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The Middle and Upper Permian Deposits in Gorski Kotar: Facts and Misconceptions

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Abstract

The frequent occurrence of sandstones and other coarse-grained sedimentary rocks in Gorski Kotar indicates molasse type sedimentation as a consequence of the intensive erosion of an uplifted terrain in a tectonically active area. The indirect assumptions indicate that the age of the Gorski Kotar Palaeozoic complex, with the exception of a limited occurrence of Carboniferous clastic rocks, corresponds to the clastic Trogkofel beds, i.e. to Middle Permian. The absence of Upper Permian carbonate deposition in Gorski kotar indicates an interruption in sedimentation at the Permo-Triassic boundary, and a possible hiatus in the Upper Permian. In previous studies it was concluded that there is a continuous transition from the Permian (developed as the Gröden clastic facies) to the Lower Triassic shallow marine sedimentary rocks, although no such transitions occur in either the neighbouring areas (Velebit, Slovenia) nor in the wider Southern Alps. The continuous transition exists only in the carbonate successions (Upper Permian dolomite in the Velebit region and the Bellerophone formation in the Alps).

1. INTRODUCTION

The studies that deal with the sedimentary rocks of the clastic facies within the Palaeozoic complex of Gorski kotar, inevitably encounter the problem of their age where they do not contain fossils or any intercalation of fossiliferous limestone. In general, the stratigraphic differentiation of clastic Palaeozoic sedimentary rocks from Gorski kotar is complicated due to the general absence of fossils in the clastic rocks, the poor preservation of ammonite fragments in black shales, poor preservation of fossils in the limestone intercalations, and also due to the extremely intensive tectonics in the region and the absence of any lithostratigraphic marker. These are the reasons why chronostratigraphic determination of the Palaeozoic sedimentary rock complex is ambiguous. The coarse-grained clastic rocks are considered the youngest facies in the Permian succession. They are usually termed as "Gröden clastites", "clastic rocks of the Gröden type" or as "deposits that correspond to Gröden beds". The aim of this paper is to discuss the ages attributed to these "Gröden clastic rocks" by various authors and to present differing and often opposing ideas about the age of the Palaeozoic complex. Also the intention is to compare the Gorski kotar Palaeozoic with the studied and described Palaeozoic deposits in the neighbouring areas, and to contemplate the justification of the assumption of a continuous sedimentation from the Permian to the Lower Triassic.

2. REVIEW OF PREVIOUS STUDIES

Previous studies of Palaeozoic rocks in the Gorski Kotar region have been aimed mainly towards the differentiation of the principal rock types, their mapping, and the description of mapped units which are sometimes termed as facies (Fig. 1).

In papers dating back to the end of the last century and the beginning of this century, various stratigraphic interpretations have been given for the Gorski Kotar Palaeozoic complex, with the majority dating it as Carboniferous (FOETTERLE, 1855; HAUER, 1868).

More recent data about the Gorski Kotar Palaeozoic are presented in papers by SALOPEK (1949a, b, 1960, 1961).

During studies of the Gorski Kotar region Salopek defined the principal Upper Palaeozoic sedimentary rock units in the vicinity of Mrzla Vodica and Crni Lug (SALOPEK, 1949a, 1960) and Gerovo and Tršće (SALOPEK, 1949b, 1961) - Figs. 1 & 2, and fig. 1 in SREMAC & ALJINOVIĆ (1997 - this Vol.) The principal sedimentary rock units were defined according to their lithology and mode of occurrence.

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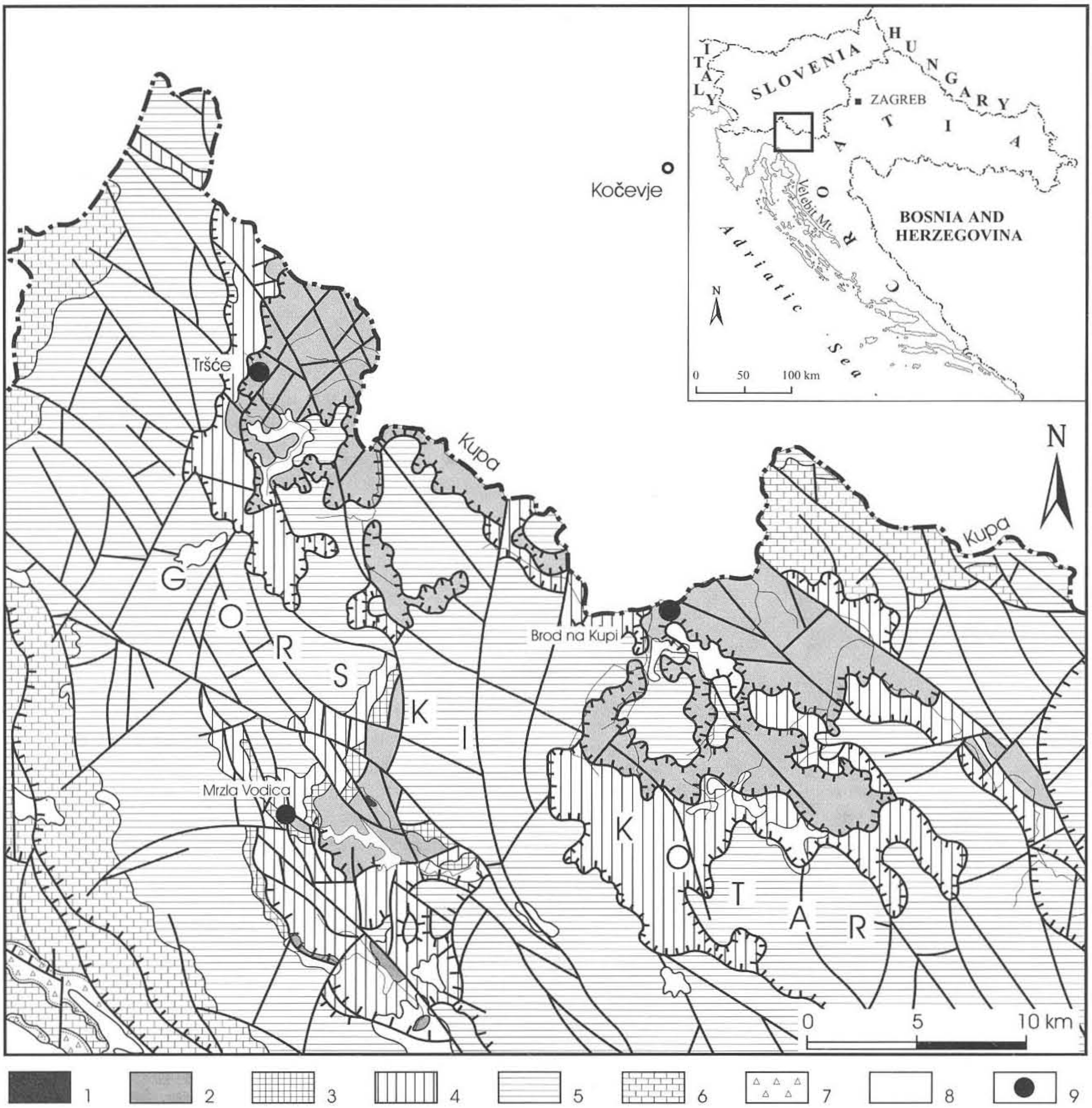

Fig. 1 Simplified geological map of Gorski Kotar (modified after SAVIĆ & DOZET, 1984). Legend: 1) Carboniferous sandstones; 2) Permian sedimentary complex; 3) Scythian clastic rocks and dolomites; 4) Upper Triassic dolomite ("Hauptdolomit"); 5) Jurassic carbonates; 6) Cretaceous limestones; 7) Eocene breccia; 8) alluvium; 9) main localities.

Apart from a limited occurrence of Upper Carboniferous Triticites sandstones on the banks of the Križ stream, SALOPEK (1949a, 1960) regarded the major part of the Palaeozoic complex to be of Permian age. In this complex he differentiated the following units: (1) the "clayey schists" in alternation with dark sandstones (pgš), (2) the "clayey schists" (gš), and (3) the gray sandstones (pš) which occur separately in the broader region. As a separate unit (4) the author distinguished also dark fossiliferous limestone (cv). This type of rock frequently accompanies the "clayey schists" in alternation with dark sandstone (pgš), and is also frequently intercalated within the "clayey schists" (gš). Within the fossiliferous limestone, a fauna was discovered that corresponds to that of the Rattendorf beds. The ensuing units (5) are the Trogkofel limestone which differs in the presence of intersecting calcite veins, the occurrence of numerous calcite and quartz pebbles, and rarer occurrences of fusulinids than in the previous limestone types. A distinct (6) type termed the "cephalopod clayey schists" occurs in alternation with sandstone in a restricted area around Mrzla Vodica. Also he distinguished a different type of limestone (7) from the previous ones, the "limestone with Lithoniae".

According to SALOPEK (1960) these seven rock types contain enough fossil data to confirm a Lower and Middle Permian age (which was later verified by MILANOVIĆ & KOCHANSKY-DEVIDÉ, 1968, and KOCHANSKY-DEVIDÉ, 1973) - Fig. 2. After these conclusions SALOPEK (1960) described an eighth independent rock type (8), the Gröden conglomerates, and (9) gray to light gray Gröden sandstone (pcp).

SALOPEK (1949b) outlined the Upper Palaeozoic in the vicinity of Gerovo and Tršće (Figs. 1 & 2) and differentiated five rock types, i.e. facies which correspond to those near Mrzla Vodica. However, he noticed that "the most striking difference is the lack of significant limestone intercalations, which are present in all Upper Palaeozoic cross sections adjacent to Mrzla Vodica, where they were the principal bearers of a fusulinid and brachiopod fauna" (SALOPEK, 1949b, p. 194).

Later, SALOPEK (1949a, b, 1960) also attempted to solve the stratigraphic questions connected with the Palaeozoic complex (Fig. 2). His conclusions were as follows: "The fusulinid sandstone undoubtedly proves the very limited occurrence of the Upper Carboniferous in the Palaeozoic rocks near Mrzla Vodica. According to the fauna determined they belong to the Uralien. The basis for the Permian differentiation was the determination of ammonites found in the "black schists" by VOGL (1913) as being related to the Sossio fauna type. The Sossio beds are represented by a goniatite cephalopod fauna. These layers are confined to the upper part of the succession of clayey schist in alternation with dark sandstones (pgš). Therefore, "the clayey schists and sandstones" (pgš) reach and enclose the Middle Permian Sossio beds. The sporadic dark limestone intercalation with fusulinids contains a scant fauna, which indicates the Rattendorf and in part maybe the Trogkofel beds. A gradual transition exists from the "pgš" into the Gröden deposits which consist of conglomerates and sandstone. The Upper Permian Bellerophone facies is absent" (SALOPEK, 1960, p. 128).

Although Salopek does not stress it, it is obvious from his papers that the rocks called "Gröden conglomerates" and "Gröden sandstone" he associates with the rocks that, by the fossil content, are attached to the Lower and Middle Permian. So, he concludes: "Within the clayey schists and sandstones (pgš) in their upper part sporadically an intercalation of conglomerate can be found. This is the transition into the Permian clastic series." However, he considers that the mentioned conglomerates occur in the **upper part of that Permian series**, therefore they are still confined to the Middle Permian (Fig. 2). The confirmation of this opinion is found in the paper by SALOPEK (1961, p. 245), where in the description of Palaeozoic rocks in the areas of Smrečje, Tršće and Čabar (Fig. 1) he states the following: "The typical cephalopod schist facies does not occur in the Gerovo-Čabar Palaeozoic, nevertheless on the basis of the significant "pgš" series, these deposits in the Gerovo-Čabar Palaeozoic can be, together with overlying sandstones and conglomerates, connected to the Wordian (Middle Permian) which was palaeontologically determined near Mrzla Vodica." It is important to stress that Salopek tried to find the equivalent sedimentary rocks to those that he had previously studied (SALOPEK, 1948), and that he associates the Gorski kotar Palaeozoic development with the development of the Palaeozoic in the Velebit region (and not in the Alps).

From the description of Gröden conglomerates in Gorski Kotar made by Salopek which he claimed to belong to the "Upper Permian series" some later misinterpretations were inferred. According to some later citations (JURKOVIĆ, 1959; RAMOVŠ & KOCHANSKY-DEVIDÉ, 1965; ŠUŠNJARA & ŠINKOVEC, 1973) it is stated that Upper Permian Gröden clastic rocks exist, which is a total misinterpretation of conclusions made by Salopek. An accurate confirmation of the Upper Permian in Gorski kotar documented by fossils has not been made.

The problem whether Upper Permian rocks do or do not occur in Gorski Kotar, consequently raises the question of a continuous or discontinuous transition at the Permo-Lower Triassic boundary. The question of this contact was raised by ŠĆAVNIČAR & ŠUŠNJARA (1967, p. 93) - Fig. 2, who determined that "at several places it is possible to observe a direct contact, and no elements indicating transgression are visible, but an impression exists that there was a continuous succession." These authors tried to solve this problem with the aid of petrographic methods. These methods revealed only the quantitative differences in associations of heavy minerals between the Palaeozoic clastic rocks (for which it is claimed that they are the transitional lithofacies) and the Triassic clastic rocks. The difference is primarily manifested through the content of chlorite and apatite, the quantity of which rises from the Permian sedimentary rocks and is significantly enhanced in the Lower Triassic sedimentary rocks. The same authors, on the basis of these analyses emphasise the tight connection between the sedimentary rocks which are presumably Upper Permian with the Lower Triassic rocks. The authors themselves conclude that "further field and analytical studies are necessary in order to solve the relationship between the Upper Palaeozoic and the Lower Triassic". RAFFAELLI & ŠĆAVNIČAR (1968, p. 25) state that "the coarse-grained petromictic conglomerates and sandstone, according to their petrographic composition and their stratigraphic position, match the Gröden deposits from the Carnian Alps". These authors also state their doubt: "... that it is not known whether the whole Upper Permian in the Gorski Kotar region is developed as a clastic facies or that equivalents of the Bellerephon limestone might exist."

The authors of the Explanatory notes for the Delnice Sheet of the Basic Geological Map SAVIĆ & DOZET (1985), state that the Gorski Kotar Palaeozoic complex contains Upper Carboniferous deposits (C_3) as well as Lower and Middle Permian deposits.

The frequent occurrence of coarse grained sedimentary rocks and sandstones (Gröden facies) HERAK &

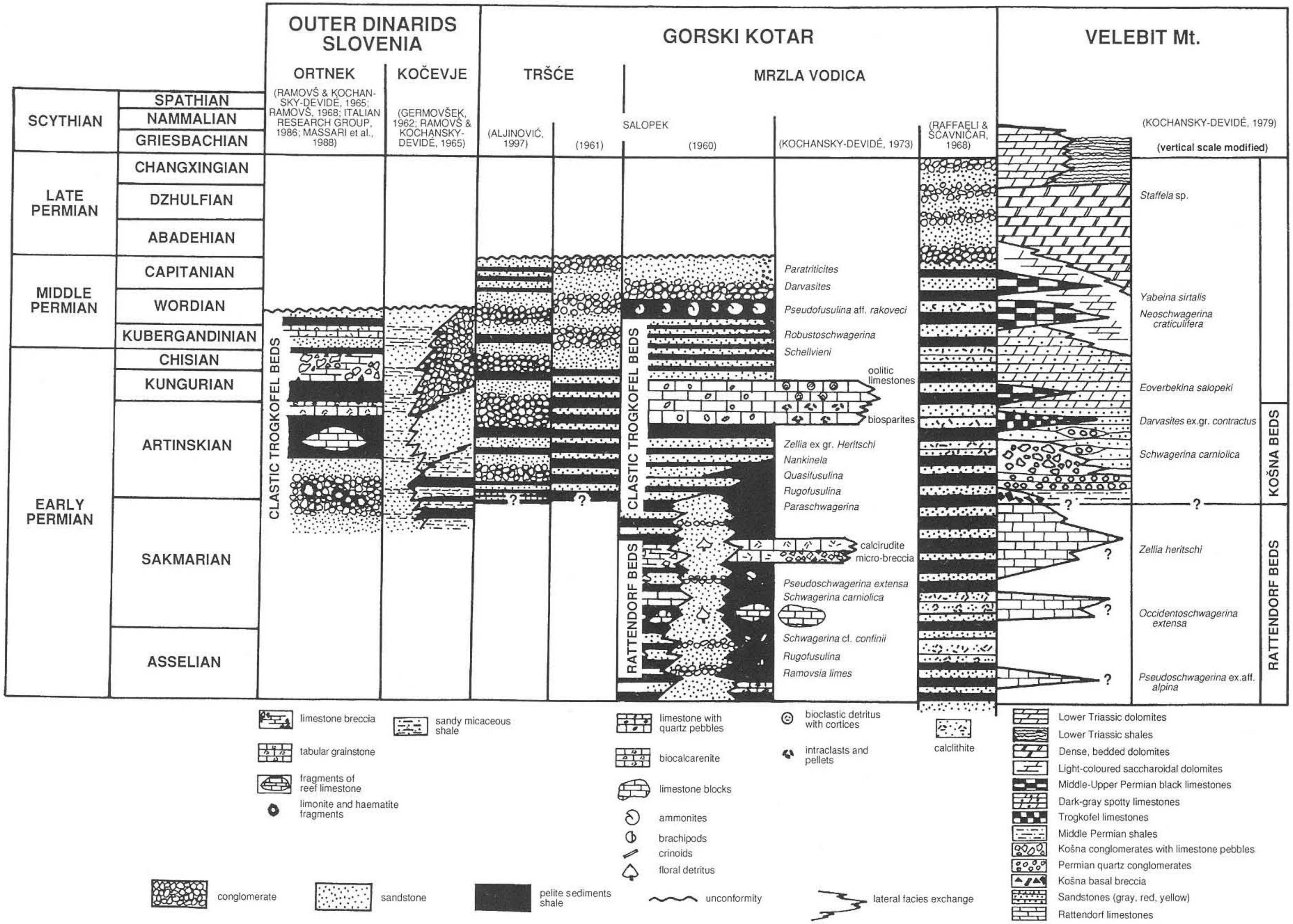

Fig. 2 Schematic stratigraphic column through Permian and Scythian sediments in Gorski Kotar and correlation with adjacent areas (Slovenian part of the Outer Dinarides and Velebit Mt.). Vertical scale after ITALIAN RESEARCH GROUP (1986), CASSINIS et al. (1988) and MASSARI et al. (1988).

TOMIĆ (1995) considered as molasse type sedimentation occurred in Upper Permian.

Since the studies published by SALOPEK (1949a, b, 1960, 1961), and the paper by ŠĆAVNIČAR & ŠUŠNJARA (1967), who on the basis of petrological evidence regard the coarse-grained facies as the youngest Upper Permian deposits, not a single paper has been published that gives either new palaeontological or petrological evidence or data that could be used to clarify the problem of the Upper Permian in Gorski Kotar. Nevertheless, a widespread idea that "Upper Permian Gröden clastic rocks" exist, is expressed by citations made by various authors (ŠUŠNJARA & ŠINKOVEC, 1973; ČERINA, 1986; PALINKAŠ & SREMAC, 1989; PALINKAŠ et al., 1993), although their studies did not deal with the stratigraphy of the rocks present.

3. DISCUSSION

In the rather few papers that deal with the problems of the youngest Palaeozoic sedimentary rocks in Gorski Kotar several inconsistent interpretations can be observed. Firstly, there is an inconsistency in the petrographic definition of the youngest facies. As can be observed in the paper by ŠĆAVNIČAR & ŠUŠNJARA (1967) it is asserted that in the boundary region towards the Lower Triassic at the studied localities near Suha Rečina, Podtisovac, Zelin and Tršće, sandstones occur which have the characteristics of transition rocks. Due to their red colour they resemble the Lower Triassic sedimentary rocks. However, red sandstones also have grey equivalents. A year later RAFFAELLI & ŠĆAVNIČAR (1968, p. 25) determined that the "coarse-grained petromictic conglomerates and sandstones" are transition deposits and compared them with the Gröden type deposits from the Carnian Alps. ŠĆAVNIČAR et al.[3] (p. 46) substantiated a facies differentiation, i.e. the existence of "coarse-grained and fine-grained conglomerates inserted between sandstones" which represent the "members of the youngest Palaeozoic clastic series". However, the same authors (p. 47) state that "occasionally the terminating members are fine-grained micaceous sandstone and silty-pelitic sedimentary rocks of a grey-purplish to a reddish colour which are lithologically similar to the Lower Triassic deposits at the Tršće, Podtisovac and Suha Rečina localities". PALINKAŠ & ŠINKOVEC (1986) consider shale, siltite and sandstone as the youngest Permian clastic sedimentary rocks. PALINKAŠ et al. (1993) adopted the opinion from earlier studies (ŠĆAVNIČAR & ŠUŠNJARA, 1967) about the Upper Permian greyish-green and purplish-grey fine-grained siltite and pelite which are in conformable succession with the Lower Triassic peritidal basal dolomites. However, PALINKAŠ et al. (1993) stated, that "according to a cross section near Lokve and Školski Brijeg, the Upper Permian clastics are represented by black shales and sandstones the layers of which are several centimetres thick. Red shales and "Gröden" type sandstone equivalents underlie these deposits".

From the above statements it is obvious that the answer to "what underlies the Lower Triassic sedimentary rocks" is ambiguous. Red and grey conglomerates and sandstone are present below the Lower Triassic rocks (ŠĆAVNIČAR & ŠUŠNJARA, 1967; RAFFAELLI & ŠĆAVNIČAR, 1968), also red coloured conglomerates, sandstone and pelitic rocks (ŠĆAVNIČAR et al.[3]; PALINKAŠ & ŠINKOVEC, 1986), as well as black shale and sandstone (PALINKAŠ et al., 1993). No single facies can be inferred as the sole Upper Permian member, excluding therefore the lithological criterion as being satisfactory for stratigraphic evaluation. It is apparent that the colours are also not characteristic. RAFFAELLI & ŠĆAVNIČAR (1968) determined that there are red Gröden clastic rocks that also have grey equivalents. Although ŠĆAVNIČAR et al.[3] concluded that the transition deposits are red and can be mistaken for Lower Triassic, PALINKAŠ et al. (1993) found black shale and sandstone in contact with the overlying dolomites, and in boreholes bluish and gray sandstones were determined.

Since SALOPEK (1949a, b, 1960) interpreted the facies that the above mentioned authors present as the upermost part of the Upper Permian sequence, as Middle Permian, it is possible that these are the same facies but their age was interpreted differently.

In the longest encountered cross section through Palaeozoic sedimentary rocks (approximately 150 m) situated in the valley of the Sokolica stream near Tršće (SALOPEK, 1961; ALJINOVIĆ, 1997) - Figs. 1 & 2, it is possible to distinguish several facies of coarse-grained quartz conglomerates and sandstone. These facies are laterally contemporaneous (ALJINOVIĆ, 1997). Moreover, in the uppermost part of the cross section, black shales occur in alternation with sandstone containing large quantities of plant detritus. It is indisputable that the conglomerate facies alternating with shales and sandstones form a unique genetic sequence and are interpreted as facies of a fan delta complex (ALJINOVIĆ, 1997).

It is important to stress that SALOPEK (1961) believed that this Palaeozoic sequence was folded during the Variscan orogeny which he represents with a sketch (p. 248, fig. 4).

Very close to this outcrop, i.e. in the Sokolska stijena cross section, ŠĆAVNIČAR et al.[3] determined a continuous transition over the Palaeozoic/Lower Triassic boundary in the following way: "The starting point for the study was located in grey dolomites, and the outcrops of Upper Palaeozoic clayey schists and sandstone occur some 10 m below them". The real contact

[3] ŠĆAVNIČAR, B., SOKAČ, B. & VELIĆ, I. (1972): Paleogeografija trijasa u području Vanjskih Dinarida, 1 Gorski kotar.- Unpublished report, Archive of the Institute of Geology, Zagreb.

therefore is absent, but the effect of a continuous transition remains, probably due to the lack of any angular discordance. The lack of any angular discordance was, it seems, the principal criterion indicating continuous deposition between the Palaeozoic and Lower Triassic. Some authors have questioned the validity of the character of this contact. ŠĆAVNIČAR & ŠUŠNJARA (1967, p. 93), and ŠĆAVNIČAR et al.[3] state that there are no elements of Lower Triassic transgressive relationships, nor an angular discordance, "but an impression exists that there is a continuous sequence and a normal transition". In their report ŠĆAVNIĆAR et al.[3] conclude that continuous deposition exists on the basis of characteristics of 6 studied cross sections across the Palaeozoic/Lower Triassic boundary. On four of the studied cross sections the contact was covered so that direct observations were not possible. The same authors state that the character of the transition is gradual, but, nevertheless, in their conclusion claim that the contact with the Palaeozoic is marked by an abrupt appearance of Lower Triassic dolomites accompanied by variable amounts of barite. The following question remains: If the change from Palaeozoic sedimentation to Lower Triassic sedimentation is expressed as an abrupt change from a principally clastic deposition (sandstone, shale, red conglomerates, or black shale and sandstone) into oolitic lightly coloured dolomites, is the presumption of continuous sedimentation justified? Perhaps less so, as the character of the contact cannot frequently be observed due to the surface cover and tectonics. It has been recognized that a few metres of a cross section can contain whole geological periods (e.g. the Upper Aptian and Lower Albian in Istria - VELIĆ et al., 1995). If a continuous transition exists, and it can only be documented petrographically, it is then necessary to show the cross section in detail accompanied by almost continuous sampling, in order to determine the changing character of the petrographic parameters.

The attempt to determine the transitional deposits, i.e. the character of the Palaeozoic/Lower Triassic transition by the analysis of the heavy mineral fraction (ŠĆAVNIČAR & ŠUŠNJARA, 1967) seems to be completely justified. The difference is mainly expressed in the quantity of apatite and chlorite in the rocks. The rocks that were determined as Upper Permian transitional rocks have higher quantities of apatite and chlorite than the underlying Palaeozoic rocks, and are similar to the Lower Triassic sedimentary rocks. However, elevated quantities of apatite and chlorite as the only differentiating parameter between Palaeozoic rocks and Lower Triassic rocks was disputed by the discovery of apatite and chlorite as the main mineral components in the heavy mineral fractions in succession that were documented as Middle Permian (JELASKA & PROHIĆ, 1982). Therefore, these Middle Permian sedimentary rocks, due to the elevated quantities of apatite and chlorite have the character of transition deposits towards Lower Triassic. It should be noted that the Lower Permian sedimentary rocks from the Alps also contain apatite and chlorite in the heavy mineral fraction (KRAINER, 1993, p. 546, fig. 9).

In the light of these questions and inconsistancies, an open dilemma remains as to which criterion to use for age determination of the unfossiliferous clastic facies, i.e. how to interpret the transitional nature of the Palaeozoic/Lower Triassic boundary. With this objective in mind it is necessary to review the definitions of Palaeozoic and Lower Triassic successions in adjacent areas and present some of the more recent developments that deal with the problems of similar lithofacies.

3.1. GEOLOGICAL SETTING OF PALAEOZOIC AND LOWER TRIASSIC ROCKS IN ADJACENT REGIONS (VELEBIT AND THE SLOVENIAN PART OF THE OUTER DINARIDS)

The geographical position of the Gorski Kotar, between the Velebit Palaeozoic complex to the East, and the Slovenian Palaeozoic to the West (Figs. 1 & 2), necessarily imposes the need for comparison with these areas both in the lithological and biostratigraphical sense. Revealing the lithostratigraphical problems in Gorski Kotar would provide the answer to the problem of the "missing link". This would not only be of local importance but would also contribute to the studies that deal with global events within the Palaeozoic.

The Palaeozoic sedimentary sequence in Velebit (Fig. 2) was described in detail and biostratigraphically documented by SALOPEK (1948), KOCHANSKY-DEVIDÉ (1965, 1982), SREMAC (1991), and TIŠLJAR et al. (1991). The Permian deposits unconformably overlie Carboniferous deposits. They commence with limestone containing *Schwagerina* and *Pseudoschwagerina,* which are equivalent to the Rattendorf beds that occur in the Alps. The middle Rattendorf beds are especially well developed (sandy clays with shale intercalation - Gränzlandbänke) with fusulinids of the *Zellia*-type, *Quasifusulina nimia* KOCHANSKY-DEVIDÉ, *Neospirifer* (KOCHANSKY-DEVIDÉ, 1982) and the problematica *Ramovsia limes* KOCHANSKY-DEVIDÉ. The Košna beds consist of coarse-grained conglomerates which often contain limestone pebbles that range from Moscovian to Upper Asselian (KOCHANSKY-DEVIDÉ et al., 1982). Apart from these extraordinary mottled limestone conglomerates, the Košna series also includes fine-grained quartz conglomerate and also red, yellow and grey pyritic sandstone (RAFFAELLI & ŠĆAVNIČAR, 1968) which are usually found in the basal part together with the breccias (SALOPEK, 1942). Limestones containing *Darvasites, Pseudoschwagerina* and algae (KOCHANSKY-DEVIDÉ, 1973) are rarely found in this series. The Košna series is considered to be the continuation of the clastic Trogkofel beds deposits from Slovenia, which form a dominantly carbonate limestone evolution in the Alps, passing gradually in the east into a more clayey-sandy-conglomerate type of sedimentation (KOCHANSKY-DEVIDÉ, 1982).

The Middle and Upper Permian deposits consist of dolomites and limestones which conformably overlie the red Košna-sandstones (KOCHANSKY-DEVIDÉ, 1982). Occasionally it is possible to observe the transition from the red sandstone into the so-called First zone of black limestone (the zone with *Eoverbekina salopeki* KOCHANSKY-DEVIDÉ). The First zone limestone contains *Orthoceras* and the large gastropods *Platystoma indicium* WAAGEN and *Bellerophon* cf. *jonesianus* KONINCK, and also an extraordinary microfauna of the *Eoverbeekina-Sphaerulina* and *Staffella*-type (KOCHANSKY-DEVIDÉ, 1982). The narrow limestone zone is overlain by a succession (up to 300 m thick) of dark gray dolomite, sometimes filled with *Waagenophyllum* (non indicum), *Mizzia, Eoverbeekina, Staffella* exposed sections, and occassionally with *Neoschwagerina*.

The Second zone of black limestone (the Neoschwagerina craticulifera zone) is most abundant in macrofossils, among which over 45 brachiopod genera were determined (SREMAC, 1991) together with the aberrant lamellibranchiata *Tanchintongia ogulineci* KOCHANSKY-DEVIDÉ (KOCHANSKY-DEVIDÉ, 1978). In the Upper Permian from Velebit, only carbonate beds were deposited as follows: 1) subtidal to intertidal fusulinid grainstone-packstone limestones, 2) early diagenetic supratidal dolomites, 3) black organic rich shales which alternate with bioclastic packstones/grainstones, 4) supratidal dolomites with red shale intercalations (TIŠLJAR et al., 1991). The Upper Permian deposition therefore occurred in a shallow marine, supratidal to intertidal environment, in locally isolated lagoons or bays rich in organic mud (TIŠLJAR et al., op. cit.). The transition into the Lower Triassic is characterised by a more frequent alternation of dolomite and shale. The dense, so called boundary well bedded grey dolomite is poor in fossils, but nevertheless it contains Permian microforaminifera and gymnocodiacea up to the boundary with the Werfen slightly sandy yellowish dolomites (SALOPEK, 1942, 1948; RAMOVŠ & KOCHANSKY-DEVIDÉ, 1981; TIŠLJAR et al., 1991).

The Lower Palaeozoic of the Slovenian Outer Dinarides outcrops mainly in Dolenjska and near Kočevje (Fig. 1). This complex extends across the rivers Kupa and Čabranka into Croatia. The Palaeozoic succession near Ortnek (Dolenjska) corresponds to the clastic facies of the Trogkofel beds and can be differentiated into three main facies types which alternate both vertically and laterally (RAMOVŠ & KOCHANSKY-DEVIDÉ, 1965; RAMOVŠ, 1968) - Fig. 2. According to these authors it was possible that the clastic deposition commenced in this area even in the Lower Permian and continued into the Middle Permian. The whole Palaeozoic complex in this area is approximately 2,000 m thick (RAMOVŠ, 1968) and is a coherent lithostratigraphic unit.

The lower part of this unit is represented by quartz conglomerates and quartz sandstone (Fig. 2). The conglomerates are usually grey and only occasionally reddish as a consequence of the presence of haematite. In conglomerates with large pebbles, large blocks of limonite can be found (RAMOVŠ, 1968). Haematite fragments and plant remnants (according to this author) are an indication of shallow marine deposition - Fig. 2. Grey fissile quartz sandstone that dominates the intermediate lithological unit occasionally passes into grey clay sediments. Within this unit, red varieties of sandstones with floral remnants can also be found, as well as black sandstone with veinlets containing anthracite. It was a shallow marine environment surounded by a rich vegetated hinterland (RAMOVŠ, 1968).

The upper part is dominated by grey schists which alternate with layers of quartz sandstone which also contains abundant organic remnants (RAMOVŠ, 1968). Within the clayey schists lenses of different reef limestone types, limestone breccia or breccia-conglomerates occur (RAMOVŠ & KOCHANSKY-DEVIDÉ, 1965; RAMOVŠ, 1968). According to the above authors (op. cit.) these limestone intercalations partly represented small reefs that developed on the clayey sandy sea floor (Fig. 2). Erosion of these reefs produced the limestone breccia and conglomerates, which, apart from limestone fragments, also contain sandstone clasts. A number of smaller reefs probably existed separated by deeper water, where clay and sand sediments were deposited (RAMOVŠ, 1968).

A similar lithological development occurs near Kočevje (the region closest to Gorski kotar, Fig. 2), but it does not contain limestone sediments (RAMOVŠ, 1968). Also in the Gerovo-Čabar Palaeozoic on the other side of the Kupa river no limestones were found (SALOPEK, 1949b, 1961; ALJINOVIĆ, 1997).

In the Idrija region the equivalents of the Trogkofel limestone are continental clastic facies and the Upper Permian is represented by gray marine dolomites of the Žažar formation (RAMOVŠ, 1968).

The description of the sediments near Mrzla Vodica and Crni Lug given by SALOPEK (1960) corresponds in many details to the successions observed at Ortnek, while the Tršće-Gerovo Palaeozoic complex shows a similarity with the Kočevje succession (Fig. 2). The correlation is mainly in the description of three lithofacies: quartz conglomerates, quartz sandstone and shale alternation, as well as the presence of limestone intercalations. The vertical succession of any particular lithofacies is not, however, the same in the descriptions given by SALOPEK (1960) and RAMOVŠ (1968). SALOPEK (op. cit.) presumes that in the upper part of the sequence, conglomerates and sandstone occur, while RAMOVŠ (op. cit.) places them in the basal part of the sequence. However, since Ramovš also presumes that a lateral facies differentiation exists, it is possible that the strict superposition order is missing. These differences can be interpreted as lateral facies differentiation as mentioned by RAMOVŠ (1965). The absence of limestone intercalation in distinct areas can be interpreted as a departure from the small reefs from where limestone clasts were derived.

The Gröden clastic rocks as described by ŠĆAVNIČAR & ŠUŠNJARA (1967), RAFFAELLI & ŠĆAVNIČAR (1968, fig. 5) and PALINKAŠ et al. (1993) do not correspond, however, to the Gröden clastic rocks of neighboring Velebit and Slovenian (Idrija) areas, where this facies is considered to be Middle Permian by SALOPEK (1948) and RAMOVŠ (1968), but to the Gröden clastic rocks of the Carnian Alps. Nevertheless, their features (colour and composition) could also correspond to the Gröden clastic rocks described by SALOPEK (1949a, b, 1960, 1961) in the vicinity of Mrzla Vodica and Crni Lug, as well as Gerovo, Tršće and Čabar, and are also similar to the lithofacies near Ortnek and Kočevje. This diversity highlights the necessity to analyse the characteristics of a broader region, i.e. the Gröden clastic rocks from the Southern Alps (the Southern Alps are defined according to FLÜGEL & FAUPL, 1987, as the southern part of the Eastern Alps).

3.2. THE GEOLOGICAL FRAMEWORK OF THE PALAEOZOIC AND LOWER TRIASSIC ROCKS IN THE SOUTHERN ALPS

The geological framework of the Palaeozoic sedimentary rocks from several sites in the Southern Alps is presented by the ITALIAN RESEARCH GROUP (1986, p. 37), and modified by MASSARI et al. (1988). In short, the framework characteristics are as follows: The results of recent studies of this area are summarized in the papers by SWEET et al. (1992). RAUMER & NEUBAUER (1993) distinguish the Carboniferous-Permian sedimentary rocks and Lower Triassic sedimentary rocks, also termed late- to post-Variscan sedimentary rocks, as two megacycles. The late-Variscan and the post-Variscan movements commence in the Southern and Eastern Alps in the Upper Carboniferous (Moscovian/Cantabrian), which resulted in molasse type sedimentation which dominated the lower sedimentary cycle, and persisted until the Lower Permian (KRAINER, 1993). It is separated from the upper sedimentary cycle by a hiatus caused by the Saalian orogenic movements. The upper cycle commenced in different areas at different times, but in general it consists of (?)Middle-Late Permian and Lower Triassic sedimentary rocks. Tectonic and climate changes are the main factors that diversified the sedimentation processes of these two cycles (SCHÖNLAUB, 1993).

The lower cycle (Upper Carboniferous - Lower Permian) is characterized by the formation of intramontane basins filled with molasse type sediments. Within the lower cycle the transgressive-regressive clastic-carbonate sedimentary rocks are interpreted as a consequence of eustatic sea level oscillations, caused by glaciation on Gondwana (KRAINER, 1993). This in turn caused the climate to change from humid to semi-arid during the Middle Permian (SCHÖNLAUB, 1993).

The most important event which occurred in the Permian was the hiatus caused by the Saalian orogenic movements which divided the two cycles. The Saalian movements are characterized by block- and wrench-faulting (KRAINER, 1993, p. 549). In the basal part of the upper cycle, in semi-arid conditions conglomerates, sandstone and mudstones are present as well as the "red bed type" sedimentary rocks deposited as periodic braided streams and playa sediments (ASSERETO et al., 1973; BUGISCH et al., 1976). These sedimentary rocks are designated as the Gröden formation (according to KRAINER, 1993). In the Carnian Alps and the Karavanke, deposition commences with the Tarvissio breccia, and the Gröden formation consists of carbonate shales and siltites with thin dolomite intercalations, and sandstones that represent fluvial sediments, alluvial plain sediments, playas and shallow sea sediments (BUGGISCH et al., 1976; BUGGISCH, 1978; ORI & VENTURINI, 1981; FARABEGOLI et al., 1986). During the upper cycle (?Middle-Late Permian - Lower Triassic) deposition is characterized by the Tethyan transgression from the SE towards the NW which caused a change in depositional type manifested in the frequent alternation of shallow marine sediments with clastic continental sediment types (Gröden formation). The tectonic movements gradually abate during the upper cycle so the sedimentation in the broader region became more homogenous and is characterized by shallow marine carbonate and evaporite sedimentation represented by the Bellerophone formation. In the Julian Alps near Bled marine deposition is characterized by spongy-algal reefs (KRAINER, 1993).

Apart from western Dolomites (Lombardy) where the "red bed" fluvial sediments of the Verucano-Lombardo formation are the equivalents of Gröden and Bellerophone formation (CASSINIS et al., 1988), the Palaeozoic successions of all other regions terminate with the Bellerophone formation. Deposition of the upper cycle continuously proceeds with similar depositonal style to the Lower Scythian where the upper boundary of the second cycle is traced. However, the climatic conditions changed from arid to humid (BRENDNER et al., 1986) which caused drastic faunal changes.

If the clastic facies of Gorski Kotar is compared with the Gröden formation from the Carnian Alps (RAFFAELLI & ŠĆAVNIČAR, 1968; PALINKAŠ et al., 1993), it is presumed that at least some alternation with the carbonate facies (equivalent of Bellerophone formation) has to be expected as is the case with all the studied profiles in the wider region. If this is not the case, can we expect an continuous transition into Lower Triassic carbonate sedimentation?

The deposition of the Bellerophone formation is characterized by a transgression in the north-western direction (BROGLIO LORIGA & CASSINIS, 1992, p.79, fig. 8.1.), explaining why it pinches-out in that direction and passes into the continental facies. The deposition of the Werfen, i.e. Lower Triassic Servino formation (represented by alternating clastic and carbonate sedimentary rocks) continues in the westward direction from the east, into the Gröden formation (or its equivalent the Verucano-Lombardo formation), and afterward into lagoon, evaporite or shallow marine facies of the Bellerophone formation (BROGLIO LORIGA & CASSINIS, 1992). Only in the region east of the Adige Valley can this contact be considered as a continuous conformable sequence (BROGLIO LORIGA & CASSINIS, op. cit.).

4. CONCLUSION

From the numerous papers that dealt with the Palaeozoic complex of the Gorski Kotar, no explicit criteria are available for the exact definition of the youngest Permian facies, due to the absence of autochthonous fossils. Also none of the facies referred to can be recognized with certainty as of Upper Permian age. The complex tectonics in the Gorski Kotar region do not allow conclusions to be drawn about the unique Middle - Upper Permian sedimentological succession. The facies diversity and their frequent vertical and lateral variation does not permit conclusions about their unique superposition, and therefore it cannot be stated that the youngest facies corresponds to conglomerates and sandstones. The superposition criterion used for the determination of the youngest facies is therefore not applicable. The interpretation of a continuous transition from the Permian, developed as Gröden clastic rock facies, into shallow marine sedimentary rocks of the Lower Triassic, does not exist either in the adjacent areas (Velebit, Slovenia) or the wider region of the Southern Alps. The continuos transition can only be found in carbonate successions (Upper Permian dolomites from Velebit, and the Bellerophone formation in the Alps).

The frequent occurrence of coarse grained sedimentary rocks and sandstone permits the assumption that molasse type sedimentation occurred as a consequence of intensive erosion of uplifted areas as inferred by HERAK & TOMIĆ (1995). Although no direct evidence exists for the age of the Permian facies, an indirect conclusion about the age can be made from the fossil analysis of limestone pebbles and calclithites, which indicate that the age of the Gorski Kotar Permian complex corresponds to the clastic Trogkofel beds, i.e. Middle Permian (SREMAC & ALJINOVIĆ, 1997 - this. vol.). The molasse type deposition is the consequence of intensive tectonics in the Lower Permian or at the beginning of Middle Permian, as indicated by GRUBIĆ (1980).

The absence of Upper Permian carbonate deposition in Gorski Kotar, that would be similar to that which existed in the adjacent Velebit region (TIŠLJAR et al., 1991) or further to the east and southeast in middle Bosnia and Dalmatia (TIŠLJAR, 1992), also supports the presumption that a break in sedimentation exists at the Permo-Triassic boundary. The lack of carbonate and evaporite sedimentation, which is in contradiction with the Upper Permian characteristics of the wider region indicates that the Gorski Kotar region was under the influence of an emergence phase at that time. Deposition recommences in the Lower Triassic after a hiatus in the Upper Permian with a transgression of a shallow sea onto a flattened relief, which is the reason why an angular discordance, and other elements characteristic of a gradual transition across the boundary between the Upper Permian and the Lower Triassic are missing.

The gradual transition, as was until now presumed for the Permo-Triassic boundary in Gorski Kotar, should be manifested either with a gradual increase or decrease of certain parameters across a very short segment of the column. This means that only the outcrops permitting continuous sampling can document these changes. For the Permo-Triassic boundary, generally accepted criteria exist (see SWEET et al., 1992) that must be displayed within a small segment of a vertical sequence, thus further work on this task seems to be inevitable. From the known, published data it is not possible to infer the conclusion about continuous sedimentation on Permo-Triassic boundary.

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