

THERMAL AND BURIAL HISTORY OF THE SUB-TATRIC NAPPES AND THE PODHALE BASIN - CONSTRAINTS FROM PRELIMINARY MATURITY ANALYSIS AND MODELLING

P. POPRAWA, J. GRABOWSKI and I. GROTEK

Polish Geological Institute, Department of Regional Geology and Geophysics, ul. Rakowiecka 4, 00-975 Warszawa, Poland;

ppop@pgi.waw.pl; jgra@pgi.waw.pl; igro@pgi.waw.pl

Abstract: Thermal maturity (vitrinite reflectance; VRo) of surface samples from the northern Tatra Mts. and southern-most Podhale Basin varies in a range of ~0.85-1.8 %Ro, corresponding to palaeotemperatures of ~105-150 °C respectively. This is related to the burial and thermal regime during development of the Paleogene Basin and/or during the Late Cretaceous orogenic burial. Obtained results suggest that during maximum burial the heat flow was substantially higher than the recent one.

Key words: Tatra Mountains, Podhale, Mesozoic, Paleogene, thermal history, erosion, vitinite reflectance, maturity modelling

Sedimentary rocks of the Križna and Choč Units were deposited in the Mesozoic basins of the Tethyan realm. During the late Cretaceous (pre-Senonian) orogenic phase they were detached from the basement, deformed and tectonically transported towards the north. During the Eocene-Oligocene (? -early Miocene) the nappe stack was buried under sedimentary cover of the Central Carpathian Paleogene Basin (CCPB) (e.g. Passendorfer & Roniewicz 1963; Nemcok et al., 1996; Sotak et al., 2001). This was followed by regional uplift and selective erosion, which started during the Miocene orogenic phase (e.g. Burchard, 1972; Kovac et al. 1994) and continues until recent time. The Paleogene sediments in the area of Tatra Mountains were removed almost completely. Therefore it is difficult to justify if this area was buried equally as its surroundings with preserved Paleogene basin-fill, or it experienced less subsidence, as it could be inferred from directions of sediment transport (e.g. Marschalko & Radomski, 1960).

The present research aims reconstruction of the thermal and burial history of the Sub-Tatric nappes and Podhale Basin by means of vitrinite reflectance (VRo)

measurements and 1-D maturity modelling. Based on thermogram of Zakopane IG-1 well the recent heat flow was recalculated. Obtained value was 50-55 mW/m², which is by ~5 mW/m² lower than previously suggested. Maturity was calculated with Sweeney & Burnham (1990) algorithm.

Other authors discussed different aspects of thermal and burial history of the analysed area previously. Preliminary analysis of conodont colour alteration for the highest Sub-Tatric units suggested relatively low thermal maturation (CAI 1.5-2), corresponding to palaeotemperatures of ~50-80 °C (Grabowski et al., 1999). Marynowski et al. (2001) studied bituminous matter from tectonic zones in the Western Tatra Mts and defined its maturity for $R_{CS} = 0.74-0.82$ %. Apatite fission track ages obtained by Burchard (1972) and Kovac et al. (1994) indirectly indicate, that prior to the middle Miocene crystalline rocks of Tatra Mountains experienced temperatures higher than 100-120 °C. Further to the SE of the analysed area Sotak et al. (2001) based on VRo estimated thickness of missing section for approx. 1000-3000 m.

In the present, preliminary study vitrinite reflectance was measured for 8 surface samples, representing sedimentary rocks of the Sub-Tatric nappes and 1 representing basal part of the Podhale Paleogene Basin succession. VRo ranges between ~0.85 and ~1.8 %Ro (Tab. 1). Maximum palaeotemperatures, corresponding to the measured VRo (c.f. Robert, 1998) varies in a range of 105 °C to 150 °C respectively (Tab. 1).

Measured VRo values do not show positive correlation with stratigraphic age of sampled rock (Fig. 2). 1-D modelling shows that VRo observed for the Sub-Tatric nappes could not be achieved during the Mesozoic phase of burial in sedimentary basins of the Tethyan realm (Fig. 3). Therefore VRo records either tectonic burial during the late Cretaceous orogenic phase, or is related to burial and/or thermal regime of the CCPB. At the present state of knowledge it is difficult to justify between the above options.

For each analysed location only a single VRo measurement was available. Lack of representative VRo profile unable constraining maturity gradient in the section. Therefore in each case it was not possible to calculate unique palaeoburial and palaeoheat flow. Instead range of possible solutions was calculated (Fig. 4), with two alternative end-member models. The first, assuming constant in time heat flow equal to the recent one (i.e. 50 mW/m²), requires high thickness of removed section,

~6000 m and ~9000 m in the case of sample No 9 and sample No 8 respectively. The second model, assuming that burial was laterally constant, requires hot palaeothermal regime. Using the concept of high palaeoheat flow alone, to feet maturity in the model one need to accept ~65 mW/m² and 85 mW/m² or higher in the case of sample No 9 and sample No 8 respectively.

Extremely high magnitude of erosion required by the first model seems to be unrealistic. Any decrease in magnitude of erosion requires higher heat flow (Fig. 4). Therefore at the time of maximum burial, i.e. during the development of the CCPB and/or during tectonic burial during the Late Cretaceous orogenic phase, thermal regime was substantially 'hotter' than the recent one. This could be explained by increase of palaeoheat flow and/or by common presence of anomaly hot fluids at that time. Present analyses are based on limited amount of VRo measurements, which recently are continued. Therefore interpretation must be treated as a preliminary. Also anomaly hot fluids recently present in the northern part of the analysed area might influence observed VRo and therefore obscure subsequent reconstruction.

References

- Burchart J., 1972. Fission-track age determinations of accessory apatite from the Tatra Mountains, Poland. *Earth. Planet. Sc. Lett.*, 15: 418-422
- Grabowski J., Narkiewicz K & Poprawa P., 1999. First results of paleomagnetic and paleothermal (CAI) investigations of the highest Sub-Tatric units in the Polish Tatra Mts. *Prz. Geol.*, 47(2): 153-158 (in Polish with English abstract)
- Gradstein F.M. & Ogg J., 1996. A Phanerozoic time scale. *Episodes*, v. 19: nos. 1-2
- Marynowski L., Gawenda A., Cebulak S. & Jędrysek M., 2001. Hydrocarbon migration in tectonic zones of the Western Tatra Mountains crystalline basement (Central Western Carpathians). *Geol. Carpath.*, 52(1): 3-14
- Kovac M., Kral J., Marton E., Plašienka D. & Uher P., 1994. Alpine uplift history of the Central Western Carpathians: geochronological, paleomagnetic, sedimentary and structural data. *Geol. Carpath.*, 45: 83-96
- Nemčok M., Keith J.F. Jr, & Neese D.G., 1966. Development and hydrocarbon potential of the Central Carpathian Paleogen Basin, West Carpathians, Slovak Republic. In: Ziegler P.A. & Horvath F. (Eds), *Peri-Tethys Memoir 2: structure and prospects of Alpine basins and forelands*. *Mem. Mus. natn. Hist. nat.*, Paris, 170: 321-342
- Passendorfer E. & Roniewicz P., 1963. Jeszcze w sprawie wyspy tatrzańskiej w eocenie (Additional notes on an Eocene island in the Tatra Mts). *Acta Geol. Pol.*, 13: 1-13
- Marschalko R. & Radomski A., 1960. Wstępne wyniki badań nad kierunkami transportu materiału w basenie fliszowym centralnych Karpat. *Ann. Soc. Geol. Pol.*, 30(3)
- Robert P., 1998. *Organic Metamorphism and Geothermal History: Microscopic Study of Organic Matter and Thermal Evolution of Sedimentary Basins*. Elf-Aquit. & D. Reidel Publ. Comp., Dordrecht, 311 pp.
- Soták J., Pereszlenyi M., Marschalko R., Milická J. & Starek D., 2001. Sedimentology and hydrocarbon habitat of the submarine-fan deposits of the Central Carpathian Paleogene Basin (NE Slovakia). *Marine and Petroleum Geology*, 18(1): 87-114
- Sweeney J.J. & Burnham A.K., 1990. Evaluation of a Simple Model of Vitrinite Reflectance Based on Chemical Kinetics. *AAPG Bull.*, 74(10): 1559-1570

Figure 1

Simplified tectonic sketch map of Tatra Mts and their foreland with sampling localities. For each locality number of sample and measured range of values of vitrinite reflectance (% Ro) is given. CAI for the sample representing Choč Unit adopted after Grabowski et al. (1998).

Figure 2

Measured vitrinite reflectance versus stratigraphic aged of the analysed samples. Note lack of correlation. Numerical ages after Gradstein & Ogg (1996) time scale.

Figure 3

Changes of thermal maturity in time reconstructed for chosen, representative sample (No 8). Note that observed VRo (in this case 1.55 %) could not be obtained during the Mesozoic burial.

Figure 4

Relation between calculated thickness of eroded section and palaeoheat flow for chosen samples. A – sample No 8; B – sample No 9. Observed relation of the two above parameters suggest, that realistic range of thickness of eroded sediments is achieved only with the assumption of heat flow substantially higher then the recent one, equal to $\sim 50 \text{ mW/m}^2$.

Table 1

Measured VRo for the analysed samples and corresponding maximum palaeotemperatures calculated with assumption of heating time equal to approx. 35 My.

Sample number	Tectonic position	Stratigraphic age	Reflectance of insitu vitrinite (%)	Approx. maximum palaeotemp. (°C)
1	Tatra Mts. – Bobrowiec unit	Hettangian	1.12 – 1.15	~120-125
2	Tatra Mts. – (?) Bobrowiec unit	upper Lias	1.37	~135
3	Tatra Mts. – (?) Bobrowiec unit	upper Lias	1.30 – 1.80	~130-150
4	Tatra Mts. – (?) Bobrowiec unit	Tythonian	1.4 (1.22 – 1.73)	~135 (125-145)
5	Tatra Mts. – near Suchy Wierch unit	Rhaetian	1.0	~115-120
6	Tatra Mts. – Suchy Wierch unit	Ladynian	1.38 (1.26 – 1.79)	~135 (125-150)
7	Tatra Mts. – Suchy Wierch unit	Ladynian	0.9 (0.87 – 0.95)	~105-115
8	Tatra Mts. – Samkowa Czuba unit	Hettangian	1.55 (1.5 – 1.8)	~140-150
9	Podhale – Paleogene Basin	Eocene	0.85 – 1.3	~105-130

Figure 1
(Poprawa, Garbowski, Grotek)

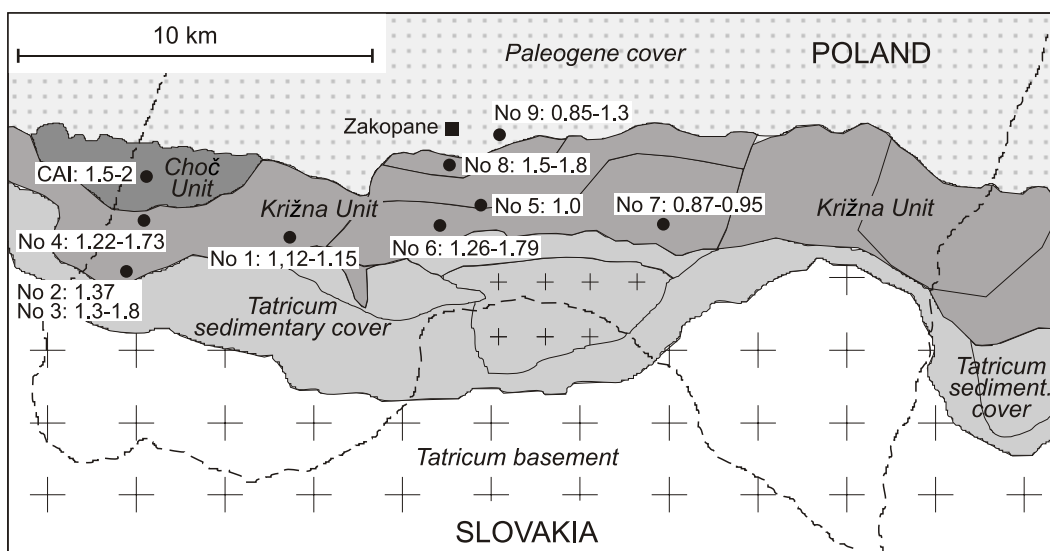


Figure 2
(Poprawa, Garbowski, Grotek)

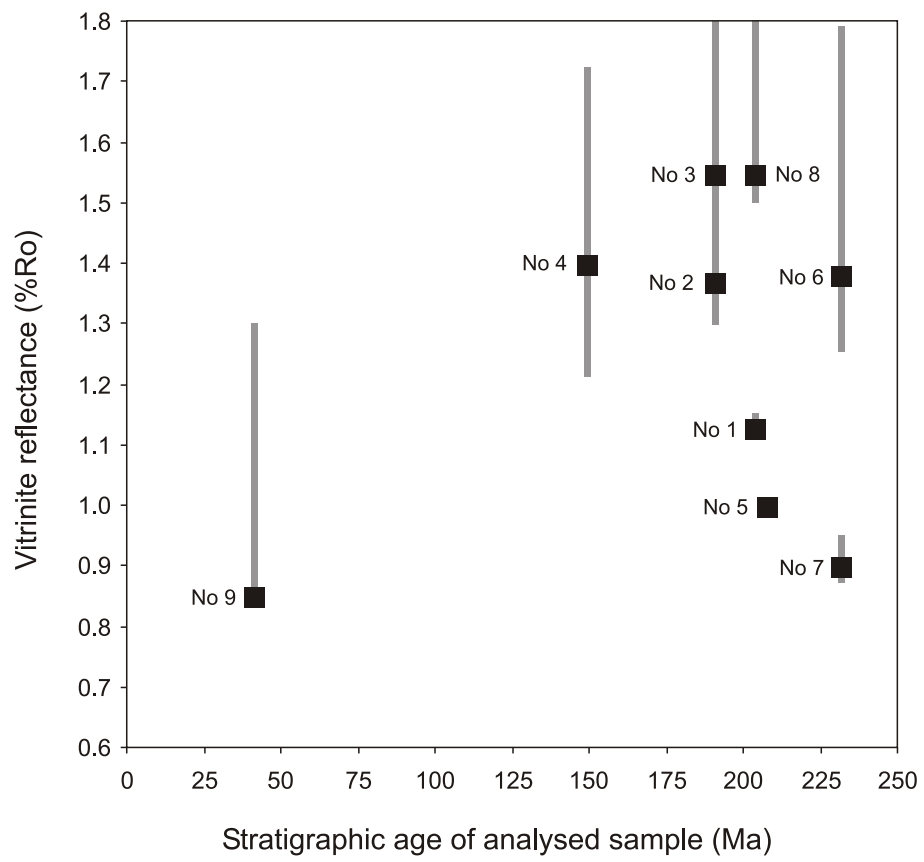


Figure 3
(Poprawa, Garbowski, Grotek)

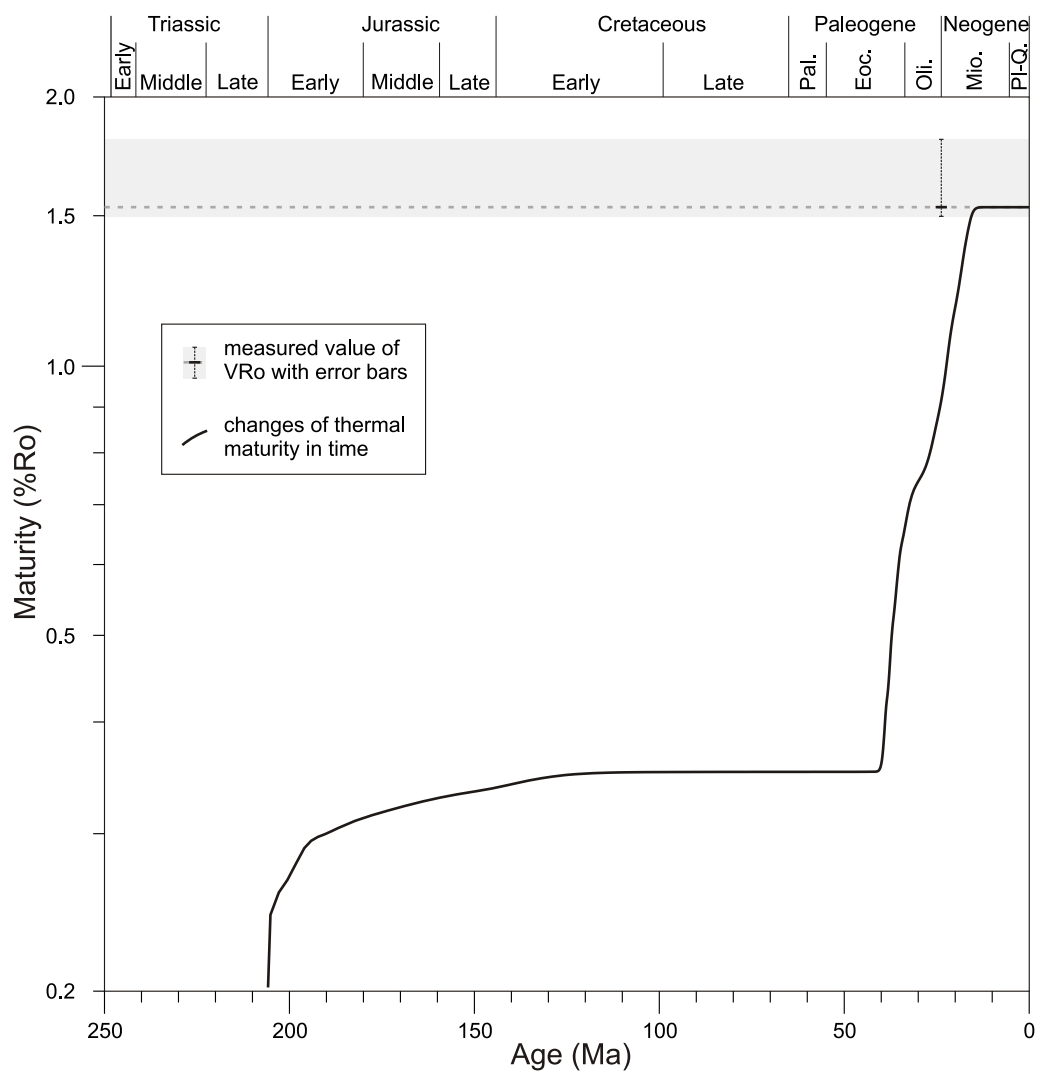


Figure 4a
(Poprawa, Garbowski, Grotek)

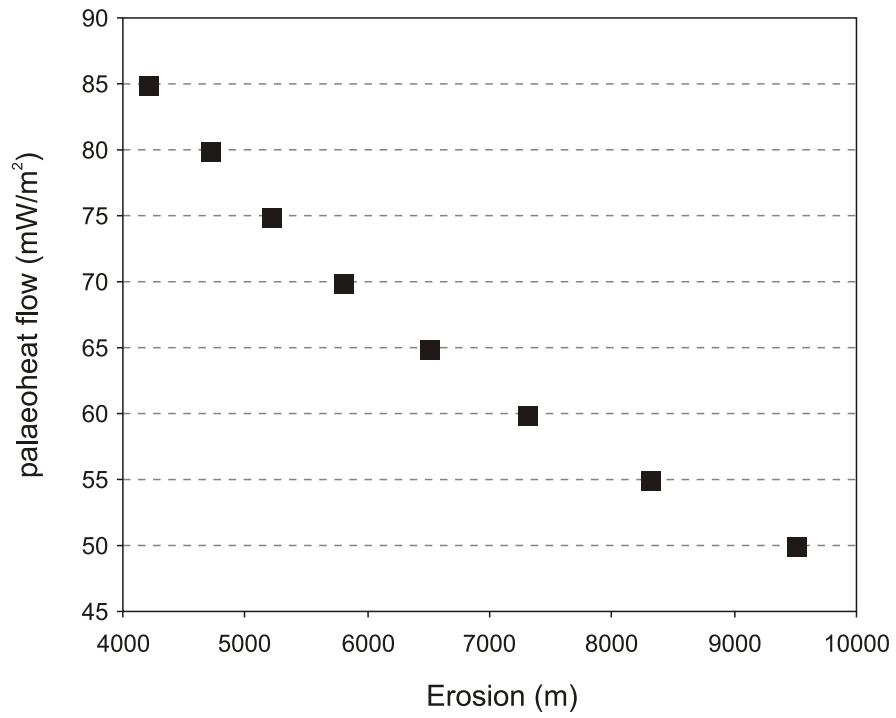


Figure 4b
(Poprawa, Garbowski, Grotek)

