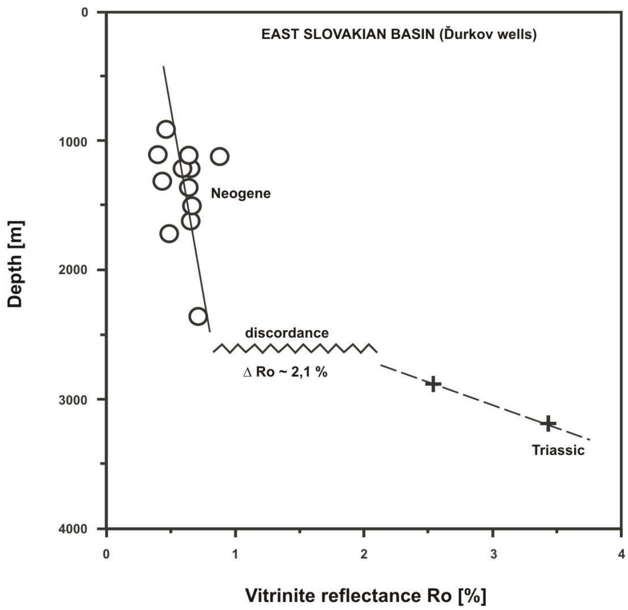

Fig. 4. Metamorphic discordance between Neogene and Mesozoic sediments in the East Slovakian Basin, being indicated by the vitrinite reflectance data.

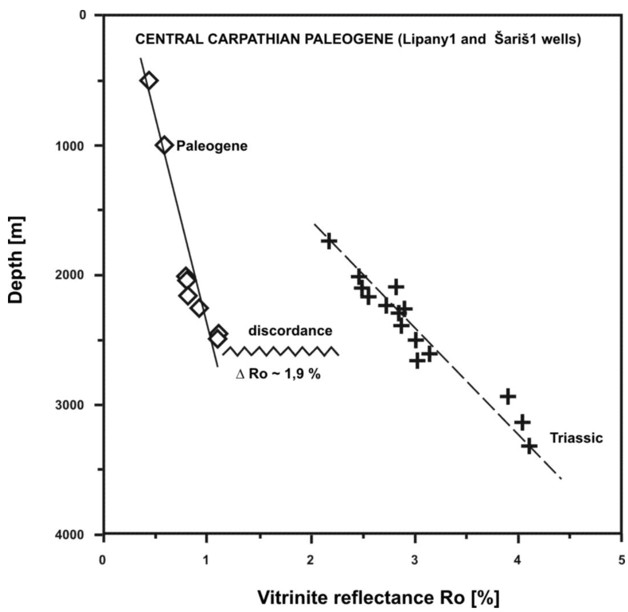

Fig. 5. Metamorphic discordance between Paleogene and Mesozoic sediments in the Central Carpathian Paleogene sediments (the Levoča Basin) indicated by the vitrinite reflectance data.

The Central Carpathian Paleogene sediments

Besides the Neogene basins and the Flysch Belt, the Central Carpathian Paleogene Basin (CCPB) is one of the most prospective regions for oil and gas exploration. It extends over a large area and overlies the pre-Senonian basement units. The Paleogene sediments are preserved in several sub-basins comprising e.g. Žilina, Rajec, Turiec, Orava, Liptov, Poprad and Hornad depressions.

The hydrocarbon potential of the CCPB was most intensively studied in the Levoča Basin from a deep well cores in Lipany, Šariš, Šambron and Plavnica area. Most of the analysed surface and well core samples are moderate (TOC > 0.5 %) to fair (TOC > 2.0 %) source rocks with maximum values of hydrocarbon index (Tab. 1) up to 667 mg/g in Š1NBIII Prievidza well (Milička, 1998). The kerogen type is prevailingly of terrestrial type III, locally there occurs also mixed terrestrial marine to marine type II kerogen, e.g. in the Huty Formation.

The content and vertical distribution of the free hydrocarbons and the vitrinite reflectance indicate the source rocks which reached the oil generation window (Soták et al., 2001). The content of hydrocarbons bound to kerogen is not fully exhausted and in greater depths they can actively generate oil and gas. An average hydrocarbon potential is about 1.0 kg HC/t of rock, however regarding the actual kerogen maturation stage, the initial HC potential was already partially released and entrapped in local accumulations. This is indicated by the occurrences of small non-commercial oil accumulations in the Lipany area.

Based on n-alkane-, sterane and triterpane distribution, there exists a positive correlation between the oils from Paleogene sandy- and intra-formation breccia reservoirs. A similar correlation is observed between these oils and rock extracts from the Paleogene source rocks. Contrary, strong differences are indicated by the biomarker study in comparison with the underlying Mesozoic extracts to both Paleogene rock extracts and oils.

The vitrinite reflectance data indicate that the post-sedimentary organic matter alteration is different within the CCPB area. Most thermal mature kerogen corresponding to the oil to dry gas generation stage occurs in the north-western part near the Klippen Belt, e.g. in the Plavnica and Šambron wells. The maturity stage was determined according to burial history- and generation zones modelling and was reached 2 000 m deeper during Oligocene to Early Miocene.

The maturity stage of kerogen in prevalent part of the area is actually relict (passive). Metamorphic discordance between Paleogene and underlying Mesozoic sediments indicated by vitrinite reflectance is shown in Fig. 5. Actual depth position and geothermal conditions do not allow any active hydrocarbon production from the Mesozoic formations.

Despite of numerous negatives, like low quality Paleogene reservoirs, absence of source rocks in Mesozoic basement and considerable uplift and erosion, we can expect the occurrence of HC accumulations mainly near depositional centers – in the Levoča Basin it is in depths below 2 500 m where more convenient conditions for HC accumulation exist.

Accretionary wedge of Western Carpathians (Flysch Belt)

The accretionary wedge of Western Carpathians in Slovakia (Flysch Belt) consists of a system of nappes differentiated from unknown basement and thrusted to the North European platform units. The Flysch sediments are mostly composed of Cretaceous to Oligocene pelitic and sandy formations and they are thrusted over the crystalline basement of the Bohemian Massif platform and its Paleozoic to Mesozoic-Tertiary sedimentary cover.

The Flysch Belt sediments have a fairly good hydrocarbon generating potential regarding their thickness (up to 10 km) and great areal extent. The Late Cretaceous to Oligocene pelitic shales – mainly the Menilite shales and Cergow Beds represent rich potential source rocks. Present organic matter alteration suggests that a part of hydrocarbon potential was realized in original sedimentary basins to the end of Oligocene. Sedimentary organic matter of the Late Eocene to Oligocene Flysch sequences was not enough deep buried to reach a sufficient alteration for an active hydrocarbon generation. These sediments entered the hydrocarbon generation stage only after deeper burial by thrusting of the Magura nappe system.

After overthrusting of the Flysch nappes in Miocene there was activated the hydrocarbon potential of the youngest Late Eocene to Oligocene formations, in our territory mainly of the Krosno-Menilite Beds in Silesian and Dukla nappes. In Fig. 6 the vitrinite reflectance discontinuity documents the overthrusting of Magura nappe on the Obidowa Slopnice unit, the maturity is however relict.

Organic-geochemical research has shown that the most prospective potential source rocks are represented by the Krosno-Menilite Beds with TOC values over 10 %,

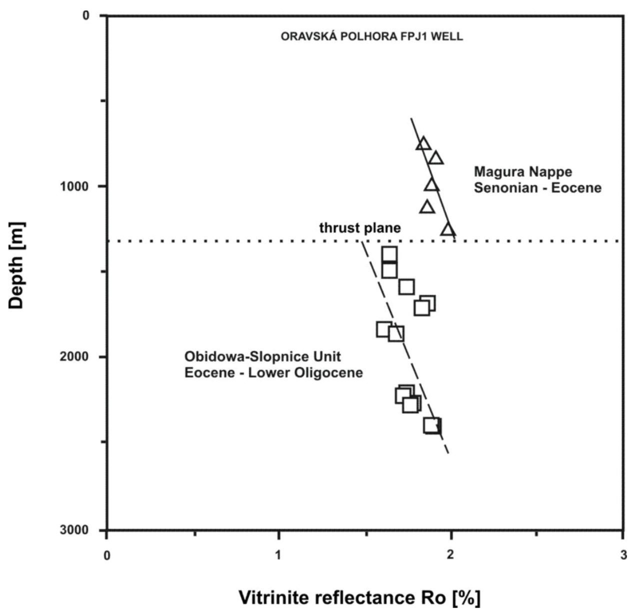

Fig. 6. The maturation discontinuity at the thrust plane of Magura nappe to Obidowa Slopnice unit in Oravská Polhora FPJ1 well indicated by vitrinite reflectance data.

the residual hydrocarbon potential up to 50 mg/g (Tab.1). Early mature kerogen comprised in shales is of mixed to marine type II with HI values between 400–670 mg HC/g TOC. Less prospective potential source rocks were found in shales of underlying older beds with terrestrial kerogen type. Potential data measured in cores of existing deep wells indicate high stages of maturation (top oil – condensate – gas) from the surface towards the depth in older Late Cretaceous to Middle Eocene formations of the flysch sequences. Menilite shales were identified as the best early mature source rocks in the Silesian unit in the western part and in the Dukla nappe in the eastern part. Comparison of sterane and triterpane distribution indicates a positive correlation of oil from Korňa and solid bitumen in the western part with Bóbrka oil in the eastern part.

The sediments of the underlying North European Platform in the most of the Flysch Belt area in the Slovak territory are submerged into the depth more than 8 km. In this depth they are most probably overmature. However, we could expect the hydrocarbons generation in the northwestern territory of Slovakia where they are situated at the depth of 3 to 8 km below the overthrusted Flysch belt. New interpretations of reprocessed seismic sections show favorable geological structure from the viewpoint of hydrocarbon accumulation both in the Flysch nappes and underlying West Carpathian Foreland (Pereszlényi, 1998). The comparison of organic geochemical results from Slovakia with those from the Czech Republic and Poland and the new interpretations of geological structures confirm the potential occurrence of interesting hydrocarbon accumulations in this region.

Conclusions

Presented study of hydrocarbon potential and thermal maturity state of investigated sediments with regard to actual depth and temperature conditions exclude the sediments older than Late Cretaceous as the active generative source rocks. Geological reconstruction indicates that present maturation stage of Mesozoic-Paleozoic sediments was reached before the Late Cretaceous era and was not significantly influenced by sedimentation of overlying Tertiary formations.

The hydrocarbon potential of pre-Neogene units indicates that to the prospective areas for hydrocarbon accumulations discoveries besides the Neogene basins there belongs the accretionary wedge of the Western Carpathians (Flysch Belt) and selected regions of the Central Carpathian Paleogene Basin. These areas are covered by considerable number of organic-geochemical analyses. Considering the analyses number, estimated hydrocarbon potential and a relative complicated geological structures in these regions an individual oil geological and geochemical detailed exploration approach to each of them is necessary.

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Uhľovodíkový potenciál predneogénnych jednotiek Západných Karpát na Slovensku

Napriek tomu, že najpreskúmanejšími a v súčasnosti stále najperspektívnejšími oblasťami uhľovodíkového prieskumu na Slovensku sú veľké neogénne panvy, prvými oblasťami, kde sa koncom devätnásteho a začiatkom dvadsiateho storočia ťažila ropa, bola oblasť západného a východného úseku flyšového pásma zahŕňajúca okrem Slovenska aj Českú republiku na západe, Poľsko a Ukrajinu na východe. V rámci systematického výskumu uhľovodíkového potenciálu Západných Karpát sa však začali študovať prakticky všetky geologické jednotky (obr. 1) s výnimkou kryštalinika jadrových pohorí. Analyzované boli najmä vzorky vrtných jadier, ale aj povrchových odkryvov s dostatočným minimálnym obsahom organickej hmoty.

Metóda Rock-Eval bola využitá na zistenie uhľovodíkového potenciálu, typu kerogénu a čiastočne aj stupňa premeny. V súvislosti s interpretáciami geologického potenciálu sú v tab. 1 a 2 uvedené priemerné hodnoty TOC, S2 a HI pre jednotlivé skúmané geologické jednotky. Na základe týchto výsledkov boli niektoré vzorky najmä z oblasti flyšových sedimentov analyzované tiež metódami GC a GC-MS. Hlavnou metódou využitou pri štúdiu najmä predneogénnych jednotiek bolo však meranie odraznosti vitrinitu. Nárast odrazivosti je ireverzibilný proces a progresívne ďalej vzrastá s pokračujúcou diagenézou až po metamorfózu. Vlastné meranie odrazivosti vitrinitu je jednou z metód zhodnotenia miery tepelnej alterácie sedimentárnej horniny. Táto metóda teda poskytla informácie o stupni premeny kerogénu a spolu s aktuálnou hĺbkou uloženia a teplotnými pomermi danej oblasti bolo možné potvrdiť alebo vylúčiť aktívnu tvorbu uhľovodíkov z týchto hornín v súčasnosti. Výsledkom meraní je stredná odraznosť vitrinitu meraná v nepolarizovanom svetle a maximálna (Rmax), resp. minimálna (Rmin) odrazivosť meraná v polarizovanom svetle. Výsledky sú vyjadrené graficky na obr. 2 a 3.

Paleozoické, prípadne prekambrické a mezozoické jednotky Vnútorných (Centrálnych) Západných Karpát, ktoré sa formovali v hercýnskej a v paleoalpínskej etape orogénneho vývoja, teda pred obdobím vrchnej kriedy, majú uhľovodíkový potenciál prakticky vyčerpaný. Staropaleozoické jednotky tatrika, veporika a gemerika sú postihnuté rôznym stupňom metamorfózy a za zdrojové horniny nemožno považovať ani mladopaleozoické a mezozoické sedimenty tatrika, veporika, gemerika, fatrika, hronika, meliatika, turnaika, silicika, zemplinika, ani sedimenty iňačevsko-kričevskej jednotky. Tieto sú buď postihnuté anchimetamorfózou, alebo uhľovodíkový potenciál týchto hornín sa vyčerpal pravdepodobne už pred obdobím vrchnej kriedy možno ešte v pôvodných sedimentačných bazénoch, na čo poukazujú v mnohých prípadoch organickogeochemické analytické údaje ako z povrchových vzoriek, tak aj z hlbokých vrtov z podložia terciérnych panví. Trend tepelnej premeny sedimentárnej organickej hmoty v jednotlivých regionálno-geologických jednotkách je uvedený na obr. 2, zostrojenom na základe viac ako 840 meraní odrazivosti vitrinitu. Globálny trend nárastu odrazivosti vitrinitu od neogénnych po paleozoické sedimenty je dokumentovaný na obr. 3. Diskordancia v stupni premeny medzi sedimentmi terciéru až vrchnej kriedy a mezozoickými a paleozoickými horninami sa prejavuje výraznými diskontinuitami v rámci hĺbkového priebehu odrazivosti vitrinitu. Príklady takýchto diskontinuít sú znázornené na obr. 4 a 5.

Vzhľadom na zložitý geologický vývoj pieninského bradlového pásma a jeho nízky stupeň preskúmanosti vznik, migráciu a akumuláciu uhľovodíkov v tejto geologickej jednotke možno posúdiť len orientačne.

Charakteristickým znakom pre bradlové pásmo je, že silne deformované jurské a spodnokriedové, prevažne karbonátové, sedimenty tvoria chaoticky rozmiestnené bradlá vo vrchnokriedových a paleogénnnych, prevažne ílovito-piesčitých sedimentoch. Jurské a spodnokriedové sedimenty obsahujú organickú hmotu vo vysokom štádiu premeny a nemajú žiadny uhľovodíkový potenciál. Hĺbková distribúcia obsahu celkového organického uhlíka vo vrte Hanušovce-1 indikuje potenciálne zdrojové horniny v bradlovom pásme na niekoľkých vzorkách vrchnokriedových a paleogénnych hornín v hĺbkovom intervale 1 300 až 4 000 m (obsah TOC v niektorých vzorkách od 0,5 po 0,8 hm. %). Obsah viazaných uhľovodíkov S2 v niektorých vzorkách dosahuje 0,5 – 0,8 mg HC/g horniny, vodíkový index 100 – 150 mg HC/g TOC, odrazivosť vitrinitu 0,57 – 0,89 % v hĺbke 685 až 3 000, teda generačné okno ropy. S ohľadom na hĺbkové a teplotné podmienky ide o reliktnú zrelosť. Vrchnokriedové formácie sa na väčšine územia Vnútorných Západných Karpát zachovali len v menších zvyškoch a z hľadiska uhľovodíkového potenciálu sú s výnimkou predterciérneho podložia Viedenskej panvy prakticky bezvýznamné.

Oblasť centrálnokarpatského paleogénu predstavuje popri neogénnych panvách a flyšovom pásme Vonkajších Západných Karpát ďalšiu perspektívnu oblasť. Uhľovodíkový potenciál CKP bol najviac skúmaný v rámci Levočských vrchov. Z hľadiska obsahu TOC spĺňa prevažná časť analyzovaných povrchových vzoriek a vzoriek vrtných jadier paleogénnej sedimentárnej výplne kritériá na potenciálne zdrojové horniny – obsah TOC nad 0,5 hm. % – a niektoré z nich možno hodnotiť ako veľmi dobré s obsahom TOC nad 2,0 hm. %. Typ kerogénu, od ktorého priamo závisí uhľovodíkový potenciál, je prevažne terestrický (typ III), lokálne však aj zmiešaný terestricko-morský typ (typ III – II) a morský typ (typ II). Maximálne hodnoty vodíkového indexu (HI do 667 mg/g), uvedené v tabuľke 1, indikujúce kvalitnejší typ kerogénu pochádzajú z hutianskeho súvrstvia vo vrte Š1NBIII Prievidza.

Obsah a hĺbková distribúcia voľných uhľovodíkov, resp. odrazivosť vitrinitu, indikujú dosiahnutie štádia tvorby ropných uhľovodíkov. Obsah viazaných uhľovodíkov v kerogéne nie je úplne vyčerpaný a vo väčších hĺbkach pochovania môže aktívne generovať uhľovodíky. Priemerný uhľovodíkový potenciál sa pohybuje okolo 1,0 kg HC/t horniny, ale vzhľadom na súčasný stupeň tepelnej premeny organickej hmoty možno predpokladať, že jeho časť sa už zrealizovala a môže byť potenciálne zachytená v pasciach. Dôkazom toho je výskyt ropy, aj keď nekomerčného významu, v niekoľkých hlbokých vrtoch v oblasti Lipian. Organická hmota v prevažnej časti rozšírenia CKP sa v súčasnosti nachádza v reliktnom (pasívnom) štádiu zrelosti. Metamorfná diskordancia medzi paleogénnymi a podložnými mezozoickými sedimentmi je znázornená na obr. 5. Na základe súčasnej hĺbky uloženia, teplotných podmienok a zisteného stupňa premeny nemožno v súčasnosti predpokladať aktívne generovanie uhľovodíkov z mezozoických komplexov.

Väčšinu akrečnej prizmy Západných Karpát na území Slovenska tvorí zvrásnené flyšové pásmo so sedimentmi kriedovo-paleogénneho veku. Na základe analógie s Českou republikou a Poľskom sa pod zvrásneným flyšovým pásmom predpokladajú ponorené svahy severoeurópskej platformy, avšak vrtnými prácami na Slovensku zatiaľ overené neboli. Flyšové sedimenty majú pomerne dobrý uhľovodíkový potenciál aj s ohľadom na ich veľkú mocnosť a veľký plošný rozsah. Dobrými zdrojovými horninami sú vrchnokriedové až oligocénne ílovce, z nich najmä menilitové vrstvy. Súčasný stupeň premeny organickej hmoty poukazuje na to, že časť uhľovodíkového potenciálu sa zrealizovala už v pôvodných sedimentárnych bazénoch pred oligocénom. Po násune flyšových príkrovov v oligocéne bol znovu aktivovaný potenciál najmladších vrchnoeocénnych až oligocénnych súvrství, na našom území najmä krosniansko-menilitových vrstiev v rámci sliezskej a dukelskej jednotky. Násun magurskej jednotky na jednotku Obidowej Slopnice vo vrte FPJ 1 Oravská Polhora je dokumentovaný diskontinuitou v odrazivosti vitrinitu na obr. 6. Organická hmota vo vrchnokriedových až oligocénnych súvrstviach nebola pochovaná dostatočne hlboko nato, aby získala potrebný stupeň zrelosti na aktívnu produkciu uhľovodíkov. Tieto sedimenty vstúpili do generačných okien až po hlbšom ponorení po násune magurskej skupiny príkrovov.

Organickogeochemický výskum potvrdil, že všetky geologické jednotky Západných Karpát na Slovensku staršie ako vrchná krieda majú uhľovodíkový potenciál prakticky vyčerpaný. Súčasný stupeň zrelosti mezozoických a paleozoických sedimentov bol získaný pred obdobím strednej až vrchnej kriedy a sedimentáciou nadložných terciérnych sedimentov už nebol významne ovplyvnený.

Na základe stručného náčrtu uhľovodíkového potenciálu predneogénnych geologických jednotiek možno konštatovať, že popri neogénnych panvách ďalšími perspektívnymi oblasťami na potenciálne objavenie ložísk uhľovodíkov je oblasť akrečnej prizmy Západných Karpát (flyšové pásmo) a niektoré oblasti centrálnokarpatského paleogénu. Z týchto území existuje značné množstvo organickogeochemických analýz. Z hľadiska počtu analýz, potenciálneho významu regiónov pre výskyt uhľovodíkov a ich pomerne zložitej geologickej stavbe si však vyžadujú samostatné detailné spracovanie.