Austrian Journal of Earth Sciences | Volume 102/2 | 120 - 133 | Vienna | 2009

Organic maturity trends across the Variscan discordance in the Alpine-Dinaric Transition Zone (Slovenia, Austria, Italy): Variscan versus Alpidic thermal overprint

Thomas RAINER[1)3)*)], Reinhard F. SACHSENHOFER[1)], Gerd RANTITSCH[1)],
Uroš HERLEC[2)] & Marko VRABEC[2)]

[1)] Mining University Leoben, Department for Applied Geosciences and Geophysics, 8700 Leoben, Austria;

[2)] University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Aškerčeva 12, 1000 Ljubljana, Slovenia;

[3)] Present Address: OMV Exploration & Production GmbH, Trabrennstrasse 6-8, 1020 Wien, Austria;

[*)] Corresponding author, thomas.rainer@omv.com

KEYWORDS

Vitrinite reflectance
Variscan Discordance
Northern Dinarides
Southern Alps
Carboniferous
Eastern Alps

Abstract

In the Southern Alps and the northern Dinarides the main Variscan deformation event occurred during Late Carboniferous (Bashkirian to Moscovian) time. It is represented locally by an angular unconformitiy, the “Variscan discordance”, separating the pre-Variscan basement from the post-Variscan (Moscovian to Cenozoic) sedimentary cover. The main aim of the present contribution is to investigate whether a Variscan thermal overprint can be detected and distinguished from an Alpine thermal overprint due to Permo-Mesozoic basin subsidence in the Alpine-Dinaric Transition Zone in Slovenia. Vitrinite reflectance (VR) is used as a temperature sensitive parameter to determine the thermal overprint of pre- and post-Variscan sedimentary successions in the eastern part of the Southern Alps (Carnic Alps, South Karawanken Range, Paški Kozjak, Konjiška Gora) and in the northern Dinarides (Sava Folds, Trnovo Nappe). Neither in the eastern part of the Southern Alps, nor in the northern Dinarides a break in coalification can be recognized across the “Variscan discordance”. Consequently the post-Variscan thermal overprint during Permo-Mesozoic passive continental margin evolution and/or Cenozoic Alpine orogeny reached at least the same intensity as the Variscan (Late Carboniferous) one. In the northern Dinarides (Sava Folds, Trnovo Nappe) Triassic and Cretaceous rocks reached a similar thermal maturity as the pre-Variscan ones. Therefore in these regions the Alpidic thermal overprint exceeded the Variscan one. The Alpidic thermal overprint in the northern Dinarides (Sava Folds, Trnovo Nappe) occurred in post-Late Cretaceous and pre-Mid Oligocene times. This is testified by a substantial gap in thermal maturity across the Upper Cretaceous – Middle Oligocene unconformity. Nappe stacking in the northern Dinarides had no impact on regional maturity patterns. Thermal maturity of post-Variscan Permo-Carboniferous rocks of the northern Dinarides is generally higher than in the South Karawanken Range and the Carnic Alps. This is a result of both, a deeper burial during Permo-Mesozoic basin subsidence and an accumulation of thick Paleogene flysch sediments during the Paleocene to Eocene Dinaric orogeny.

Die Hauptphase der variszischen Gebirgsbildung datiert in den Südalpen und den nördlichen Dinariden ins Oberkarbon (Bashkirian bis Moscovian). Ausdruck der tektonischen Bewegungen ist die „variszische Winkeldiskordanz“, die das prä-variszische Grundgebirge von der post-variszischen sedimentären Überlagerung (Moscovian bis Känozoikum) trennt. Vorrangiges Ziel dieser Studie ist es zu untersuchen, ob eine variszische thermische Überprägung der Gesteine im Bereich der alpin-dinarischen Übergangszone (Kärnten, Slowenien) nachgewiesen und von der durch die permo-mesozoische Beckenabsenkung verursachten alpinen thermischen Überprägung getrennt werden kann. Im Rahmen des Projektes wurde die Vitrinitreflexion (VR) als Indikator der thermischen Überprägung prä- und post-variszischer sedimentärer Abfolgen in den östlichen Ausläufern des Südalpins (Karnische Alpen, Südkarawanken, Paški Kozjak, Konjiška Gora) und den nördlichen Dinariden (Sava Falten, Trnovo Decke) bestimmt.

Ein Inkohlungssprung entlang der variszischen Winkeldiskordanz kann weder im Südalpin, noch in den nördlichen Dinariden nachgewiesen werden. Dies bedeutet, dass die post-variszische thermische Überprägung während der permo-mesozoischen Beckenabsenkung (passiver Kontinentalrand) und/oder der känozoischen alpinen Gebirgsbildungsphasen zumindest die Intensität der oberkarbonen variszischen Überprägung erreicht hat. In den nördlichen Dinariden (Sava Falten, Trnovo Decke) erreichen auch triassische und kretazische Gesteine die thermische Überprägung des prä-variszischen Hochwipfelflyschs (Oberkarbon). In diesen Gebieten sollte folglich die alpine thermische Überprägung die variszische übersteigen. Die alpine thermische Überprägung des Sedimentstapels ereignete sich nach der Oberkreide, jedoch vor dem Mitteloligozän. Dies wird durch einen bedeutenden Inkohlungssprung zwischen den Gesteinen der Oberkreide und des Mitteloligozäns der Sava Falten belegt. Deckenstapelung hat in den nördlichen Dinariden keinen erkennbaren Einfluss auf die Höhe der thermischen Überprägung der Gesteine. Die thermische Reife des post-variszischen Permokarbons ist in den nördlichen Dinariden generell höher als in den südalpinen Karnischen Alpen und den Südkarawanken. Dies wird durch eine tiefere Beckenabsenkung während des Permo-Mesozoikums und die Akkumulation mächtiger paleozäner und eozäner Flyschsedimente während der dinarischen Gebirgsbildung erklärt.

1. Introduction

The Variscan orogeny resulted from the Late Paleozoic continental collision of Laurussia (Laurentia-Baltica) with North-

Gondwana and some intervening microplates (e.g. Neubauer, 1988; Stampfli et al. 2002; Von Raumer et al. 2002; Ebner et al. 2008). In the Southern Alps and the northern Dinarides the main Variscan deformation event occurred during Late Carboniferous (Bashkirian to Moscovian; Schönlaub and Forke, 2007; Ebner et al., 2008) time. It is represented locally by an angular unconformitiy, the "Variscan discordance", separating the pre-Variscan basement from the post-Variscan (Moscovian to Cenozoic) sedimentary cover. In many areas of the Circum-Pannonian Realm the Variscan deformation is associated with a metamorphic overprint (e.g. Ebner et al., 2008).

The main aim of the present contribution is to investigate whether a Variscan thermal overprint can be detected and distinguished from an Alpine thermal overprint due to Permo-Mesozoic basin subsidence in the Alpine-Dinaric Transition Zone in Slovenia. To reach this goal, the thermal overprint of pre- and post-Variscan sedimentary successions is investigated in the eastern part of the Southern Alps (Carnic Alps, South Karawanken Range, Paški Kozjak, Konjiška Gora) and in the northern Dinarides (Sava Folds, Trnovo Nappe; Figs. 1, 2). Vitrinite reflectance is used as a sensitive parameter of maximum temperature (Taylor et al., 1998).

Previous investigations in the Southern Alpine realm (Carnic Alps, South Karawanken Range) demonstrated a continuous coalification trend across the "Variscan discordance" (Rantitsch, 1997; Rantitsch et al., 2000; Rantitsch and Rainer, 2003; Rantitsch, 2007). In the Carnic Alps, VR of the syn-orogenic Hochwipfel Formation and the post-Variscan Auernig Group along the Straninger and Waidegger Alm Section (Fig. 3) ranges from 3.8 to 5.9 % Rmax (Rantitsch et al., 2000). In the South Karawanken Range near Trögern (Fig. 3), VR in the same stratigraphic interval ranges from 5.3 to 6.8 % Rmax (Rantitsch et al., 2000).

No data are yet available from the Northern Dinarides.

2. Geological Setting

This contribution focuses on very low- to low-grade metamorphic Upper Paleozoic units of the eastern segment of the Southern Alps and the northern Dinarides (Fig. 1). The Southern Alps and the northern Dinarides form part of the Adria-Dinaria Megaterrane sensu Ebner et al. (2008). This megaterrane is of Mesozoic/Cenozoic (Alpine) age, but includes pre-Mesozoic sequences. The most complete Paleozoic succession is preserved in the Carnic Alps (Schönlaub and Forke, 2007), where Upper Ordovician to Lower Visean "pre-flysch" sediments are overlain by 1000 m thick siliciclastic flysch sediments (Hochwipfel Formation; Visean to Bashkirian). The Variscan climax occurred between the Bashkirian and the Early Moscovian and is documented locally by a spectacular angular unconformity ("Variscan discordance").

Both in the Southern Alps and the northern Dinarides, the "Variscan discordance" is overlain by shallow marine molasse sediments (e.g. Auernig, Rattendorf and Trogkofel Groups) with a late Moscovian to early Permian (Artinskian) age (Schönlaub and Forke, 2007; Ebner et al., 2008; Vozárová et al., 2009). The Trogkofel Group is unconformably overlain by non-marine (Tarvis Breccia, Gröden Formation) and shallow marine (Bellerophon Formation) deposits with a Kungurian to late Permian age.

A carbonate platform of a passive continental margin formed during Triassic times. It has been intersected by elongated deep-water basins, e.g. the E-W trending Slovenian Basin (Buser, 1987). The Slovenian Basin remained in a deep water setting from the Mid Triassic (Ladinian) to the Late Cretaceous. Within the study area, sediments of the Slovenian Basin crop out north of the Trnovo Nappe and in the Sava Folds (see Fig. 2).

The Alpine-Dinaric Transition Zone was affected by polyphase Alpine tectonics comprising the Maastrichtian "Eoalpine phase" (S directed thrusts), the Paleocene to Eocene „Dinaric" phase (SW directed thrusts), the Mid to Late Oligocene "South-Alpine" phase (S directed thrusts) and the "Alpine" event (S-SE directed thrusts) from Late Miocene onward (e.g. Doglioni and Bosellini, 1987; Placer and Čar, 1998; Placer, 1999a,b; Castellarin and Cantelli, 2000; Fig. 2).

In the western Southern Alps, N-S compression during the Maastrichtian "Eoalpine phase" constituted S directed overthrusts. Since Eocene flysch sediments lie discordantly on

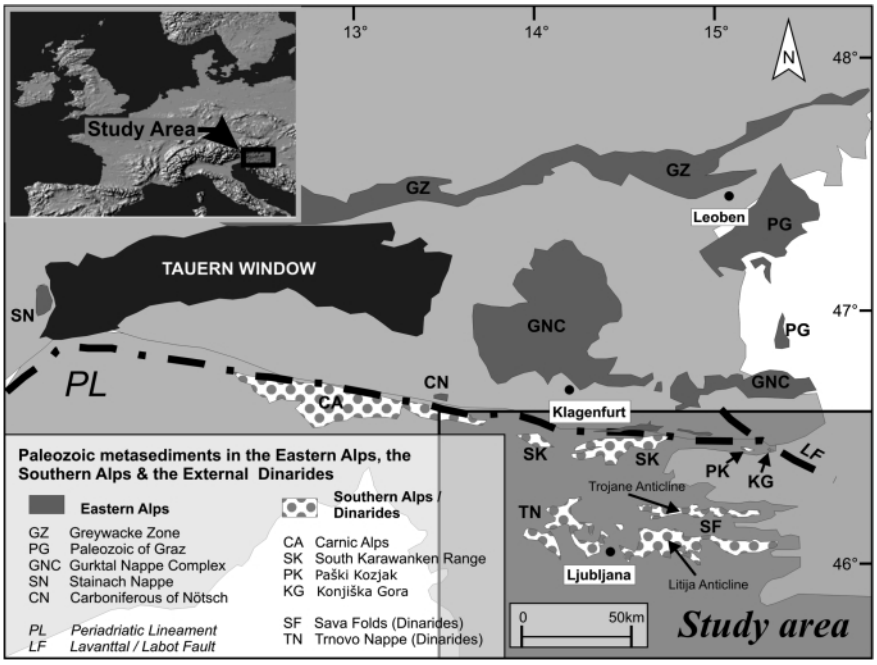

Figure 1: Paleozoic very low- to low-grade metamorphic units in the Eastern Alps, the Southern Alps and the Northern Dinarides (the study area is indicated by the grey shaded rectangle).

folded Maastrichtian flysch (e.g. Natisone Valley/Italy, see Fig. 2; Doglioni and Bosellini, 1987), the Late Cretaceous orogenic phase possibly affected the eastern Southern Alps and parts of the Dinarides as well. In the well Cargnacco-1 (Fig. 2), a maturity break between Upper Cretaceous and Lower Paleogene sediments was recognized by Fantoni et al. (2002). “Eoalpine” heated sediments are also reported from the Mt. Medvednica (Dinarides, Judik et al., 2008; Fig. 2) and the basement of the Pannonian Basin System (Igal unit; Árkai et al., 1991).

The “Dinaric” phase was accompanied by the deposition of thick Eocene flysch sediments (e.g. Rainer, 2003).

During the Cenozoic “Alpine” orogeny compressional and extensional phases occurred. A main extensional phase during the Oligocene (Läufer, 1996) is recorded by the emplacement of intrusives along the Periadriatic Lineament (e.g. Laubscher, 1983).

Apatite fission track cooling ages of the South Karawanken Range vary from Late Eocene (36.48 +/- 1.49 Ma) to Early Oligocene (31.72 +/- 1.89 Ma), investigated on rocks of the Werfen Grp. and Auernig Grp. of the Seeberg Rise (Nemes, 1997). Compression resulted in S-SE directed thrusting and in the reactivation of Mesozoic normal faults and Dinaric thrusts as strike-slip faults. Some of these SE trending dextral faults are still active, e.g. the Idrija Line (e.g. Mlakar, 1969) and the Periadriatic Lineament (e.g. Vrabec et al., 2006).

3. Samples and analytical techniques

3.1 Samples

Samples have been taken from sediments beneath (up to Baskirian) and above the “Variscan discordance” (Kasimovian and younger) in the Southern Alps and the northern Dinardes.

Southern Alps: The thermal overprint across the “Variscan discordance” in the Carnic Alps and the Trögern section in the South Karawanken Range was investigated by Rantitsch (1997), Rantitsch and Rainer (2003) and Brime et al. (2008). In order to achieve a better regional coverage, additional samples from the syn-orogenic Hochwipfel Formation and the post-Variscan Auernig Group have been taken in the central and eastern part of the Carnic Alps (8 samples), the South Karawanken Range and its eastern continuation in the Paški Kozjak and the Konjiška Gora (19 samples). An additional sample represents the Auernig Group south of the Sava Fault in the Julian Alps.

Northern Dinarides: Carboniferous and Lower Permian strata

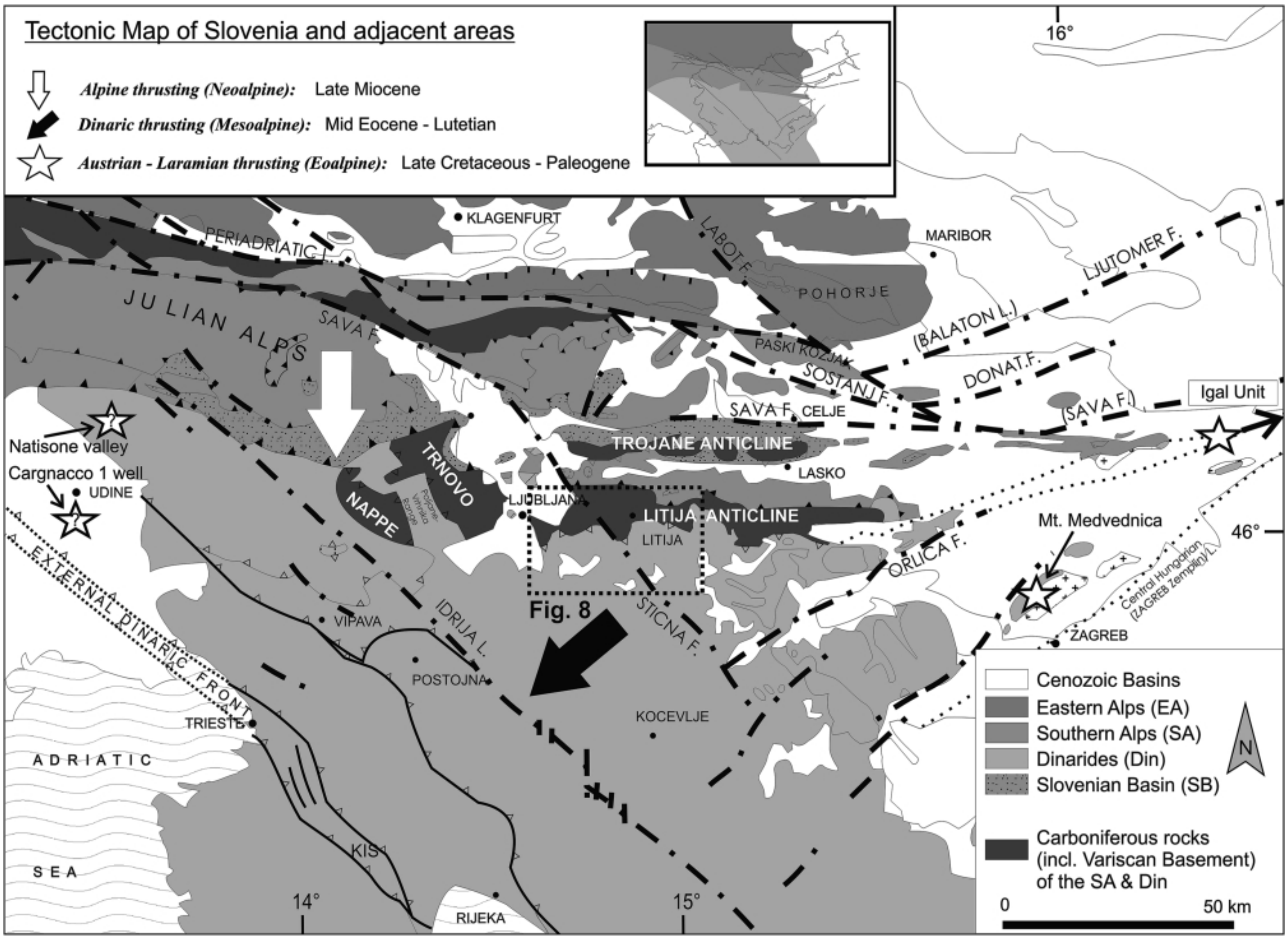

Figure 2: Tectonic map of the Alpine–Dinaric transition zone (modified from Placer, 1999b). The direction of Alpine and Dinaric thrusting is indicated by arrows. Carboniferous rocks of the Southern Alps and the Dinarides are shaded in dark gray (see legend). Note the rectangle for the location of the pre-Mid or pre-Late Oligocene nappe structure shown in Fig. 7.

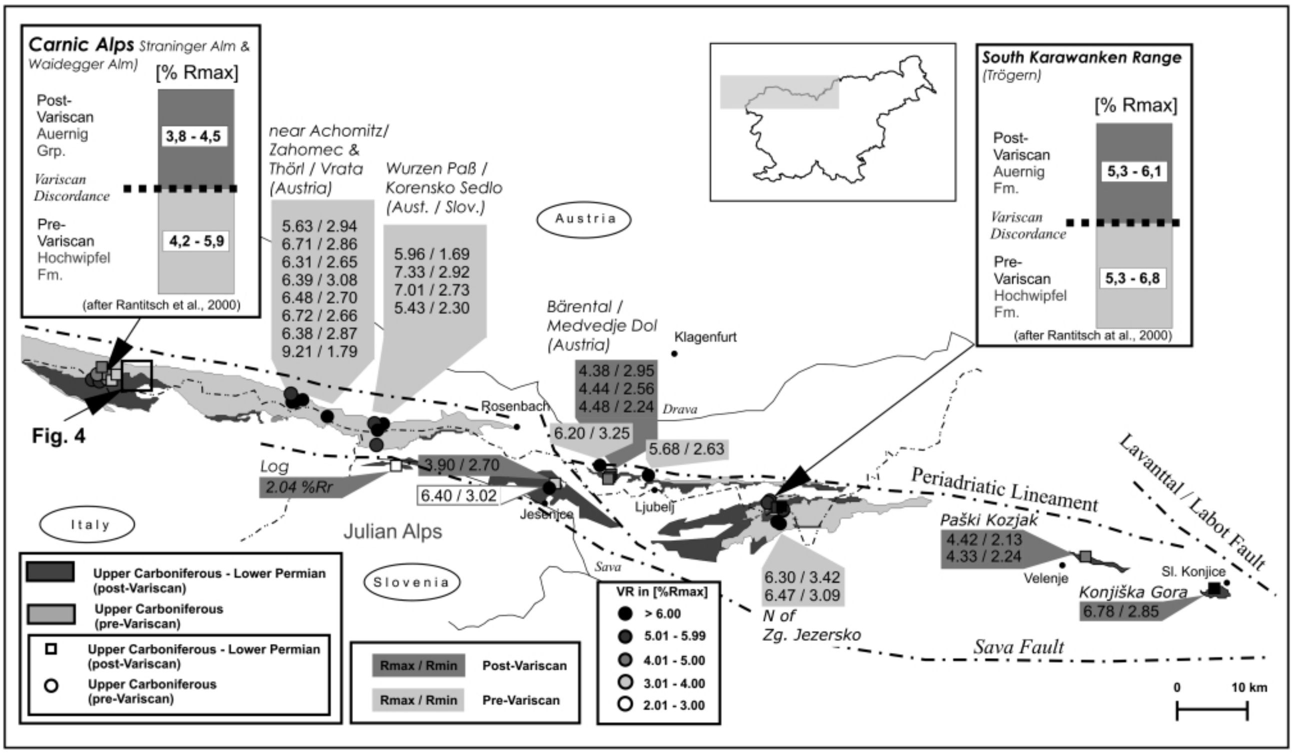

Figure 3: Vitrinite reflectance (% Rmax / % Rmin) of pre-Variscan and post-Variscan Upper Carboniferous to Lower Permian sediments in the Carnic Alps, the South Karawanken Range and its eastern continuation – the Paški Kozjak and the Konjiška Gora (Southern Alps).

are not differentiated in the geological maps 1:100.000 of central Slovenia, but are mapped as “Permocarboniferous” (see sheets Kranj: Grad and Ferjančič, 1974; Ljubljana: Premru, 1982; Celje: Buser, 1977; Rogatec: Aničić and Juriša, 1984). However, Mlakar (1985/86, 1994/95a,b, 2001a,b) and Mlakar et al. (1992) provided the exact (pre-Variscan vs. post-Variscan) stratigraphic position of some localities.

In the Trojane Anticline (northern anticline of the Sava Folds; Fig. 2) three pre-Variscan (Hochwipfel Fm.) and 14 post-Variscan (fluvial sandstones of the Permian Gröden Formation and black shales of the Ladinian Pseudozilian Formation) samples were investigated. In the southern Litija Anticline six slates of the Hochwipfel Formation and five samples of the Auernig Group have been taken near the village Litija. Thermal maturity data of Upper Triassic (Carnian) coals and Cretaceous rocks are included in this study. In the Trnovo Nappe (W of Ljubljana; Fig. 2) the thermal overprint of three slates from the Hochwipfel Formation is compared with the overprint of six samples from the Gröden Formation.

The exact stratigraphic pre- or post Variscan age of 27 Permo-Carboniferous samples (according to the geological maps 1:100.000) in the Sava Folds and the Trnovo Nappe remains uncertain.

3.2 Analytical techniques

Vitrinite reflectance (VR) was used to determine the organic maturity of the samples. Vitrinite is formed by humification of higher plant remnants. During thermal maturation the reflectance of non-polarized light on vitrinite (random VR; % Rr) increases. Rising temperature and stress result in observable reflectance anisotropy in polarized light. Measuring reflectance in polarized light during microscope stage rotation gives information about the maximum (% Rmax), the minimum (% Rmin) reflectance and the bireflectance (Rmax-Rmin). Polished samples cut perpendicular to the bedding of foliation are used to evaluate the reflectance anisotropy. The relationship

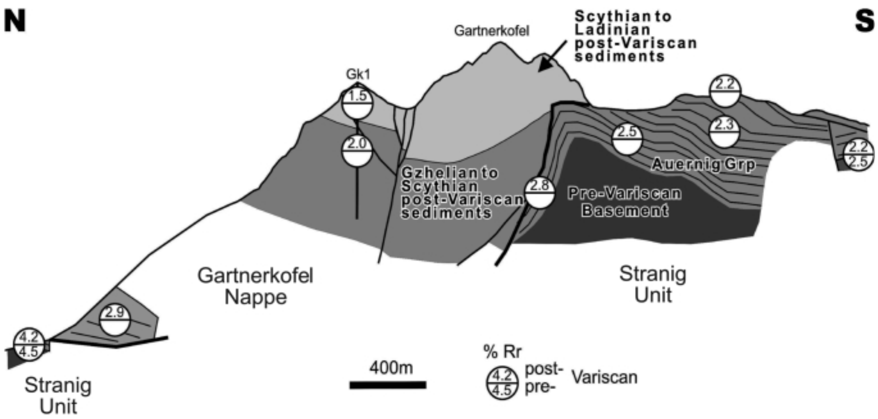

Figure 4: Vitrinite reflectance (% Rr) in the Naßfeld Section (redrawn from Schönlaub and Forke, 2007) including the data of the Gartnerkofel1 (Gk1) well (Rainer and Rantitsch 2002) and the data of Rantitsch (2007). VR in the Gartnerkofel Nappe (Schönlaub and Forke, 2007) corresponds to the data from the southern segment of the tectonically lower Stranig Unit (Schönlaub and Forke, 2007), but shows lower VR values than the northern segment of the Stranig Unit.

between random VR (% Rr) and maximum VR (% Rmax) was described by Koch and Günther (1995).

The investigated samples were mainly siliciclastic, e.g. dark slates, siltstones, sandstones and marls. Locally the maturity was also evaluated from coals or marly carbonates. VR measurement was performed on whole rock samples with the advantage that the organic material can be studied in its original position within the mineral matrix. Weathered and oxidized organic remains can be more easily recognized. Oxidized vitrinites, which may occur e.g. along the bedding planes of sandstones, are not incorporated in the present study due to sometimes dramatically reduced reflectance. Vitrinites and inertinites can be distinguished from solid bitumen only in an undisturbed sample, organolite concentrates are unsuitable (Jakob, 1989). Moreover, only polished blocks of whole rock samples cut perpendicular to the bedding lead to exact measurements of reflectance anisotropy.

Solid bitumen occurred mainly in carbonatic samples within pores and microfractures. However, since the reflectance of solid bitumen differs from VR (Jakob, 1989; Schönherr et al., 2007), the focus was put on measuring the reflectance of vitrinites. Solid bitumen reflectance is available for sample 377 (Carnian; Sava Folds).

VR measurements were carried out using a Leica MPV-SP microscope and 50/0.85 and 125/1.30 oil immersion objectives and following standard procedures (Taylor et al., 1998). A synthetic garnet standard (1.69 % Rr) and a wolfram-carbid standard (7.24 % Rr) were used for calibration. The aim was to measure at least 30 particles per sample.

Random VR (% Rr) is an input parameter for the estimations of peak paleotemperatures after Barker (1988) or Barker and Pawlewicz (1994), which are widely used time-independent tools to convert VR values into paleotemperatures. In the present study the formula Tpeak = (lnRr + 1.68)/0.0124 for burial heating after Barker and Pawlewicz (1994) is used. The formula is calibrated up to 7 %Rr (Tab. 1 in Barker and Pawlewicz, 1994). According to Underwood et al. (1993) estimates of paleotemperature should be rounded to the nearest

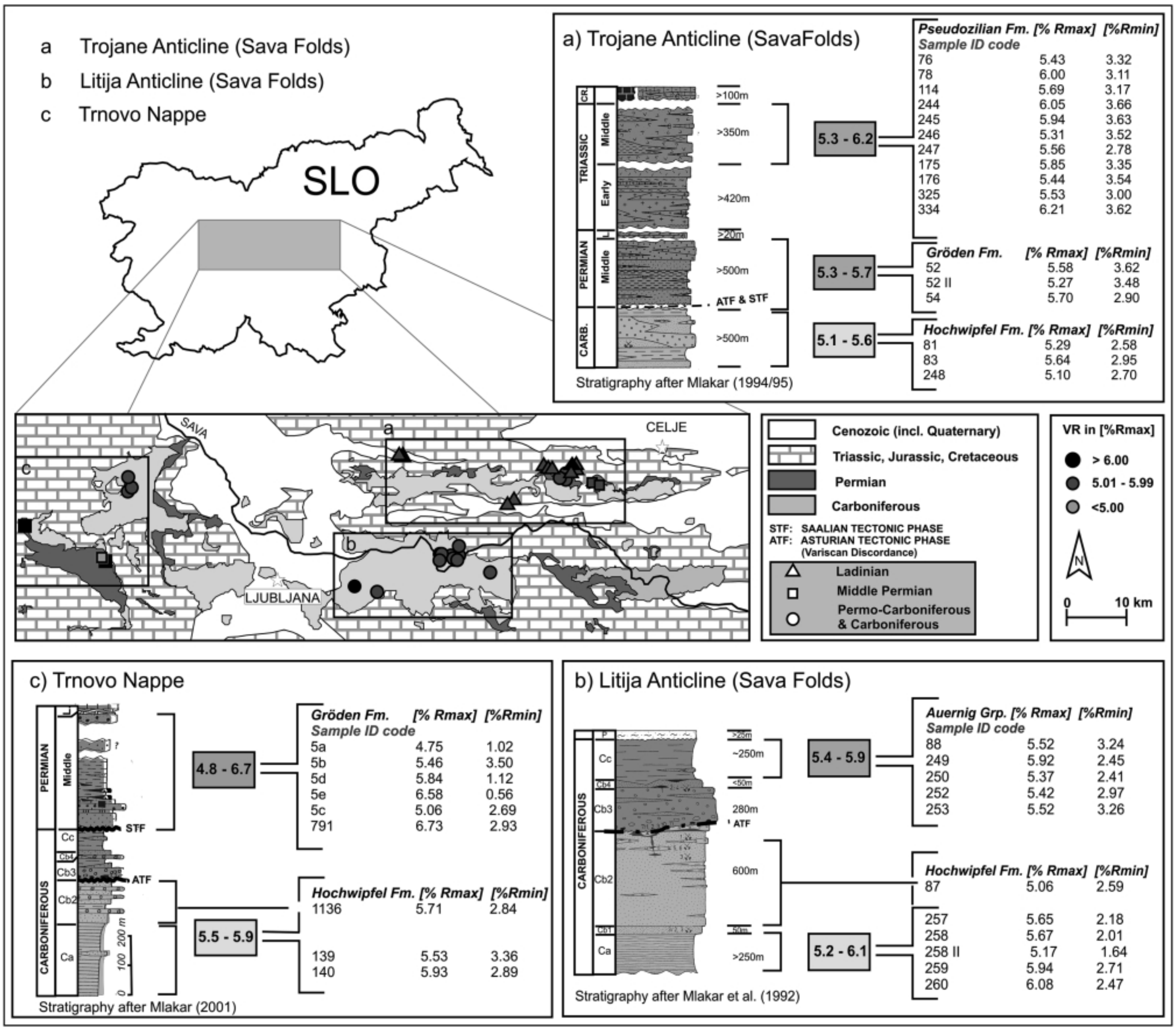

FIGURE 5: Vitrinite reflectance of pre-Variscan and post-Variscan sediments of the northern Dinarides (Sava Folds, Trnovo Nappe).

10 °C. The error associated with paleotemperature estimates is roughly ±30 °C.

A LECO CS-300 TM analyzer was used to determine the total organic carbon (TOC = Corg) content of selected samples. The TOC describes the quantity of organic carbon in a rock sample, including both kerogen and bitumen. The analysis results are shown in the tables.

4. Results and Discussion

VR data for the Carnic Alps and the South Karawanken Range are presented in Figs. 3, 4 and Tabs. 1, 2. Data for the Sava Folds and Trnovo Nappe are shown in Figs. 5, 6 and Tabs. 3a,b and 4. The maturity of all Carboniferous samples reaches the anthracite, partly also the meta-anthracite stage of organic metamorphism (Taylor et al., 1998). This fits well with the observation that according to clay mineral diagenesis (Illite-“Crystallinity”, contents in pyrophyllite and paragonite; Rainer et al., 2003) the studied Carboniferous samples are late diagenetic to anchimetamorphic. Illite-“Crystallinity” data are incorporated in the Tables of the present study. Pyrophyllite, detected in the Upper Carboniferous of the South Karawanken Range (sample 963), is an indicator mineral for late diagenesis and anchizone. For additional data and details see Rainer et al. (2003). Cleavages e.g. parallel to the bedding give also indications of metamorphism (e.g. in Carboniferous slates and siltstones of the Sava Folds; Trajanova, 2001).

4.1 Carnic Alps and South Karawanken Range

New VR data are available from the Carnic Alps, the South Karawanken Range and its eastern continuation – the Paški Kozjak and the Konjiška Gora (Fig. 3). One sample from the area of the Julian Alps (S of the dextral Sava Fault) completes the set. Since no continuous stratigraphic sections from pre-Variscan to post-Variscan sediments were available, the samples were taken from “isolated” localities.

Organic maturity of the Hochwipfel Formation and the Auernig Group at the Naßfeld Section (Carnic Alps) is presented in Fig. 4. The data (Fig. 4) prove a break of organic maturity across the northern trace of a thrust fault of uncertain age (Schönlaub and Forke, 2007) which was reactivated as a normal fault (Gartnerkofel Normal Fault) during Miocene times. This pattern may be explained by a thrust-related overprint of the autochthonous Stranig-Unit below the Gartnerkofel Nappe (Schönlaub and Forke, 2007).

Slates of the pre-Variscan Hochwipfel Formation of the Carnic Alps near Achomitz (Zahomec) and Thörl (Vrata) show VR values from 5.63 to 6.72 % Rmax. One sample (949) has an abnormally high VR value (9.21 % Rmax). In coarser parts of the samples also “graphitic particles” were recognized. The “graphitic particles” usually have a fine anisotropic mosaic texture.

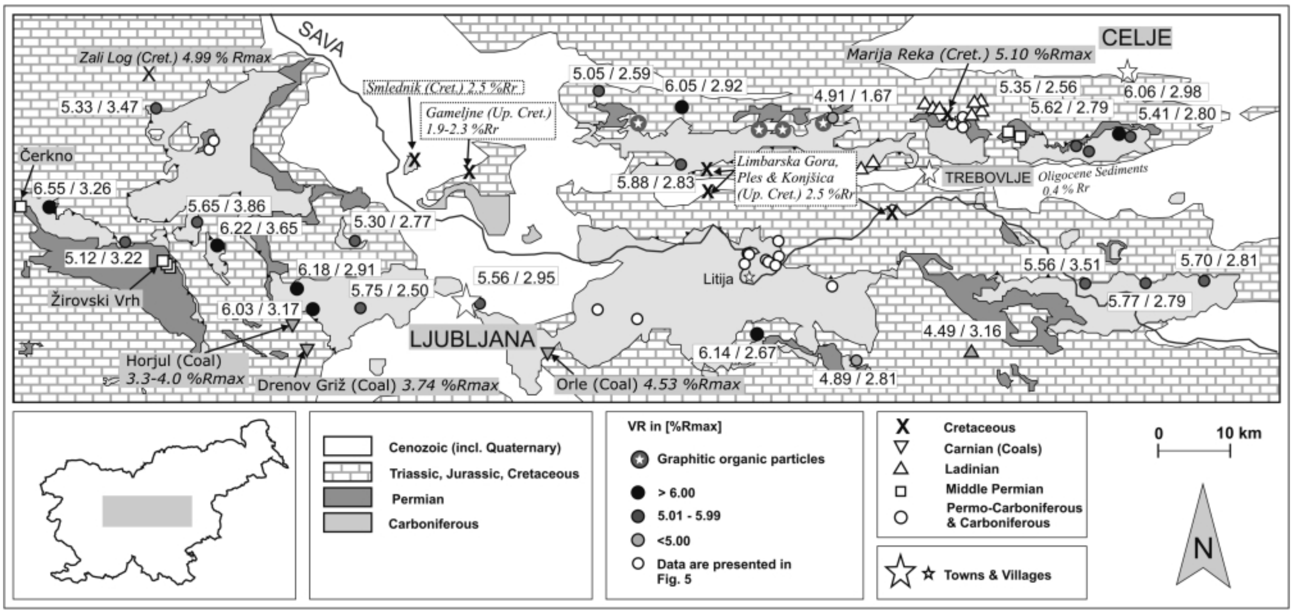

Figure 6: Vitrinite reflectance (Rmax / Rmin) of Permo-Carboniferous rocks in the northern Dinarides (Sava Folds and Trnovo Nappe) with uncertain stratigraphic position in relation to the Variscan discordance. Note also localities and vitrinite reflectance of Triassic and Cretaceous rocks (Rr) mentioned in the text. Samples presented in Figure 5 are shown as white icons.

As demonstrated by the values at the Wurzen Pass (Korensko sedlo), NW of Ljubelj and N of Zg. Jezersko (5.43 to 7.33 % Rmax), the maturity pattern within the central Carnic Alps is prolonged to the South Karawanken Range.

Post-Variscan slates and carbonates of the Auernig Group north of Jesenice (Planina pod Golico) and NW of Ljubelj (Bärental/Medvedje Dol) show VR values between 3.90 % (sample 159a) and 4.48 % Rmax, corresponding to Rr values between 2.58 and 3.20 % Rr. These maturity values are slightly higher than VR of other Upper Carboniferous to Lower Permian (Pečar, 1985/86; Jurkovšek, 1986, Budkovic, 1999; Brenčič et al., 1995) black shales in the Jesenice area (1.9 and 2.3 % Rr; Rainer, 2003).

Locally north of Jesenice, slates with Rmax values >6 % were sampled (samples 159b and 390). Since the sample 159b was taken from the same outcrop as sample 159a (VR 3.90 % Rmax), reworked organic material may have caused the high VR values. Sample 390 contains rock chips taken from the soil along a road cut and is therefore not shown in Fig. 3. The high Rmax values suggest a pre-Variscan age of the sample. However, no pre-Variscan strata was mapped in this area, therefore the region north of Jesenice should be re-evaluated, when new geological maps are available.

The mean random VR for selected samples of the Hochwipfel Formation and the post-Variscan Auernig Group within the South Karawanken Range varies from 2.58 to 4.54 % Rr (see Tab. 2). According to the equation of Barker and Pawlewicz (1994) these values correspond to peak-paleotemperatures of 210 to 260 ± 30 °C. This is consistent with results of numeric 1D basin models for the Carnic Alps (Rantitsch, 1997) and the South Karawanken Range (Rantitsch and Rainer, 2003), indicating that the Auernig Group at the base of the Alpidic sedimentary cycle was heated to 200-270 °C during Mesozoic maximum sedimentary burial.

In the eastern continuation of the South Karawanken Range, in the area of the Paški Kozjak mountain ridge (E of Velenje, situated between the PL and the Sostanj Fault), post-Variscan Carboniferous slates show a similar thermal overprint as the South Karawanken Range (4.33 – 4.42 % Rmax). A higher maturity was recognized at the Konjiška Gora (S of Konjiška Vas), where slates, presumably with a post-Variscan age, reach 6.78 % Rmax. However, the high thermal overprint suggests a pre-Variscan age of these sediments.

A thermal overprint similar to the Naßfeld section (Fig. 4) and the area north of Jesenice (Rainer, 2003) is recognized in the Julian Alps, south of the dextral Sava Fault (see Fig. 2). Clastics of the post-Variscan Auernig Group reach 2.04 % Rr. In that area rocks of the South Karawanken Range are overlain by the Triassic sequence of the Julian Alps (Ramovš and Kochanksy-Devide, 1979; 1981). Generally the thermal maturity of Mesozoic rocks in the Julian Alps is lower than the maturity of the South Karawanken Range and the Slovenian Basin (e.g. Rainer, 2003, Rainer et al., 2005).

In summary, the present study broadens the data base of thermal maturity data in the area of the Carnic Alps and the South Karawanken Range. The maturity data of the investigated localities fit well with published data from sections across the Variscan discordance (Rantitsch et al., 2000, Rantitsch, 2007) and confirm the missing break in thermal overprint across the Variscan discordance in the Carnic Alps and the South Karawanken Range. A local variation of organic maturity within

ID-	Sampling location			Sht	Lithostratig.	Rr	Stdev	n	PPT	Rmax	Stdev	Rmin	Stdev	n	BR
Code	X	Y			Unit	[%]			[°C]	[%]		[%]			
Carnic Alps (Nassfeld) *Note: Coordinates acc. Österr. Bundesmeldenetz*															
P1	5447460	5156494	Naßfeld		Hochwipfel Fm.	2,16	0,25	30	198						
P2	5447465	5156590	Naßfeld		Hochwipfel Fm.	2,25	0,21	30	201						
P2A	5446530	5156880	Naßfeld		Hochwipfel Fm.	2,44	0,30	43	208						
P3	5445680	5157105	Naßfeld		Hochwipfel Fm.	2,60	0,27	44	213						
P4	5445900	5157150	Naßfeld		Hochwipfel Fm.	2,51	0,24	35	210						
P5	5445860	5157280	Naßfeld		Hochwipfel Fm.	2,37	0,25	30	205						
P8	5446159	5157254	Naßfeld		Hochwipfel Fm.	2,31	0,32	50	203						
P9A	5446760	5157260	Naßfeld		Hochwipfel Fm.	2,06	0,20	35	194						
P9B	5446760	5157260	Naßfeld		Hochwipfel Fm.	2,13	0,30	28	197						
P9	5446760	5157260	Naßfeld		Auernig Grp.	2,01	0,21	30	192						
P10	5447550	5157145	Naßfeld		Auernig Grp.	2,13	0,16	30	197						
P11	5447824	5156945	Naßfeld		Auernig Grp.	2,01	0,23	30	192						
GR0906	5447376	5158127	Naßfeld		Auernig Grp.	2,25	0,14	30	201						
GR1006	5447361	5158277	Naßfeld		Auernig Grp.	2,25	0,26	30	201						
GR1106	5447226	5158172	Naßfeld		Auernig Grp.	2,09	0,12	30	195						
GR1206	5446446	5157947	Naßfeld		Auernig Grp.	2,32	0,14	30	204						
GR1306	5445651	5158067	Naßfeld		Auernig Grp.	2,46	0,24	32	208						
GR1406	5445646	5158287	Naßfeld		Auernig Grp.	2,77	0,28	30	218						
GR1506	5445926	5158792	Naßfeld		Auernig Grp.	2,76	0,2	30	218						
GR1606	5445666	5160242	Naßfeld		Auernig Grp.	2,89	0,23	40	221						
GR1706	5446281	5161292	Naßfeld		Auernig Grp.	2,79	0,2	30	219						
GR1806	5445976	5161937	Naßfeld		Auernig Grp.	4,21	0,3	30	252						
GR1906	5446656	5162282	Naßfeld		Hochwipfel Fm.	4,05	0,28	30	249						
Carnic Alps (near Achomitz)															
940	5397280	5155775	Maglern, river Gailitz (highway-bridge)	26	Hochwipfel Fm.					6,38	0,62	2,87	0,41	30	3,52
941	5392180	5159665	SW of Feistritz ca. 1 km to Omberg	25	Hochwipfel Fm.					5,63	0,43	2,94	0,31	23	2,70
948	5393725	5158920	SW of Achomitz	25	Hochwipfel Fm.					6,72	0,49	2,66	0,30	30	4,06
949	5393240	5159070	SW of Achomitz	25	Hochwipfel Fm.					9,21	0,57	1,79	0,30	30	7,42
950	5392665	5159000	SW of Achomitz	25	Hochwipfel Fm.					6,48	0,44	2,70	0,39	30	3,78
951	5392495	5158990	SW of Achomitz	25	Hochwipfel Fm.					6,39	0,32	3,08	0,31	30	3,31
952	5392350	5158975	SW of Achomitz	25	Hochwipfel Fm.					6,31	0,45	2,65	0,27	30	3,65
953	5392210	5158945	SW of Achomitz	25	Hochwipfel Fm.					6,71	0,52	2,86	0,37	30	3,85

Table 1: Vitrinite reflectance of Carboniferous pre- and post-Variscan sediments of the Carnic Alps (Southern Alps).
Note: Sampling location according to Slovenian Coordinate System; Sht: Sheet in Slovenian Atlas 1:50.000; Rr: mean random vitrinite reflectance; Stdev: standard deviation; n: number of measurements; PPT: peak-paleotemperature after Barker and Pawlewicz, 1994; Rmax: maximum vitrinite reflectance; Rmin: minimum vitrinite reflectance; BR: Bireflectance; IC: Illite-“Crystallinity” (taken from Rainer et al., 2002).

the Naßfeld section is explained by Alpine thrust faulting.

Maturity at the base of the "Alpine" sedimentary cycle (Auernig Group) is similar in the Carnic Alps, the western part of the South Karawanken Range (Jesenice area and NW of Ljubelj) and the basement of the Julian Alps. Data from the Trögern section are significantly higher and indicate an eastward increase in thermal overprint in the post-Variscan cover sequence (Rantitsch and Rainer, 2003). This eastward increase

ID-	Sampling location			Sht	Lithology	Lithostratig.	Rr	Stdev	n	PPT	Rmax	Stdev	Rmin	Stdev	n	BR	IC
Code	X	Y				Unit	[%]			[°C]	[%]		[%]				[d2°O]
South Karawanken Range																	
159	5427835	5147635	300 m NE of the church in Planina	55	black slate w/ mica-rich sandst.	Auernig Grp.	2,58	0,23	50	212	3,90	0,22	2,70	0,28	30	1,20	
159	5427835	5147635	300 m NE of the church in Planina	55	black slate w/ mica-rich sandst.						6,40	0,28	3,10	0,23	30	3,30	
390	5427370	5146820	Planina (300 m S of Dom pod Golico)	55	black mica-rich sand- / siltstone						6,29	0,34	3,02	0,44	30	3,27	
961	5437591	5148167	E Kosiak-hut	56	black carbonate	Auernig Grp.					4,26	0,19	2,82	0,30	30	1,43	
962	5437743	5148126	E Kosiak-hut	56	black carbonate	Auernig Grp.					4,48	0,20	2,24	0,36	30	2,24	
963	5437806	5148085	E Kosiak-hut	56	greysh-blueish siltstone	Auernig Grp.	3,20	0,13	50	230	4,44	0,19	2,56	0,32	30	1,88	0,44
964	5437829	5147989	E Kosiak-hut	56	greysh-blueish marly siltstone	Auernig Grp.	3,18	0,20	50	229	4,38	0,19	2,95	0,35	30	1,43	
901			Village Trögern	58	black siltstone	Auernig Grp.	3,56	0,26	66	238	5,26	0,45	2,46	0,74	30	2,80	
902			Village Trögern	58	black slate with mica	Auernig Grp.	4,40	0,29	40	255	6,09	0,65	2,90	0,60	30	3,19	0,43
903			Village Trögern	58	black slate with mica	Hochw. Fm.	3,68	0,22	51	241	5,35	0,47	3,32	0,44	30	2,03	0,41
904			Village Trögern	58	black slate	Hochw. Fm.	4,88	0,29	66	264	6,77	0,64	3,44	0,57	30	3,32	
905			Village Trögern	58	black slate	Hochw. Fm.	4,13	0,41	88	250	5,84	0,68	3,06	0,43	30	2,78	
906			Village Trögern	58	black slate	Hochw. Fm.	4,54	0,31	50	258	5,26	0,41	2,49	0,45	30	2,76	
1022	5443500	5147918	1 km north of Brodi / Loibl-Valley	57	blue-black siltstone	Hochw. Fm.					5,68	0,43	2,83	0,57	30	2,85	
956	5436620	5149423	Medvodje dol; 4.8 km S of Feistritz	56	blue-black shist	Hochw. Fm.					6,20	0,32	3,25	0,43	30	2,94	0,45
934	5404655	5154521	Wurzenpass - sea-level ca. 1000 m	27	grey-blue shist (loc.graph. Part.)	Hochw. Fm.					7,01	0,44	2,73	0,33	30	4,28	0,34
937	5404130	5155400	Wurzenpass	27	grey shist	Hochw. Fm.					5,96	0,58	1,69	0,28	30	4,26	
938	5405355	5155492	Wurzenpass - sea-level ca. 800 m	27	grey shist	Hochw. Fm.					7,33	0,88	2,92	0,59	30	4,41	
500	5404461	5152480	1 km S of the Wurzenpass	27	grey laminated siltstone	Hochw. Fm.					5,43	0,57	2,30	0,57	30	3,13	
155	5462032	5141442	800 m N of farm Zakovo / Zg. Jezersko	59	grey sericitic slate	Hochw. Fm.					6,30	0,59	3,42	0,51	30	2,89	0,39
156	5462503	5141184	1400 m N from farm Zak. to Zg. Jezersko	59	black slate	Hochw. Fm.					6,47	0,37	3,09	0,50	30	3,38	
Eastern continuation of the South Karawanken Range (Paški Kozjak, Konjiška Gora)																	
1050	5512691	5136914	Between Redrjak and Dren / Paški Kozjak	64	bright carbonate + black shist	Auernig Grp.	3,26	0,20	50	231							
394	5512378	5137169	N of the mountain Jesenik	64	grey siltstone with mica	Auernig Grp.					4,33	0,32	2,24	0,32	4	2,09	
741	5534691	5130293	Ca. 1 km S Konjiška vas	92	grey siltstone with mica	Auernig Grp.					6,78	0,47	2,85	0,38	30	3,93	
741	5534691	5130293	Ca. 1 km S Konjiška vas	92	grey siltstone with mica	Auernig Grp.					6,78	0,47	2,85	0,38	30	3,93	
Julian Alps																	
1114	5408675	5149221	In gorge ca. 500 m S Log / Kranjška Gora	53	grey marly sericitic siltstone	Auernig Grp.	2,04	0,09	20	193							0,68

TABLE 2: Vitrinite reflectance of Carboniferous pre- and post-Variscan sediments of the South Karawanken Range and its eastern prolongation (Southern Alps).
Note: Sampling location according to Slovenian Coordinate System; Sht: Sheet in Slovenian Atlas 1:50.000; Rr: mean random vitrinite reflectance; Stdev: standard deviation; n: number of measurements; PPT: peak-paleotemperature after Barker and Pawlewicz, 1994; Rmax: maximum vitrinite reflectance; Rmin: minimum vitrinite reflectance; BR: Bireflectance; IC: Illite-"Crystallinity" (taken from Rainer et al., 2002).

ID-	Sampling location			Sht	Lithology	Age	Lithostratig.	Rr	Stdev	n	PPT	Rmax	Stdev	Rmin	Stdev	n	BR	IC	TOC
Code	X	Y					Unit	[%]			[°C]	[%]		[%]				[d2°O]	[wt.%]
Sava Folds																			
326	5503914	5116799	50 m S of farm Urancar / Marija Reka	111	carbonate / marl	Lo. Cret.		4,33	0,28	50	254	5,10	0,34	2,59	0,37	30	2,51		
9	x	x	Coal mine Orle - Collection Univ. Ljubljana	127	coal	Carnian	Raibl Fm.	3,20	0,23	50	230	4,53	0,33	2,60	0,31	30	1,93		74,6
376	5496948	5091666	Near Catez (50 m; direction Razbore)	150	black marl	Carnian		3,23	0,24	50	230							0,60	
377	5496819	5091722	Near Catez (200 m; direction Razbore)	150	black marl	Carnian	*Solid Bit. ->*	4,10	0,24	50	250								0,4
372	5506815	5095813	Street Ravne to Brod	131	grey-blue siltstone	Ladinian	Pseudocil. Fm.	3,76	0,23	50	243	4,49	0,28	3,16	0,36	30	1,34		
334	5480746	5119279	From the main road to Stebljevek	109	black siltstone	Ladinian	Pseudocil. Fm.	5,06	0,36	50	267	6,21	0,46	3,62	0,37	30	2,59		
114	5480224	5119400	At the junction to Selise (near Smartno)	108	black shale	Ladinian	Pseudocil. Fm.	3,83	0,31	52	244	5,69	0,35	3,17	0,36	30	2,53		1,8
76	5502668	5117876	Ca. 800 m E of house Konjsca (Miklavz)	111	black-grey shale.	Ladinian	Pseudocil. Fm.	4,49	0,41	50	257	5,43	0,43	3,32	0,29	30	2,11		0,2
78	5503094	5117421	300 m N of house Grmarenk (Klickov vrh)	111	black shale	Ladinian	Pseudocil. Fm.	4,25	0,27	64	253	6,00	0,43	3,11	0,57	30	2,89		0,5
244	5506863	5117919	400 m NE of Kranjcev mlin; Marija Reka	111	black slate	Ladinian	Pseudocil. Fm.	4,67	0,50	50	260	6,05	0,52	3,66	0,35	32	2,40	0,30	
245	5507225	5118151	Forest-road opposite Strgar; Marija Reka	111	black slate	Ladinian	Pseudocil. Fm.	3,97	0,26	50	247	5,94	0,47	3,63	0,44	30	2,31	0,42	
246	5507491	5117257	Ca. 50 m S of Zapeternik, Marija Reka	111	black slate	Ladinian	Pseudocil. Fm.	4,15	0,34	50	251	5,31	0,34	3,52	0,55	30	1,79		
247	5506792	5116945	400 m N of farm Baker, Marija Reka	111	black slate.	Ladinian	Pseudocil. Fm.	4,38	0,28	31	255	5,56	0,59	2,78	0,56	30	2,78		
325	5503721	5116982	20 m W of farm Urancar / Marija Reka	111	grey-blue siltstone	Ladinian	Pseudocil. Fm.	4,88	0,27	50	264	5,53	0,49	3,00	0,38	30	2,53		1,5
175	5497151	5112088	Between Sp. Izlake and Gamberk	110	black slate.	Ladinian	Pseudocil. Fm.	4,77	0,58	50	262	5,85	0,32	3,35	0,39	30	2,50	0,34	1,4
176	5497908	5112678	200 m SE of Gamberk	110	black slate.	Ladinian	Pseudocil. Fm.	3,75	0,35	50	242	5,44	0,48	3,54	0,60	45	1,90	0,35	
447	5493448	5094064	From Misji Dol to Gradisce (after u-turn)	150	grey marl (coaly frag.)	Ladinian	Pseudocil. Fm.	3,39	0,23	54	234								
457	5493416	5094112	From Misji Dol to Gradisce (near u-turn)	150	black marl	Ladinian	Pseudocil. Fm.	3,52	0,30	50	237								
446	5484879	5093967	500 m N of M. Goricica (N Sticna)	149	grey marl	Ladinian	Pseudocil. Fm.	3,11	0,28	14	227								
52	5511418	5114812	Graben E of farm Podebarsek (Zg. Recica)	112	black slates	M. Perm.	Gröden Fm.	4,39	0,14	30	255	5,58	0,63	3,62	0,49	30	1,96		1,2
52G	5511458	5115068	Graben E of farm Podebarsek (Zg. Recica)	112	black slates	M. Perm.	Gröden Fm.					5,27	0,38	3,48	0,39	30	1,79		
54	5510058	5115401	Along the forest-road S of Mt. Suhi Hrib	112	dark slate	M. Perm.	Gröden Fm.					5,70	0,41	2,90	0,32	30	2,80		1,1
455	5498474	5092560	Street from Tlaka to Krzisce (roadcut)	150	black siltstone	M. Perm.		3,73	0,21	50	242								

TABLE 3A: Vitrinite reflectance of Permian to Cretaceous sediments of the Sava Folds (Northern Dinarides).
Note: Sampling location according to Slovenian Coordinate System; Sht: Sheet in Slovenian Atlas 1:50.000; Rr: mean random vitrinite reflectance; Stdev: standard deviation; n: number of measurements; PPT: Peak-paleotemperature after Barker and Pawlewicz, 1994; Rmax: maximum vitrinite reflectance; Rmin: minimum vitrinite reflectance; BR: Bireflectance; IC: Illite-"Crystallinity" (taken from Rainer et al., 2002); TOC: Total Organic Carbon content.

in thermal maturity is also visible in Triassic sediments (Rantitsch and Rainer, 2003; Rainer, 2003). It may reflect a higher geothermal gradient or a thicker overburden succession accumulating during basinal subsidence in the Trögern area.

The interpretation of the VR pattern in the Jesenice area is hampered by an uncertain stratigraphy and has to be confirmed by further studies.

4.2 Northern Dinarides (Sava Folds and Trnovo Nappe)

In the area of the Trojane Anticline (i.e. northern anticline of the Sava Folds; Fig. 5a) dark slates of the pre-Variscan Hochwipfel Formation reach VR values up to 5.64 % Rmax, whereas VR in the post-Variscan rocks of the Permian Gröden Formation and the Middle Triassic (Ladinian) Pseudozilian Formation reaches 5.58 and 6.21 % Rmax, respectively. It is important to note, that Lower Cretaceous rocks (e.g. near the village Marija Reka) at the northern limb of the Trojane Anticline also

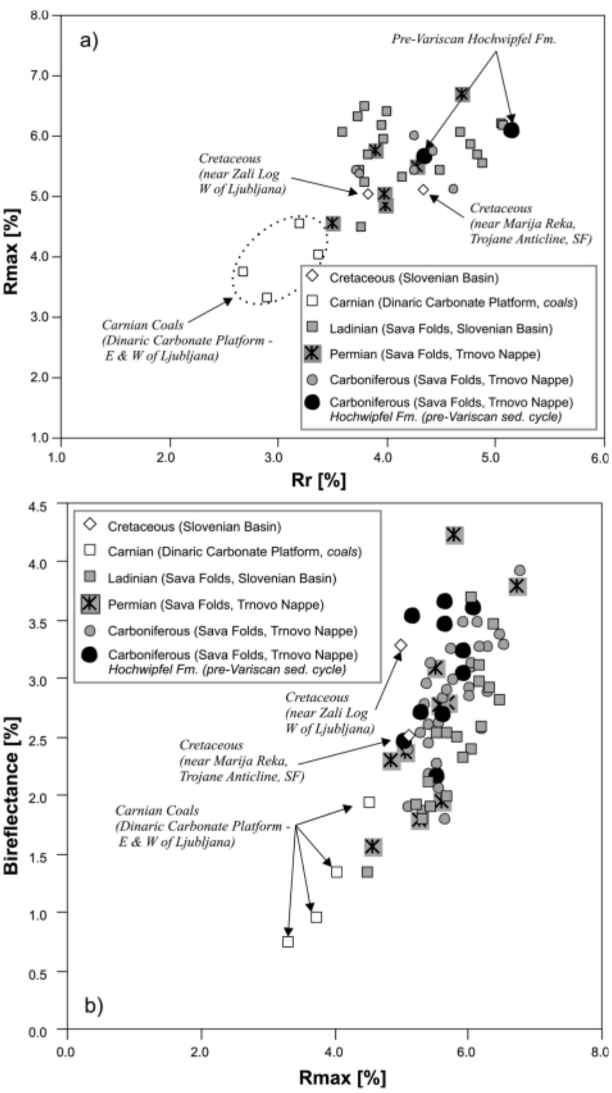

Figure 7: (a) Rmax versus Rr and (b) Bireflectance (Rmax - Rmin) versus Rmax cross-plots of pre- and post-Variscan sediments of the Sava Folds, the Trnovo Nappe and the Dinaric Carbonate Platform. Selected samples of the Slovenian Basin are included.

reach a similar maturity (5.10 % Rmax). Locally, especially in the western part of the Trojane Anticline (between Obrše and Šentgotard), "graphitic particles" with a fine anisotropic mosaic texture occur (Fig. 6). These particles are not favourable for reflectance measurements, due to their small size and the mosaic texture.

In the Litija Anticline (southern part of the Sava Folds; Fig. 5b) VR values in slates of the Hochwipfel Formation are similar (5.06 - 6.08 % Rmax) to VR values in rocks of the Auernig Group (5.42 - 5.92 % Rmax).

In the Trnovo Nappe west of Ljubljana (Fig. 5c), slates of the Hochwipfel Formation show VR values between 5.53 and 5.93 % Rmax, whereas VR of drift wood in the Permian Gröden Formation from the former Uranium mine at Žirovski Vrh ranges from 4.75 to 6.58 % Rmax. Coaly sandstone of the Gröden Formation from the abandoned copper mine near Čerkno reaches 6.73 % Rmax.

VR of Permo-Carboniferous slates of uncertain stratigraphic position in relation to the Variscan discordance results in similar maturity data (Fig. 6). VR results of Triassic and Cretaceous rocks are also shown in Fig. 6.

The VR data clearly show that in the northern Dinarides of central Slovenia (Sava Folds, Trnovo Nappe) the post-Variscan rocks reach the same maturity level as the pre-Variscan one. The high thermal maturity of the post-Variscan sedimentary cycle is also demonstrated by cross-plots of bireflectance [% Rmax – % Rmin] vs. % Rmax and % Rmax vs. % Rr (Fig. 7). Triassic (Ladinian Pseudozilian Fm.) and Lower Cretaceous rocks in the Trojane Anticline (e.g. near Marija Reka) and Cretaceous rocks from the Slovenian Basin W of Ljubljana (e.g. near Zali Log) suffered the same thermal overprint as the pre-Variscan Upper Carboniferous sediments. This is also approved by clay mineralogical investigations (Rainer et al., 2002), which indicate that Cretaceous rocks reach the anchizone.

Presented mean random VR of Carboniferous to Cretaceous rocks in the Sava Folds and the Trnovo Nappe varies from 3.75 to 5.18 % Rr (see Tabs. 3a,b and 4). According to the equation of Barker and Pawlewicz (1994), these VR values correspond to peak-paleotemperatures of 240 to 270 ± 30 °C.

Carnian coals from the N Dinarides east and west of Ljubljana (Orle, Drenov Griž, Horjul; Fig. 6) show a slightly lower thermal maturity (Fig. 7): Rmax ranges from 3.31 to 4.53 %. The mean random VR of 2.69 - 3.38 % Rr correspond to peak-paleotemperatures of ~215 to 235 °C +/- 30 °C.

In the Sava Folds no break in thermal maturity between pre-Variscan Carboniferous slates and post-Variscan Carboniferous to Lower Cretaceous sediments is recognized. According to Rainer (2003) high thermal maturity characterizes Upper Cretaceous rocks (Fig. 6): VR in Aptian to Cenomanian rocks near Smlednik (NW of Ljubljana) is ~2.5 % Rr, VR in Turonian to Senonian marls of the southern limb of the Trojane Anticline (S of Limbarska Gora) is ~2.4 % Rr, VR in coeval marls from the northern limb of the Litija Anticline (near the villages Ples and Konjšica) is ~2.5 % Rr, and VR in Upper Cretaceous black marls from a quarry N of Gameljne (N of Ljubljana) is

1.9 to 2.3 % Rr. Consequently, the thermal overprint was achieved during post-Senonian (post-Maastrichtian) times. On the other hand, VR in middle Oligocene rocks of the Pannonian Basin System preserved in the synclines of the Sava Folds shows a much lower thermal overprint (~0.4 % Rr; Sachsenhofer et al., 2001). Therefore, a post-Late Cretaceous pre-Mid Oligocene thermal overprint is responsible for the high maturity of Carboniferous to Cretaceous sediments at the NW edge of the Dinarides. Considering the equation of Barker and Pawlewicz (1994) the Upper Cretaceous (Senonian) rocks experienced a paleotemperature of ~190 °C, whereas the Middle Oligocene deposits reached only ~60 °C.

During Cenozoic times the Dinaric (Mid Eocene-Lutetian), South-Alpine (Mid to Late Oligocene) and Alpine (Mid to Late Miocene) orogenic events affected the Alpine-Dinaric transition zone. Deep burial due to thrusting can cause a thermal overprint. The thermal effect of nappe stacking is fairly easy recognizable when VR data are integrated into a tectono-stratigraphic framework.

In the area of the Sava Folds, a pre-Mid (Late?) Oligocene nappe structure is reported from the Litija Anticline (Mlakar, 1985/86; Fig. 8). The uppermost tectonic unit, the Dolsko overthrust, rests on top of the Žiri overthrust (Mlakar, 1985/86). The latter, mainly composed of Upper Paleozoic clastic rocks, is locally thrusted onto the Dinaric Carbonate Platform. The Dolsko overthrust can be divided into a lower ("1st part") and an upper tectonic slice ("2nd part"). Mainly Middle and Upper Triassic carbonate rocks occur in the lower part, whereas the upper part starts with Upper Paleozoic strata and terminates with Upper Triassic sediments.

The integration of the VR data into the tectono-stratigraphic model of Mlakar (1985/86) shows a maturity inversion between the upper and lower part of the Dolsko overthrust (Fig. 8a). If the VR data of all investigated overthrust units are ordered according to their depositional age, a clear stratigraphic "top to bottom" increase from Upper Triassic (~3.2 % Rr) to Lower Carboniferous (>4 % Rr) strata is recognized (Fig. 8b). Consequently, the pre-Mid or Late Oligocene nappe piling post-dates the thermal overprint.

No other Dinaric (Paleogene) thrusts are known in the study area, which could have caused the thermal overprint. The intensive folding and uplift of the W-E oriented Sava Folds within the Sava compressive wedge during the Miocene (post-Sarmatian) or presumingly Pliocene (Placer, 1999a) post-dates the pre-mid Oligocene maturation of the Paleozoic and Mesozoic basement.

This proves that nappe stacking in this region had no impact on the thermal maturity. Consequently, the regional maturity pattern is a result of basin subsidence. Most likely the accumulation of thick Paleogene flysch sediments in the vicinity of

ID-	Sampling location			Sht	Lithology	Age	Lithostratig.	Rr	Stdev	n	PPT	Rmax	Stdev	Rmin	Stdev	n	BR	IC	TOC
Code	X	Y					Unit	[%]			[°C]	[%]		[%]				[d2°O]	[wt.%]
Sava Folds																			
42	5486224	5114769	S of Petelinjek	109	black slate	Carb.		graphitic										0,30	0,9
43	5490343	5115623	N of Ucak	109	black slate	Carb.		graphitic											1,3
61	5493737	5116242	800 m from Sentgotard to Zaplanina	110	dark slate	Carb.		graphitic										0,34	0,6
44	5520240	5114723	From Jagosce to Doblatina	113	black slate	Carb.						5,41	0,54	2,80	0,58	30	2,61		0,5
45	5519475	5115048	From Jagosce to Doblatina	113	silver-black slate	Carb.						6,06	0,56	2,98	0,43	30	3,09		1,0
46	5515714	5114271	Outcrop along the street 400 m W of Slivno	112	black siltstones	Carb.						5,35	0,36	2,56	0,42	30	2,78		0,6
50	5516592	5113746	From Sp. Recica to Slivno	112	silver-grey slate	Carb.						5,62	0,46	2,79	0,51	30	2,83		0,6
1054	5494372	5116576	Near Laznik in Limovce	110	grey siltstone	PermCarb.		3,58	0,26	50	239	4,91	0,34	1,67	0,22	30	3,24		
115	5480218	5117604	Above the farm Kavkez near Psajnovica	108	black slate	Carb.						6,04	0,54	2,92	0,43	30	3,13		1,1
118	5476894	5116266	400 m SW Obrse	108	black slate	Carb.		graphitic										0,29	1,1
127	5480844	5112101	150 m E Sv Mohor	109	black slate	Carb.		3,81	0,38	50	244	5,88	0,65	2,83	0,46	10	3,05		0,8
261	5521403	5101770	Road from Breg to Polana	133	dark slate	Carb.						5,77	0,54	2,79	0,47	30	2,98		
265	5526720	5102150	Podgorje - ca. 500 m W of farm Stope	133	black slate	Carb.						5,70	0,51	2,81	0,46	30	2,89		
306	5516358	5101858	400 m NW Loka pri Zidanem Mosta	132	black slate	Carb.						5,56	0,49	3,51	0,35	30	2,05		
337	5473014	5118925	W of G. Palovce; junction Trebelno	108	silvery siltstone	Carb.						5,05	0,37	2,59	0,47	16	2,46		
456	5496200	5094661	From Moravce to Kamni Vrh (ca. 1.5 km)	150	black siltstone	Carb.		4,18	0,29	16	251	4,89	0,31	2,81	0,42	18	2,09		
458	5486903	5097284	S of farmer Rojsek near Podroje	129	grey sandstone	Carb.		5,18	0,22	30	269	6,14	0,54	2,67	0,46	50	3,48		
15	5462414	5100546	Ljubljana; near the castle; stari grad	127	dark slate	Carb.						5,56	0,46	2,95	0,57	30	2,62		
88	5489092	5104153	Forest road near Ponovice (to the W)	129	black slate	Carb.	Auernig Grp.	3,71	0,40	57	242	5,42	0,59	3,24	0,45	30	2,18	0,47	0,7
249	5488270	5103732	1.7 km to the W alongroad near Pomovice	129	blueblack slate	Carb.	Auernig Grp.	4,87	0,27	30	263	5,92	0,47	2,45	0,50	30	3,48		
250	5488198	5103812	1.9 km to the W along road near Pomovice	129	blueblack slate	Carb.	Auernig Grp.	3,75	0,26	51	243	5,37	0,57	2,41	0,50	30	2,96		
252	5488560	5103795	1.5 km to the W along road near Pomovice	129	blueblack slate	Carb.	Auernig Grp.	4,26	0,20	26	253	5,42	0,33	2,97	0,37	30	2,45		
253	5489071	5105582	On the way to the farm Osredek (just N)	129	grey siltstone	Carb.	Auernig Grp.					5,52	0,35	3,26	0,52	30	2,26		
81	5504454	5115881	Near Podprecna (S of Marija Reka)	111	black slate	Carb.	Hochwipfel Fm.					5,29	0,41	2,58	0,55	30	2,71		0,6
83	5505587	5115762	Along the road from Vrhe to the E	111	dark slate ; HCl-	Carb.	Hochwipfel Fm.					5,64	0,42	2,95	0,55	23	2,69		0,9
248	5505554	5116672	500 m S Kregar, Marija Reka	111	grey-black slate	Carb.	Hochwipfel Fm.					5,10	0,35	2,70	0,38	30	2,40		
257	5486022	5103577	Street Pogonik-Sv. Jurij (600m N of Sv. J.)	129	blueblack slate	Carb.	Hochwipfel Fm.					5,65	0,13	2,18	0,30	30	3,46		
258	5486612	5104469	Curve at Pogonik (site of road works)	129	blueblack slate	Carb.	Hochwipfel Fm.	4,35	0,21	121	254	5,67	0,85	2,01	0,61	30	3,66	0,26	
258	5486612	5104469	Curve at Pogonik (site of road works)	129	dark sandstone	Carb.	Hochwipfel Fm.					5,17	0,84	1,64	0,56	29	3,53		
259	5476288	5098920	Sp. Besica; junction to Gabrje pri Jancah	128	blue-grey siltst.	Carb.	Hochwipfel Fm.	4,32	0,34	30	254	5,94	0,66	2,71	0,58	30	3,24		
260	5472720	5099701	From Besnica to farm Pecar (ca. 900 m)	128	sericite; grey slate	Carb.	Hochwipfel Fm.	5,15	0,46	52	268	6,08	0,60	2,47	0,41	30	3,60		
87	5493939	5101712	Ca. 500 m S of Sv. Janez (near Mamolj)	130	black slate	Carb.	Hochwipfel Fm.					5,06	0,15	2,59	0,87	6	2,47		0,4

Table 3b: Vitrinite reflectance of Carboniferous pre- and post-Variscan sediments of the Sava Folds (Northern Dinarides).
Note: Sampling location according to Slovenian Coordinate System; Sht: Sheet in Slovenian Atlas 1:50.000; Rr: mean random vitrinite reflectance; Stdev: standard deviation; n: number of measurements; PPT: Peak-paleotemperature after Barker and Pawlewicz, 1994; Rmax: maximum vitrinite reflectance; Rmin: minimum vitrinite reflectance; BR: Bireflectance; IC: Illite-"Crystallinity" (taken from Rainer et al., 2002); TOC: Total Organic Carbon content.

the uplifting Dinaric orogen has caused the post-Late Cretaceous pre-Mid Oligocene thermal overprint of the Alpine-Dinaric Transition Zone (Rainer, 2003; Rainer et al., 2005). Due to uplift, the thick Paleogene flysch sediments were subsequently eroded in the area of the Sava Folds and the Trnovo Nappe. However, these sediments are preserved on the Adriatic-Dinaric Carbonate Platform (e.g. SW Slovenia, Croatia) and in eastern Friuli (Italy), where according to Tunis and Ven-

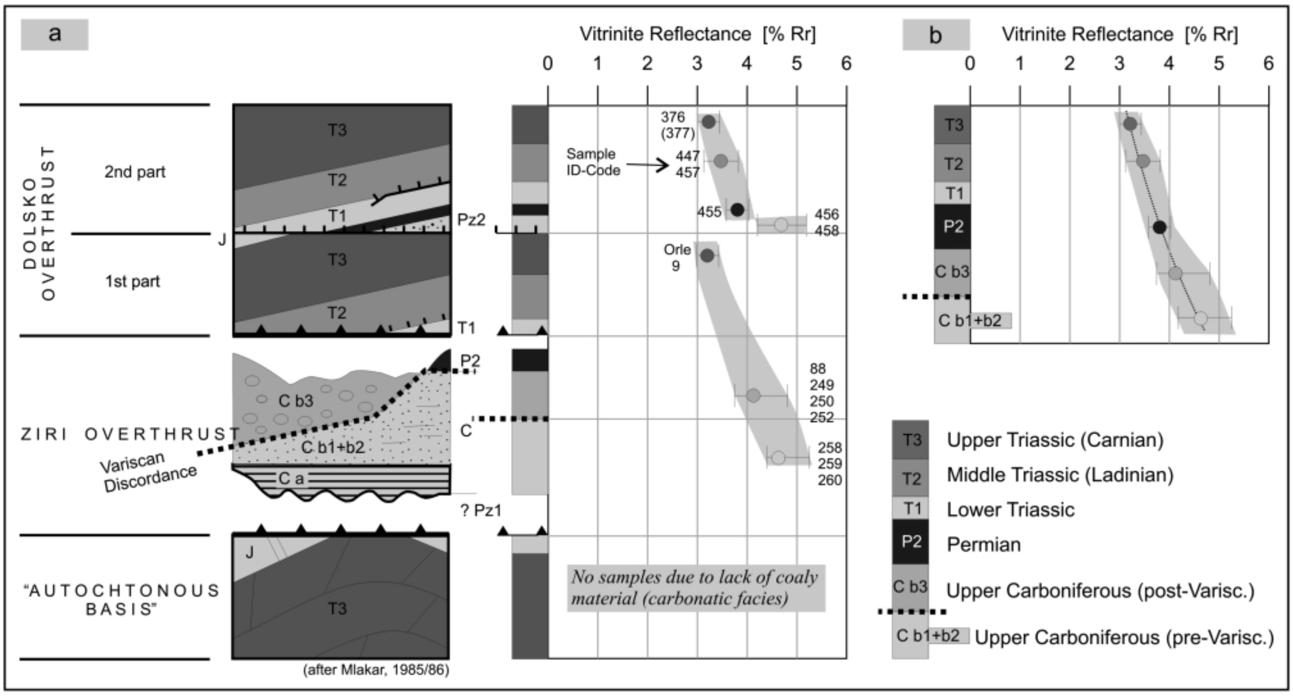

FIGURE 8: Pre-Middle or pre-Late Oligocene nappe structure of the southern Sava Folds. The maturity study indicates a pre-tectonic thermal overprint of the sediment stack. At the transition zone from the Sava Folds to the Dinaric Carbonate Platform ?pre Middle - Late Oligocene thrusting caused a disruption of the former uniform Upper Carboniferous to Triassic sediment sequence (a). The observed vitrinite reflectance values show a clear top-to-bottom increase from Upper Triassic (~3.2 % Rr) to Lower Carboniferous (>4 % Rr) strata (b). Therefore a pre-tectonic thermal overprint of the transition zone from the Sava Folds to the Dinaric Carbonate Platform is confirmed.

ID-	Sampling location			Sht	Lithology	Age	Lithostratig.	Rr	Stdev	n	PPT	Rmax	Stdev	Rmin	Stdev	n	Br	IC	TOC
Code	X	Y					Unit	[%]			[°C]	[%]		[%]				[d2°O]	[wt.%]
Trnovo Nappe																			
5a	Žirovski Vrh		Uranium mine; Obzorje 430 m; P-10; Vzorec I2/1	124	coal	M. Permian	Gröden Fm.					4,75	0,32	1,02	0,18	17	3,72		
5b			Uranium mine; Obrusek 7/1-2 - Univ. Ljub.	124	coal	M. Permian	Gröden Fm.					5,46	0,27	3,50	0,26	26	1,96		
5c			Uranium mine - Collection Univ. Ljubljana	124	coal	M. Permian	Gröden Fm.	3,97	0,29	50	247	5,06	0,41	2,69	0,66	30	2,37		
5d			Obzorje 480m; H54; 35-40 m; Vzorec 2c/2 - Univ. Ljubljana	124	coal	M. Permian	Gröden Fm.	3,88	0,95	50	245	5,84	0,60	1,12	0,34	30	4,72		
5e			Obzorje 480m; H54; 35-40 m; Vzorec 2c/l - Univ. Ljubljana	124	coal	M. Permian	Gröden Fm.	3,90	0,69	50	246	6,58	0,28	0,56	0,56	30	6,02		
791	Cerkno		Cu-mine; 47 m - Collection Univ. Ljubljana	102	sandstone with coal	M. Permian		4,69	0,70	107	260	6,73	0,42	2,93	0,73	30	3,79		
131	5450490	5106235	6,9 km S Sora junction	125	black shale	Carb.						5,30	0,63	2,77	0,45	30	2,54	0,42	0,6
141	5434036	5117432	Junction near Farm Vancer	104	dark slate	Carb.						5,33	0,33	3,47	0,48	6	1,86		0,4
290	5451654	5099575	50 m E of farm Skodlar, Brezje pri Dobrovi	126	silver-grey-black slate	Carb.		4,43	0,29	88	256	5,75	0,47	2,50	0,55	30	3,25		
301	5430669	5105437	1 km S Trebija (in direction Selo)	123	black slate	Carb.		4,62	0,18	25	259	5,12	0,51	3,22	0,30	30	1,90	0,43	
700	5447636	5099185	1.2 km N Zaklanec (after the junction to the Roznik)	125	grey siltstone	Carb.						6,03	0,63	3,17	0,48	30	2,85	0,41	
717	5437639	5106456	N of the farm Kocar at Vinharje	124	black finely foliat. slate	Carb.						5,65	0,28	3,86	0,53	30	1,79		
719	5446249	5101025	1 km S Brise	125	black slate with mica	Carb.						6,18	0,27	2,91	0,35	30	3,27	0,36	
720	5438612	5105568	near Kremenik (Strzinar farm)	124	black slate	Carb.						6,22	0,33	3,65	0,39	30	2,57		
726	5424190	5108531	Ca. 1 km SE Planina pri Cerknem	123	grey slate	Carb.						6,55	0,64	3,26	0,45	30	3,29	0,36	
139	5438766	5113750	Junction Javorje / Mlaka	104	dark slate	Carb.						5,53	0,50	3,36	0,49	30	2,17		1,1
140	5438691	5114294	100 m S of Mlaka	104	black slate	Carb.						5,93	0,39	2,89	0,44	30	3,04		0,7
1136	5437798	5115788	Near the cableway SW of Lenart nad Luso	104	fine grained congl.	PermCarb.						5,71	0,54	2,84	0,46	30	2,87		
173	5429496	5119750	In the gorge E of Lajtnik (sealevel: ca. 1000 m)	103	black-blue slate	Lo. Cretac.	*Tithon-Berr.*	3,80	0,43	150	244	4,99	0,55	1,70	0,36	30	3,29		0,3
1a	Horjul		Coal mine - Collection University Ljubljana	125	coal	Carnian	Raibl Fm.	2,90	0,10	50	222	3,31	0,12	2,58	0,21	12	0,73		77,0
1b	Horjul-Lesno Brdo		Coal mine - Collection Univ. Ljubljana	125	coal	Carnian	Raibl Fm.	3,38	0,15	50	234	4,04	0,36	2,71	0,25	30	1,33		59,9
1c	Drenov Griž		Coal mine - Collection University Leoben	125	coal	Carnian	Raibl Fm.	2,69	0,17	50	216	3,74	0,35	2,80	0,31	30	0,94		

TABLE 4: Vitrinite reflectance of pre- and post-Variscan sediments of the Trnovo Nappe (Northern Dinarides).
Note: Sampling location according to Slovenian Coordinate System; Sht: Sheet in Slovenian Atlas 1:50.000; Rr: mean random vitrinite reflectance; Stdev: standard deviation; n: number of measurements; PPT: Peak-paleotemperature after Barker and Pawlewicz, 1994; Rmax: maximum vitrinite reflectance; Rmin: minimum vitrinite reflectance; BR: Bireflectance; IC: Illite-“Crystallinity” (taken from Rainer et al., 2002); TOC: Total Organic Carbon content.

turini (1992) the thickness of the Upper Cretaceous to Middle Eocene sediment stack exceeds 4000 m.

Early Cenozoic heating overprinted the earlier Late Paleozoic to Mesozoic thermal events (e.g. related to Permian and Middle Triassic magmatic activity or Triassic-Jurassic rifting). Also the Maastrichtian "Eoalpine phase", which caused a maturity break between Upper Cretaceous and Lower Paleogene rocks in the well Cargnacco-1 (near Udine/Italy; Fig. 3; Fantoni et al., 2002), is not recognizable in the Alpine-Dinaric Transition Zone. VR of flyschoid overstep sequences in the Soča-valley (W Slovenia), resting on the Trnovo Nappe, decreases continuously from Upper Cretaceous rocks in the north (e.g. ~2 % Rr; near Most na Soči) to Eocene rocks in the south (e.g. ~0.8 % Rr; Goriška Brda; Rainer, 2003).

5. Conclusions

The comparison of the thermal overprint of pre-Variscan and post-Variscan rocks of the eastern Southern Alps and the northern Dinarides leads to the following conclusions:

- Neither in the eastern part of the Southern Alps, nor in the northern Dinarides a break in coalification can be recognized across the "Variscan discordance".
- Consequently the post-Variscan thermal overprint during Permo-Mesozoic passive continental margin evolution and/or Cenozoic Alpine orogeny reached at least the same intensity as the Variscan (Late Carboniferous) one.
- In the northern Dinarides (Sava Folds, Trnovo Nappe) Triassic and Cretaceous rocks reached a similar thermal maturity as the Pre-Variscan ones. Therefore also in these regions the Alpidic thermal overprint exceeded the Variscan one.
- The Alpidic thermal overprint in the northern Dinarides (Sava Folds, Trnovo Nappe) occurred in post-Late Cretaceous and pre-Mid Oligocene times. This is testified by a substantial gap in thermal maturity across the Upper Cretaceous – Middle Oligocene unconformity.
- The Early Cenozoic thermal overprint in the northern Dinarides was strong enough to reset the earlier Late Paleozoic and Mesozoic thermal events, maybe related to Permian and Middle Triassic magmatic activity or Triassic-Jurassic rifting.
- Nappe stacking in the northern Dinarides had no impact on regional maturity patterns.
- Thermal maturity of post-Variscan Permo-Carboniferous rocks of the northern Dinarides is generally higher than in the South Karawanken Range and the Carnic Alps. This is a result of both, a deeper burial during Permo-Mesozoic basin subsidence and an accumulation of thick Paleogene flysch sediments during the Paleocene to Eocene Dinaric orogeny.

Acknowledgments

Financial support within the frame of FWF project P13309-Tec is gratefully acknowledged.

References

Aničić, B. and Juriša, M., 1984. Osnovna geološka karta SFRJ, 1:100.000, Sheet Rogatec. L33-68, Geološkega zavoda Beograd.

Árkai, P., Lantai, C., Fórizs, I. and Lelkes-Felvári, G., 1991. Diagenesis and low-temperature metamorphism in a tectonic link between the Dinarides and the Western Carpathians: the basement of the Igal (Central Hungarian) Unit. Acta Geologica Hungarica, 34/1-2, 81-100.

Barker, C. E., 1988. Geothermics of petroleum systems: Implications for stabilization of kerogen maturation after a geologically brief heating duration at peak temperature. In: L. Magoon (ed.), Petroleum Systems of the United States. U.S. Geological Survey Bulletin, 1870, 26-29.

Barker, C. E. and Pawlewicz, M. J., 1994. Calculation of vitrinite reflectance from thermal histories and peak temperatures. A comparison of methods. In: P. K. Mukhopadhyay and W. G. Dow (eds.), Vitrinite reflectance as a maturity parameter – Applications and limitations. ACS Symp. Ser., 570, 216–229.

Brenčič, M., Budkovič, T., Ferjančič, L. and Poltnig, W., 1995. Hydrogeologie der westlichen Karawanken. Beiträge zur Hydrogeologie, 46.

Brime, C., Perri, M.C., Pondrelli, M., Spalletta, C. and Venturini, C., 2008. Polyphase metamorphism in the eastern Carnic Alps (N Italy-S Austria): clay minerals and Conodont Colour Alteration Index evidence. International Journal of Earth Sciences, 97, 1213-1229.

Budkovič, T., 1999. Geology of the Slovene Part of the Karavanke Road Tunnel. Abh. d. Geol. Bundesanstalt, Wien, 56/2, 35-48.

Buser, S., 1977. Osnovna geološka karta SFRJ, 1:100.000, Sheet Celje, L33-67. Geološkega zavoda Beograd.

Buser, S., 1987. Development of the Dinaric and Julian Carbonate platforms and of the intermediate Slovenian basin (NW Yugoslavia). Mem. Soc. Geol. It., 40, 313-320.

Castellarin, A. and Cantelli, L., 2000. Neo-Alpine evolution of the Southern Alps. Journal of Geodynamics, 30, 251-274.

Doglioni, C. and Bosellini, A., 1987. Eoalpine and mesoalpine tectonics in the Southern Alps. Geologische Rundschau, 76, 735-754.

Ebner, F., Vozárová, A., Kovács, S., Kräutner, H.-G., Krstic, B., Szederkényi, T., Jamicic, D., Balen, D, Belak, M. and Trajanova, M., 2008. Devonian-Carboniferous pre-flysch and flysch environments in the Circum Pannonian Region. Geologica Carpathica, 59, 159-195.

Fantoni, R., Podda, F., Ponton, M. and Scotti, P., 2002. Maturita della materia organica e storia termica in alcune successioni del Triassico superiore (Friuli Venezia Giulia, Italia). Maturity of organic matter and thermal history of some Upper Triassic successions (Friuli-Venezia Giulia, Italy). In: G. B. Carulli and M. Ponton (eds.), Tra Alpi, Dinaridi e Adriatico; Atti dell' 80 (super a) riunione estiva della Societa Geologica Italiana. Among the Alps, Dinarides and the Adriatic; proceedings of the 80th meeting of the Societa Geologica Italiana, Mem. Soc. Geol. It., 57/1, 79-87.

Grad, K. and Ferjančič, L., 1974. Osnovna geološka karta SFRJ, 1:100.000, Sheet Kranj. L33-65, Geološkega zavoda Beograd.

Jakob, H., 1989. Classification, structure, genesis and practical importance of natural solid oil bitumen ("migrabitumen"). International Journal of Coal Geology, 11, 65-79.

Judik, K., Rantitsch, G., Rainer, Th. M., Árkai, P. and Tomljenović, B., 2008. Organic metamorphism in metasedimentary rocks from Mt. Medvednica (Croa¬tia). Swiss Journal of Geosciences, 101, 605-616.

Jurkovšek, B., 1986. Osnovna geološka karta SFRJ, 1:100.000, sheet Beljak in Ponteba, L33-52, Geološkega zavoda Beograd.

Koch, J. and Günther, M., 1995. Relationship between random and maximum vitrinite reflectance. Fuel, 74, 1687-1691.

Laubscher, H.P., 1983. The Late Alpine (Periadriatic) intrusions and the Insubric Line. Mem. Soc. Geol. It., 26, 21-30.

Läufer, A.L., 1996. Variscan and Alpine tectonometamorphic evolution of the Carnic Alps (Southern Alps) – structural analysis, illite crystallinity, K-Ar and Ar-Ar geochronology. Tübinger geowissenschaftliche Arbeiten, A26, 1-102.

Mlakar, I., 1969. Krovna zgradba idrijsko žirovskega ozemlja / Nappe structure of the Idrija-Žiri region. Geologija, 12, 5-72.

Mlakar, I., 1985/1986. Prispevek k poznavanju geološke zgradbe Posavskih gub in njihovega južnega obrobja / A contribution to the knowledge of the geological structure of the Sava Folds and their Southern Border. Geologija, 28/29, 157-182.

Mlakar, I., 1994/95a. Nekaj novih podatkov o rudiščih Češnjice in Zlatenek / Some new data on the Češnjice and Zlatenek deposits. Geologija, 37/38, 377-390.

Mlakar, I., 1994/95b. O marijareškem živosrebrnem rudišču ter njegovi primerjavi z Litijo in Idrijo z aspekta tektonike plošč / On the Marija Reka mercury deposit and on it´s comparison with the Litija and Idrija deposits from the aspect of plate tectonics. Geologija, 37/38, 321-376.

Mlakar, I., 2001a. Grödenska formacija na območju Radeč / Val Gardena Formation in Radeče region (Slovenia). Geologija, 44, 243-261.

Mlakar, I., 2001b. Paleozojski skladi na območju Lenarta nad Lušo / Paleozoic beds in the Lenart at Luša area (Slovenia). Geologija, 44, 217-225.

Mlakar, I., Skaberne, D. and Drovenik, M., 1992. O geološki zgradbi in orudenju v karbonskih kameninah severno od Litije / On geological structure and mineralization in Carboniferous rocks north of Litija, Slovenia. Geologija, 35, 229-286.

Nemes, F., 1996. Kinematics of the Periadriatic fault in the Eastern Alps. Evidence from structural analysis, fission track dating and basin modelling. PhD-thesis, University of Salzburg, Salzburg, 255 pp.

Neubauer, F., 1988. The Variscan orogeny in the Austroalpine and Southalpine domains of the Eastern Alps. Schweiz. Mineral. Petrogr. Mitt., 68, 339-349.

Pečar, J., 1985/1986. Upper Carboniferous and Permian mesolobid chonetacean brachiopods of Karavanke Mountains (Yugoslavia) and Carnian Alps (Italy). Geologija, 28/29, 9-53.

Placer, L., 1999a. Structural meaning of the Sava folds. Geologija, 41, 191-221.

Placer, L., 1999b. Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. Geologija, 41, 223-255.

Placer, L. and Čar, J., 1998. Structure of Mt. Blegoš between the Inner and the Outer Dinarides. Geologija, 40, 305-323.

Premru, U., 1982. Osnovna Geološka Karta SFRJ, 1:100.000, Sheet Ljubljana. L33-66, Geološkega zavoda Beograd.

Rainer, T., 2003. Thermal History and Hydrocarbon Potential of Carboniferous to Eocene Sediments of the Alpine-Dinaric Transition Zone (Austria, Slovenia). PhD Thesis, University of Leoben, Leoben, 379 pp.

Rainer, T. and Rantitsch, G., 2002. Vitrinitreflexion im Bohrkern Gartnerkofel-1 (Perm bis Skyth, Karnische Alpen, Kärnten). Carinthia II, 192, 449-454.

Rainer, T., Herlec, U., Rantitsch, G., Sachsenhofer, R.F. and Vrabec, M., 2002. Organic matter maturation vs. clay mineralogy: A comparison for Carboniferous to Eocene sediments from the Alpine-Dinaride junction (Slovenia, Austria). Geologija, 45, 513-518.

Rainer, T., Green, P., Sachsenhofer, R.F., Herlec, U. and Vrabec, M., 2005. The Thermal history of the Alpine-Dinaric Transition Zone – implications from Vitrinite Reflectance Data, Apatite Fission Track Dating and 1D Numerical Modelling. Abstract Book of the Alpine Geological Workshop (Opatija, Croatia), 83-84.

Ramovš, A. and Kochansky-Devide, V., 1979. Karbonske in permske plasti v severnih Julijskih Alpah / Carboniferous and Permian beds from the northern Julian Alps. Geologija, 22, 21-54.

Ramovš, A. and Kochansky-Devide, V., 1981. Karbonske in permske plasti pri Logu v Julijskih Alpah / Carboniferous and Permian beds at Log in the Julian Alps. Geologija, 24, 91-107.

Rantitsch, G., 1997. Thermal history of the Carnic Alps (Southern Alps, Austria) and its palaeogeographic implications. Tectonophysics, 272, 213-232.

Rantitsch, G., 2007. Organische Metamorphose am Auernig (Naßfeld, Karnische Alpen). Jahrbuch der Geologischen Bundesanstalt, 147, 331-334.

Rantitsch, G. and Rainer, T., 2003. Thermal modeling of Carboniferous to Triassic sediments of the Karawanken Range (Southern Alps) as a tool for paleogeographic reconstructions in the Alpine-Dinaridic-Pannonian realm. International Journal of Earth Sciences, 92, 195-209.

Rantitsch, G., Rainer, T. and Russegger, B., 2000. Niedriggradige Metamorphose im Karbon der Südalpen (Kärnten, Österreich). Carinthia II, 190, 537–542.

Sachsenhofer, R.F., Jelen, B., Hasenhüttl, C., Dunkl, I. and Rainer, T., 2001. Thermal history of Tertiary basins in Slovenia (Alpine-Dinaride-Pannonian junction). Tectonophysics, 334, 77-99.

Schoenherr, J., Littke, R., Urai, J. L., Kukla, P. A. and Rawahi, Z., 2007. Polyphase thermal evolution in the Infra-Cambrian Ara Group (South Oman Salt Basin) as deduced by maturity of solid bitumen. Organic Geochemistry, 38, 1293-1318.

Schönlaub, H.P. and Forke, H.G., 2007. Die postvariszische Schichtfolge der Karnischen Alpen - Erläuterungen zur geologischen Karte des Jungpaläozoikums der Karnischen Alpen 1:12500. Abh. Geol.B.-A., 61, 3-157.

Stampfli, G. M., von Raumer, J. F. and Borel, G. D., 2002. Paleozoic evolution of pre-Variscan terranes; from Gondwana to the Variscan collision. In: J. R. Martinez Catalan, R. D. Hatcher, R. Arenas and F. Diaz Garcia (eds.), Variscan-Appalachian dynamics; the building of the late Paleozoic basement. Special Paper - Geological Society of America, 364, 263-280.

Taylor, G. H., Teichmüller, M., Davis, A., Diessel, C. F. K., Littke, R. and Robert, P., 1998. Organic Petrology. Gebrüder Borntraeger, Berlin, Stuttgart, 704 pp.

Trajanova, M., 2001. O stabilnosti karbonskega glinastega skrilavca ob avtocesti Ljubljana – Celje s petrografskega stališča. / Stability of the Carboniferous Slate along the Ljubljana – Celje Highway from the Petrographic Point of View. Geologija, 44/1, 81-88.

Tunis, G. and Venturini, S., 1992. Evolution of the southern margin of the Julian Basin with emphasis on the Megabeds and turbidites sequence of the southern Julian Prealps (NE Italy). Geologia Croatica, 45, 127- 150.

Underwood, M. B., Laughland, M. M. and Kang, S. M., 1993. A comparison among organic and inorganic indicators of diagenesis and low-temperature metamorphism, Tertiary Shimano Belt, Shikoku, Japan. Special Paper - Geological Society of America, 273, 45-61.

Von Raumer, J. F., Stampfli, G. M., Borel, G. and Bussy, F., 2002. Organization of pre-Variscian basement areas at the north-Gondwanan margin. International Journal of Earth Sciences, 91, 35-52.

Vozárová, A., Ebner, F., Kovács, S., Kräutner, H.-G., Szederkényi, T., Krstic, B., Karamata, S., Sremac, J., Aljinovic, D., Novak, M. and Skaberne, D. 2009. Late Variscan (Carboniferous to Permian) environments in the Circum Pannonian Region. Geologica Carpathica, 60, in press.

Vrabec, M., Pavločič Prešeren, P. and Stopar, B., 2006. GPS study (1996–2002) of active deformation along the Periadriatic fault system in northeastern Slovenia: tectonic model. Geologica Carpathica, 57, 57-65.

Received: 2. February 2009
Accepted: 20. June 2009

Thomas RAINER[1)3)*)], Reinhard F. SACHSENHOFER[1)], Gerd RANTITSCH[1)], Uroš HERLEC[2)] & Marko VRABEC[2)]

[1)] Mining University Leoben, Department for Applied Geosciences and Geophysics, 8700 Leoben, Austria;

[2)] University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Aškerčeva 12, 1000 Ljubljana, Slovenia;

[3)] Present Address: OMV Exploration & Production GmbH, Trabrennstrasse 6-8, 1020 Wien, Austria;

[*)] Corresponding author, thomas.rainer@omv.com