Organic geochemical study in the junction zone of the Danube Basin and the Inner West Carpathians

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Introduction

The area studied is situated in Western Slovakia. It belongs to a 'non-traditional' region for hydrocarbon exploration and represents the northern margin of the Danube Basin and adjacent folded Inner West Carpathians.

The presence of gas and oil shows in wells drilled mainly for geothermal and coal exploration and for regional geological information was the impetus for this study.

Geological outline

The study was restricted to Mesozoic and Tertiary rocks. Tertiary sediments occur in the Bánovce and Horná Nitra depressions and partially cover the Mesozoic units of the Strážovské Vrchy, Považský Inovec, Tríbeč and Žiar Mountains (Fig. 1).

The Pre-Tertiary basement (Fig. 2) consists of igneous and metamorphic rocks of the Tatric Crystalline Complex, which are covered by several hundred metres of Mesozoic sequences comprising the Autochthonous Tatric Unit, Krížna and Choč Nappes. The Mesozoic sequences are represented mainly by Triassic carbonates (dolomites and limestones) and quartzites. Locally Jurassic to Lower Cretaceous carbonates and clastics are preserved.

Basal Palaeogene sediments comprising carbonaceous breccias, conglomerates, sandstones and fossiliferous limestones lie transgressively on Pre-Tertiary basement—most often on carbonates of the Choč Nappe. The age of this unit, which is about 150 m thick, ranges from Upper Palaeocene to Middle Eocene. Sedimentation continued with the deposition of deeper water shales and culminating in the Oligocene with flysch deposition. The maximum preserved thickness of the Palaeocene rocks is about 1200 m. This represents only a remnant of the original sedimentary area which had direct connection with open sea (Vass *et al.* 1992).

Lower Miocene sediments (Eggenburgian–Karpatian) are represented at the base by breccia, conglomerates and sandstones locally with tuffites. These sediments were derived from regions close to the studied area. Overlying siltstones and shales are about 900 m thick, and the entire thickness of Lower Miocene sediments does not exceed 1000 m. The dark colour of the rocks and the presence of pyrite were cited by Vass *et al.* (1992) as evidence of anoxic conditions during deposition.

The Lower Miocene and Palaeogene sediments, and the Pre-Tertiary basement are covered by sediments of Middle Miocene to Pliocene age. These sediments, up to 3000 m thick, are developed mainly in the southern part of Rišňovce Depression with conglomerates at the margins. In the centre off the depression siltstones and shales with intercalations of sandstones, tuffs and tuffites are dominant. In Sarmatian and Pontian sediments lignite seams are locally present. Originally a shallow-water marine environment changed during Sarmatian and Pontian times to more brackish and finally to limnic conditions (Vass *et al.* 1992).

From the viewpoint of hydrocarbon generation, the Palaeocene and Lower to Middle Miocene shales are considered to be the best potential source rocks. The best potential migration channels and reservoirs are the Mesozoic dolomites, basal Palaeogene and Lower Miocene clastics and the sandstone layers of Middle and Upper Miocene age.

Geophysical studies utilizing satellite imagery, gravimetric, magnetic and thermal measurements (Šefara *et al.* 1987) suggest that the region is prospective for hydrocarbons.

Results and Discussion

Well cores and some Mesozoic subsurface samples were studied using Rock–Eval pyrolysis, microphotometry and gas chromatography. Modelling was used for reconstruction of the geological history and hydrocarbon generation. The organic geochemical data from this region are given in Table 1.

The residual organic carbon content of the Mesozoic rocks, both from the cores and subsurface samples, varies from 0.1 to 1.0 per cent in weight. Vitrinite reflectance values (Fig. 4) indicate a high level of maturity of the organic matter in relation to depth. Gas production

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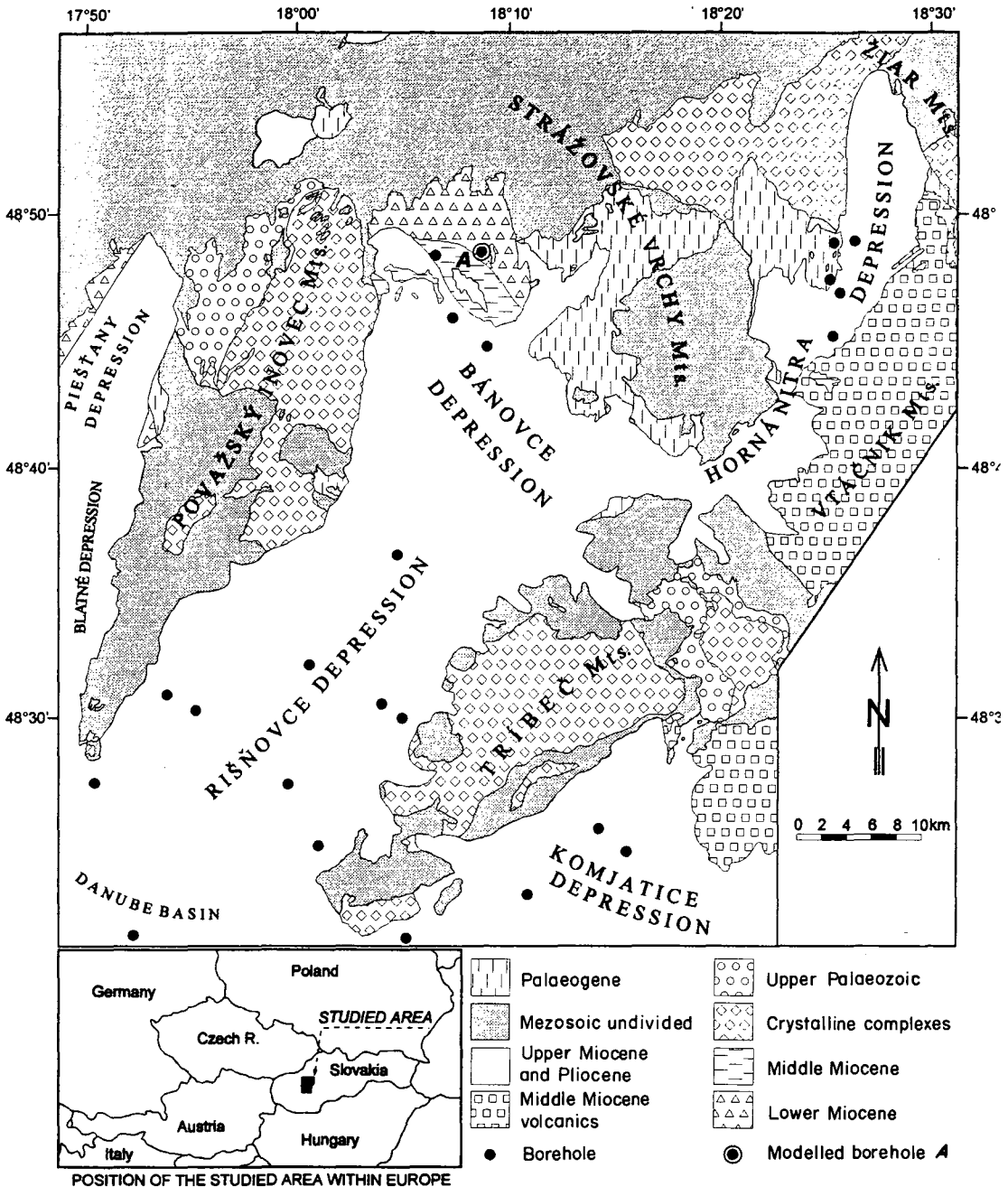

Fig. 1. Simplified geological map of the studied area with location map of the region within Central Europe.

can be expected where depth is sufficient. The Rock–Eval pyrolysis data confirm the high state of maturity of the organic matter. The fixed hydrocarbon amount (S2 parameter) refers to almost completely exhausted kerogene. On the other hand no significant amounts of free hydrocarbons (S1 parameter) are present, most probably as a result of the tectonic history of the region. Folding, uplift and extensive erosion took place after the peak hydrocarbon generation level was reached (Fig. 3).

The TOC content (0.5–3.0 weight %) and the hydrocarbon (HC) potential (S2 = 0.5–6.5 mg HC/g rock) of the Palaeocene and Lower Miocene sediments represent relatively good source rocks. The hydrogen index, mainly in the case of Palaeogene sediments, refers locally to mixed marine-terrestrial kerogene-type II (Espitalié *et al.* 1986). The gas-chromatographic characteristics of two Lower Miocene rock extracts indicate the presence of two facies of organic matter, one mixed marine-terrestrial (Fig. 6a) and one terrestrial (Fig. 6b).

Palaeogene and partly Lower Miocene sediments are in the main oil generation windows at a depth of 700–900 m in the Horná Nitra Depression and at 1000 m in the Bánovce Depression. However, these conditions were reached before the Middle to Lower Miocene, i.e. these sediments are at present in a passive maturation stage (Figs 4 and 5). The hydrocarbons generated in the

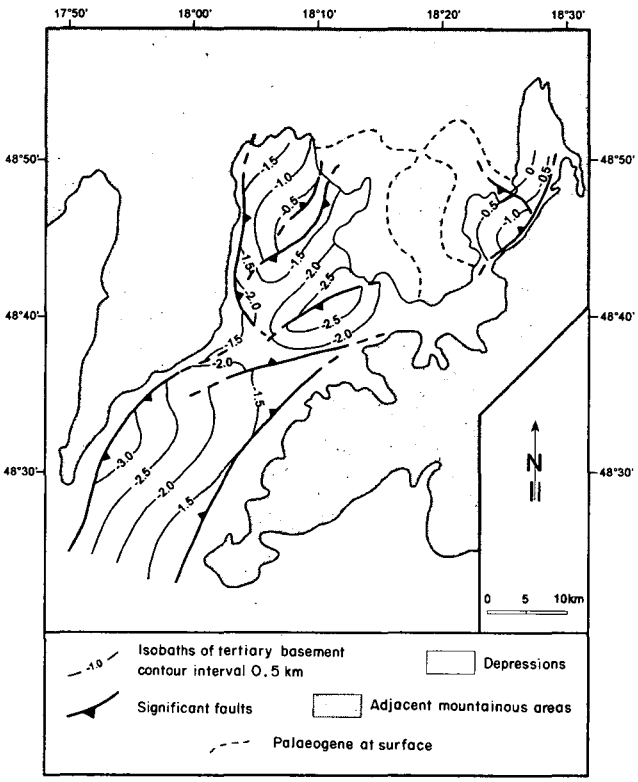

Fig. 2. Configuration of the Pre-Tertiary basement; depth values are based on deep borehole data.

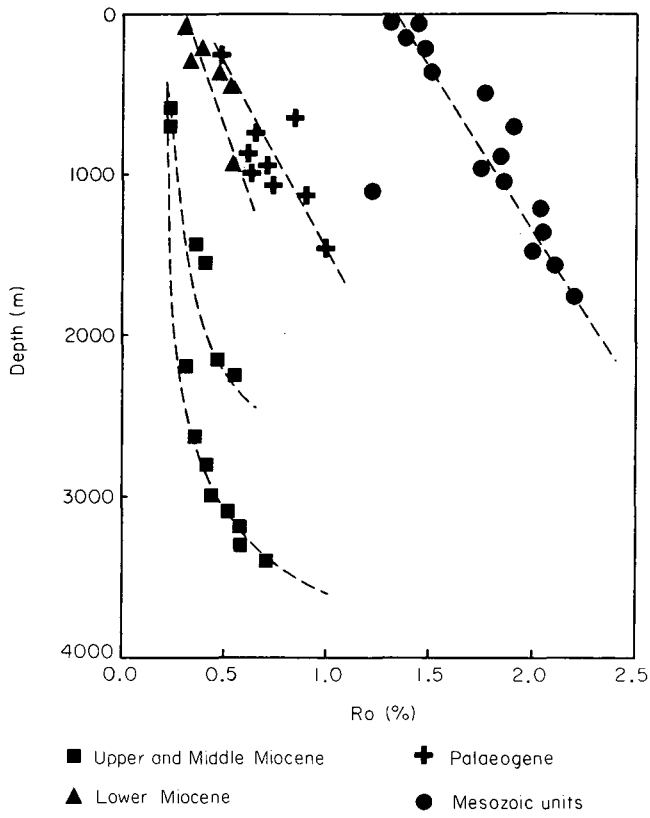

Fig. 4. Vitrinite reflectance characteristics of Tertiary and Pre-Tertiary rocks.

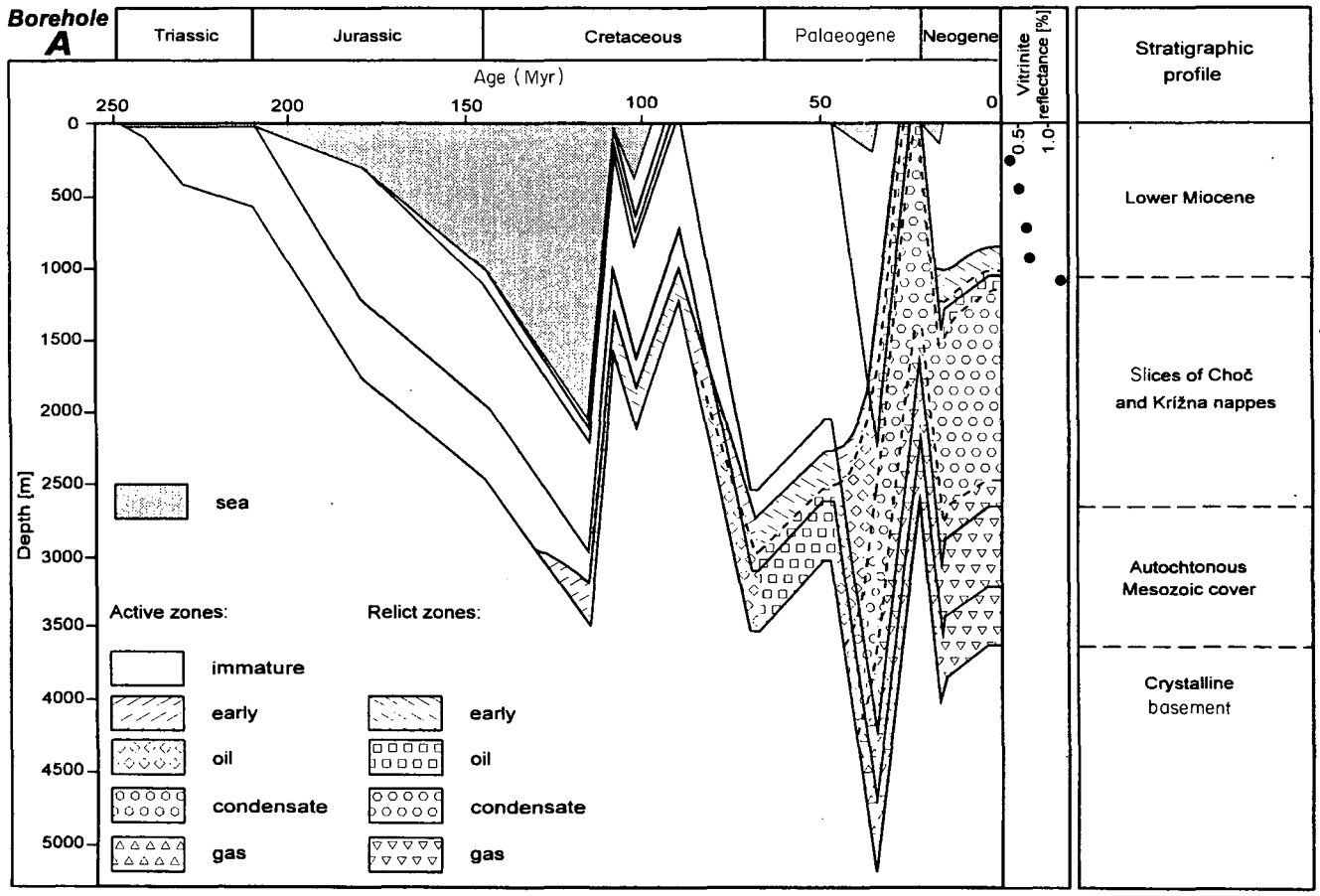

Fig. 3. Burial history curves and hydrocarbon generation windows of modelled borehole A.

Table 1. *Summary of the initial organic-geochemical results based on Rock–Eval pyrolysis and microphotometry*

Stratigraphy	TOC (weight %)	S1 (mg HC/g rock)	S2 (mg HC/g rock)	HI (mg HC/g TOC)	Ro (%)	Kerogen type
Upper and Middle Miocene	0.4–1.0	0.03–0.2	0.4–1.3	50–180	0.24–0.70	III
Lower Miocene	0.5–3.0	0.02–1.0	0.5–6.5	100–380	0.30–0.61	III–(II)
Palaeogene	0.5–3.0	0.05–1.0	0.4–3.0	100–520	0.50–1.00	III–II
Mesozoic units	0.1–1.0	0.01–0.3	< 0.3	< 100	1.30–2.20	?

TOC, total organic carbon; S1, free hydrocarbon amount; S2, fixed hydrocarbon amount; HI, hydrogen index; Ro, vitrinite reflectance.

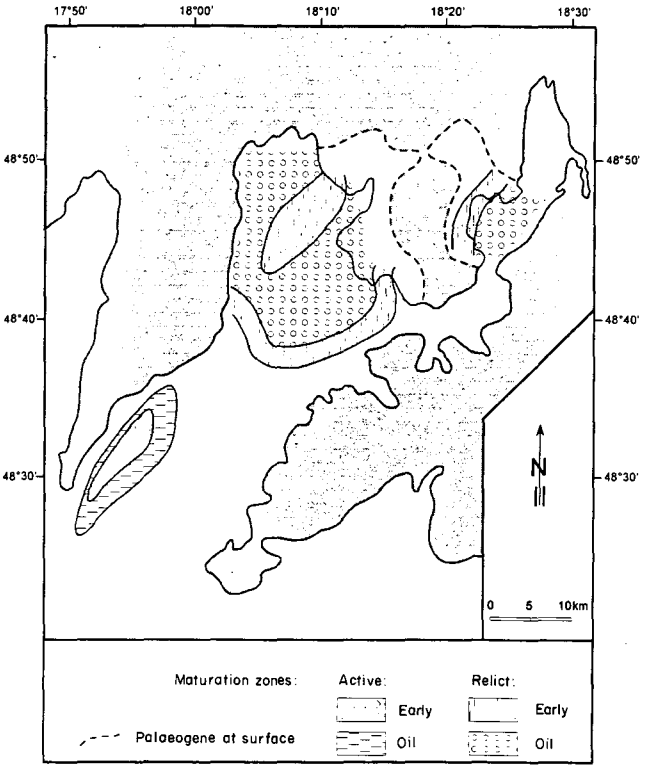

Fig. 5. Maturation zones of potential source rocks at the base of the Tertiary.

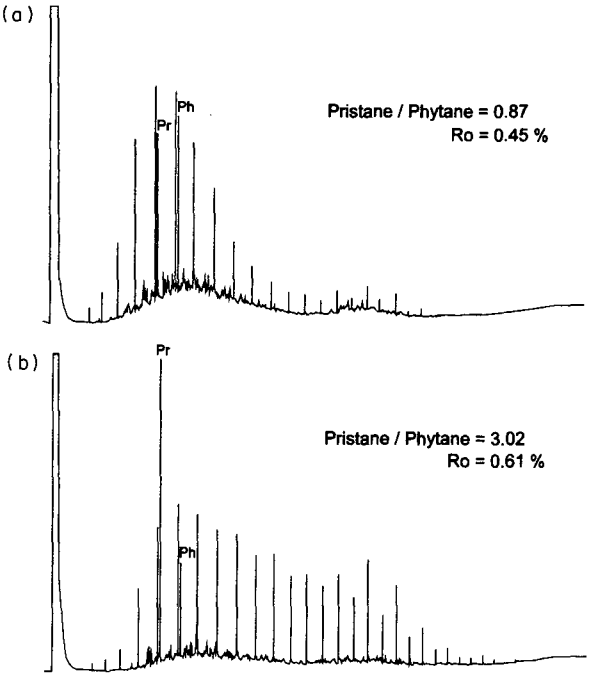

Fig. 6. Gas-chromatographic characteristics of saturated hydrocarbons from two Lower Miocene rock extracts.

Middle to Lower Miocene are considered to be the source of free hydrocarbon indices deduced from Rock Eval pyrolysis data, i.e. S1 = 0.2–1.0 mg HC/g rock; 2.7 mg HC/g rock at maximum. The Upper Miocene sediments in the southern part of the Rišňovce Depression are at present actively generating hydrocarbons (Fig. 5).

Conclusions

Total organic carbon content, as well as the analytical results based on Rock–Eval pyrolysis, are evidence of relatively good source rocks with good hydrocarbon potential in the study area.

The degree of organic matter maturation and modelling indicate active hydrocarbon generation from the Palaeogene and in part the Lower Miocene to the commencement of Upper Miocene sedimentation in the northern part of the area, and from Middle Miocene rocks in southern part of the studied area at the present time.

The most prospective areas for exploration are the Bănovce and Horná Nitra Depressions near the edge of the Strážovské Vrchy Mountains.

References

ESPITALIÉ, J., DEROO, G. and MARQUIS, F. 1986. La pyrolyse Rock–Eval et ses applications. Partie III. *Revue d'Institut France Pétrole* **41**, 73–89.

ŠEFARA, J. *et al.* 1987. Structural-tectonic map of Inner West Carpathians for prognosing mineral deposits—geophysical interpretations (manuscript in Slovak). Slovak Geological Office, Bratislava, 267 pp.

VASS, D. *et al.* 1992. Organic matter maturation study in Neogene and Pre-Neogene rocks of Danube basin and adjacent areas. Internal report. Dionýz Štúr Geological Institute, Bratislava, 210 pp.