

Stratigraphy of the Hallstatt region

By

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Introduction

Our excursion deals mainly with the Hallstatt Limestone development and its conodont fauna.

In the Hallstatt facies belt sedimentation started in the Upper Permian which is represented by clastic and evaporitic rocks known as „Haselgebirge“. During the Lower and Middle Triassic shallow water limestones and dolomites dominated. Sandwiched between these carbonates of mainly Anisian age and clastic sediments of the Upper Norian/Rhaetian Zlambach Fm. the Hallstatt Lst. is placed. Stratigraphically the Hallstatt Lst. spans the time from Upper Anisian (Illyrian) to Upper Norian (Sevastian).

The Triassic of the Northern Calcareous Alps is characterized by several main facies zones which from N to S reflect an increasing open marine environment. The greater part of the Calcareous Alps comprises thick cyclic shallow water carbonates; in the Lower and uppermost Triassic they can be replaced laterally by pelitic basinal sediments. Particularly in the Upper Triassic the original transition from lagoonal deposits (so-called Hauptdolomit-Fazies) to normal saline intertidal Dachstein Lst. with large „barriere reefs“ (Dachstein Reef Lst.) in the south can be traced although most of these blocks were strongly affected by Alpine nappe tectonics. In this paleogeographic restoration the pelagic fossiliferous Hallstatt Lst. presumably were located on the outer (?) shelf edge. However, they may have been deposited on an oceanic crust too as can be inferred from their connection with oceanic basement rocks (pillow lavas etc.) in the Eastern Tethys realm, e. g., in Greece and Turkey.

Although it has been known for more than a century that the Hallstatt Lst. ranges from the Anisian to the Norian the representation and extent of the individual stages has been a matter of a long discussion. For example, as concern the Ladinian Stage, a stratigraphic gap was assumed not only in the last century but also 10 years ago. The main reason for this conclusion was actually the poor representation of Ladinian faunas. Also, detailed sections were missing for comparison of the mostly isolated Hallstatt Limestone occurrences. The ammonite chronology of MOJSISOVICS was thus based more on phylogenetic considerations and less on biostratigraphic study of certain sections.

The zonal concept of MOJSISOVICS was widely used as a standard until recent times. On the other side it was very much disputed and even questioned very early (KITTL 1903, p. 16; ARTHABER 1906; SPENGLER 1919, p. 307). Finally, it was revised by TOZER 1965, 1967 and SILBERLING & TOZER 1968.

Biostratigraphy

The fauna of the Hallstatt Lst. consists of an abundant and diversified cephalopod fauna (orthoconerats, nautiloids, ammonoids), gastropods, bivalves (in particular of halobiids), brachiopods, crinoids, and even a few occurrences of corals. For detailed stratigraphic studies ammonoids, conodonts, and halobiids are most important. The microfauna includes conodonts, foraminiferas, sponge spicules, radiolaria, floating crinoids and holothurian sclerites.

The megafauna is concentrated in laterally limited thin layers („Lager“). Generally, the Hallstatt Lst. is more or less poor in fossils with the exception of conodonts which occur in almost every sample. The megafossil bearing „lenses“ are either distinct beds or they are infillings of tectonic fissures which cut deep into the underlying limestone. According to WENDT 1971 cross cuttings and those which are parallel to bedding planes can be distinguished, the latter often hardly recognizably.

Individual zones established by MOJSISOVICS were founded on such fissure fillings and thus explain some of the mistakes of his zonal sequence.

The equivalent of the Anisian Stage is particularly fossiliferous in the surroundings of Hallstatt (Schreyeralp, Schiechlinghöhe). In that area the cephalopod fauna comprises some 20 genera (MOJSISOVICS 1882, DIENER 1901). Middle and Upper Anisian (Binodosus Zone, Trinodosus Zone) and probably also lowermost Ladinian (ASSERETO 1971) is indicated by representatives of the genera *Acrochordiceras*, *Paraceratites* and *Anolcites*. In other regions of the Salzkammergut proper megafossils of Anisian age have not been found at any other place yet.

As far as ammonoids are concerned the situation is comparable in the Ladinian. Due to the „Hornstein“ limestone facies (Grauvioletter Bankkalk) megafossils are completely lacking in the Lower Ladinian. Upper Ladinian is represented by newly collected and undescribed *Protrachyceras pseudoar-*

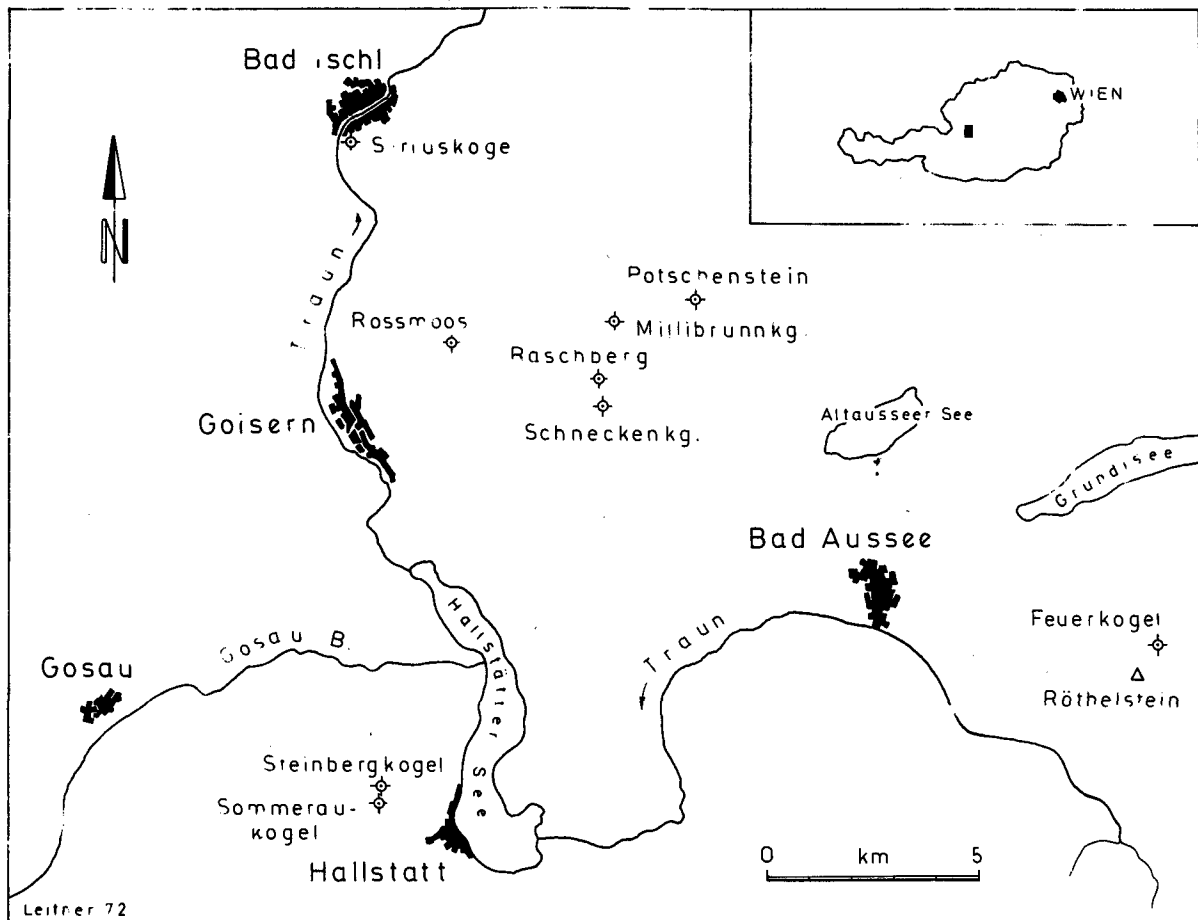


Fig. 4: Index map of Salzkammergut showing location of Hallstatt Limestone outcrops mentioned in text.

chelaus (BOECKH) and *Sturia sansovinii* MOJS. from Sommeraukogel resp. *Sturia* sp. and *Daonella lommeli* from Raschberg; some well known Ladinian genera (*Protrachyceras* s. str., *Sturia*, *Gymnites*, *Romanites* and *Daonella lommeli*) form part of the condensed „Ellipticus-Fauna“ at Feuerkogel (see KRYSTYN & GRUBER 1974).

The Upper Triassic Hallstatt Lst. yielded a well known association of megafossils, predominantly ammonoids referred to at least 50 genera (MOJSISOVICS 1873–1902). Pelagic bivalves (halobiids) are frequent (KITTL 1912); according to GRUBER (in press) they are of great stratigraphic significance. Brachiopods (BITTNER 1890) and gastropods (KOKEN 1897) are present and well known from various places (Feuerkogel, Sommeraukogel, Millibrunnkogel). According to TICHY (pers. comm.) in the Hallstatt Lst. the gastropods are of some ecological importance indicating deeper but distinct neritic environment (100–200 m).

Karnian ammonites form by most the widest distributed faunas of the Salzkammergut (Feuerkogel, Raschberg, Millibrunnkogel). The Lower Karnian *Trachyceras* fauna is also widely distributed outside the Hallstatt facies in the Northern and Southern Alpine Raibl Beds („*Trachyceras*-Schiefer“; see KRYSTYN 1978). Contrary, the Upper Karnian *Tropites* fauna is restricted to three localities in the Salzkammergut (Feuerkogel, Raschberg, Millibrunnkogel) of which the latter two form isolated fissure fillings in older rocks. Hence, their biostratigraphic significance is not unambiguous.

Lower and Middle Norian Hallstatt Lst. is poor in megafossils. Ammonoid faunas representing this time interval are only known at Feuerkogel and at Sommeraukogel. Although ammonites are lacking the Karnian/Norian boundary approximately can be drawn by the presence of a coquina bed composed of the pelagic bivalve *Perihalobia styriaca*, a species stratigraphically restricted to the lowermost Norian (GRUBER 1976).

The uppermost part of the Hallstatt Lst. representing the Upper Norian yielded a well known and wide occurring association of megafossils, the most conspicuous of which are leiostracous ammonites, e. g., *Pinacoceras metternichi*, *Cladiscites tornatus*, the bivalve *Monotis salinaria*, and the pelagic hydrozoan *Heterastridium*. More prominent fossil localities are Steinbergkogel near Hallstatt and Rossmoosalm near Bad Goisern (see fig. 1).

Lithostratigraphy

A comprehensive study on lithology, thickness and petrology of the Hallstatt Limestone of the Salzkammergut region was carried out by SCHLAGER 1969. According to him the Hallstatt sequence can be divided into five major parts each characterized by distinct lithologic features. All types of Hallstatt Lst. will be shown during the excursion to Feuerkogel and Sommeraukogel. The following summary mainly follows SCHLAGER 1969, p. 293, with amendments made by the author.

„Grauioletter Bankkalk“ (= greyish-violet bedded lst.):

Well bedded to nodular bedded, 10 to 20 cm thick microsparitic to pelsparitic, in part siliceous limestone beds. At its base chert nodules may frequently occur. Colour and the brittle fracture are distinct features of this type which hardly can be mixed with any other limestone type.

„Roter Knollenflaserkalk“ (= red nodular Flaser-limestone):

Reddish and regularly bedded, nodular Flaser-limestone consisting of 10 to 30 cm thick beds separated by thin marly partings. In terms of microfacies this limestone is a biomicrite with bivalves and radiolarians as main constituents of the fauna. Formation of nodules and flaser structure is explained by pressure solution during an early diagenetic stage.

„Roter Bankkalk“ (= red bedded limestone):

Reddish to pink coloured biomicritic limestone with strong bioturbation causing mottled and irregular structures. Beds are 20 to 50 cm thick and well bedded. Individual beds are mostly homogenous but locally interstratal reworking can be found. Particularly at Feuerkogel subsolution patterns with Fe-Mn crusts are frequently. In the upper part lateral changes may occur within short distances. The transition to the overlying massive „Hellkalk“ is gradually; locally an alternation between both types occur.

„Massiger Hellkalk“ (= massive light limestone):

Irregularly thick bedded to massive micritic limestone. Colour predominantly white or grey, yellowish or pink. Another characteristic feature is the great thickness. First reports on this rock were published by MOJSISOVICS 1905 from Raschberg („Wandkalk“) and from Sommeraukogel.

„Hangendrotkalk“ (= upper red limestone):

Platy to nodular bedded biomicritic limestone with mostly strong bioturbation pattern. Locally flaser-structure can be found but this feature is less dominating than in the „Knollenflaserkalk“. Subsolution patterns occur frequently, in particular at Sommeraukogel (thinning of individual beds in the direction of a submarine ridge). The so-called „Hangendgraukalk“ is regarded as a lateral equivalent of the „Hangendrotkalk“; apart from the colour, this type is also more argillaceous. It replaces the Upper Norian portion of the „Hangendrotkalk“ at Steinbergkogel near Hallstatt.

Upper Triassic ammonoid and conodont time scales (fig. 5)

Ammonoid zonation (fig. 5)

Since publication of TOZER's ammonoid zonation in „Standard of Triassic Time“ more than 10 years have gone and his zonal scheme which originally was established for North America has been successfully applied in various parts of the world. Different from North America in the meantime, however, new biostratigraphic studies have been carried out particularly in Europe and Asia (KRYSZYN 1978, TATZREJTER 1978, KRYSZYN in press) which have provided more detailed data for a refinement of the ammonoid based subdivision of the Triassic system.

The major object of these studies is a subdivision of the currently used zonal concept into smaller intervals, for example, into subzones which are regarded as biozones. Such a biozone is defined by the total life span (= range zone) of a certain index species on a world wide scale. However, in many regions our present knowledge about distribution and ranges of Triassic ammonoids does not favour this theoretical consideration. Particularly in the Upper Karnian and Lower Norian no subdivision into subzones exists which is, for example, comparable to that of the Jurassic (see MOUTERDE 1971, URLICH 1977). Hence, presently the corresponding index ammonoids are supposed to represent the best and most diagnostic species for Upper Karnian and Lower Norian times.

It is interesting to note that almost all of the new faunal subdivisions have been established in the Hallstatt Limestone of different regions in the Tethys realm (Alps, Greece, Turkey, Timor). The Hallstatt facies bears the richest ammonoid faunas of the Triassic but its successions normally are very re-

		ZONES	SUB-Z	CHARACTERISTIC SPECIES
NORIAN	RHAETIAN	<i>Choristoceras marshi</i>	II	<i>Choristoceras marshi</i>
			I	<i>Vandaites stuerzenbaumi</i>
	SEVATIAN	<i>Rhabdoceras suessi</i>	II	<i>Sagenites reticulatus</i>
			I	<i>Sagenites quinquepunctatus</i>
	ALAUANIAN	<i>Himavatites columbianus</i>	IV	"catenate halorites"
			III	<i>Amarassites s. semiplicatus</i>
			II	<i>Himavatites hogarti</i>
			I	<i>Himavatites watsoni</i>
	ALAUANIAN	<i>Cyrtopleurites bicrenatus</i>		?
	LACIAN	<i>Juvavites magnus</i>		?
	LACIAN	<i>Malayites paulckeii</i>	II	"Militites beds"
			I	<i>Malayites paulckeii</i>
	LACIAN	<i>Guembelites jandianus</i>	II	<i>Dimorphites selectus</i>
			I	<i>Dimorphites n.sp.1</i>
KARNIAN	TUVALIAN	Anatropites-Bereich	II	<i>Gonionotites cf. italicus</i>
			I	<i>Discotropites plinii</i>
	TUVALIAN	<i>Tropites subbullatus</i>	II	<i>Tropites subbullatus</i>
			I	<i>Projuvavites crassiplicatus</i>
	TUVALIAN	<i>Tropites dilleri</i>		?
	JULIAN	<i>Trachyceras austriacum</i>	II	"Sirenites subzone"
			I	<i>Trachyceras austriacum</i>
		<i>Trachyceras aonoides</i>	II	<i>Trachyceras aonoides</i>
			I	<i>Trachyceras aon</i>

Fig. 5: Tethyan Upper Triassic Ammonoid Time Scale (Zones and Subzones)

duced and therefore are supposed to represent no suitable lithologies for detailed zonations. It is hoped that further study in areas with any thicker successions (Himalayas, western North America) will contribute to the new concept, confirm it or even refine the present state. The general zonal scheme presented here follows wholly TOZER's work but uses pre-existing Tethyan indices.

In a series of papers KOZUR 1972, 1973, 1974 a, b, 1975 contributed to the Upper Triassic ammonoid time scale. However, most of the proposed modifications are either based on hypothetical considerations or are subject of unsatisfying changes in the content of the historical stages and substages. KOZUR's contradicting opinions have been treated elsewhere (TOZER 1974, KRYSTYN 1974 b, 1978, TATZREITER 1978).

Lower Karnian (= Julian)

The Lower Karnian has been subdivided by KRYSTYN 1978 into two zones (Aonoides and Austriacum Zone) each of it including two subzones (Aon and Aonoides Subzone, Austriacum and „Sirenites“ Subzone respectively). The same sequence has newly been recognized in the Nepalese Himalayas (KRYSTYN in press) and thus suggests an adequate standard for expressing worldwide correlations within this interval of time (KRYSTYN 1978, p. 53).

Upper Karnian (= Tuvalian)

TOZER 1967 and SILBERLING & TOZER 1968 distinguish three Upper Karnian zones, i. e., the Dilleri, Welleri, and Macrolobatus Zones. According to KRYSTYN 1973 the Welleri Zone is a junior synonym of the Tethyan Subbullatus Zone.

The Dilleri Zone is one of the most poorly represented zones in the Tethyan Upper Triassic. Within the Salzkammergut it has been found only in quarry F 5 at Feuerkogel together with a distinct ammonoid fauna which is well comparable to that of the Californian type locality. The faunas of the two beds at Feuerkogel are identical, thus at the moment a subdivision of this zone is not possible.

The middle Tuvalian Subbullatus Zone is subdivided mainly on the base of the later appearance of *Tropites subbullatus* (HAUER) together with a large and distinct tropitid fauna. The lower subzone is characterized by *Projuvavites crasseplicatus* (MOJS.), its first appearance marks the base of the zone. This subzone also represents the typical level with *Discotropites sandlingensis* (HAUER). Concerning the results mentioned above contrary to the opinion of KOZUR 1973 a Dilleri portion within the Subbullatus faunas of the Raschberg and Millibrunnkogel must be surely excluded. Despite of the tropitids clear correlation of Subbullatus and Welleri Zones is indicated by the presence of *Projuvavites* species (*P. brockensis*) which are closely related to *Projuvavites crasseplicatus* in the stratotype of the Welleri Zone.

At present faunas of the Upper Tuvalian „*Anatropites*-Bereich“ are by far the best known. The division into two subzones has been proposed by KRYSTYN as early as 1974 a and has been confirmed in all sequences studied from Europe (Alps, Sicily) to the Far East (Himalayas, Timor). The lower subzone is characterized at its base by the appearance of *Discotropites plinii* (MOJSISOVICS) but the main feature of this subzone is the abundance of *Jovites* and *Hoplotropites*. The upper subzone apparently corresponds to the main layer of *Anatropites*, though the genus extends as far as the base of the zone. Other genera characterizing the upper subzone are *Microtropites*, *Euisculites* and *Thisbites*, the latter ranging to the lowermost Norian. *Gonionotites* cf. *italicus* GEMMELLARO has been designated as index because it is fairly abundant and yet the only species which spans the whole subzone.

By comparison with the North American Macrolobatus Zone some problems arise. At its type-locality the lower Macrolobatus Zone is represented by a rich *Tropites* fauna (SILBERLING 1959). In the Tethys realm, however, *Tropites* s. str. ends at the upper boundary of the Subbullatus Zone. Hence, we assume that the lower part of the Macrolobatus Zone is coeval with the upper part of the Subbullatus or Welleri Zone, respectively. Good correlation exists between the *Anatropites* level of the upper Macrolobatus Zone described at its type-locality and faunas of the upper subzone of the *Anatropites*-Bereich elsewhere. *Discotropites plinii* and *G. cf. italicus* are both found in Canada (Mc LEARN 1960, TOZER pers. comm.).

Lower Norian (= Lacian)

The name of the lowermost Lacian zone has been changed by KRYSTYN (in press) to *Guembelites jandianus* Zone. The advantage of this species is its worldwide distribution and its well known stratigraphic range. The zone is divided into two subzones based on a phyletic line between *Dimorphites* n. sp. 1 and *Dimorphites selectus* MOJSISOVICS; both species have been known from Feuerkogel.

The characteristic ammonoid faunas of the subzones have been stressed by KRYSTYN 1974 a. The

before only additional remarks will be presented here. The lower subzone is characterized at its base by the appearance of *Griesbachites* and *Dimorphites*. The upper subzone is the main and exclusive layer of the genus *Guembelites*. From this viewpoint it can be stated that the North American Kerri Zone only comprises the upper subzone of the Jandianus Zone as defined by KRYSTYN (in press); it does not represent the entire base of the Norian.

With the beginning of the Paulcke Zone faunal records become poor especially in the Salzkammergut area. At Feuerkogel the lower part of this zone is highly fossiliferous but grades upwards into beds without any ammonoids. The proposed subdivision of the zone is very preliminary and based on investigations in the Nepalese Himalayas (KRYSTYN in press). In this region a sequence of typical Paulcke beds is overlain by rocks containing an ammonite fauna dominated by the genus *Miltites* (e. g. *Miltites rastli* MOJS.) together with *Malayites*. At present nothing comparable has been described elsewhere.

Within the Salzkammergut diagnostic ammonoids of the uppermost Lower Norian Magnus Zone have only been found at Sommeraukogel. Recognition of subzones has not been achieved at this locality.

Middle Norian (= Alaunian)

The two zones attributed to the Alaunian have been in poor state of knowledge until recently. Though geographically widely distributed studies within the lower zone or Bicenatus Zone have revealed no significant faunal changes. It must be noted, however, that *Cyrtopleurites bicrenatus* (HAUER) occurs as far as Canada where it is associated with *Drepanites rutherfordi* (E. T. TOZER pers. comm.).

Based on the studies of TATZREITER (1978 and unpubl.) the upper Middle Norian Columbianus Zone has become well known in different parts of the Tethys region. His careful stratigraphic survey of the famous Hallstatt Limestone of Timor has led to the discovery of four distinct subzones which are in succeeding order the Watsoni, Hogarti, Semiplicatus Subzones, and the yet unnamed „No. IV“ Subzone. Subzone IV correlates with the so-called *Halorites* Beds widely distributed throughout the Tethys region. The rich ammonite fauna previously described by MOJSISOVICS (1893) from Sommeraukogel includes all four subzones. However, at present only the *Halorites* Beds (= Subzone IV) can be assigned to certain beds at Sommeraukogel.

Upper Norian (= Sevatian)/Rhaetian

During the last few years many papers have dealt with the stratigraphic subdivision of the uppermost Triassic (for reference see FABRICIUS 1974, TOLLMANN 1978, WIEDMANN et al. 1979). As a result of these discussions some proposals have been submitted to the meeting of the „Subcommission on Triassic Stratigraphy“ held in Munich from July 3–4, 1978. During the session it was proposed to combine the Upper Norian with the Rhaetian Stage and to treat the expanded Rhaetian as uppermost stage of the Triassic. Consequently, the Middle Norian would have changed to Upper Norian and the original Upper Norian would be named Lower Rhaetian. It is outside of the scope of this introduction to a conodont guide to contribute to this merely academic discussion. However, to avoid any errors which may arise by comparing data presented here and those from previously published literature it seems more reasonable to keep on with the old nomenclature.

The terminological problem arose from the necessary change of names between the historical Metternichi Zone and the zone of *Rhabdoceras suessi* as proposed by TOZER 1967. In the meantime this generally accepted change of names turned out to bear problems. As has been earlier suggested by KOZUR 1973 and has been confined independently by WIEDMANN et al. 1979 in Europe as well as by E. TOZER 1979 in Canada, *Rhabdoceras suessi* extends somewhere above the typical Sevatian *Pinacoceras metternichi* Zone of MOJSISOVICS. Moreover, based on a detailed biostratigraphic survey of the Alpine Koessen Beds WIEDMANN et al. 1979 have found that *Choristoceras marshi* begins much lower than had been suggested previously; also, it is associated with *Rhabdoceras suessi* during a longer period than formerly thought. To resolve the problem some differing zonations have been published recently (KOZUR 1973, 1975; GAZDZICKI & al. 1979; TOZER 1979, WIEDMANN et al. 1979).

Further use of Suessi and Marshi Zones is favoured by the author because it needs no nomenclatural changes. In the new context it also agrees with the current use of the two zones. What is needed is a new definition of the two zones in question to become the status of „overlap range zones“ (see JOHNSON 1979).

The proposed Sevatian subzonal indices are widely distributed (*Sagenites quinquepunctatus* as far as South America, *S. reticulatus* at least as far as Timor). They have been proved to form a distinct faunal sequence. *Sagenites giebeli* originally introduced by MOJSISOVICS 1893 as a Lower Norian zonal guide most probably reflects the same age as *S. quinquepunctatus*. It is, however, only known from two

localities (Taubenstein, Leislingwand near Raschberg) both forming stratigraphically isolated fissure deposits. *Choristoceras haueri* is a long ranging species and occurs both in the Upper Norian and in the Rhaetian. Therefore it serves no place in a standard zonation. The Reticulatus Subzone correlates with the *Cochloceras* Subzone of TOZER 1967 and the *Cochloceras suessi* Zone of KOZUR, respectively.

At the top of the so defined Suessi Zone the major part of Triassic ammonites belonging to subordo Trachyceratina disappears and only some Ceratitinas (*Cycloceltites*, *Rhabdoceras*, *Choristoceras*, *Vandaites*) and the long ranging leiostracean genera *Arcestes*, *Placites*, *Cladiscites*, *Rhacophyllites* and *Megaphyllites* survive into the lower Rhaetian.

For the Rhaetian Marshi Zone a two fold division has been proposed by WIEDMANN & KRZYSTYN (in WIEDMANN et al. 1979, p. 145). The base of the newly defined Marshi Zone is marked by the appearance of *Vandaites stuerzenbaumi* (BOECKH), simplified described as a „helicoid choristoceras“. Another distinct ammonite species of the lower subzone is *Epsiloceras planorboides* (GUEMBEL). At the end of the subzone some more ammonoid genera disappear. Thus the impure fauna of the topmost Triassic Marshi Subzone consists of not more than the four genera *Choristoceras*, *Arcestes*, *Rhacophyllites* and *Megaphyllites*. The two subzones have been found in a vertical sequence within different sections of the Alpine Koessen Beds.

A revised North American biochronological scale for the interval between the Middle Norian and the Jurassic has been provided by E. T. TOZER 1979. This new division comprises three zones which are in ascending order the Cordilleranus, Amoenum and Crickmayi Zones. They can be exactly correlated with the Alpine Quinquepunctatus, Reticulatus and Stuerzenbaumi Subzones. A remarkable fact at present, however, is the missing of an equivalent of the topmost Triassic in North America.

Conodont zonation

General remarks

This section treats with some 10 species of platform conodonts assigned to the form genera *Gladi-gondolella*, *Gondolella*, *Metapolygnathus* and *Epigondolella*, their phylogenetic relationships are outlined in fig. 6. In addition two species of the „neospathodid“ genus *Misikella* KOZUR & MOCK are discussed. Most of these species have been described during the past 10 years, either based on too few specimens or with unprecise and even wrong stratigraphic ranges (HAYASHI 1968, KOZUR 1972). Due to the fact that the ontogenetic evolution of many species has not been treated to such an extent as is needed specific identification of Upper Triassic platform conodonts is highly problematic at present. Hence, the author has followed no other currently applied concepts than the one suggested by MOSHER 1968. Several taxa can be revised on the basis of our collections available and notes on these species are given in the following paragraphs. However, this paper is intended to provide a summary of stratigraphy and thus, systematic treatment of the categories are not included here.

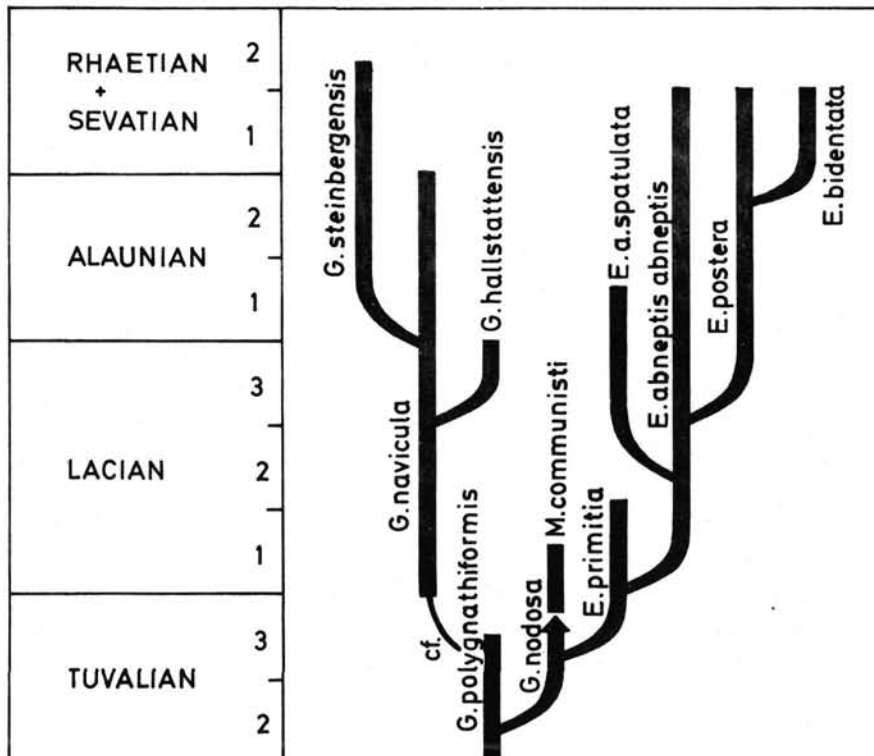


Fig. 6: Phylogenetic diagram of Upper Triassic platform conodonts.

Contrary to the view of KOZUR 1972 (and later) the author has continued to discriminate the two genera *Metapolygnathus* and *Epigondolella*. The main reason is the outline of the denticles on the margin of the platform which clearly demonstrates a distinct and definite separation of the two genera: Within *Metapolygnathus* they are either missing or form weak and rounded nodes; *Epigondolella* on the other side is characterized by spinelike nodes on the platform margin.

Gondolella navicula HUCKRIEDE, 1958: This well known species has been misinterpreted both phylogenetically and stratigraphically by all previous workers. Based on our studies in various regions of the Tethys realm (Alps, Yugoslavia, Greece, Timor) it can be demonstrated that the first appearance of *G. navicula* is at the base of the Norian Stage; its ancestor is *G. polygnathiformis*. Transitional forms occurring in the uppermost Upper Karnian are very rare, their similarity with *G. reversa* (MOSHER, 1973) is considerable. It is supposed that all earlier reports of the species from Anisian, Ladinian and Karnian strata were based on *navicula*-type variants of different species of *Gondolella*.

Gondolella hallstattensis MOSHER, 1968, and *G. steinbergensis* MOSHER, 1968: Both species were described thoroughly by MOSHER 1968 and his definitions have been followed in this study. The only difference is the treatment as independent species.

Metapolygnathus communisti HAYASHI, 1968: Due to the badly figured holotype this unusual named species has been misinterpreted by several authors for a longer period (KOZUR 1972, KRYSZTYN 1973, MOSHER 1973). KOZUR 1972 who gave an adequate description of the adult growth stage figured under the same name a clearly different species referred by MOCK 1979 to *G. carpathica*, a species treated herewith as junior synonym of *G. nodosa*. MOSHER 1973 and KRYSZTYN 1973 independently concluded that *M. communisti* represents a junior synonym of *G. polygnathiformis*. Based on REM-fotos of the holotype at hand (provided by S. HAYASHI and kindly forwarded to the author by S. KOVACS, Budapest) and on new material obtained from Timor as well as from Feuerkogel a revised description of the species can be given. Study of subsequent growth stages within one sample revealed that the two species *Gladigondolella abneptis echinatus* HAYASHI, 1968 and *Metapolygnathus parvus* KOZUR, 1972 must be regarded as juvenile representatives of *M. communisti*. Moreover, the study of fairly large collections of *M. communisti* suggests identity of *Metapolygnathus linguiformis* HAYASHI, 1968 with the former species. *M. angustus* KOZUR, 1972 shows a considerable similarity with *M. communisti* although only one specimen has been figured yet. According to KOZUR 1972, however, it occurs below the first known occurrence of *M. communisti*.

Metapolygnathus communisti can be shortly defined as a mixture of (highly evolved) *G. polygnathiformis* and *G. nodosa* with a basal pit migrated towards the center of the platform. The common occurrences of specimens of *M. communisti* with smooth crenulated and platform margins suggest that *G. nodosa* and *G. polygnathiformis* biologically form a single species.

Within the uppermost Karnian a rapid transition links *G. nodosa* with *M. communisti* the latter replacing the former. In samples collected from the lowermost Norian section B at Feuerkogel two distinct morphotypes named *M. communisti* morphotype A and morphotype B have been found which exclude each other by their stratigraphic ranges (see fig. 11). Interestingly, *M. communisti* morphotype B shows a re-appearance of such features which already had characterized *G. polygnathiformis*.

Gondolella nodosa (HAYASHI, 1968): Different from KRYSZTYN 1973 *G. nodosa* and *Epigondolella primitia* are regarded as two separate species which, however, are closely related. *G. nodosa* is closely similar to *G. polygnathiformis*, the only difference being the formation of nodes on the platform margins. In phylogenetically early representatives of *G. nodosa* growth of nodes begins at the anterior end of the platform; highly evolved specimens on the other side show the extent of nodes towards the lateral margins of the platform. This type is represented by the holotype. Since the early morphotype has also been found together with late ones of the species, *G. carpathica* MOCK, 1979 (primitive type) can not be accepted as independent species.

Epigondolella primitia MOSHER, 1970: This species evolved from *G. nodosa*. It forms the initial stage of the *E. abneptis* lineage. The species was described and discussed thoroughly by MOSHER 1970; his concept has been followed in this study. *Metapolygnathus spatulatus pseudodiebeli* KOZUR, 1972 may be a junior synonym of the species.

Epigondolella abneptis (HUCKRIEDE, 1958): Reference collections in hand confirm MOSHER's treatment of the species (1968, 1973). Additional study of material available has proved *E. permica* (HAYASHI) to represent a juvenile stage of this species rather than an independent taxon as had been treated by KRYSZTYN 1973. This is also suggested for *Metapolygnathus slovakensis* KOZUR, 1972.

In accordance with KOZUR 1972 two subspecies can be distinguished which morphologically are

similar but have different ranges (fig. 8). In *E. a. spatulata* the outline of the platform is posteriorly expanded to form a triangular shape. A similar feature, however, may also be observed in some adult representatives of the nominate subspecies. Hence, discrimination of the two subspecies seems only possible in early ontogenetic stages during which the outline of the platform either forms a square (= *E. abneptis* s. str.) or a triangle (= *E. a. spatulata*). *Ancyrogondolella triangularis* BUDUROV, 1972 is considered as junior synonym of *E. a. spatulata*. According to the author's opinion *Tardogondolella postera hayashii* KOZUR & MOSTLER, 1972 represents a juvenile growth stage of *E. abneptis* s. str.

Epigondolella postera KOZUR & MOSTLER, 1971: The current concept about this species is the same as in 1973. *Epigondolella zapfei* KOZUR & MOSTLER is thus regarded as an adult growth stage of *E. postera*. The species is a morphologic link between *E. abneptis* and *E. bidentata* as has already been demonstrated by KOZUR & MOSTLER 1971.

Epigondolella bidentata MOSHER, 1968: This well established species was thoroughly re-discussed by MOSHER 1973. His arguments to include *E. mosheri* KOZUR & MOSTLER, 1971 as junior synonym are fully accepted. Another probable synonym may be *E. misiki* KOZUR & MOCK, 1973.

From the uppermost Norian KOZUR & MOCK 1972 described the evolution of *E. bidentata* to such forms in which platforms are completely lacking; they were named *Parvigondolella andrusovi*. With material at hand it can be demonstrated that all *bidentata* faunas from the early beginning of the species in the upper Middle Norian in a certain number include even large „*Parvigondolella andrusovi*“. Furthermore, a distinct *andrusovi*-horizon as described by MOSTLER et al. 1978 has not been confirmed in the Hallstatt Lst. of the Salzkammergut yet. Hence, at present this separation is not followed by the author.

Conodont zonation (figs. 7 and 8)

Within this paper a sequence of 16 faunal assemblages is described most of them being recognized in the Karnian and Norian Hallstatt Lst. of the Salzkammergut area. In the Rhaetian Stage no Hallstatt Lst. occurs. Therefore the topmost Triassic representing two zones were investigated outside the Salzkammergut in the Koessen Beds of the Provinces of Salzburg and Tyrol.

Many of these assemblages are very widespread and it is supposed that they may provide a tool for at least Tethys-wide correlations of Upper Triassic rocks. Of the various zonal indices only a few are short ranging taxa restricted to specific conodont zones. Most of the taxa discussed range through several zones. Therefore, the zonation scheme presented here (fig. 7, 8) is based on the overlap of ranges of taxa and within subzonal units also on the relative abundance of important taxa.

Almost all of the zonal indices have been in use by KOZUR since 1972. However, age assignment varies slightly in his many publications. This fact has caused serious troubles and errors during the past 10 years and even raised some doubts about utility of conodonts in the Upper Triassic. Actually, the zonal assignments of KOZUR are either based on historical Alpine ammonite material from different museum collections or on samples from sections which are lacking megafossils (e. g., Siliza Brezova, cf. KOZUR 1972, KOZUR & MOCK 1974 a). By means of conodonts in a further step these sections were correlated with certain ammonite zones. However, his errors are less burdening as compared with his outstanding contributions to the stratigraphy of the Tethys realm deduced from his restricted environment in East Germany.

K a r n i a n

1. *Carinella diebeli*-Assemblage Zone

Carinella diebeli is not restricted to this zone but it is a characteristic species of it. The base of the zone is defined by the appearance of *G. polygnathiformis* which was found in the ammonite bearing sequence at Epidaurus (Greece) to extend to the upper part of the *Frankites ? regoledanum*-Zone (= Tethyan counterpart of the Sutherlandi Zone). The base of the zone therefore encompasses the Ladinian/Karnian boundary.

2. *Gladigondolella tethydis*-Assemblage Zone

The base of the zone is defined – mainly negatively – by the disappearance of species of the *mungoensis*-group. In terms of ammonoid stratigraphy it corresponds to the upper Aonoides Zone (Julian 1/II) and the lower Austriacum Zone (Julian 2/I). The platform conodont fauna comprises *Gladigondolella tethydis* and *Gondolella polygnathiformis*, both, however, are not restricted to the zone.

3. *Gondolella polygnathiformis*-Assemblage Zone

The zone is defined by the exclusive presence of *G. polygnathiformis* and at its base by the disappea-

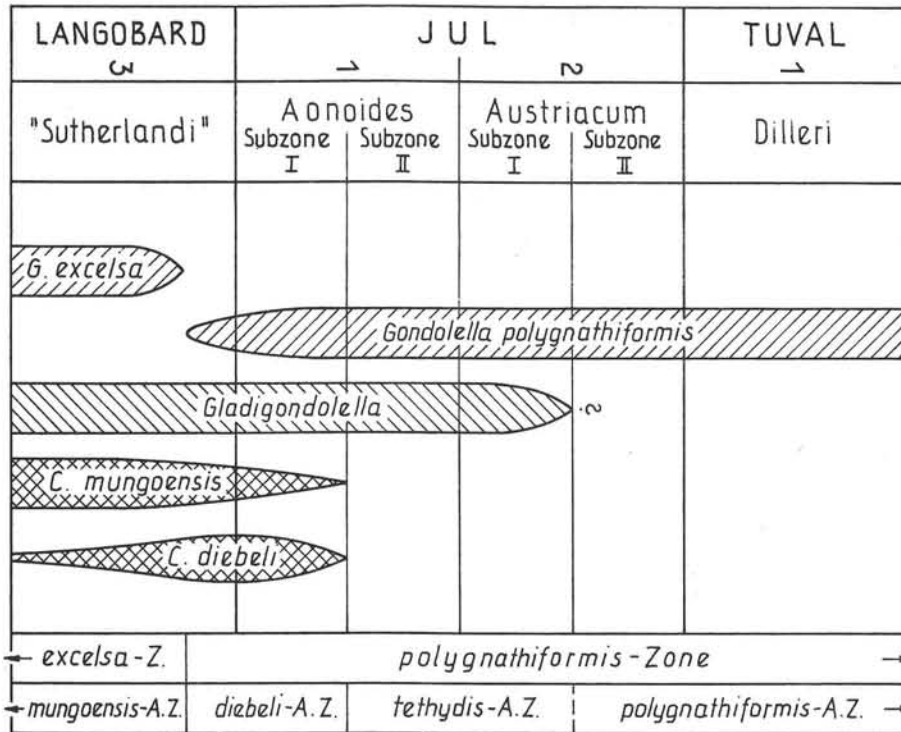


Fig. 7: Lower Upper Triassic platform conodont zonation and its correlation with the ammonoid time scale. From KRYSZTYN 1978.

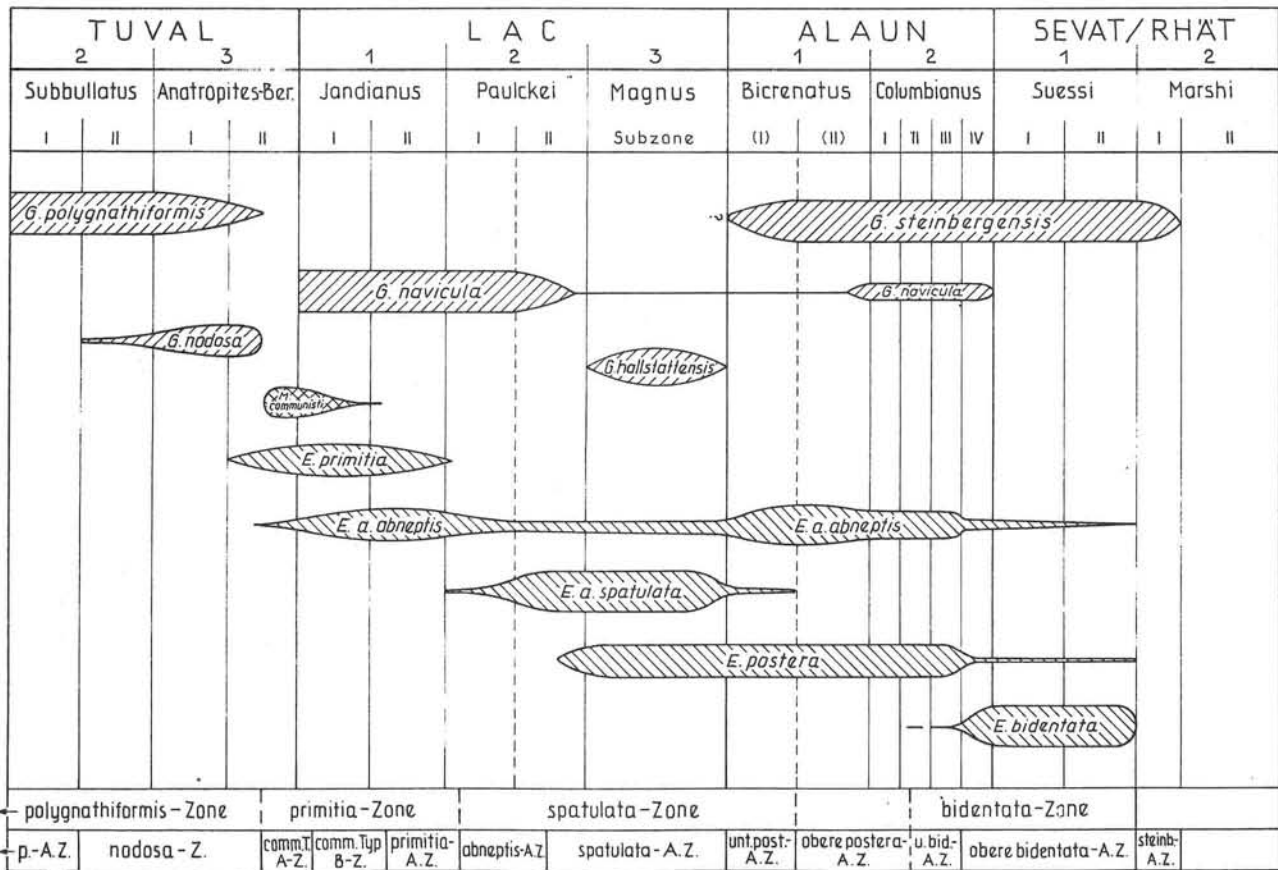


Fig. 8: Upper Karnian and Norian revised platform conodont zonation and its correlation with the ammonoid time scale. Stratigraphic distribution and relative abundance of zonal guides are shown.

range of *Gladigondolella tethydis*. It is a long ranging zone corresponding to the upper Austriacum Zone (Julian 2/II), the Dilleri and the lower Subbullatus Zones (Tuvalian 2/I) in terms of ammonoid zonation.

***Gondolella nodosa*-Zone**

The range of *Gondolella nodosa* defines this zone which can be divided by the latter appearance of *Epigondolella primitia*.

4. Lower Nodosa-Assemblage Zone:

This time marked by the presence of abundant *G. polygnathiformis* and rare *G. nodosa* is a correlative of the upper Subbullatus Zone (Tuvalian 2/II) and the lower *Anatropites*-Bereich (Tuvalian 3/I). Samples from the Hallstatt Lst. generally rich in platform conodonts allow a more precise correlation with the ammonoid stratigraphy by changing frequency rates of the two conodont species: In the Tuvalian 2/II the ratio between *G. polygnathiformis* and *G. nodosa* is approx. 10:1, in the Tuvalian 3/I it is 3–5:1.

5. Upper Nodosa-Assemblage Zone:

This subzone is defined by the appearance of *E. primitia* and further occurrences of *G. nodosa* and rare *G. polygnathiformis*. The upper subzone is a short ranging correlative of the upper *Anatropites*-Bereich (lower Tuvalian 3/II).

6. *Metapolygnathus communisti* morphotype A-Zone

This zone correlates to the range of the index species which is most frequent in all samples studied. Other platform conodonts are *Epigondolella primitia* and rare *Epigondolella abneptis*. So far this short time interval is known at Feuerkogel, Slovakia, Yugoslavia (Sarajevo) and Timor. At both, Feuerkogel and Timor the zone correlates to the upper part of the upper *Anatropites*-Bereich (upper Tuvalian 3/II) and basalmost Norian. The short Norian portion has been easily recognized in all sections studied by the sudden and rich appearance of *Gondolella navicula* which evidently indicates the base of the Norian Stage.

N o r i a n

7. *Metapolygnathus communisti* morphotype B-Zone

This species is an index to the lowermost Norian and corresponds well to the Lacion 1/I ammonoid zone. Associated with the name bearer are *Epigondolella primitia*, *E. abneptis* and frequent *Gondolella navicula*. At yet this zone has only been recognized at Feuerkogel where it has been found at different places.

8. *Epigondolella primitia*-Assemblage Zone

The base of this zone is defined by the disappearance of *Metapolygnathus communisti* morphotype B which, by comparison with the ammonoid stratigraphy, shortly extends into the upper Jandianus Zone (Lacion 1/II). The platform conodont fauna is composed of *E. primitia*, *E. abneptis* s. str. and *Gondolella navicula*; the latter may also be missing sometimes. This zone seems of worldwide utility because the index species is distributed as far as Canada and Western North America (MOSHER 1973).

9. *Epigondolella a. abneptis*-Assemblage Zone

This zone is marked at its base by the disappearance of *Epigondolella primitia* and contemporaneously, by the beginning of *Epigondolella abneptis spatulata*. The base of the zone is not correlative to the base of the Paulcke Zone directly, but somewhat younger. Though no further distinct separation is possible a more detailed correlation with the two ammonoid levels of the Paulcke Zone is suggested by different ratios of the two subspecies: In the Lacion 2/I subzone *E. a. abneptis* is frequent and *E. a. spatulata* rare whereas the Lacion 2/II subzone contains reverse frequency ratios.

10. *Epigondolella a. spatulata*-Assemblage Zone

The base of this zone is defined by the appearance of *Epigondolella postera* and by abundant representatives of *E. a. spatulata*. Furthermore, this zone is the exclusive level for *Gondolella hallstattensis*. In terms of ammonoid stratigraphy it corresponds to the uppermost Paulcke and the Magnus Zones.

***Epigondolella postera*-Assemblage Zone**

This zone is subdivided into two faunal units, the lower and upper Postera Assemblage Zones.

11. Lower Postera Assemblage Zone

The subzone is marked at its base by the appearance of *Gondolella steinbergensis* and by a change in the relative abundance ratios of the two subspecies of *E. abneptis*: *E. a. abneptis* becomes frequent

as compared with *E. a. spatulata* which is represented rarely. Another common species is *Epigondolella postera*. Fauna representing this interval were found in ammonite bearing rocks to be restricted to the lower part of the Bicrenatus Zone.

12. Upper Postera-Assemblage Zone

Platform conodonts of this unit comprise *E. abneptis* s. str., *Epigondolella postera* and *G. steinbergensis*; *E. a. spatulata* has already disappeared at the base of the subzone which is an equivalent of the upper Bicrenatus and the lower Columbianus ammonoid Zones.

Epigondolella bidentata-Zone

The base of this zone is marked by the appearance of *Epigondolella bidentata* approximately in the middle part of the Columbianus Zone. At present the lower limit has not been dated precisely. MOSTLER 1977 reported *E. bidentata* from the type locality of the Pötschen Lst. which according to TATZREITER 1978 corresponds to the lower Columbianus Subzone II. In the ammonoid controlled conodont sequence of the Hallstatt Lst. of Timor the first occurrence of *E. bidentata* was found in subzone III and more abundantly in subzone IV. This discrepancy may be explained by that juvenile specimens of *E. postera* resemble *E. bidentata* and thus may have been misidentified in the past. Based on the relative abundance ratios of different species of *Epigondolella* two subzones are discriminated. *Gondolella steinbergensis* ranges through both subzones.

13. Lower Bidentata-Assemblage Zone

This subzone is marked by rare occurrences of *E. bidentata* together with abundant representatives of *E. abneptis* and *E. postera*. It is equivalent to the Columbianus Subzone III and perhaps to Subzone II.

14. Upper Bidentata-Assemblage Zone

In this faunal unit *Epigondolella bidentata* is most common and is associated with *Gondolella steinbergensis* together with rare occurrences of *E. abneptis* as well as *E. postera*. In terms of ammonoid zonation this subzone correlates to the uppermost Columbianus Zone (Subzone IV) and to the Suessi Zone as defined in this paper. Moreover, it is a close relative of the *bidentata*-Zone introduced by SWEET et al. 1971.

15. *Gondolella steinbergensis*-Assemblage Zone

This zone includes the youngest platform conodonts of the Triassic and is represented in the Salzkammergut in the transitional beds from the Hallstatt Lst. to the marls of the Zlambach Fm. At its base the zone is marked by the complete disappearance of all species of *Epigondolella* and at its upper limit by the disappearance of *Gondolella steinbergensis*. In accordance with the ammonoid record it is dated as lowermost Rhaetian.

16. *Misikella rhaetica* and *Misikella posthernsteini*-Zones

Both zones were recognized by MOSTLER et al. 1978 in the Koessen Beds of the Weißloferbach section close to the village Koessen in Tyrol. They contain various conodonts but lacking any platform type conodonts. According to MOSTLER 1978 and personal observations *Grodella delicatula* (MOSHER), *Neohindeodella triassica* (MÜLLER), *Hibbardella magnidentata* (TATGE), *Hindeodella suevica* (TATGE) and *Prioniodina muelleri* TATGE were found. *Misikella rhaetica* MOSTLER, 1978 is the successor of *Misikella hernsteini* (MOSTLER, 1967), a species widespread in the Upper Norian Hallstatt Lst. but also represented in the Lower Rhaetian (Stuerzenbaumi Subzone) Zlambach marls of the Salzkammergut and in the lowermost Koessen facies of the Osterhorn syncline.

The *Rhaetica*-Zone as defined by MOSTLER 1978 may be correlated to the lower part of the Marshi Zone, i. e., to the upper part of the Stuerzenbaumi Subzone and to the lower Marshi Subzone as newly defined.

The *Posthernsteini*-Assemblage Zone represents the youngest conodont fauna of the Triassic. It was found in the Kendlbach and the Fonsjoch section to range as high as 7 m below the base of the Jurassic. This zone is marked by the presence of the long ranging species *Misikella posthernsteini* KOZUR & MOCK, 1974 and at its base by the disappearance of *M. rhaetica*. So far it is only known from the Upper Zlambach and Koessen Beds corresponding there approximately to the topmost Triassic Marshi Subzone.

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