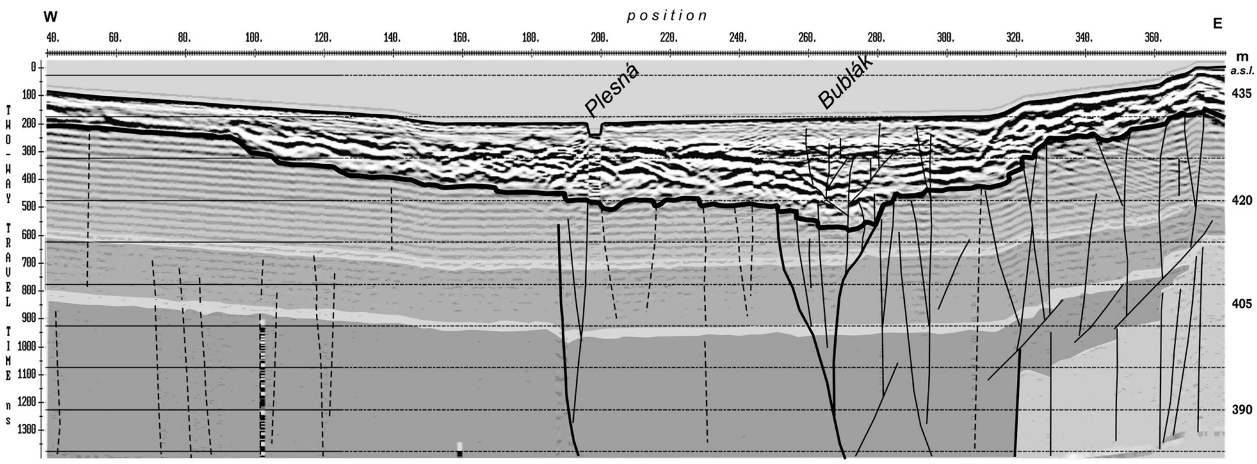

Fig.1. Interpretation of the W-E georadar profile across the alluvial plain of the Plesná river. The young (Quaternary?) basin structure overlying the Upper Pliocene clays of the Vildštejn Formation of the Cheb Basin is highlited. The central part of the young basin depression beneath the Bublák moffete seems to be bounded by fsurcated fault structure. Vertical exaggeration 1:2.

To contribute to the investigation of recent crustal movements above the Nový Kostel focal zone, eight ground penetrating radar profiles of the total length of 1700 m were measured in the region in question in October 2003. The measurements were done by georadar instrument Pulse Ekko 100A system using 50 MHz antennae and 4 m source-receiver offset. To provide sufficient horizontal resolution of recorded data, 0.5 m recording interval was used for the survey. The data were processed using Ekko commercial software with signal saturation correction, trace stacking and point stacking and corrected for topography. The average near-surface velocity was determined from common mid-point surveys. The effective velocity used for the depth conversion was 0.08 m/ns.

Figure 1 shows the data of one of the two-dimensional georadar profiles – that across the Bublák moffete. The length of the profile is 380 m. The data visualize an approximately 200 m wide and 10 m deep depression centered on the river Plesná. Beneath the Bublák moffete, the depression reaches its maximum depth of 15 m and the data indicate diffraction of electromagnetic waves on a faulted structure. The fault pattern beneath Bublák could be interpreted as a negative flower structure. The two white strips running along the whole profile were interpreted as sandy horizons.

The relatively large penetration depth of the measurements and sufficient contrast in dielectric properties of the shallow sediments of the Cheb basin justify our plan to measure a denser set of georadar profiles above the Nový Kostel focal zone with the aim to construct a three-dimensional data cube. The time slices across such a data cube enable visualization of the electromagnetic reflection strength across the whole zone of interest.

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Methane Degassing and Exhumation of the Tertiary Accretionary Complex and Fore-arc Basin of the Western Carpathians

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Cretaceous-Oligocene flysch of the Western Carpathians contains mineralised joints filled with several generations of calcite and quartz. Composite textures of the mineral infillings reflect a multi-stage development coincidental with diagenesis, syn-sedimentary folding, thrusting, and regional collapse of the Outer Carpathians (Świerczewska et al., 1999, Świerczewska et al., 2000). Blocky and drusy quartz of the joints represents the latest stage, corresponding to the regional collapse-related extension.

Fluid inclusion study on the blocky and drusy quartz has corroborated circulation of hydrocarbons in flysch sediments of Central and Outer Carpathians (Świerczewska et al., 1999, Hurai et al., 2002, and references therein). Methane-dominated fluids are typical of the Magura and Dukla Nappes, and the Spišská Magura segment of the Central Carpathian fore-arc basin (CCB). Fluids dominated by condensate (mixture of C_nH_n gaseous hydrocarbons) mixed with crude oil are typical of the remaining segments of the CCB. Immiscibility phenomena in both fluid types have permitted determination of PT parameters using microthermometry data (e.g. Hurai et al., 2002).

Upgraded set of the PT data from the methane zone (Fig. 1) shows temperatures between 130 and 205 °C in the CCB, 155 and 210 °C in the Magura Nappe, and 195–220 °C in the Dukla Nappe. The wide range of temperatures in the CCB and the Magura Nappe is interpreted as having resulted from influx of hot fluids (220 °C) into colder flysch sediments. Thus, the lowest temperatures recorded by fluid inclusions are believed to correspond to those of the surrounding rocks.

Boiling condensate-oil mixtures indicate trapping temperature of 45 °C in external growth zones of quartz crystals, and the temperature around 100 °C in cores of the crystals from the condensate zone of the Skorušiná Mts. Similar temperatures are supposed in the Levoča Mts., where the condensate+oil immiscibility has been observed in surface outcrops and in the depth of 2 km in the Upper Eocene-Lower Oligocene sediments intersected by the Lipany-5 borehole.

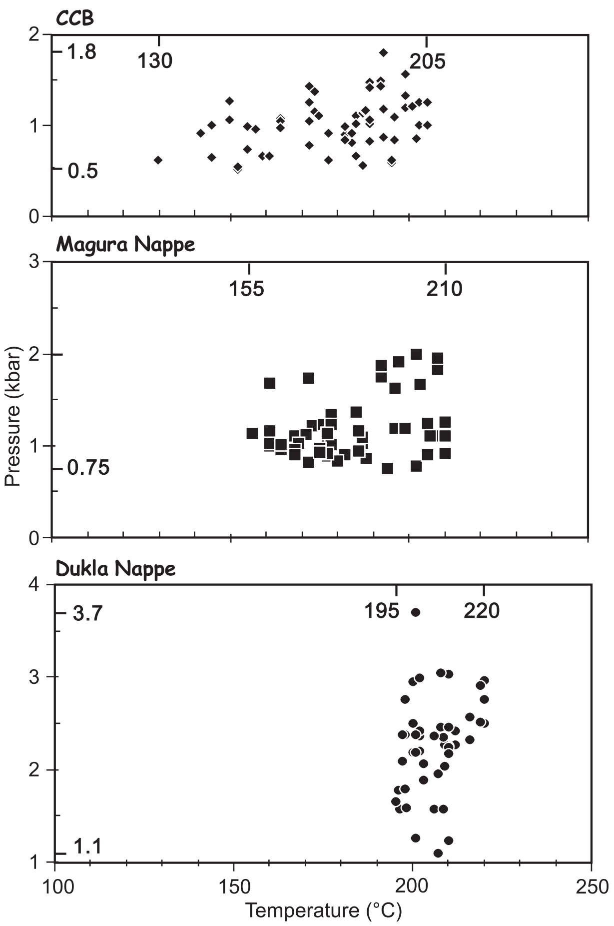

Fig. 1. Summary of PT parameters in methane zone.

The maximum temperature of 100 °C in the condensate zone is consistent with fission-track data on detritus apatites, which exhibit only cooling ages in the source not overprinted by a secondary thermal event. The fluid inclusion-derived temperatures are consistent with reflectance of vitrinite in flysch sediments, indicating as much as 200 °C in Spišská Magura Mts. and below 100 °C in other segments of the CCB basin. Similarly, maximum paleotemperatures up to 175 °C in the Spišská Magura Mts. and considerably lower values in other segments of the CCB have been recorded by smectite-to-illite reaction. The illite/smectite diagenesis indicates eastward increasing temperatures from 70 °C to 165 °C in the Podhale basin (Kotarba, 2003).

An approximate 1:3 ratio between minimal and maximal inclusion trapping pressures in the methane zone indicates cyclically changing hydrostatic and lithostatic fluid regimes and a crack-seal mechanism (Holbrook 1999 and references therein) during quartz crystallisation. The model is most plausible in the Magura Nappe, where the full range of determined pressures (0.75–2.0 kbar) could be explained in terms of a load induced by 7.7 km rock column and <0.1 km water column (Fig. 2). Similarly, the pressures between 1.1 and 3.7 kbar in the Dukla Nappe correspond to 11.2 km of overburden, and an excess pressure of 0.7 kbar attributed to an episodic supralithostatic fluid overpressure generated during thermal cracking of oil and kerogen (Hurai et al., 2002).

The overburden of 5.3–6.5 km pertaining to Oligocene-Miocene sediments is recorded by fluid inclusions in methane zone of the CCB. Pressures in condensate zone could not be determined precisely using equations of state, because of lacking compositional and density data on the condensate. Hence, depths of burial have been estimated from minimal temperatures and geothermal gradient of ~25 °C/km determined in the methane zone. The inferred maximum depths in the condensate zone have not exceeded 3 km. Throw of at least 3 km between

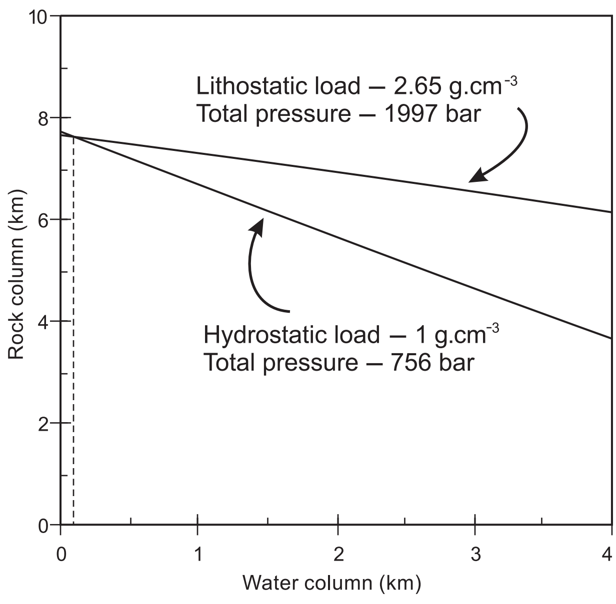

Fig. 2. Quantitative crack-seal model applied to the Magura Nappe (gravitational acceleration g = 9.81 m.s^{-2}, cohesive rock strength = 0 bar).

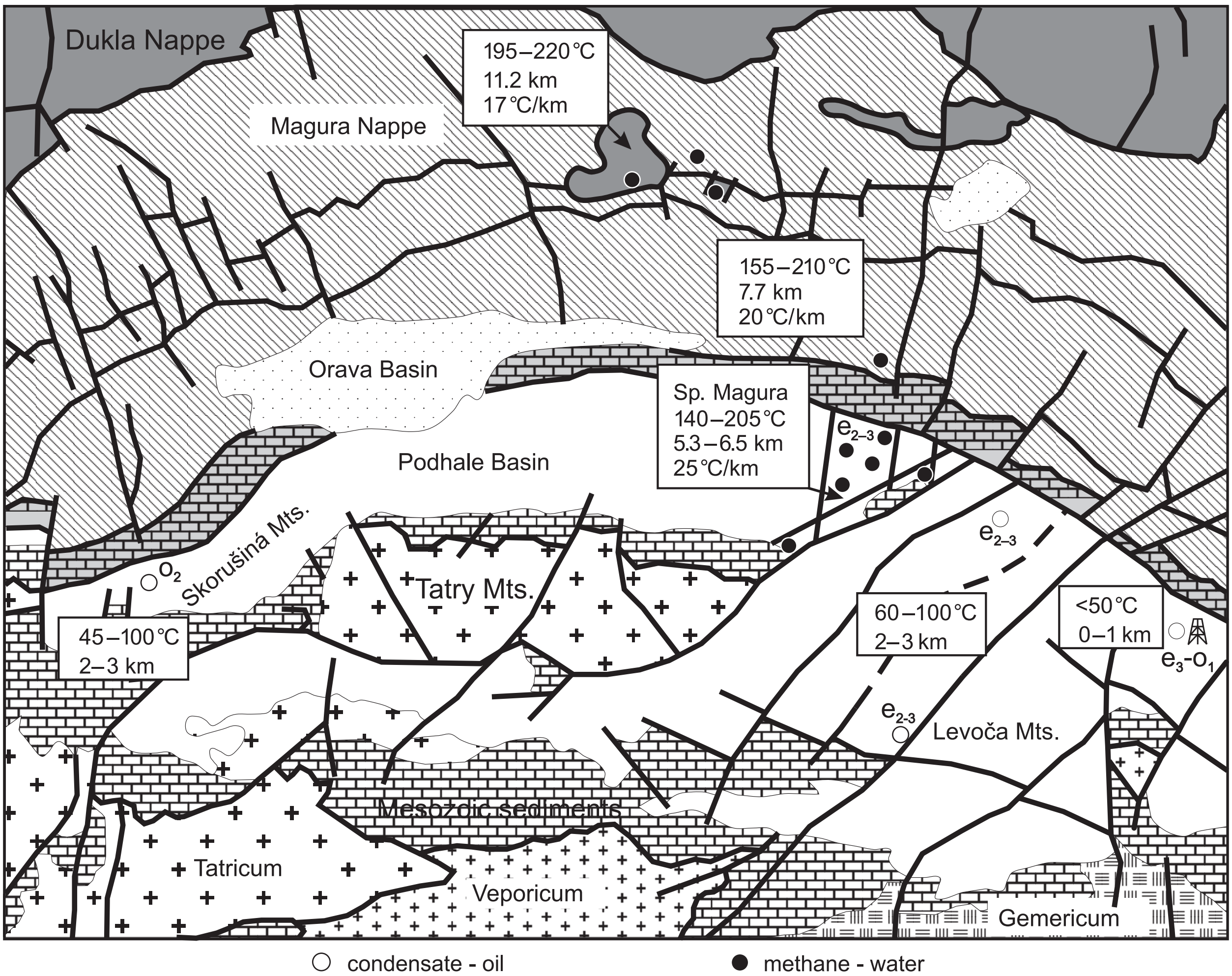

Fig. 3. Schematic geological map with location of samples, temperatures, geothermal gradients and depths of burial inferred from fluid inclusions.

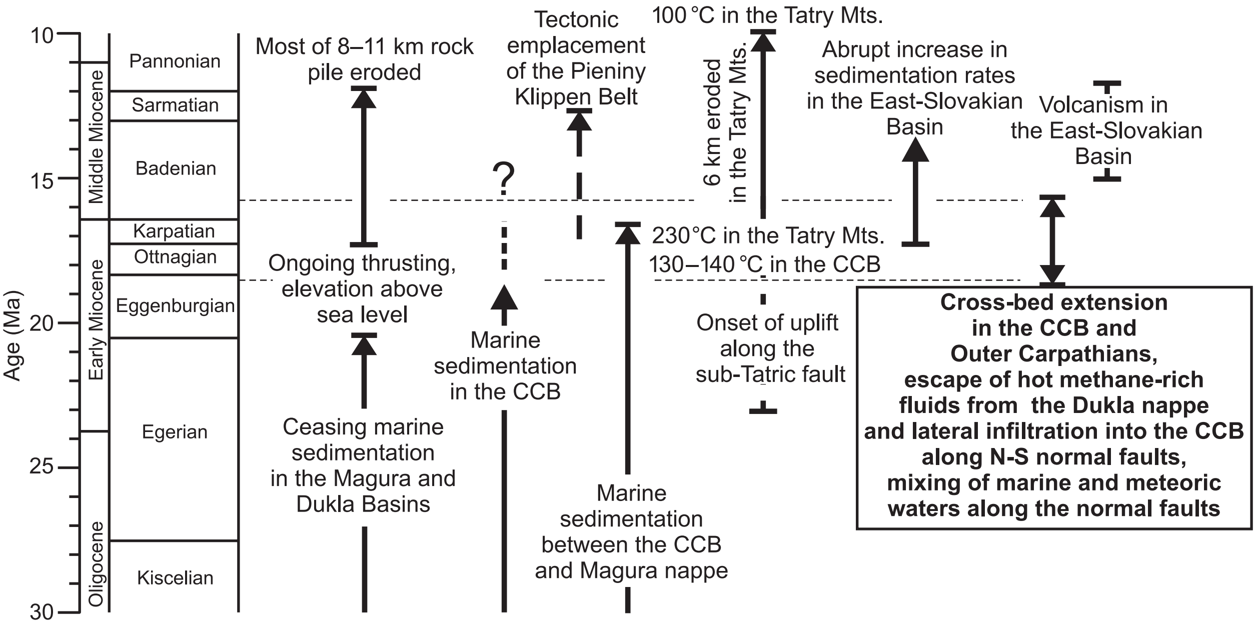

Fig. 4. Timing of events in the Western Carpathians during Tertiary times.

the methane and condensate zones (Fig. 3) must have been established prior to tectonic emplacement of the Pieniny Klippen Belt (PKB) and prior to/during early tectonic activity along the sub-Tatric detachment fault, which commenced in Late Oligocene (Kohút – Sherlock, 2002) or Early-Middle Miocene (Janák et al., 2001).

Rock temperatures in the CCB and the Magura Nappe have been insufficient for generation of thermogenic methane trapped in fluid inclusions. Hence, vertical upward infiltration of hot fluids from the Dukla Nappe and/or subjacent units into Magura Nappe and lateral infiltration into the Spišská Magura segment of the CCB must be invoked. The methane zone of the CCB overlaps region with N-S-trending normal faults originated during local, pre-Middle Miocene cross-bed W-E extension (Sperner et al., 2002). The local extension is believed to be coeval with the onset of the cross-bed extension in the Outer Carpathians. Geological, geochronological and fluid inclusion data indicate onset of the extension accompanied by incursion of hot methane-bearing fluids during Ottnangian-Karpatian times (Fig. 4). This scenario is supported by K/Ar record of maximum paleotemperature overprint of bentonite, tending to increase from 16 Ma in west to 18.5 Ma in eastern part of the Podhale Basin (Kotarba, 2003).

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Lithostratigraphy and Tectonics of the Krynica Unit, Magura Nappe in the Vicinity of Krościenko on Dunajec River, Poland

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The Magura Nappe forms the largest tectonic unit of the Outer Western Carpathians running from Austria through Czech Republic, western Slovakian, Polish Beskids, and eastern Slovakia to Ukraine. To the south it borders the Pieniny Klippen Belt (PKB). It is subdivided into several subunits, from North to South: the Siary subunit, the Racza subunit, the Bystrica subunit and the Krynica subunit. This division is based on the lithostratigraphic differences. The Krynica and Bystrica subunits form regional thrust-sheets. These separate thrust-sheets are especially visible in the western part of the Magura Nappe in Slovakia. Slovak geologists even use the term "Magura Group of Nappes" (e. g. Kováč and Plašienka, 2002).

The Krościenko area is located in the central part of the Krynica subunit, near the border with the PKB, according to Birkenmajer and Oszczypko (1988, 1989) it is peri – klippen zone and south – central zone.

The oldest rocks belong to PKB and are represented by the Jurassic Cretaceous radiolarites , chert limestones and red marls and knew from the Łupisko klippen and small klippen found in the Ścigocki Creek (Golonka and Sikora, 1981). The tectonic position of this klippens is uncertain. Łupisko outcrop was folded with peri - klippen flysch according to Książkiewcz (1972) but it is also possible that this fragment could be separated from PKB and overthrust on Szczawnica Fm. as a klippe. In Ścigocki stream is probably uplifted klippen at the strike - slip fault (Birkenmajer, 1986).

Similar rocks deposited in the deepest part of the Jurassic-Early Cretaceous Magura basin (Birkenmajer, 1986, Golonka et al., 2003) are involved in the PKB tectonic structure. Oucrops of the Palaeocene-Lower Eocene Szczawnica Fm. occur along the PKB border in the Krośnica-Krościenko area and in Szczawnica Wyżnia. This formation is represented by thin - bedded flysch with thick and very hard sandstones. In the upper part of the Szczawnica Fm. there are very thick - bedded sandstones of the Życzanów Mbr (Lower Eocen). They occur between Krośnica and Szczawnica Wyżna.

The Życzanów Mbr is covered by the thin - bedded turbidites of the Zarzecze Fm. (Lower Eocen) locally with the intercalations of Łącko type marls (Lower Eocen) which were localised in Zawiasy and Czarna Krośnica stream. Above of the Zarzecze Fm. they are the Piwniczna Sandstones (Lower - Middle Eocen) with the red shales, which may be belong to Kowaniec shales (Middle Eocen) occurring in the eastern part of the area. The poorly outcropped red shales, known only from