Schriftenreihe der Erdwissenschaftlichen Kommissionen, Band 5, Seiten 93—106

Veröffentlichung des Österreichischen Nationalkomitees für das
International Geological Correlation Programme Project Nr. 73/I/4.
Triassic of the Tethys Realm

The Lower Triassic of Muć — Proposal for a standard section of the European Upper Scythian

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With 3 figs.

Abstract

In the Zmijavac valley (Muć, Mt. Svilaja, Croatia, Yugoslavia) four informal lithostratigraphic units are distinguished: (1) Permo(?)-Triassic dolomitic limestones, (2) brown reddish sandstone-siltstone beds, (3) grey limestone-marl beds, and on the top the Anisian dolomite rock complex. The third unit, being lithologically well defined, without breaks of sedimentation and rich in fossils (ammonoids, pelecypods, gastropods, foraminifers and conodonts) has been studied in detail. Two biostratigraphic zones have been distinguished, characterized by *Tirolites cassianus* and *Tirolites carniolicus* respectively. Due to obvious lithostratigraphic and biostratigraphic features this unit is proposed as a standard section of the Upper Scythian within the Werfen facies of the Western Tethys area.

Introduction

When the Yougoslav Working Group joined the International Geological Correlation Programme (Unesco — IUGS), Project 4 (Triassic of the Tethys Realm), it was decided to start also with the re-examination of the Lower Triassic area of Muć in Southern Croatia (Dalmatinska Zagora), a well known and unique locality with respect to its ammonoid fauna.

The locality has been of special interest since E. Kittl (1903) described an unusually rich collection of tirolitid ammonoids, establishing numerous new species. He distinguished the following species: *Dinarites laevis* Tomm., *Dinarites mucianus* (Hau.), *D. evolutior* Kittl, *D. biangulatus* Kittl, *D. nudus* Mojs., *D. dalmatinus* (Hau.), *D. multicostatus* Kittl, *D. tirolitoides* Kittl, *D.* (?) *angulatus* Kittl, *D.* (*Hercegovites*) *mohamedanus* Mojs., *D.* (*Liccaites*) *connectens* Mojs., *D.* (*Liccaites*) *progressus* Kittl, *Stacheites prionoides* Kittl, *Ceratites* (*Paraceratites*) *prior* Kittl, *Tirolites* (*Holobus*) *monoptychus* Kittl, *T. carniolicus* Mojs., *T. heterophanus* Kittl, *T. mercurii* Mojs., *T. paucispinatus* Kittl, *T. seminudus* Mojs., *T. distans* Kittl, *T. quenstedti* Mojs., *T. robustus* Kittl, *T. dimidiatus* Kittl, *T. stachei* Kittl, *T. dinarus* Mojs., *T. hybridus* Kittl, *T. angustus* Kittl, *T. subillyricus* Kittl, *T. illyricus* Mojs., *T. repulsus* Kittl, *T. rotiformis* Kittl, *T. rectangularis* Mojs., *T. undulatus* Kittl, *T. angustilobatus* Kittl, *T. cassianus* (Quenst.), *T. spinosus* Mojs., *T. haueri* Mojs., *T. multispinatus* Kittl, *T. percostatus* Kittl, *T. turgidus* Mojs., *T. darwini* Mojs., *T. spinosior* Kittl, *T. smiriagini* (Auerbach), *T. kerneri* Kittl, *T. toulai* Kittl, *T.* (*Svilajites*) *cingulatus* Kittl, *T.* (*Svilajites*) *tietzei* Kittl, *T.* (*Bittnerites*) *malici* Kittl, *T.* (*Bittnerites*) *bittneri* Kittl, *T.* (*Bittnerites*) *telleri* Kittl, *Kymanites svilajanus* Kittl, *Dalmatites morlaccus* Kittl.

The sampling localities have not been precisely established. Only Gornji Muć has been mentioned. Therefore taxonomic and evolutionary questions were analysed without necessary respect to the time factor. Consequently, only morphologic variability was applied as criterion for establishing new taxa. This may be the reason why from 53 species 16 were considered to be new. The list of species has been diminished by B. KUMMEL (1969), who revised KITTL's material and diminished the number of species to thirteen (see KUMMEL, 1969, 343).

The next step has been made by L. KRYSTYN (1974). He sampled two sections on the slope of Bukova gora (near Mijići), between Muć and Sinj. Ammonoids were collected at 3 horizons. The first horizon is about 20 m above the contact between the brown reddish sandstone-siltstone beds and the grey limestone-mark beds. The dominant species is *Tirolites cassianus* (QUENSTEDT) accompanied by *Diaplococeras liccanum* (HAUER) and *Dinarites* cf. *dalmatinus* (HAUER). The second horizon is about 50 m below the contact with the dolomites (mapped as Anisian). The ammonoid fauna is quite different—containing *Tirolites bi-idrianus-carniolicus, Tirolites carniolicus Mojsisovics, Stacheites* cf. *prionoides* KITTL, *Stacheites* cf. *concavus* SHEVYREV, and *Dinarites* sp. indet. The third horizon is located in a profile in the vicinity. It is about 8—10 m below the contact with the dolomites. The ammonoids are represented by *Tirolites carniolicus* MOJSISOVICS and *Tirolites mangyshlakensis* (SHEVYREV).

Analizing the variation curve concerning the number of ribs resp. of marginal nodes within adult *Tirolites cassianus* KRYSTYN concluded that the forms *Tirolites darwini, T. haueri, T. illyricus, T. rectangularis, T. spinosus, T. turgidus, T. angustilobatus, T. dimidiatus, T. hybridus, T. kerneri, T. multispinatus, T. percostatus, T. repulsus, T. rotiformis, T. spinosior, T. toulai, Ceratites (Paraceratites) prior* (as well as *T. bispinatus* GANEV) are synonyms of *Tirolites cassianus* (QUENSTEDT). He also suspected that *T. mangyshlakensis* may represent only an extreme variety of *Tirolites carniolicus* MOJSISOVICS. Summarizing the stratigraphical data KRYSTYN proposed to distinguish two zones, i. e. a lower *Tirolites cassianius* zone and an upper *Tirolites carniolicus* zone. Their regional distribution may be influenced by facies changes.

Our additional field investigations have shown that the sequence at Mijići, compared with some other profiles, seems to be reduced. Therefore, for our purposes we have chosen the profile in the valley of the Zmijavac brook, where a continuous thick sequence of Upper Scythian rocks is exposed. The layers have been suitable for individual treatment and their exact thickness was easily to be measured. The fact that in this profile the lowermost Triassic is partly reduced due to tectonics, has been considered as less important, because the main task of our investigations was to locate the vertical distribution of the ammonoids and other faunal remains within the Upper Scythian as precisely as possible. On the other hand, a series of characteristic rock samples has been taken from the whole section for micropaleontological purposes as well as for studying their microfacies. The goal was the reconstruction of the original biotopes (paleoenvironment), but due to insufficient data it has not been reached so far.

The co-ordination and finalisation of the research project has been performed by M. HERAK. The field work was carried out by A. ŠUŠNJARA, B. ŠĆAVNIČAR, Ž. ĐURĐANOVIĆ, J. BENIĆ and M. HERAK (Zagreb). The fauna has been determined by various specialists, the conodonts and foraminifers by Ž. ĐURĐANOVIĆ, ammonoids and gastropods by L. KRYSTYN (Vienna), pelecypods by B. GRUBER (Linz), and the fish remains by S. STEFANOV (Sofia). The sedimentologic and petrographic data are the result of detailed analyses done by B. ŠĆAVNIČAR and A. ŠUŠNJARA. All the authors of the paper have contributed to the final version of the text.

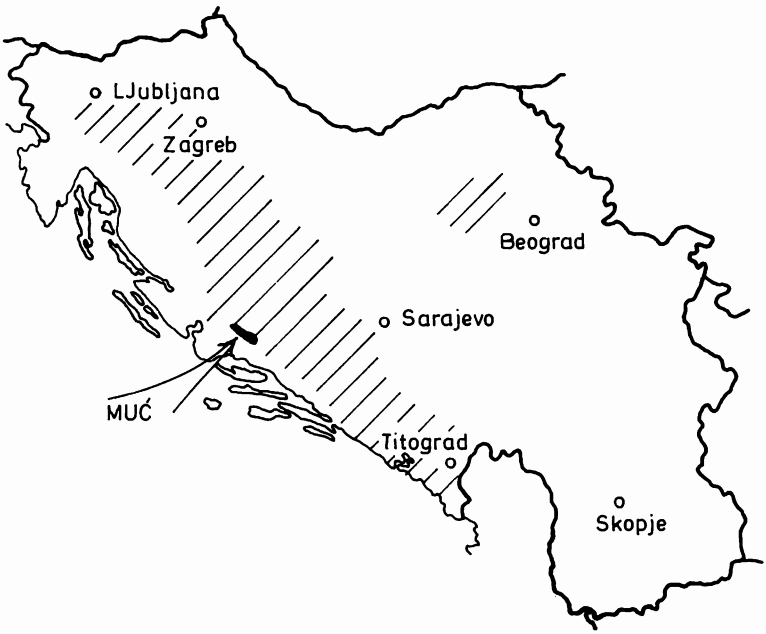

Fig. 1. Distribution of Upper Scythian ammonoid bearing rocks in the Dinarides with location of Muć.

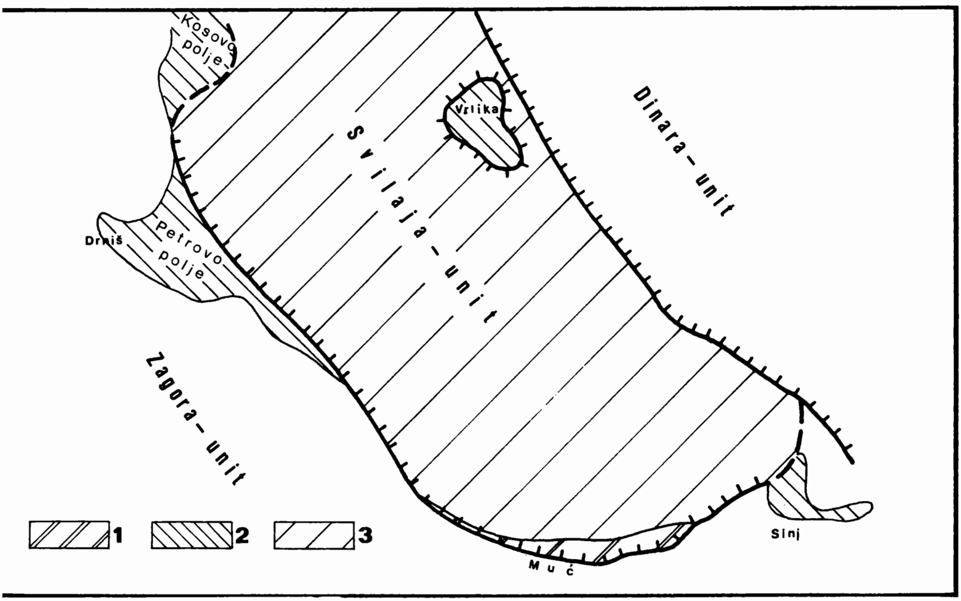

Fig. 2. Tectonic sketch-map of the surroundings of Muć; 1) Lower Triassic of Muć; 2) Permo-Triassic and Lower Triassic of the underlying tectonic unit; 3) Mesozoic carbonate rocks of the Svilaja-unit.

The authors are very grateful to S. STEFANOV and J. BENIĆ for their technical assistence, and to the Institutes in Zagreb, Vienna, Linz and Sofia for full support during the preparation of this paper.

Geological outline of the region of Muć

The Triassic of Muć is extending along the southern slope of Mt. Svilaja (Figs. 1 and 2). The whole area belongs to the Carbonate ("outer", "miogeosynclinal") Dinarides displaying a complex overthrust tectonics. Mt. Svilaja, including the Lower Triassic of Muć, represents a nappe-unit composed of Mesozoic beds in a normal north-dipping sequence from Lower Triassic to the Cretaceous. It is one of the various units which form the so called "High Karst Zone" (or "High Karst Nappe"). To the north and north-east the Svilaja nappe is overlain by the Dinara-unit.

The southern border of the Svilaja-unit is marked by a strong neotectonic fault which hides the true character of the contact with the southern area. This area between Muć and Kozjak (N. of Split) is composed of a set of thrust-units moved relatively into southwestern direction over the coastal zone. It consists of Cretaceous and Paleogene beds with a predominance of the Cretaceous rocks. In recent times the zone between Muć and Kozjak has been described by the names "Zagora-zone" (CHOROWICZ 1977) or "Promina-Moseć-Muć-zone" (IVANOVIĆ et al. 1978) but most often it has been attributed to the "High Karst Zone" s. l.

Due to tangential tectonics, the Lower Triassic of Muć has been brought into closer contact with rocks of the same age in Sinj, Vrlika, Petrovo polje and Kosovo polje (fig. 2). They belong to the underlying structural complex and show a different lithological as well as facies development.

Continuing to the northwest, i. e. in Lika, Mt. Velebit, Gorski Kotar, and in the neighbouring part of Slovenia, the Upper Scythian is lacking ammonoids. Its lithology is rather specific, characterized by a predominance of dolomites or sandy dolomites (Lika and Mt. Velebit), whereas in Gorski Kotar the time equivalents to a great extent have been removed by erosion. Only fragments are presently proven by *Meandrospira pusilla* (HO). The reduction of clastics and the predominance of carbonates (Lika, Mt. Velebit) may be explained by a rapid lowering of reliefs causing the break or diminishing of the supply of clastic components into the basin where shallow water dolomite sedimentation prevailed. In the Lika this happened already in the upper part of the Middle Permian, in Slovenia in the Upper Permian, and in Gorski Kotar in the time-span connecting the Permian and the Triassic (ŠĆAVNIČAR 1973).

Parallel, along the eastern margin of the mentioned zone, from Crmnica (Monte Negro) to Idria (Slovenia), Upper Scythian beds have been formed in a somewhat deeper and less mobile sedimentation area which was extended also over some neighbouring parts of Serbia, Bosnia, Croatia, and Slovenia.

In the region of Muć the topmost Permian and the lower part of the Scythian consist of limestones and breccias (Sinj, Muć) overlain by reddish siltstones, pelites, and locally by porous breccias. The exposures have been explained by "diapiric" tectonic windows within allochthone units (HERAK 1973).

The Upper Scythian is generally composed of less differenciated, thin-bedded, predominantly carbonate rocks, formed in a somewhat deeper, sea-water environment. Terrigenous silt is subordinate. Besides the remains of the most common benthonic fossil groups as gastropods ("*Turbo*", "*Naticella*"), foraminifer (*Mean-*

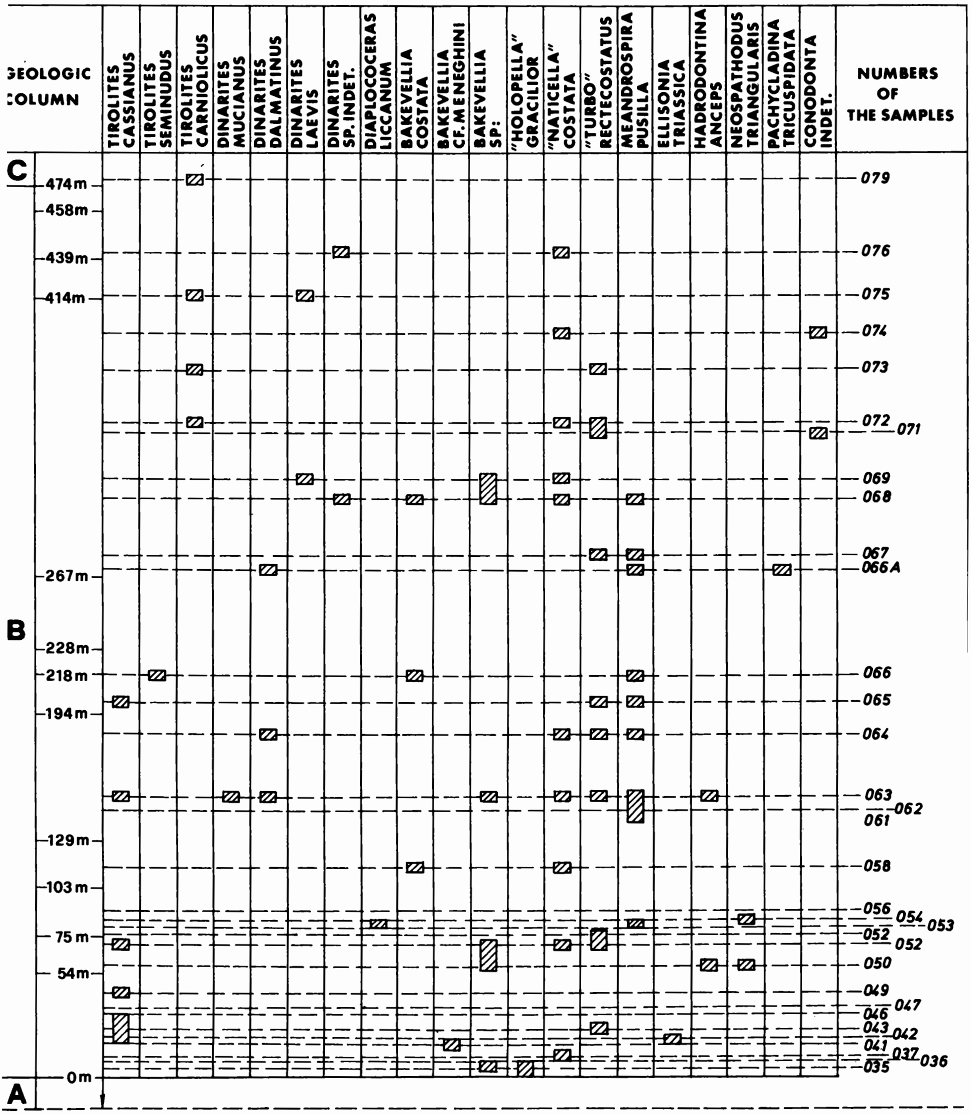

Fig. 3. Vertical distribution of invertebrate fossils in the Upper Scythian standard section at Muć (layers 041—078).
A — final part of the sandstone-siltstone complex
B — the limestone-marl complex
C — the dolomite complex.

drospira) and also ammonoids have been found in many localities in the area delimited by Rumija (Monte Negro), Fruška gora (Vojvodina) and Idrija (Slovenia). Muć is only one of them, but due to its ammonoid fauna evidently best known. The local fossil sites are Gornji Muć, Donji Muć, Mijići and Sutina. They are located along the whole Lower Triassic zone. Only the sampling points at Mijići are precisely indicated (KRYSTYN 1974).

The Lower Triassic of the Zmijavac brook valley

Besides the general characteristics, already mentioned, the exposed beds have been suitable for distinguishing several more or less specific intervals which are consequences of successive changes of conditions within the sedimentation area. Therefore, our sampling was very intensive. More than 80 samples have been analysed for both sedimentologic and paleontologic purposes.

The rock sequence in the valley can be divided into four informal lithostratigraphic units: the basal carbonate complex, the sandstone-siltstone beds unit, the limestone-marl beds unit and the overlying dolomite unit.

(1) The basal carbonate complex

At the base of the section in Zmijavac creek approximately 100 m upwards the asphalt road of Muć, greyish recrystallized dolomitic limestones are to be found. They are thinner bedded and laminated in the upper part. The topmost portion contains some terrigenous silty admixtures, identical to those which prevail in the overlying clastics. This is the reason why these limestones are thought to belong to the Lower Triassic. However due to a fault no transition into the overlying clastics is visible and age diagnostic fossils are also missing.

(2) Brown reddish sandstone-siltstone complex

This unit consists mainly of thin-bedded, fine-grained sandstones, siltstones and pelites with subordinate intercalations of carbonate rocks. In some horizons the carbonate rocks prevail, but terrigenous material is always present either as components within the limestones or as interstratified sandstone layers.

The lowest part of the exposed complex consists of horizontally or cross laminated micaceous sandstones, siltstones and silty pelites. The colour is brownish-grey, partly violet. They are composed of detrital quartz, muscovite, chlorite, biotite, feldspars and illite. All the clastic members are calcareous (24—49% $CaCO_3$). The carbonate content consists of fossil debris and calcite cement. Rarely syntaxial cement is present. Partially preserved pyrite testifies a partly reducing sedimentary environment. Otherwise oxydizing conditions are testified by the common presence of limonite. The thickness of this interval is approximately 30 m.

The next part is characterized by an increase of allochemical carbonate rocks. First (8 m) bio-oosparites predominate, followed by intrasparites indicating shallow turbulent sea. These calcarenites are accompanied by fine-grained partly recrystalized limestones, lacking allochems. At least in 4 levels the dolomitisation is to be noticed. Due to the hematite and limonite content the colour is reddish-brown indicating oxydizing depositional environments. The terrigenous detritus is continuously present as components and/or layers in between. The thickness is approximately 45 m.

The uppermost part of the unit contains again predominantly clastic rocks, i. e. micaceous sandstones, siltstones and pelites. Sandy fine-grained limestones are interbedded in several levels. Allochemical limestones occur in the upper part, as rare intercalations. They are composed of rudite size intraclasts, derived from contemporaneous weakly consolidated carbonate sediments on the sea floor, which are reworked and redeposited. So, the intrasparrudites have been found, indicating shallow water, lowered wave base or possibly tectonic uplift. Pitching out of beds, erosional contacts between them, and desiccation structures speak also in favour of an extremely shallow water environment interferring with short-lived emersion phases, mud drying etc. Yellowish thin-bedded dolomicrites of early diagenetic origin mark the end of this interval which is approximately 55 m thick.

The fauna of this complex has not been intensively studied. In general it can be said that only bivalves, e. g. *Anodontophora* and *Claraia* are common; the latter has been registered within 9 horizons.

(3) Grey limestone-marl complex

A 474 m thick complex which is rather monotonous, consisting of fossiliferous limestones (biomicrites, biomicrudites), fine-grained marly limestones and limey marls which are in a continuous irregular rhythmic exchange. The colour of the limestone varies from dark-grey to grey-brown. Marly intercalations are yellow to brown. Silty components are present through the whole complex, and several siltstone beds are to be found in the lower and middle part of the complex. Parallel with the increase of the terrigeneous detritus, the violet-brown tint predominates. The bedding is obvious. Mostly thin-bedded series are present. The thickness of the limestone layers varies from 5 to 40 cm. The layers become thinner (1,5—5 cm) with increasing clay content. Mega-fossiliferous limestones are mostly interbedded within marly limestones or limey marls. They contain 80—90% $CaCO_3$, while in the marls 50—63% (most frequently 60%) is present.

The beginning of the limestone-marl complex is marked by an exchange of coarse-grained recrystalized fossiliferous limestones (biomicrites), fine-grained marly limestones, and fissile marls. Despite frequent exchange, limestones seem to be dominant. Silty components are always present, more frequently in the marly limestones. Authigenic pyrite is common as a minor constituent. The thickness of the observed interval is approximately 54 m.

Fossils are very frequent and have been found in several horizons. They are cited beside the sample numbers (Fig. 3):

035: "*Holopella*" *gracilior* (SCHAUROTH)
036: *Bakevellia* sp.
"*Holopella*" *gracilior* (SCHAUROTH)
037: "*Turbo*" *rectecostatus* HAUER
041: *Bakevellia* cf. *meneghini* (TOMMASI) (abundant)
Mysidioptera sp.
042: *Tirolites cassianus* (QUENSTEDT) (abundant)
"*Turbo*" *rectecostatus* HAUER
Ellisonia triassica MÜLLER
Lonchodina muelleri TATGE
Conodonta indet.
Ammodiscus sp., *Nodosaria* sp.
Saurichthys apicalis AGASSIZ
Saurichthys acuminatus AGASSIZ
Colobodus varius GIEBEL

043: *Pleuromya* cf. *fassaensis* WISSMANN (abundant)
"*Turbo*" *rectecostatus* HAUER
044: *Tirolites cassianus* (QUENSTEDT)
Mysidioptera sp.
"*Turbo*" *rectecostatus* HAUER
Ostracoda, Echinodermata
045: *Tirolites cassianus* (QUENSTEDT) (abundant)
Nodosaria sp., Ostracoda
046: *Tirolites cassianus* (QUENSTEDT)
047: *Tirolites cassianus* (QUENSTEDT)
Mysidioptera sp.
49: *Tirolites cassianus* (QUENSTEDT)
Ostracoda, Echinodermata
Saurichthys acuminatus AGASSIZ

The next interval (54—267 m) is characterized by a similar series of well bedded grey limestones (beds 40 cm thick), flaggy marly limestones and fissile calcareous marls. This sequence (213 m thick) is periodically enriched by silt admixtures and siltstone intercalations (4 levels). Parallel with the concentration of silt the violet colour appears. Within the silty limestones and siltstones a fine cross and horizontal lamination is present. Various deformation structures (tortuous lamination) as convolute lamination, load casts, and rarely pillow structures are present, sporadically also graded bedding is to be noticed. In the upper part some organic traces can be found. Fossil remains are various and abundant:

050: *Bakevellia* sp. (+ div. Pelecypods)
"*Holopella*" *gracilior* SCHAUROTH
Hindeodella triassica MÜLLER
Hadrodontina anceps STAESCHE
Neospathodus triangularis (BENDER)
? *Ellisonia* sp.
Colobodus varius GIEBEL
Gyrolepis albertii AGASSIZ
Saurichthys apicalis AGASSIZ
051: *Tirolites cassianus* (QUENSTEDT)
Tirolites sp. indet.
Pleuromya sp.
Mysidioptera sp.
Bakevellia sp.
"*Naticella*" *costata* ZENKER
"*Turbo*" *rectecostatus* HAUER
Foraminifera, Ostracoda, Echinodermata
Gyrolepis albertii AGASSIZ
Saurichthys apicalis AGASSIZ
Saurichthys acuminatus AGASSIZ
053: *Diaplococeras liccanum* (HAUER)
Colobodus varius GIEBEL
054: *Diaplococeras liccanum* (HAUER)
Neospathodus triangularis BENDER
Spirilina gurgitata TAPPAN

Meandrospira pusilla (Ho)
Saurichthys apicalis AGASSIZ
Saurichthys acuminatus AGASSIZ

055: Gastropoda

056: *Aeolisaccus dunningtoni* ELLIOT
Ostracoda

058: *Bakevellia* cf. *costata* ZENK. (abundant)
"*Naticella*" *costata* ZENK.

061: *Meandrospira pusilla* (Ho)
? *Ellisonia* sp.
Ostracoda, Echinodermata

062: *Meandrospira pusilla* (Ho)
Ostracoda, Mollusca
Gyrolepis albertii AGASSIZ

063: *Tirolites cassianus* (QUENSTEDT)
Dinarites mucianus (HAUER)
Dinarites dalmatinus (HAUER)
Pleuromya sp. (abundant)
Bakevellia sp. (abundant)
"*Turbo*" *rectecostatus* HAUER
Hadrodontina cf. *anceps* STAESCHE
Meandrospira pusilla (Ho)

064: *Dinarites dalmatinus* (HAUER)
"*Naticella*" *costata* ZENK.
"*Turbo*" *rectecostatus* HAUER
Meandrospira pusilla (Ho)

065: *Tirolites cassianus* (QUENSTEDT), transitional form to *Tirolites seminudus* (MOJSISOVICS)
? *Ellisonia* sp.
Meandrospira pusilla (Ho)
Mollusca div.

066: *Tirolites seminudus* (MOJSISOVICS)
Bakevellia costata (ZENKER) (abundant)
Pleuromya cf. *lettica* (QUENSTEDT)
Hoernesia sp.
Pachycladina tricuspidata STAESCHE
Ellisonia sp.
Hadrodontina sp.
Meandrospira pusilla (Ho).

In the upper part of the unit (267—474 m) the same kind of sediments is present. In general grey limestones are dominant. Silty admixtures are very rare though present. Different load structures are visible as well as bioturbation structures which are more frequent. The thickness is approximately 207 m. In the interval between 414 and 429 m mechanical deformations are visible. Fossils have been found in the following horizons:

066A: *Dinarites dalmatinus* (HAUER)

067: *Meandrospira pusilla* (Ho)

068: *Dinarites* sp. indet.
Bakevellia costata (ZENKER) (abundant)
Bakevellia sp.
Pleuromya cf. *ambigua* BITTNER
Ammodiscus sp.
069: *Dinarites laevis* TOMMASI
Myophoria balatonis FRECH
Costatoria cf. *costata* (ZENKER) (abundant)
Pleuromya cf. *fassaensis* WISSMANN
Bakevellia sp.
071: Conodonta indet.
Ammodiscus sp.
Crinoidea
072: *Tirolites carniolicus* MOJSISOVICS
"*Naticella*" *costata* ZENKER
"*Turbo*" *rectecostatus* HAUER
073: *Tirolites carniolicus* MOJSISOVICS
074: Conodonta indet.
Ammodiscus cf. *incertus* (D'ORB.)
Glomospirella sp.
075: *Tirolites carniolicus* MOJSISOVICS
Dinarites laevis TOMMASI
Fish-remains
076: *Dinarites*? sp. indet.
Ammodiscus sp.
Glomospira sp.
077: Mollusca, Crinoidea, Foraminifera (indet.).

The final interval of the unit (458—474 m) is characterized by last traces of silty admixtures and by the beginning of an intensified dolomitization (dolomitized limestones and early diagenetic dolomicrites) which points to a hypersaline shallow water environment. Due to the silty admixtures, this interval is attributed to the underlying sequence with a sharp contact to the overlying beds.

(4) The dolomite complex

Above the before mentioned sharp contact only carbonate sediments occur, completely lacking silty admixtures. The first 15 m are represented by somewhat disturbed early-diagenetic stromatolitic dolomites and doloarenites. At the base of this horizon (079) the last specimen of an ammonoid has been found: *Tirolites carniolicus* MOJSISOVICS together with dasyclad algae.

The overlying rocks consist of dolomite breccias composed of different dolomite rock fragments. This carbonate rock complex is in geologic practice unseparable from the overlying mass of carbonate rocks and that is the reason why it is treated as a part of the Anisian. We therefore strongly argue in favour of a Scythian-Anisian-boundary placed between the Werfen Formation and the overlying carbonate rocks.

Interpretation of sedimentary environments

Though all the investigated rocks contain terrigenous as well as autochthonous carbonatic components, it is obvious that within the lower part of the sequence terrigenous material prevails, whereas within the Upper Scythian carbonate sediments are dominant.

The terrigenous detritus is fine-grained and well sorted throughout the sequence. This may indicate that the source area was remote during the entire Lower Triassic. The terrigenous detritus, especially heavy minerals, suggest low grade metamorphic schists, acid igneous rocks and older sediments to be the source rocks of the clastics in question. Consequently the Paleozoic of Europe is considered as possible source area.

It is impossible to trace any coast line. However, where exposed, the Werfen Formation follows concordantly above the Permian. Only a local unconformity or a short break of sedimentation is to be noticed (see also ASSERETO et al., 1971).

At the beginning of the Lower Triassic a shallow and probably hypersaline (?) sea with a very low relief and therefore with similar sedimentary environment over large areas, extended all over the Dinarides. Very soon normal marine conditions were established according to the common presence of a benthonic mollusc fauna from the beginning of the sandstone-siltstone complex upwards. During the phases of stronger turbulence carbonate detritus was built in the sea and it was mixed up with terrigenous material transported into the sedimentation area.

The common sedimentary structures in the sandstone-siltstone complex are cross bedding and horizontal lamination and wide flattened symmetric ripple marks on the upper bedding planes. Deformational structures (slump structures, pillow and ball structures) are often to be found, in some intervals erosional contacts are to be noticed. Sporadically also desiccation phenomena are present. The thickness of beds is varying and their pitching out is not rare. All this, as well as the oolites, intraclasts, and autoclasts confirm a shallow, turbulent marine environment, with sporadic local emersions. This is testified also by the presence of early-diagnetic dolomites in several intervals. The presence of oolitic limestones is also an indication of a shallow, turbulent sea water, saturated by $CaCO_3$.

In the lower part of the Upper Scythian limestone-marl complex the thickness and the strike of beds are constant. In the middle and upper parts some changes in thickness (even pitching out) have been noticed. Ripple marks on upper bedding planes otherwise are missing. Siltstones and silty limestones display horizontal and cross lamination. Erosional channels and load structures can be found on lower bedding planes of micaceous limestones. Linear current structures are rare. Pillow and ball structures appear exceptionally only in one interval of silty rocks.

All the mentioned and some other features (lacking of oolites, intraclasts and dolomites) point in favour of a deeper and stable marine depositional environment with periodical appearance of stronger currents loaded by coarse-grained shallow water biodetritus (shells, crinoidal remains etc.). Calcareous algae are absent, while authigenic pyrite and some organic structures (tracks, trails, burrows) can be found. This suggests that the limestone-marl complex most probably was deposited below the wave base under partly reducing conditions in a low energy environment. It is obvious that the depth, turbulence and alcalinity were different in comparison to the underlying sandstone-siltstone complex.

Stratigraphic conclusions

Lithostratigraphically the Lower Triassic of Muć is being devided into 4 informal units ("members"), which with regard to their lithology, facies and vertical sequence correspond remarkably well with those of the Werfen beds of the

Dolomites (Upper Italy). Surely it would be possible and also desirable to extend the already in the Dolomites established lithostratigraphic members (see BOSSELINI 1968, ROSSI 1969, FARABEGOLI et al., 1977) to Muć, respectively all in all to the Werfen beds of the entire Alpine-mediterranean realm (Alps, Dinarides).

Because of the large lateral distance between the Dolomites and Muć, as well as the absence of comparable sections in between, at present a direct, e. g. nominal identification of the "South Tyrol" members in the Muć section does not seem appropriate. On the other hand we regard it as unjustified to introduce new names to the identified lithostratigraphical units. Subsequent research on the regional and facies distribution of the Werfen beds of the Western Tethyan area will probably bring clearness into this question. By the following lines the lithostratigraphic sequence of Muć and its correlation with that of the Dolomites is being summarized:

1) The basal carbonate complex, consisting of grey, bedded, laminated dolomitic limestones can — inspite of certain circumstances — be quite well compared with the Mazzin member and the Andraz horizon of the Dolomites.
2) The sandstone-siltstone complex (Member A) comprises 3 subunits which should become discussed separately: a) the basal series of reddish brown calcareous siltstones and sandstones has great similiarity with the Siusi Member and is overlayn by b) an 8 m thick sequence of brown reddish oolitic calcarenites which apparently become directly correlated with the Gastropode Oolite Member. On top again follow c) brown reddish sandstones and siltstones, interlayered with calcarenites and silty micrites, fully corresponding with the Campilian Member.

   A confirmation and important support for this correlation seems to us also the abundant representation of the bivalve *Clarai* restricted to Member A in Muć.
3) Member B, the biostratigraphically more precisely studied limestone-marl complex (fig. 3), is lithologically identical with the Val Badia Member and with this also has the same fauna in common (*Tirolites cassianus*, *Dinarites*, "*Naticella*", "*Turbo*"). In Muć however the Val Badia Member seems to have a larger stratigraphical range than in the Dolomites, as here a counterpart to the overlying Cencenighe member, which represents the highest part of the Werfen Formation in the Dolomites, is missing. The direct comparison is further being made difficult by the lower Anisian regression which has led to the transgression of the Richthofen conglomerate and to the erosion of parts of the Werfen beds in the Dolomites. According to biostratigraphic data at least equivalents of the Carniolicus-Zone are widely missing.

Member B is overlayn by unfossiliferous light grey bedded dolomites (c), which however on lithostratigraphic grounds only have been dated long ago as Lower Anisian. This age assignment has been questioned only by KRYSTYN 1974, who correlated the basal dolomite with the Subrobustus zone, conventionally regarded as Lower Triassic (see TOZER 1978). MOSTLER & ROSSNER 1977, who mentioned a conodont fauna of Scythian affinity from the lowermost part of the Gutenstein dolomite in the Salzkammergut area (Northern Calcareous Alps), came to the same conclusion.

Due to the otherwise pure fauna, a detailed biostratigraphical analysis of the Lower Triassic of the Muć region has to be restricted to the limestone-marl complex (member B) representing the upper half of the sequence. As can be seen on the distribution chart (fig. 3), most of the examined taxa range through a greater part of the section. Only the ammonoids are short-ranging enough to provide a tool for subdividing the whole unit. Conodonts are rare and proven in a few horizons in order to allow stratigraphically relevant statements. They may be divided into a lower, comparatively rich fauna, composed of *Ellisonia triassica*, *Hadrodontina anceps* and — surprisingly — *Neospathodus triangularis*. The pure fauna of the higher part contains only *Pachycladina tricuspidata* and some undeterminable remains. Among the foraminifera considered stratigraphically valuable, *Meandrospira pusilla* is to be mentioned. It is being found in the middle part of the sequence, where it occurs almost exclusively in silty limestones and siltites. Its distribution seems to be highly facies controlled, because it is more or less missing in the clayey and marly beds in between.

Combining both lithostratigraphic and biostratigraphic data, the Member B can be taken also as a very distinct chronostratigraphic unit which is defined by the two Tirolites zones introduced by KRYSTYN 1974, namely the *Tirolites carniolicus* and the *Tirolites cassianus* zones, the latter forming the base of it. The new unit for the time being may be introduced as a local substage for the Upper Scythian of the Werfen facies area distributed over wide parts of the Western Tethys (Turkey as far as the Alps).

According to the described characteristics of the profile in the Zmijavac brook valley at Muć, it deserves to be used as standard section or neostratotype for the new unit. It is very suitable for this purpose because it is lithologically and palaeontologycally well defined, temporarily and spatially homogenous; the beds are well exposed, the locality accessable, the rocks well recognizable and measurable. Out of practical reasons it would have been desirably for the name "Campillian" to serve as chronostratigraphic term for this time interval, but unfortunately the Campill beds s. str. (=the Campill member sensu BROGLIO LORIGA & al. 1981) of the type region in the Dolomites are older than it.

As this profile crosses the beds which display some transitional features between epicontinental and pelagic environments, it may be very useful for correlation, especially in the discussion concerning the Lower/Middle Triassic boundary.

References

ASSERETO, R., BOSSELLINI, A., FANTINI-SESTINI, N., SWEET, W. C.: The Permian-Triassic boundary in the Southern Alps (Italy). Mem. Canad. Soc. Petroleum Geol., 2, pp. 176—199, 6 figs., Calgari/Alberta 1973.

ASSERETO, R., JACOBSHAGEN, V., KAUFFMANN, G. & NICORA, A.: The Scythian, Anisian boundary in Chios, Greece — Riv. Ital. Paleont., 85/3—4, 715—736, 6 figs., Milano 1979.

BOSELLINI, A.: Paleogeologia pre-anisica delle Dolomiti centro-settentrionali. Mem. Acc. Naz. Lincei ser. 3, 9 (1), pp. 3—33, ff. 1—5, tt. 1—16, Roma 1968.

BROGLIO LORIGA C., MASETTI, D., NERI, C.: The Werfen Formation in the Dolomites (in press).

CHOROWICZ, J.: Étude géologique des Dinarides le long de la structure transversale Split-Karlovac (Yougoslavie). — Soc. géol. du Nord, Publ. n° 1, 1—331, pl. X, 156 figs., S. G. N. Villeneuve d'ASCQ 1977.

Farabegoli, E., Pisa, G., e Ott, E.: Risultati preliminari sull'Anisico della conca di Agordo e dell'alta Val di Zoldo. — Boll. Soc. Geol. Ital., **95** (1976), pp. 659—703, 11 ff., Roma 1977.

Herak, M.: Some tectonical problems of the evaporitic area in the Dinarids of Croatia. — Geol. vjesnik, **26**, 29—40, 1 text-fig., Zagreb 1972.

Ivanović, A., Sikirica, V. and Sakač, K.: Osnovna geološka karta S. F. R. J. — Tumač za list Drniš, K-33-9; Inst. geol. istraž. Zagreb 1972, Savezni geološki zavod, 1—59, Beograd 1978.

Kittl, E.: Die Cephalopoden der oberen Werfener Schichten von Muć in Dalmatien sowie von anderen dalmatinischen, bosnisch-herzegowinischen und alpinen Lokalitäten. — Abh. Geol. R.-A., **20**, 1—77, 1 fig., 11 pls., Wien 1903.

Krystyn, L.: Die Tirolites-Fauna (Ammonoidea) der untertriassischen Werfener Schichten Europas und ihre stratigraphische Bedeutung. — Sitzber. Österreich. Akademie Wiss., Mathem.-naturw. Kl., Abt. I, **183**/1—3, 29—50, 5 text-figs., 1 pl., Wien 1974.

Kummel, B.: Ammonoids of the Late Scythian (Lower Triassic). — Bull. Mus. Comp. Zool., **137**/3, 311—702, 20 figs., 7 pl., Cambridge (Mass.) 1969.

Mostler, H. & Rossner, R.: Stratigraphisch-fazielle und tektonische Betrachtungen zu Aufschlüssen in skyth-anisischen Grenzschichten im Bereich der Annaberger Senke (Salzburg, Österreich). — Geol. Paläont. Mitt. Innsbruck, **6**, 1—44, 13 Abb., 6 Taf., Innsbruck 1977.

Rossi, D.: Formazione di Werfen. — In: Note illustrative della Carta Geologica d'Italia, folio 11 "M. Marmolada". Servizio Geologico d'Italia. Roma 1969.

Šćavničar, B.: Klastiti trijasa u Gorskom kotaru (Clastic sediments of the Triassic in the Gorski Kotar Region). — Acta geol. Jugosl. akad. znan. i umjetn., **7**/3, 105—160, 3 text-figs., 20 tab., 10 pl., Zagreb 1973.