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The Permian-Triassic of the Gartnerkofel-1 Core (Carnic Alps, Austria): Conodont Biostratigraphy

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With 5 Text-Figures, 2 Tables and 2 Plates

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Carinthia
Carnic Alps
Permian
Triassic
Conodonts
Biostratigraphy

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Zusammenfassung

In dieser Arbeit werden zum ersten Mal Conodontenfunde aus den Perm/Trias-Grenzschichten der Karnischen Alpen mitgeteilt und ausführlich beschrieben. Das älteste Datum stammt von der Basis des 4 m mächtigen neu aufgefundenen Tesero-Horizontes im unmittelbaren Hangenden der oberpermischen Bellerophon Formation. Der Dolomit entspricht dem Tesero-Oolith im Bohrkern bzw. in den westlich anschließenden Südtiroler Dolomiten. Diagnostische Conodonten sind hier *Hindeodus* cf. *latidentatus und H. minutus*; dazu kommt das Erstauftreten von *H. parvus* und *H.* n.sp.. Aufgrund dieser Assoziation wird der Tesero Horizont mit der basalen *Otoceras woodwardi*-Ammonitenzone korreliert, die üblicherweise den Beginn der Triaszeit anzeigt. Mangels Ammoniten und anderer Leitfossilien kommt diesen Conodonten eine entscheidende Bedeutung zu. In weiterer Folge finden sich vor allem *H. parvus*, Leitform der *parvus*-Conodontenzone, *H. turgidus, Isarcicella isarcica* als namengebende Form der *isarcica*-Zone und schließlich zuoberst *Ellisonia aequabilis*.

Am Schluß des Beitrages werden kurz die Konsequenzen aufgezeigt, die diese Conodontenfunde für die weltweit im Grenzbereich Perm/Trias beobachteten isotopengeologischen und geochemischen Anomalien in Bezug auf ihren Beginn und ihre Dauer haben.

Abstract

For the first time in the Permian/Triassic boundary beds of the Carnic Alps a sequence of highly significant conodonts has been recognized both in the scientific core and in the parallel outcrop section. Our assemblage comprises more than 750 more or less well preserved and fragmentary conodont elements of which some 60 % were either identified at species level or assigned to as yet not fully determined multielement apparatuses. In ascending order this is a lowermost association with *Hindeodus* cf. *latidentatus and Hindeodus minutus* and first occurrences of *Hindeodus parvus* and *Hindeodus* n.sp. followed by the acme-Zone of *Hindeodus parvus*, the occurrence of *Hindeodus turgidus*, the *Isarcicella isarcica*-Zone and finally an occurrence characterized by the multielement *Ellisonia aequabilis*. These diagnostic conodonts provide well established age assignments that are needed because ammonoids or other short ranging fossils are missing in this dolomitic rock sequence.

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Conodonts from the base of the newly discovered Tesero Horizon overlying the Upper Permian Bellerophon Formation in the outcrop section clearly demonstrate that it corresponds with the Tesero Horizon from the nearby core and the sections in the Dolomites to the west. In addition it can be clearly correlated with the lower part of the *Otoceras woodwardi*-ammonoid-Zone generally regarded by most paleontologists as the base of the Triassic. We document the full range of *H. parvus* and the partly associated *H.* n.sp. Both species can be separated from the distinct and worldwide recognizable species *Isarcicella isarcica* the range of which coincides with the upper range of *H. parvus*. Forerunner of the latter is the distinct species *H. turgidus*, known only from a few other places in the world.

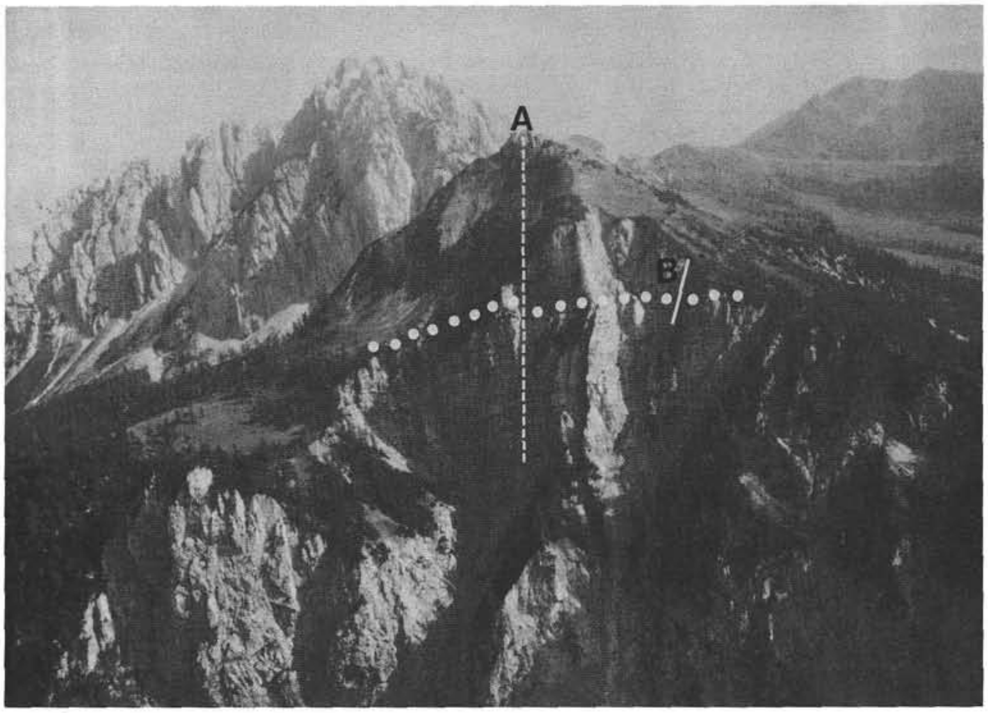
In a final chapter the implications of this material are discussed. The new conodont biostratigraphy provides an extended interval in the Lower Griesbachian as the time frame for the complex physical and chemical changes that are described in other chapters of this volume and which may have worldwide application.

1. Introduction

The greatest biological crises in Earth's history occurred in the Late Permian some 250 Million years before present but is yet poorly understood. According to N.D. NEWELL (1967), J.J. SEPKOSKI (1986, 1989), D.M. RAUP & J.J. SEPKOSKI (1986), D.M. RAUP & G.E. BOYAJIAN (1988) and others all life on Earth was affected leading to an empirically based extinction intensity of 57 to 63 % of families, and 93–96 % of all species. This catastrophe resulted in disappearances of 50 to 73 % of all non-marine terrestrial amphibians and reptiles (M.J. BENTON, 1985, 1988; W.D. MAXWELL & M.J. BENTON, 1987; E.C. OLSON, 1989) and an even larger proportion of all major groups of marine benthic, planktonic and sessile organisms. During the two terminal Permian stages background extinctions increased by factors four to five, for example, 98 % of all crinozoan families suffered, 96 % of all corals, 80 and 79 % of brachiopods and bryozoans, respectively, and 71 % of the cephalopods (M.L. MCKINNEY, 1987). Benthic mobile groups like ostracods, foraminifera and gastropods were less severely affected, with extinction of 27 to 50 %.

Less pronounced was the crises experienced by conodonts (D.L. CLARK, 1972, 1981, 1987; D.L. CLARK et al., 1986; W.C. SWEET, 1973). In the Permian at any one time species diversity fluctuated around 10 dropping to 5 at the Permian/Triassic boundary. In contrast to the Permian Period, in the Early Triassic diversity rapidly reached a high of 22, and more species originated than became extinct (W.C. SWEET, 1988b).

It is beyond the scope of the present paper to find an answer for the long lasting discussion on the ultimate forcing agents of the end-Permian crises (see other articles in this volume). The more fundamental question, however, is whether the faunal turnover was an instanteneous event or spread over several million years. In fact there is increasing evidence that its true nature was very protracted, extending not only throughout the last two stages of the Permian but already beginning in the Abadehian (H. TARAZ et al., 1981) and accelerating in the Dzhulfian and Dorashamian (Changhsingian), see T.J.M. SCHOPF, 1974; J.M. DICKINS, 1984; J.J. SEPKOSKI, 1986; A. HOFFMAN, 1989; W.D. MAXWELL, 1989). Moreover, as pointed out by W.D. MAXWELL the "Lazarus effect" known since its recognition by J.B. WATERHOUSE & B. BONHAM-CARTER (1976) in their analysis of ranges of Permian brachiopods long before D. JABLONSKI (1986) introduced the term, must also be taken into account: Due to unfavorable facies conditions and/or breaks in the stratigraphic succession across the boundary, many taxa known from the Late Permian and the Middle Triassic have no record in the intervening interval. It is reasonable to assume that most of them actually survived during the end-Permian event (W.D. MAXWELL, 1989).



Text-Fig. 1.
Aerial photograph from the north of the Reppwand with the Gartnerkofel (2195 m) in the background.
A: Drill site on Kammleiten (1998 m);
B: Top of the outcrop section.
Dotted line indicates the Permian–Triassic boundary between the Bellerophon Formation (below) and the Werfen Formation above.
Photo: G. FLAJS, Aachen.

At this point one may raise the question (and ask J. PHILIPS, 1841) why era or systemic boundaries were based on such an impoverished remainder of life, leaving as biostratigraphic tool less than 10 % of the normal variety of the animal kingdom to work with. In our present thinking such a small number of relics would hardly fullfill the requirements of a modern biostratigraphic philosophy. Another mystery, not alikely developed from tradition, is the small sedimentation rate during this interval of time, which resulted either in the worldwide occurring thin deposition per time unit or in breaks and unconformities (see below).

Recently, the historical definition of the base of the Triassic has been outlined thoroughly by E.T. TOZER (1988a,b). For more than a century the "Werfen Formation" of the Tethys Realm has been regarded and generally accepted to represent the Lower Triassic in its marine facies. Following C.L. GRIESBACH's discovery in the late 1870s (in the Himalayas) the distinct ammonoid genus *Otoceras* in association with *Claraia* has been reported from beds above certain Permian and below unquestionable Triassic strata from many localities in the world. Since W. WAGEN & C. DIENER (1895) the *Otoceras woodwardi*-Zone defined the base of the Triassic. Following C. DIENER's work in 1912 there was general agreement to correlate these *Otoceras* bearing beds with the basal Werfen Formation. Recently, however, W.C. SWEET (1979, 1988a) and others, e.g. J.B. WATERHOUSE (1978), Y. BANDO (1980) and H.F. YIN et al. (1988) questioned this correlation. Based on graphic correlation methods and assuming continuous sedimentation in the sections under consideration, SWEET concluded a partial overlap between the ranges of the "Triassic" ammonoid genus *Otoceras* from the Himalayas and the Late Permian (Dorashamian) beds with *Paratirolites* from northwestern Iran (section Kuh-e-Ali Bashi). He thus correlated the Upper Dorashamian with parts of the Griesbachian. Yet, the assumed successive ranges of these index ammonoids have never been proved. There is neither a stratigraphic sequence in the world which contains both ammonoids nor has it ever been demonstrated that the *Paratirolites* beds actually underlie the *Otoceras* beds (see article by H.F. YIN et al., 1988). In fact, the latter seems to be represented only at few places: The Himalayas (Kashmir, Tibet), Siberia, Spitsbergen, Arctic Canada, Northern Alaska and East Greenland (E.T. TOZER, 1988b; A.S. DAGYS & A.A. DAGYS, 1988). Consequently, it had been suggested that *Otoceras* is too rare to be a good guide fossil for the earliest Triassic. Its record is indeed much less widespread in the marine lowermost Triassic than in slightly younger Griesbachian strata (E.T. TOZER, 1981, 1988b).

The crucial point in the analysis of the Permian/Triassic faunal turnover is the following: There are in the Tethys Realm only few – if any – uninterrupted Permian-Triassic marine sections in which the fossil ranges of this interval are recorded. In the past, for example, "complete" sequences have only been reported from Kashmir, the Salt Range, South China, Tibet, Iran and East Greenland (K. NAKAZAWA et al., 1980; H.F. YIN, 1985; J.Z. SHENG et al., 1987; Y.G. WANG et al., 1988). Recent work, however, suggests that some of these sequences as well as others newly studied may be disconformable, e.g. in Arctic Canada, Spitsbergen, Siberia and the Himalayas (W.W. NASSICHUK et al., 1972; E.T. TOZER, 1979, 1988a,b).

Chinese workers (e.g. Z. YANG et al., 1987) believe that sedimentation is continuous across the Permian/Triassic boundary in China but E.T. TOZER (1979, 1988), A.S. DAGYS & A.A. DAGYS (1988) and others have clearly demonstrated that mixed faunas are common, even there. The so-called "Transitional Bed" of Chinese workers which rests abruptly on Changhsingian strata (e.g. Meishan section, Guryul Ravine in Kashmir or East Greenland) may include Permian-type relics such as brachiopods associated with Lower Triassic ammonoids and *Claraia*.

To summarize, the passage from the Permian to the Triassic has been a challenge to further work. Much progress has already been achieved since formation of the Permian-Triassic Boundary Working Group in 1981; many new data have accumulated from study of new sections and the distribution of various fossil groups and revised taxa ranges. Also, conodonts have become increasingly important for the definition of the Permian/Triassic boundary in recent years. However, their distribution varies widely in different sections, depending on true evolutionary changes and on their relation to facies variations. According to A.S. DAGYS & A.A. DAGYS (1988) the lower boundary of the Triassic cannot be precisely defined in terms of diagnostic conodonts nor can they be exactly correlated with the refined Griesbachian ammonoid zonation of the Boreal and Tethyan Realms. In the following article additional data are presented to contribute to our knowledge of the biostratigraphy surrounding the Permian/Triassic boundary.

2. The Permian/Triassic Boundary in the Southern Alps

In 1988 E.T. TOZER suspected that it might be very difficult if not impossible to find a place in the world in which a continuous marine Permo-Triassic transition is preserved. This pessimistic view has previously been shared for the Southern Alps by R. ASSERETO et al. (1973).

In the Dolomites of Northern Italy the Werfen Formation has long been regarded as equivalence of the Buntsandstein, the lower series from the type area for the Triassic System in Germany (Text-Fig. 2). It succeeds the Bellerophon Formation of unquestionable Permian age. According to J.B. WATERHOUSE (1976) the Bellerophon Formation contains faunas as young as Dorashamian, but no ammonoids to determine the exact stratigraphic position of the Bellerophon-Werfen boundary beds. Representatives of *Tirolites* are the oldest, that is Spathian, ammonoids known from the Dolomites. The famous cosmopolitan bivalve *Claraia* is most abundant in the Seis Member some 70 m above the base of the Werfen Formation but occurs also in the upper part of the Mazzin Member. As a supplement to this general age assignment, conodonts provide a much better base for correlation, suggesting that the lower part of the Werfen Formation, i.e. the Mazzin and Seis Members correspond with the Griesbachian Stage of the lowermost Triassic (C. BROGLIO-LORIGA et al., 1986a,b). Their base may thus very closely approximate the base of the Triassic which in other places is characterized by first appearances of specific ammonoids like the genera *Otoceras, Ophiceras* and related forms.

According to W.C. SWEET (in R. ASSERETO et al., 1973) only rare and undiagnostic conodonts like representatives of *Ellisonia* and a single specimen of *Hindeodus* have been found in the Bellerophon Formation. In the Seceda section north of St. Ulrich in the Gröden valley the overlying Mazzin Member yielded *Hindeodus typicalis* (SWEET) and *Ellisonia* sp. from as low as 1.6 m above the base of the Werfen. Higher up these taxa are associated with *Isarcicella isarcica* (HUCKRIEDE), which first occurs 28 m above the base of the Werfen in the upper Mazzin Member; its first appearance, however, varies between 15 and 45 m above the base in other sections (U. STAESCHE, 1964; R. ASSERETO et al., 1973; p.188, Fig. 4). The overlying Seis Member also contains conodonts. U. STAESCHE (1964) reported *Hadrodontina aequabilis* STAESCHE and *H. anceps* STAESCHE, which according to W.C. SWEET (1970) may represent elements of the apparatus of *Ellisonia* MÜLLER.

Subsequent work, mostly undertaken by H. MOSTLER and his co-workers, confirmed these early studies. In 1982 he and H. KOZUR published a revised and more detailed conodont zonation of the Werfen Formation in which they included data from the Pufels section south of the Gröden valley. Following their taxonomic treatment they determined *Hindeodus parvus* in the middle part of the Tesero Horizon (H. MOSTLER, 1982:58–59), *Isarcicella isarcica* some 16 m above the base of the succeeding Mazzin Member, an assemblage characterized by a new species of *Hindeodus* in the 17 m-thick Andraz Horizon, and another assemblage dominated by *Ellisonia aequabilis* in the overlying Gastropod Oolite and Seis Members. The overlying part of the Werfen sequence was subdivided into several other conodont zones, as yet not fully defined.

A few years later H. KOZUR (1985:238) added to the list of conodonts *Hindeodus latidentatus* (KOZUR, MOSTLER & RAHIMI-YAZD), and *H. minutus* (ELLISON). The latter occurred in the Tesero Horizon at its type locality (bed T-14), approx. 2 m above the base and also in the Sass de Putia section (bed PK-58). According to R. BRANDNER et al. (1986) *H. parvus* also probably occurs at this level. Unfortunately, none of these reports include plates or illustrations.

In 1986 FARABEGOLI et al. published new data from the Lavardet-Rioda and Casera Federata sections in southwestern Carnia. In addition to other fossils they mention *Hindeodus typicalis* SWEET from the top bed of the Bellerophon Formation.

At the Permian/Triassic boundary of the Southern Alps of Italy a more detailed conodont study was undertaken by M.C. PERRI & M. ANDRAGHETTI in 1987. They sampled 15 sections crossing the Bellerophon/Werfen-Formation boundary, of which 10 were productive. They recognized 9 multielement species of platform und ramiform type. As far as the boundary is concerned the authors essentially found the same conodont sequence as in our study. However, their apparent results have been masked by application of a taxonomy most conodont workers do not follow. In contrast to our work representatives of *Hindeodus* were recovered only from the uppermost Bellerophon Formation and from the Tesero Horizon. They described 20 Pa elements. We suspect that these specimens include the two following taxa:

1) *Hindeodus latidentatus* (KOZUR, MOSTLER & RAHIMI-YAZD), illustrated on plate 32, Figs. 3 and 4a,b of M.C. PERRI & M. ANDRAGHETTI, 1987, derived from Bulla (= Pufelsbach) section some 50 cm above the base of the Tesero Horizon and from the Col di Rioda section some 20 cm below the formation boundary, respectively.
2) *Hindeodus minutus* (ELLISON), illustrated on plate 32, Figs. 1a-c, Figs. 2a,b of M.C. PERRI & M. ANDRAGHETTI, 1987, from the Strigno and Pufelsbach sections, respectively, 0.5 to 1 m above the base of the 1 to 5 m thick Tesero Horizon.

Unfortunately, the authors did not report any representatives of *Hindeodus* from the Werfen strata above the Tesero Horizon. This result significantly contrasts with our relatively abundant collections of *Hindeodus parvus* (KOZUR & PJATAKOVA) in this interval. On the other side the occurrence of *Isarcicella isarcica* (HUCKRIEDE) in the Mazzin Member has been confirmed by these authors.

As mentioned earlier, up to 1985 the lithostratigraphic boundary between the Bellerophon and the Werfen Formations was regarded as the chronostratigraphic boundary between the Permian and the Triassic. Even a hiatus in sedimentation was suspected at this boundary (R. ASSERETO et al., 1973). This changed when M. PASINI (1985), C. BROGLIO-LORIGA et al. (1983, 1985, 1986), C. NERI et al. (1986) and S. NOÉ (1987) reported the common occurrences of several Permian fossils, inter alia the long-ranging fusulinids *Nankinella, Staffella* and a possible *Palaeofusulina* above this level in the lower part of the Tesero Horizon. They then suggested that

1) sedimentation was continuous across the lithologic boundary,
2) the Permian/Triassic boundary sequence is transitional
   and
3) the fauna changed gradually.

This was documented in the Tesero type area 2 to 2.5 m above the base of the oolite, that is above the formational boundary between the Bellerophon and the Werfen Formations (C. BROGLIO-LORIGA et al., 1986a,b, 1988; C. NERI et al., 1986; S. NOÉ 1987; W. BUGGISCH & S. NOÉ, 1988). At the same level in the Bletterbach – Butterloch section a major change in palynofacies has been recognized (M.A. CONTI et al., 1986; H. VISSCHER & W.A. BRUGGMAN 1988).

A different opinion, however, was recently expressed by R. POSENATO 1988 after restudy of the brachiopods from the boundary beds. He considered the fossil assemblage from the lower third of the Tesero Horizon to be a mixed fauna characterized by Permian-type brachiopod survivors associated with Triassic newcomers, for example *Bellerophon vaceki* BITTNER and the bivalve *Towapteria scythica* (WIRTH). This mixed fauna may be correlated with the *Otoceras woodwardi* Zone of the transitional beds of south China (J.Z. SHENG et al., 1984; Z. YANG et al., 1987) and the Kathwai Member (Lower Dolomite Unit) in the Narmia section of West Pakistan (R.E. GRANT, 1970). For both sections a Lower Griesbachian age was suggested, although in the latter case the exact age of the brachiopod layers has long been a matter of discussion and controversy.

The conodonts cited in the forementioned paper of R. POSENATO (*Hindeodus latidentatus, H. minutus*) seem to support the suggested Lower Griesbachian age for this part of the Tesero Horizon. There is no indication of transport or reworking from older into younger beds. These taxa range – in accordance with H. KOZUR

(1985:238) and T. MATSUDA (1981, 1985) – from the Dorashamian to the Early Griesbachian. We here disregard KOZUR's interpretation of the *Otoceras* beds of the Himalayas as Permian in age (H. KOZUR, 1980). As pointed out by E.T. TOZER (1988:298) and A.S. DAGYS & A.A. DAGYS (1988:319) this mistaken correlation is based on KOZUR's belief that *Otoceras* occurs in strata of Dorashamian age in northwestern Iran. According to E.T. TOZER the specimens assigned to *Otoceras* are actually *Julfotoceras tarazi* BANDO, first described from the Kuh-e-Ali Bashi section at Dzhulfa as well as later from the *Paratirolites* beds of Abadeh (Y. BANDO, 1973, 1979).

3. The Conodont Succession of the Permian-Triassic Boundary Beds from Core Gartnerkofel-1 and the Reppwand Outcrop Section

(Text-Fig. 3)

The contributions by K. BOECKELMANN and C. JENNY-DESHUSSES in this volume make clear that the content of microfaunas and algae in the core and in the neighbouring Reppwand outcrop section is very poor. Macrofauna such as ammonoids, brachiopods and bivalves are entirely missing. This is also true for fusulinids, the most important group of microfossils for biostratigraphy in the Late Permian – they have not been found in either section. But although the Permian and Triassic can not be separated precisely, we can make a much more detailed subdivision of the stratigraphy than has been achieved in previous studies (W. BUGGISCH 1974).

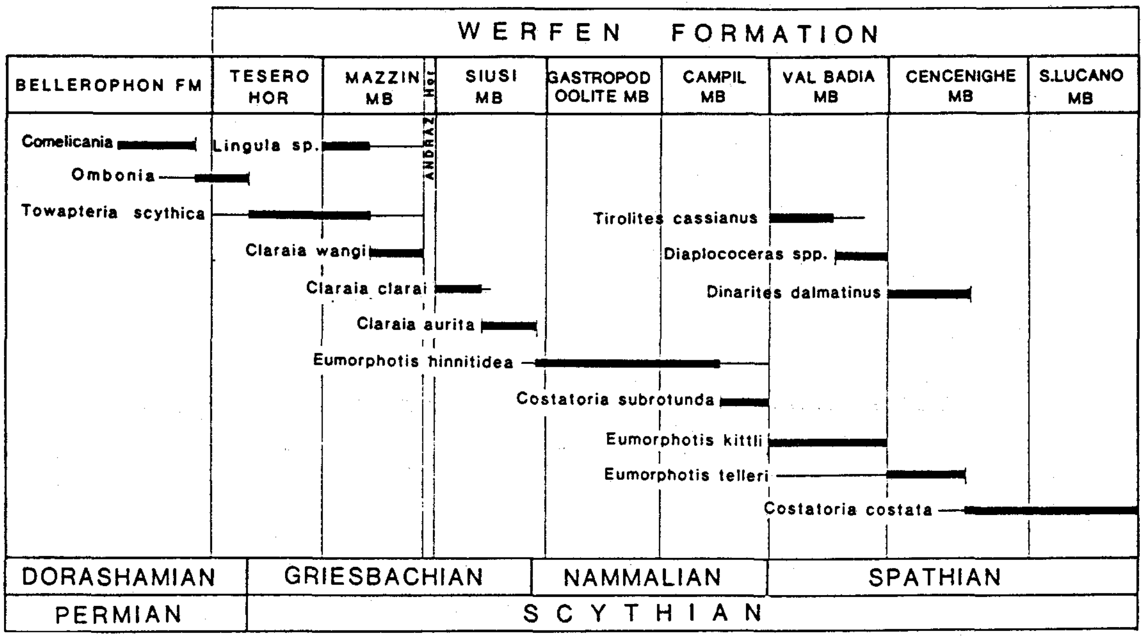
Based on thin section analysis of the microfauna, algae and other bioclasts C. JENNY-DESHUSSES (this volume) concluded that the Bellerophon Formation, i.e. the equivalent of Upper Permian ranges from the end of the core (minus 331 m) to a depth of 231.25 m. The succeeding upper portion starting at a depth of 229.92 m is characterized by an association which suggests Lower Triassic age. Interestingly, in the outcrop section sample nos. 3–11, i.e. from minus 3.7 m to the base of the Tesero Horizon contain mixed faunas but no diagnostic Permian or Triassic taxa.

The lithological analysis of the rock sequence carried out by K. BOECKELMANN (this volume), based on more than 400 thin sections recognized 6.5 m of Tesero Horizon above the Bellerophon Formation, at depths of 231.04 and 224.50 m in the core. Its possible equivalents occur in the outcrop section from the top of the Bellerophon Formation to 4 m above this level. At this horizon a distinct change of litho-and biofacies is recognized: Homogeneous dolomitic biomicrites representing the upper Bellerophon Formation are replaced by fine- and medium-grained dolomites with relics of ooids and allochems (K. BOECKELMANN, this volume).

In order to support these biostratigraphic data and to seek additional precision 44 samples of the core and 90 samples of the outcrop were processed for conodonts. The sampling began in the uppermost Bellerophon Fm. 4.4 m below its lithological upper boundary and continued upward to 59.7 m above this boundary (sample no.90) within the equivalent of the Seis Member of the Werfen Formation (K. BOECKELMANN, this volume). Conodont sampling of the core concentrated on the boundary beds, from some 5 m below to about 50 m above the presumed Bellerophon – Tesero Horizon contact (Text-Fig. 3).

The sample size from the core varied between 0.7 and 3.0 kg depending on the drilling recovery and the core diameter which decreased from 64 mm to only 48 mm at 220.50 m. In this narrowerr core the sample necessarily included up to 50 cm of the core.

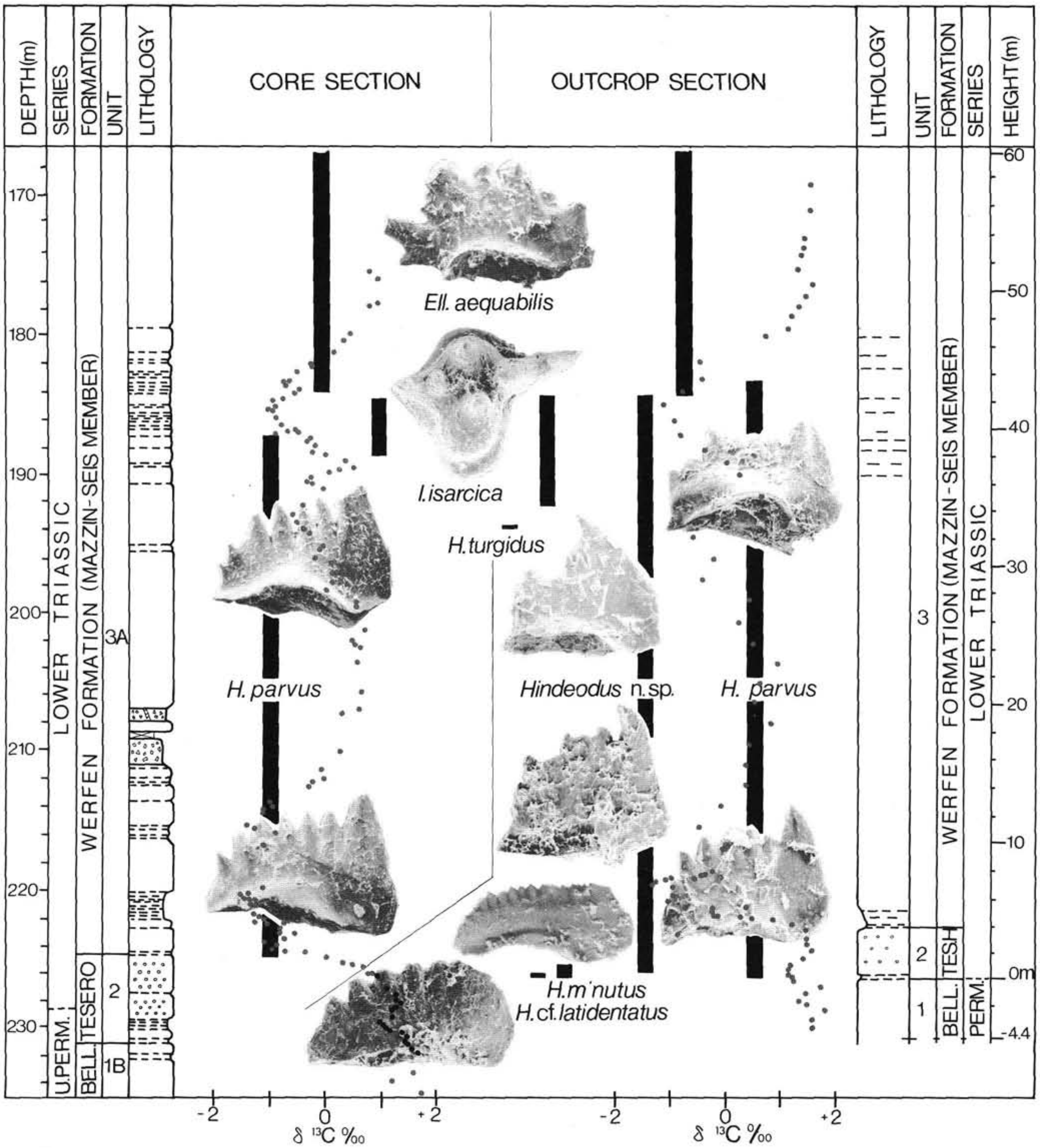
The crushed samples were processed in the customary fashion. Due to the dolomitic rock composition all samples were repeatedly (up to 4 times) treated with 8 % acetic acid until most of the sample was dissolved. The small residue was then sieved and finally separated by heavy liquid. This concentrate was picked by the author.



Text-Fig. 2.
Litho- and biostratigraphy of the Upper Permian Bellerophon Formation and Lower Triassic Werfen Formation in the Dolomites of Northern Italy.
From BROGLIO LORIGA et al. (1986).

Our study is based on more than 550 discrete conodont elements from the outcrop and some 195 mostly fragmentary elements from the core. In summary some 450 or 60 % (core 46 %, outcrop 65 %) were identifiable at species level or have been recognized as distinct ramiform elements of known or unkown apparatuses (Tables 1,2). This high level of recognition reflects the good preservation of our material but is biased by a single sample (67) containing more than 150 easily recognizable representatives of *Isarcicella isarcica* (HUCKRIEDE). The multi-element *Ellisonia aequabilis* (STAESCHE) can be definitely identified in sample no. 72, i.e., 42.40 m above the base of the Tesero Horizon. Those ramiform elements which occur below this level in the core and the outcrop were grouped into the category "elements of unspecified apparatuses". Insufficient numbers of diagnostic elements did not permit a specific designation.

The conodonts recovered from the boundary beds were affected by a weak thermal overprint which in terms of the illite crystallinity index (J.-M. SCHRAMM, this volume) does not really reflect metamorphic condi-



Text-Fig. 3.
Range chart of selected conodonts from the core and the outcrop section.
$\delta^{13}C$ curve based on the article by M. MAGARITZ & W.T. HOLSER (this volume).

Table 1.
Conodont occurrences in selected samples of core Gartnerkofel-1.
Total recovery includes identifiable plus fragmentary conodont elements. Note that certain ramiform elements were not grouped into a named multielement.

Depth [m]	Weight [g]	Total recovery	Identified elements	Species assignment uncertain						*Hindeodus parvus*	*Hindeodus* n.sp.	*Isarcicella isarcica*	*Ellisonia aequabilis*					
				Pa	Pb	M	Sc	Sb	Sa				Pa	Pb	M	Sc	Sb	Sa
170.55–171.55	2117	16	7										1	2	1	1	1	1
171.80–172.85	2163	8	4												1	2		
172.85–173.40	1826	1	1												1?			
173.95–174.50	2067	4	1												1			
175.20–175.85	1773	22	7											1		3	3	
175.85–176.50	2750	24	6											2	2		2	
176.70–177.80	2685	7	2											1				1
177.80–178.50	1751	5	1													1		
179.00–180.00	2326	9	3											1	1	1		
180.40–180.50	1911	—																
182.30–182.68	2303	—																
182.92–183.10	1251	9	3													1	2	
183.08–183.26	1548	—																
183.60–184.00	1551	3														1		
184.50–185.00	1366	30	12	1	1?	1	2	4	1			2						
185.10–185.35	1622	—																
186.04–186.22	1259	—																
186.30–186.80	1527	4	2				1	1										
186.95–187.20	932	7	4	1?								3						
187.20–187.70	1303	17	15	1			2	2	1	2		7						
187.77–188.07	2125	8	5	1		1			1	1	1							
188.20–188.60	1427	1	1									1						
188.60–189.20	1161	1	1							1								
189.50–190.00	1337	8	8			1				7								
190.00–190.62	1498	5	5							4	1							
214.22–214.65	2473	—																
215.38–215.87	1404	—																
219.55–219.95	748	—																
220.95–221.35	905	—																
221.95–222.25	862	—																
222.75–222.95	963	—																
223.72–223.92	762	2	2	1?			1											
224.74–224.97	844	4	3							3								
225.68–226.02	1151	—																
226.14–226.45	907	—																
226.55–227.00	1681	—																
227.00–227.40	944	—																
227.50–227.90	1010	—																
228.10–228.55	1518	—																
228.50–228.85	1021	—																
230.75–230.90	792	—																
232.06–232.38	1212	—																
232.40–232.75	1480	—																
234.40–234.90	1750	—																
		195	91 (46 %)							18	2	13						

Table 2.
Conodont occurrences in the Reppwand outcrop section B'.
Note cumulative thickness related to the base of Tesereo Horizon. Unproductive samples have been omitted. Total recovery includes identifiable plus fragmentary conodont elements. Certain ramiform elements were not grouped into existing apparatuses due to insufficient collections.
"Thickness" means thickness above or below (–) base of Tesero Horizon, which is marked by dotted line.

Sample No.	Thickness [m]	Weight [g]	Total recovery	Identified elements	Species assignment uncertain						*Hindeodus latidentatus*	*Hindeodus minutus*	*Hindeodus parvus*	*Hindeodus* n.sp.	*Hindeodus typicus*	*Hindeodus turgidus*	*Isarcicella isarcica*	*Ellisonia aequabilis*					
					Pa	Pb	M	Sc	Sb	Sa								Pa	Pb	M	Sc	Sb	Sa
85	55.50	3913	10	8				1										3			4	1	
84	54.40	4067	33	22														9	1?	5	3	2	2
83	53.40	3445	15	10				2										1	1	5	2	1	
82	52.60	3314	30	10				3										3	1	1	4		1
81	51.80	3297	32	12				1										5	2?		3	1	1
80	50.60	3110	16	6														1		1	3		1
77	47.60	2890	1																				
75	45.60	3484	(gastrop.)																				
73	43.40	2654	2										1?								1		
72	42.40	3577	66	18									3	1			7	2	2	1		1	1
71	41.40	3366	17	9	1?	1	1?	1					1				1	3					
70	40.40	3306	8	4		1?			1				1				1						
69	39.40	4290	2	1									1										
68	38.20	3051	11	11			2?	1	1					7									
67	37.20	4230	174	159	1?	2?	1	7	1				3	1			143						
66	35.70	3923	25	18			1?	4	3				4				6						
65	34.20	3578	14	12	2			1	2				1				6						
64	32.70	2783	7	4									3			1							
63	31.20	3367	3	3			1?						1	1									
62	29.70	3420	2	2									2										
61	28.20	3644	1	1									1										
59	25.20	3116	2	1									1										
52	14.70	2749	2	2				1		1?													
47	8.10	2745	2																				
43	7.00	2540	5	5				1					4										
36	4.80	2500	(vertebr.)																				
34	4.50	2500	2	1									1										
32	4.40	2500	6	1											1?								
31	4.20	2500	3	3	2								1										
29	4.10	2500	14	11				1	1				6	2	1?								
28	4.00	2500	1																				
26	3.80	2500	1	1											1?								
25	3.40	2500	1	1									1										
20	1.60	2500	(spicula)																				
18	1.30	2500	1	1									1?										
17	0.90	2500	2	2	1								3										
15	0.47	2500	14	10				1				4	5										
14	0.37	2500	19	8			1		2			1	4										
13	0.19	2500	10	8				2					5	1									
12	0.02	2500	3	2							1		1										
10	0.80	2500	1																				
9	0.90	2500	1																				
6	2.00	2500	1																				
5	2.40	2500	(fish teeth)																				
4	3.10	2500	1																				
			561	366 (65 %)							1	5	58	6	3	1	164						

tions (less than 200°C); except for an anomalous indication of anchimetamorphism (200–300°C) in the Tesero Horizon. The Color Alteration Index (CAI) generally exhibits a very dark brown to greyish conodont base while the upper part, including the cusp and the denticles, are light brown, yellowish or light grey in color. They can be classified as Color Alteration Index 3 suggesting a temperature range between 110 to 200°C (A.G. EPSTEIN et al., 1977).

This level of heating was too low to cause recrystallization. Whether or not it caused the mineral overgrowths on the surface cannot be definitely decided. The overgrowths affect mostly representatives of the genus *Hindeodus*, and to a lesser degree ramiform elements of *Ellisonia*. On the other hand many conodonts preserved smooth surfaces and even fine striae parallel to the axis of the denticles (see Plate 1).

From the base to the top our conodont collection of the Permian-Triassic boundary beds of the outcrop section clearly can be subdivided into five distinct assemblages (Text-Fig. 3). As yet, no diagnostic conodonts have been recovered from the topmost Bellerophon Fm., only some fish teeth and a few fragmentary ramiform elements. Above the lithologic boundary in the overlying Tesero Horizon and in the overlying Mazzin and Seis Members, the following associations occur.

Assemblage A

This assemblage is characterized by rare occurrences of *H.* cf. *latidentatus, H. minutus* and first appearances of *Hindeodus parvus* and *Hindeodus* n.sp. They occur in the Reppwand outcrop section in sample nos. 12–15, i.e. from 0.02 to 0.47 m above the base of the 4 m-thick Tesero Horizon. In comparison with the core the Tesero Horizon of the outcrop section is slightly reduced.

Assemblage B

This assemblage clearly represents the acme-Zone of *Hindeodus parvus*. Sharing taxa of this horizon are *Hindeodus* n.sp. and *Hindeodus* cf. *typicalis*. The last occurrence of *H. parvus* is in sample 72, 42.4 m above the formation boundary. *Hindeodus* n.sp. has a narrower range, its last occurrence is in sample no.63, 31.2 m above the formation boundary. An even more restricted range is shown by some representatives of *Hindeodus* assigned to *Hindeodus* cf. *typicalis* (SWEET). They were recognized in an interval from 3.8 to 4.4 m above the formation boundary (sample nos. 15–17), in the uppermost part of the Tesero Horizon and the base of the succeeding sequence.

Assemblage C

A single occurrence of *Hindeodus turgidus* (KOZUR, MOSTLER & RAHIMI-YAZD) was found in association with *Hindeodus parvus* in sample no.64, 32.7 m above the formation boundary. This horizon is 1.1 m below the onset of *Isarcicella isarcica* (HUCKRIEDE) the logical descendant of *Hindeodus turgidus*.

Assemblage D

This assemblage is characterized by rich occurrences of *Isarcicella isarcica* (HUCKRIEDE) and its associate *Hindeodus parvus*. The former ranges from sample 65 to 72, i.e. from 34.2 to 42.4 m above the formation boundary.

Assemblage E

Our youngest assemblage is characterized by the apparatus of *Ellisonia aequabilis* (STAESCHE). Its lowermost proved occurrence is in sample 72, 42.40 m above the base of the Tesero Horizon in the outcrop section. However, it may occur already in lower strata as indicated by Sb elements in sample no.65, 16.4 m below the positively proved level. This element may otherwise belong to a different species of *Ellisonia*.

*

Processing of the core yielded conodonts from 22 different levels between 170.55 and 225 m (Table 1). The the total number of recovered specimens is almost 200. However, it must be stressed that most elements are fragmentary and thus with the exception of four taxa a positive identification at species level is not possible. The well preserved elements can be easily correlated with the Assemblages B, D and E from the outcrop section. Here, also, *Hindeodus parvus* occurs with *Hindeodus* n.sp. in the two lower samples, i.e., at 223.72–223.92 and 224.74–224.97 m. In addition to these occurrences, a fragmentary platform-type conodont has been found in the sample processed from 223.72–223.92 m. It differs from all the other conodonts by its greyish color. Although diagnostic features are not preserved, this fragment is tentatively assigned to the genus *Gondolella*.

For correlation purposes, the occurrences of *Isarcicella isarcica* (HUCKRIEDE) in the core are significant. In the upper ranges of this species, there is an excellent correlation between geochemical and biostratigraphic data between the core and the outcrop. In both sections the lowermost negative excursion of the $\delta^{13}C$ values coincide with the last occurrence of *Isarcicella isarcica*.

Starting at a depth of 184.50 m in the core section ramiform elements dominate. Although most of these are fragments, they are tentatively assigned to the multielement apparatus *Ellisonia aequabilis*, which is also known from the outcrop section.

Besides conodonts the heavy fraction of the residue in the outcrop section contained fish-teeth and some other vertebrate remains (sample no. 5 = 2 m above the base of the measured section). Some tiny pyritized gastropods occur in sample no.75, some 50 m above the base of the measured section (Table 2).

4. Taxonomic-Nomenclatural Remarks and Discussion

Hindeodus latidentatus (KOZUR, MOSTLER & RAHIMI-YAZD 1975) was first described from section at Kuh-e-Ali Bashi in Upper Permian rocks of Iran. The holotype is derived from close to the upper boundary of the *Paratirolites* Beds. The only other report of this species comes from H. KOZUR (1985) who found it in bed T-14 of the type locality of the Tesero Horizon in the Southern Alps. Our figured specimen is tentatively assigned to *H. latidentatus*. It differs from concomitant representatives of *H. parvus* by its widely spaced and in lateral view triangular appearing posterior denticles.

There is an extensive literature expressing different opinions regarding *Anchignathodus typicalis* SWEET (1970a) and *A. parvus* KOZUR & PJATAKOVA 1975, nowadays assigned to the genus *Hindeodus*. I share the view of H. KOZUR that the illustrated holotype of SWEET (1970b) of *A. typicalis* does not belong to the species that W.C. SWEET originally in 1970a described and illustrated as hypotypes from sample K41 of the uppermost Guryul Ravine section, Kashmir. In 1975a and 1980 H. KOZUR claimed that SWEET's holotype belongs to *Hindeodus minutus* (ELLISON), or alternatively may be regarded as a separate species named *Hindeodus typicalis* (SWEET), see also T. MATSUDA (1981). This species ranges from the Missourian (Upper Carboniferous) to the basal Triassic *Otoceras woodwardi* Zone. At section Kuh-e-ali Bashi in Northern Iran its last (although rare) occurrence is in the upper *Paratirolites* Beds, which are of Late Permian age in the sense of E.T. TOZER and others (H. KOZUR et al., 1975). W.C. SWEET's unfigured holotype of 1970a (= *H. minutus* or *H. typicalis*) is derived "1–5 inches above the base of the Kathwai Member of the Mianwali Formation of the Salt Range" coinciding with first occurrences of Triassic ammonoids like *Ophiceras* and *Glyptophiceras* (W.C. SWEET, 1973:632). A comparable range has later been confirmed by T. MATSUDA (1981) at Guryul Ravine, Kashmir, where *H. minutus* and *H. parvus* occur in successive ranges both in the *Otoceras* Zone.

According to H. KOZUR & H. MOSTLER (1973) and H. KOZUR (1975a) the figured hypotypes of *Anchignathodus typicalis* SWEET 1970a are conspecific with *Hindeodus parvus* (KOZUR & PJATAKOVA 1975) known from the *Ophiceras* Zone. T. MATSUDA (1981) assigned them, however, to *H. minutus*. In 1977, W.C. SWEET included the three lowermost Triassic P-elements *A. parvus, A. typicalis* and *Isarcicella isarcica* into one single species named *Isarcicella isarcica* (HUCKRIEDE) consisting of three morphotypes. This was based on his erroneously regarded opinion of that time and, supported by the evidences presented by U. STAESCHE (1964), H. KOZUR (1971) and W.C. SWEET (1973a) that the stratigraphic ranges of all three are the same in the basal Triassic.

Following H. KOZUR & H. MOSTLER (1973), H. KOZUR (1975a,b) and W.C. SWEET (1973b) *Anchignathodus parvus (A. typicalis)* and *Isarcicella isarcica* range from the *Otoceras* Zone (Spiti) to the upper *Ophiceras* commune Zone. At section Kuh-e-Ali Bashi in northern Iran *I. isarcica* first occurs in the lower 4.5 m of the Elikah Formation, and in the Salt Range section it occurs 1.5–2 m above the lowermost *Ophiceras* and *Glyptophiceras*-bearing beds.

As noted in particular by T. MATSUDA 1981 there is a wide range of intraspecific variability in both *Hindeodus minutus* and *Hindeodus parvus*. The most diagnostic features of our 5 representatives of *Hindeodus minutus* are the length and the great number of small denticles posterior to the cusp: There are between 11 and 15 or 16. Due to fragmentation of our material neither the height of the cusp nor the height of the first denticle posterior to the cusp can be measured. However, a gradual decrease of the height of the denticle row towards the posterior end of the unit is clearly indicated. In this respect our specimens most closely resemble those illustrated by T. MATSUDA (1981, plate 1, figure 11) from bed no. 57 of the Guryul Ravine Section. On the other hand, these two collections are remarkably different: In our material in aboral view the basal cavity occupies no more than the half of the total length and it is more elliptical and not as widely expanded as in the Kashmir specimens. This major difference also applies for representatives of *Hindeodus parvus*.

In the Kashmir material T. MATSUDA (1981) noted many intermediate forms between the Pa elements of *Hindeodus minutus* and *Hindeodus parvus*. The latter is distinguished from the intermediate forms by its higher and narrower cusp and the lower value of the length to width ratio. Specimens in which the denticles are abruptly offset behind the cusp and then remain equal in height, were regarded by T. MATSUDA as variants of *Hindeodus minutus*; they are common in the Early Triassic of Kashmir.

In the original description of H. KOZUR & M. PJATAKOVA (1975) the main criterion for distinguishing between the two species is the shorter length of *Hindeodus parvus* compared with *Hindeodus minutus* which resulted in fewer denticles and the more pronounced cusp. The denticulation, however, varies in both species, some with irregularly high denticles, some of equal height, or some with denticles gradually decreasing in height. Fusion of denticles may also vary to a certain degree. All these variants occur in our material and the reader is referred to our Plate 1.

As mentioned already, the specimens described and illustrated by M.C. PERRI & M. ANDRAGHETTI (1987) from the basal Tesero Horizon of the Southern Alps as *Hindeodus typicalis* (SWEET) we regard as two separate species: *Hindeodus minutus* (ELLISON) and *Hindeodus latidentatus* (KOZUR, MOSTLER & RAHIMI-YAZD). We are unable to recognize any significant differences between their material from the base of the Tesero Horizon and ours from a correlative level in Austria.

Beside *Hindeodus* cf. *latidentatus, Hindeodus minutus* and *Hindeodus parvus* we have distinguished two more species of *Hindeodus*, namely *Hindeodus* n.sp. and *Hindeodus* cf. *typicalis*. The former taxon, based on same 20 specimens from the core and the outcrop section, is characterized by its short length of 1.5 or less times the width. This feature distinctly separates the two species. Denticulation, however, varies as in the other species of *Hindeodus*. Moreover, *Hindeodus* n.sp. has a very prominent cusp sometimes terminated by double points (Pl. 1, Fig. 6). Also, the cusp of *Hindeodus* n.sp. is more inclined backward than *Hindeodus parvus* and has a convex anterior slope (see Pl. 1, Fig. 22; Pl. 2, Figs. 1,3).

Other representatives of *Hindeodus* which exhibit more laterally compressed instead of rounded denticles (Pl. 1, Figs. 15–17) are assigned to *Hindeodus* cf. *typicalis*. They occur in a relatively thin interval above the first occurrences of *Hindeodus parvus* and resemble – in particular our Figure 15 on Plate 1 – the Kashmir hypotype of *Hindeodus typicalis* of W.C. SWEET (1970a, Pl. 1, Fig. 13).

According to W.C. SWEET (1977) and T. MATSUDA (1981) the multielement species *Hindeodus minutus* (ELLISON) is composed of six discrete elements. Whether or not the other species, in particular *Hindeodus parvus* consisted of homologous elements can not be confirmed in our material., Yet, we have only found one Sa, one Sb (possibly on Pl. 2, Fig. 21) and a few other fragmentary ramiform elements which might belong to the apparatus of *H. parvus*.

Hindeodus turgidus (KOZUR, MOSTLER & RAHIMI-YAZD 1975) was first described from the basal Elikah Formation of the Kuh-e-Ali Bashi section in northern Iran. Its first occurrence there is in sample AR 90 same 1.60 m below the appearance of *Isarcicella isarcica* (HUCKRIEDE). According to T. MATSUDA 1985 *Hindeodus turgidus* is limited to Iran and Transcaucasia. However, D.L. CLARK et al. (1986) also found it in the Meishan section of South China. Our single specimen (Pl. 2, Fig. 4) agrees well with the figured holotype, and there is nothing to add to its original description. It occurs 1.5 m below the first *Isarcicella isarcica* in the outcrop section.

Isarcicella isarcica (HUCKRIEDE) is the most abundant of the conodont species in our collection. Our collection contains more than 160 specimens, all showing the characteristics described in previous studies by R. HUCKRIEDE (1958), U. STAESCHE (1964), W.C. SWEET (1970b, 1973, 1977), H. KOZUR et al. (1975) and T. MATSUDA (1981). A prominent feature is the ornamentation of the asymmetrically expanded basal cavity, showing one or rarely two or three denticles on the surface of the basal cavity on the inner side of the carina. Anteriorly, the latter has a prominent cusp. The outer side of the carina is slightly thickened in some specimens; it bears no denticle in the material studied. The apparatus of *Isarcicella isarcica* has yet to be fully described. In our material the Pa element is associated with ramiform elements, but they are too few to ascertain their true relationship with the Pa-element.

In the Werfen Formation starting certainly in sample no. 72 (42.40 m above the formation boundary) the multielement species *Ellisonia aequabilis* (STAESCHE) is abundantly represented. It consists of six morphologically different ramiform elements, which occupy the S, M and P positions in the apparatus (W.C. SWEET, 1970b, 1981, 1988b). The diagnostic name-bearing element is the angulate Pa-element originally described by U.STAESCHE (1964) in terms of form-taxonomy as *"Hadrodontina aequabilis"* from the Upper Seis and the Lower Campil Members of South Tyrol. There is no objective difference between this type material and our Pb-elements. However, the remaining ramiform elements, occurring in varying abundances and degree of preservation in the same samples, can be assigned only provisionally to this species. On the other hand, their assignment to other Early Triassic species of *Hadrodontina, Furnishius* or *Pachycladina* can be ruled out by the architecture of their skeletal apparatuses and the differently shaped elements in the Pb and Sa positions. In our collection there is no indication that any elements of one of these apparatuses might actually be present. According to M.C. PERRI & M. ANDRAGHETTI (1987) the diagnostic Pa-element of the multielement *Hadrodontina anceps* STAESCHE starts in the Campil Member of the Werfen Formation, which was not sampled in our two sections.

5. Standard Conodont Zonation Across the Permian/Triassic Boundary

The exact placing of the boundary between the Permian and the Triassic systems is a matter of definition and international agreement. We have outlined the current status in the introductory chapter.

As far as the boundary interval and the overlying Triassic are concerned, pioneering work to establish a conodont-based zonation was compiled by W.C. SWEET in 1970 and compared with the standard ammonoid zones. In 1971 he and his co-authors subdivided the Lower Triassic into 13 conodont biozones or 22 for the whole Triassic (Text-Fig.4, see also R.K. PAULL, 1982). The successive biozones are limited upward by first appearances of the next diagnostic conodont species. Since 1971 the knowledge of the ranges and distribution of Lower Triassic conodonts has increased considerably, in particular from revisions and new studies in

SWEET, 1970b	SWEET et al 1971		KOZUR and MOSTLER 1972	KOZUR and MOSTLER 1973	SOLIEN 1979 CARR & PAULL 1983	MATSUDA 1981, 1985
Timorensis	SPATHIAN STAGE	Timorensis	Timorensis	Timorensis	8	Timorensis
Jubata		Jubata	Homeri	Homeri	7	Homeri
		Neosp. n.sp.G			6	
		Platyvillosus			5 B A	
Waageni	SMITHIAN STAGE	Milleri	Waageni	Elongata	4 D	Elongata
		Conservativus			C	Milleri
		Parachirogn. Furnishius	Milleri	G.aff. Milleri Eotriassica	B A	Waageni
Pakistanensis		Pakistanensis	N.gen. n.sp.	Gondolella n.sp. B		Pakistanensis
Cristagalli	DIENERIAN STAGE	Cristagalli	Dieneri	(Not discussed)	3 Dieneri	Cristagalli
Dieneri		Dieneri				Dieneri
Kummeli		Kummeli			2 Kummeli	Kummeli
Carinata	GRIES-BACHIAN	Carinata	Carinata	Carinata	1 Typicalis	Carinata Isarcica
Typicalis		Typicalis	Typicalis	Parvus Isarcica		Parvus Minutus
	PER-MIAN					

Text-Fig. 4.
Conodont based biostratigraphic schemes for the Lower Triassic.
From W.C. SWEET & S.M. BERGSTRÖM (1986) and T. MATSUDA (1981, 1985).

Kashmir, northwestern Iran, Transcaucasia, Pakistan, China, Tibet, USA and other regions (W.C. SWEET & S.M. BERGSTRÖM, 1986). The result is a more detailed biostratigraphic scheme, based on both traditional and non-traditional, in particular graphic correlation methods. The latter was first introduced by W.C. SWEET in 1979 and reconsidered in 1986 by W.C. SWEET & S.M.BERGSTRÖM, W.C. SWEET (1988a) and by H.F. YIN et al. (1988). With regard to the Permian/Triassic boundary interval E.T. TOZER (1989) questioned the results of this method. He argued that the graphic correlation method depends on an assumption of continuous unchanged sedimentation rate during the interval, which, however, was evidently not the case.

Our contribution to this problem is a detailed range chart of diagnostic uppermost Permian (?) and lowermost Triassic conodonts derived from a 60 m thick rock sequence. We are fully aware that at this time the Permian/Triassic boundary is less securely established by means of conodonts than are other systemic boundaries in the Paleozoic.

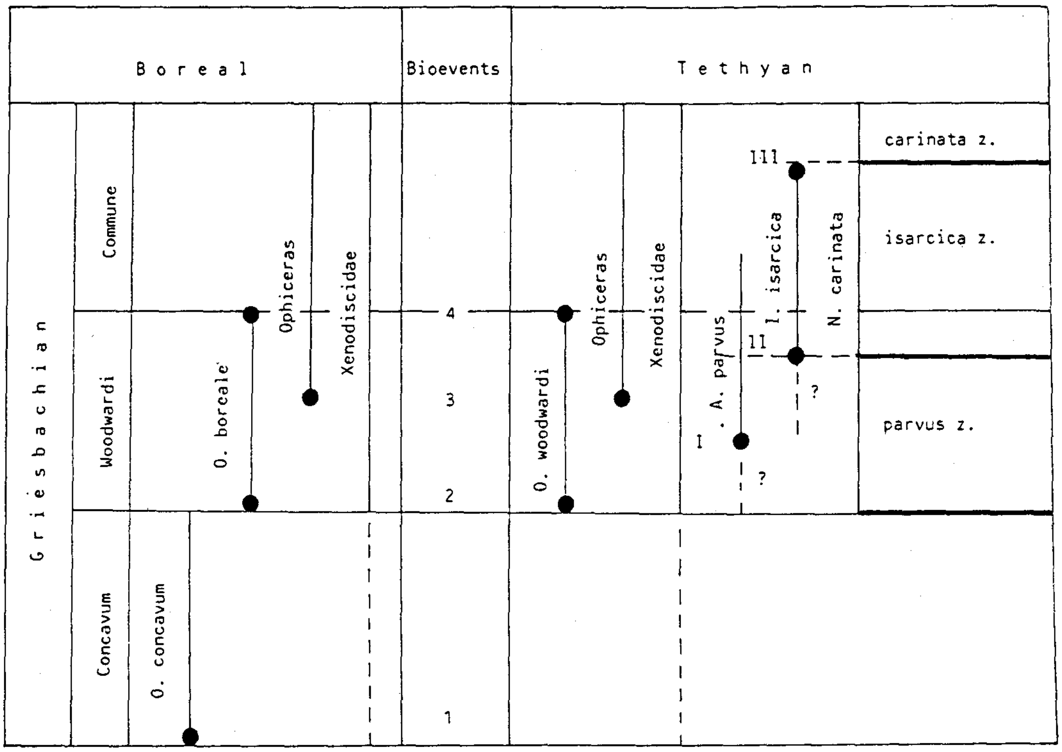
According to A.S. DAGYS & A.A. DAGYS (1988) the stratigraphic distribution of certain conodont species varies considerably in different regions. Unfortunatelly, conodonts have yet not been recorded from the *Otoceras concavum* and *Otoceras boreale* ammonoid Zones of the Boreal region, generally considered to represent the lowermost Griesbachian. In the Tethyan region, however, the following four bioevents have been recognized in ascending order (Text-Fig. 5):

1) At Guryul Ravine, Kashmir, the *Otoceras woodwardi* Zone can be divided into a lower *Hindeodus minutus* Interval Zone (1) and an upper *Hindeodus parvus* Zone characterized by the first appearance of *Hindeodus parvus* (2).
2) These two basal zones are followed by the first occurrence of *Isarcicella isarcica* defining the *isarcica* Zone (3) which marks a distinctive and worldwide recognizable biohorizon. Its upper limit coincides with event 4, i.e. the extinction of *Isarcicella isarcica* and the appearance of *Ellisonia aequabilis* in a *Gondolella*-free facies.
3) In addition to these four major bioevents the appearance of *Hindeodus turgidus* can also be considered for correlation purposes of even smaller time units in the Lower Triassic.

Correlation of these zones with standard ammonoid zones is not yet sufficiently clear although it is evident that *Hindeodus parvus* first occurs in the *woodwardi* Zone. Current studies suggest that this species is missing from the lowermost part of the *woodwardi* Zone. According to T. MATSUDA (1981), and others (see below) this part of the Lower Triassic may be represented by Permian-type relics such as *Hindeodus minutus* and/or representatives of *Neogondolella*.

The holotype of *Hindeodus parvus* (KOZUR & PJATAKOVA) was described from Transcaucasia and is clearly Triassic in age. According to H. KOZUR et al.(1975, Pl. 7, Fig. 7) its lowermost occurrence is 1.5 m above the Upper Permian *Paratirolites* Beds in layers corresponding to the *Ophiceras commune* Zone. In some sections it may extend above the range of *Isarcicella isarcica* (H. KOZUR & H. MOSTLER, 1973; H. KOZUR, 1975b; see also H. KOZUR 1975a:11). F. GOLSHANI et al. (1988) suspected that in northwestern Iran the lowermost Triassic, i.e., the lower part of the *Otoceras woodwardi* Zone is missing. The overlying basal Elikah Formation contains *Hindeodus parvus*, and higher up *Isarcicella isarcica* is associated with *Ophiceras* and other ammonoids. A gap also exists in central Iran at Abadeh. Thus, neither from Transcaucasia nor from northern Iran it can be clearly stated whether the first occurrence of *Hindeodus parvus* actually coincides with the oldest Triassic ammonoids.

At Meishan section, South China, the first occurrence of *Hindeodus parvus* and *Hindeodus minutus* is in the 15 cm thick bed no. 27 overlying the *Otoceras* sp. and *Glyptophiceras* sp. bearing boundary clay no. 26, which traditionally has been regarded as the base of the



Text-Fig. 5.
Distribution of ammonoids and related zonation for index conodonts in Permian-Triassic boundary beds.
After A.S. DAGYS & A.A. DAGYS (1988).

Lower Triassic (J.Z. Sheng et al., 1984; M. Ding, 1988). As far as the lowermost Triassic faunas are concerned, there are, however, serious claims that reworking has occurred (E.T. Tozer, 1979:1531, 1988:294). At the boundary between the Permian and the Triassic D.L. Clark et al. (1986) observed a dramatic reduction in the abundance of conodonts, although their distribution shows four to five of the six species (inter alia *H. minutus*) present in the Late Permian surviving into the Early Triassic. These ranges contrast with the above mentioned reports.

Hindeodus minutus (Ellison) has long been regarded elsewhere as a Late Carboniferous and Permian conodont species. In Permian time it has been found in Lower Dzhulfian strata of the Bükk Mountains of Northern Hungary (H. Kozur & R. Mock, 1977) but has also been reported from the Southern Alps (R. Posenato, 1988:36). J. Yao & Z. Li (1987) and Y.G. Wang et al. (1988) reported it from the *Otoceras* bearing bed in the Selong section, Tibet. In the upper part of this bed *Hindeodus parvus* first appears. This species becomes very prominent in the overlying *Ophiceras* Zone.

T. Matsuda, in studying Early Triassic conodonts from Kashmir and the Salt Range and comparing these data with those from other parts of the world, recognized provincialism among these faunas. He differentiated between a Tethys and a Peri-Gondwana Tethys conodont province. According to his paper in 1985 Griesbachian conodont assemblages of both provinces exhibit remarkable differences: For example, Salt Range and Kashmir sections are rich in *Hindeodus minutus* and neogondolellids but rare in *Isarcicella isarcica*, while in Iran and Transcaucasia, part of the Tethys Province, *Hindeodus parvus* and *Isarcicella isarcica* dominate. In this latter region *Hindeodus minutus* is either very rare or absent in rocks of Triassic age, and gondolellids are almost missing (H. Kozur et al., 1978; T. Matsuda, 1985).

In conclusion, *Hindeodus minutus* (Ellison) generally is restricted to Permian strata. It may, however, persist into the basal Triassic depending on facies and the paleogeographic setting of its sedimentary sequences. *Hindeodus parvus* (Kozur & Pjatakova) has yet not been reported from beds containing undisputed *Otoceras woodwardi* Zone ammonoids, except in the Guryul Ravine section, Kashmir, and Selong, Tibet (W.C. Sweet, 1970a; K. Nakazawa et al., 1975); T. Matsuda, 1981). Earlier reports of its occurrence in the Late Permian Changxing Formation have recently been denied (H.F. Yin et al., 1988:333).

Isarcicella isarcica only occurs within the range of the genus *Ophiceras* and, more precisely, in the lower part of the *Ophiceras tibeticum* Subzone. Whether or not this statement is also true for the following *Ellisonia aequabilis* Zone can not yet be decided. In our sequence the possibly coeval occurring name bearer of the *Neospathodus dieneri* Assemblage Zone has not yet been recognized.

6. Biostratigraphic Conclusions and Implications

Detailed research on Lower Triassic conodonts since the early seventies has made clear that these tiny fossils might eventually replace ammonoids as guide fossils for the Lower Triassic (W.C. Sweet & S.M. Bergström, 1986). In fact, during the past few years they have provided a high-resolution biostratigraphy, that in spite of lack of ammonoids (as in our case) make an excellent basis for correlation and dating of rock sequences. Based on our collection we have reached the following conclusions, which are related to the standard ammonoid zonation as outlined in the foregoing biostratigraphic sections (see Text-Fig. 3):

❶ The lowermost association of the Lower Triassic, characterized by the joint occurrences of *Hindeodus* cf. *latidentatus, Hindeodus minutus* and the first occurrence of *Hindeodus parvus* and *Hindeodus* n.sp. belongs to the *Otoceras woodwardi* Zone. More precisely, we infer an age corresponding to a lower although not the lowermost part of this zone. This correlation is in accordance with stratigraphic information from other regions presented on the previous pages, see e.g. T. Matsuda (1981, 1985), A.S. Dagys & A.A. Dagys (1988) and others.

❷ This conodont fauna is derived from the lowermost 0.47 m of the Tesero Horizon equivalent to the neighbouring Tesero Horizon of core Gartnerkofel-1 and, most probably, also to correlative strata in the Dolomites less than 100 km to the west.

❸ Consequently, it can be concluded that its lower boundary separating this unit from the underlying Bellerophon Formation in the Carnic Alps represents the base of the Griesbachian which, by convention normally has been regarded as base of the Triassic. J.B. Waterhouse (1976), H. Kozur (1977a,b, 1978, 1980a,b), N.D. Newell (1978, 1984, 1988) and K.J. Budurov et al. (1988), however, have expressed different views by including the major part of the Griesbachian into the Permian. Some authors even proposed a conodont-based lower boundary for the Triassic and suggested the onset of *Hindeodus parvus* as guide for its beginning (H.F. Yin et al., 1988).

❹ Our Lower Triassic sequence investigated in detail probably covers the entire Griesbachian. This stage may thus be represented by a rock sequence of at least 60 m thickness which seems very much when compared with other regions (see A. Baud et al., 1989). In the standard sequence of the Dolomites it extends from the Tesero Horizon to an yet unspecified level within the Seis Member.

❺ By correlating the conodont data with the geochemical data, in particular the carbon isotope signature, the first strongly negative shift starts on top of the Tesero Horizon shortly after the onset of the *Hindeodus parvus* Zone. The upper major and distinct negative shift is in the middle of the *Isarcicella isarcica* Zone some 40 m above the base of the Triassic as defined in this paper. At the top of this zone a distinct shift towards positive $\delta^{13}C$ is recognized. At least one minor excursion occurs within the interval between (see contribution by M. Magaritz and W.T. Holser in this volume). Whether the fluctuations of the carbon isotope curve from two sections of Greenland covering the Permian/Triassic boundary (K. Oberhänsli et al., 1989) correspond with our ratios cannot yet be determined, due to lack of exact biostratigraphic data. The other geochemical anomalies, i.e. concentrations of sulphur, iron, rare-earth and iridium can be similarly referred to the above mentioned conodont ranges (W.T.HOLSER et al., 1989 and this volume).

❻ The major simultaneous shifts in carbon and oxygen isotope records and the other geochemical anomalies associated with these signatures reflect a significant change in ocean chemistry and/or temperature that might have affected the biosphere. Whether they caused or were an effect of faunal extinctions is not yet clear. Our conodont based data suggest that

1) conodonts apparently were less affected by an assumed decrease in oceanic productivity and
2) these changes occured in the time equivalent to the duration of the *Hindeodus parvus* and *Isarcicella isarcica* conodont Zones of the Griesbachian Stage.

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Plate 1

Figs. 1– 8: Conodonts of the core section.
Figs. 9–25: Conodonts of the Reppwand outcrop section (B').
All illustrated conodonts are Pa elements of species of *Hindeodus*.

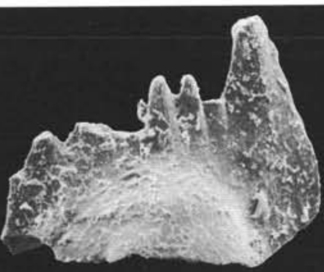
Figs. 1–3,5,7,8: ***Hindeodus parvus*** **(KOZUR & PJATAKOVA 1975).**
Fig. 1: Depth 190.00–190.62 m – ×72.
Fig. 2: Depth 190.00–190.62 m – ×50.
Fig. 3: Depth 190.00–190.62 m – ×77.
Fig. 5: Depth 190.00–190.62 m – ×81.
Fig. 7: Depth 187.77–188.07 m – ×88.
Fig. 8: Depth 224.74–224.97 m – ×70.

Figs. 4,6: ***Hindeodus*** **n.sp.**
Fig. 4: Depth 187.77–188.07 m – ×80.
Fig. 6: Depth 190.00–190.62 m – ×58.

Fig. 9: ***Hindeodus*** **cf.** ***latidentatus*** **(KOZUR, MOSTLER & RAHIMI-YAZD 1975).**
Reppwand outcrop section B', sample no. 12, 0.02 m above base of Tesero Horizon – ×60.

Figs. 12–14,18–25: ***Hindeodus parvus*** **(KOZUR & PATJAKOVA 1975).**
Fig. 12: Reppwand outcrop section, sample no. 13, 0.19 m above base of Tesero Horizon – × 79.
Fig. 13: Reppwand outcrop section, sample no. 13, 0.19 m above base of Tesero Horizon – × 68.
Fig. 14: Reppwand outcrop section, sample no. 14, 0.37 m above base of Tesero Horizon – ×103.
Fig. 18: Reppwand outcrop section, sample no. 43, 7.00 m above base of Tesero Horizon – ×100.
Fig. 19: Reppwand outcrop section, sample no. 43, 7.00 m above base of Tesero Horizon – × 77.
Fig. 20: Reppwand outcrop section, sample no. 62, 29.70 m above base of Tesero Horizon – × 94.
Fig. 21: Reppwand outcrop section, sample no. 64, 32.70 m above base of Tesero Horizon – ×100.
Fig. 22: Reppwand outcrop section, sample no. 66, 35.70 m above base of Tesero Horizon – × 68.
Fig. 23: Reppwand outcrop section, sample no. 68, 38.20 m above base of Tesero Horizon – × 55.
Fig. 24: Reppwand outcrop section, sample no. 71, 41.40 m above base of Tesero Horizon – × 64.
Fig. 25: Reppwand outcrop section, sample no. 72, 42.40 m above base of Tesero Horizon – × 45.

Figs. 15–17: ***Hindeodus*** **cf.** ***typicalis*** **(SWEET 1970).**
Fig. 15: Reppwand outcrop section, sample no. 26, 3.80 m above base of Tesero Horizon – × 83.
Fig. 16: Reppwand outcrop section, sample no. 29, 4.10 m above base of Tesero Horizon – × 94.
Fig. 17: Reppwand outcrop section, sample no. 32, 4.40 m above base of Tesero Horizon – × 88.



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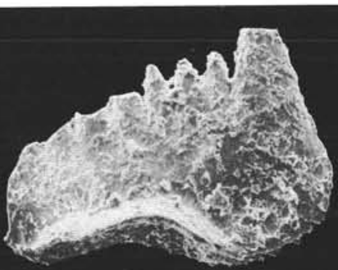

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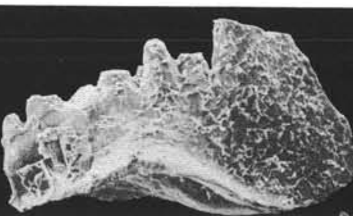

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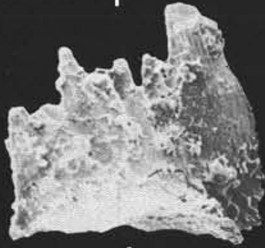

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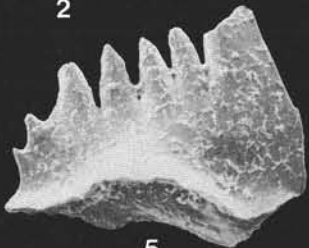

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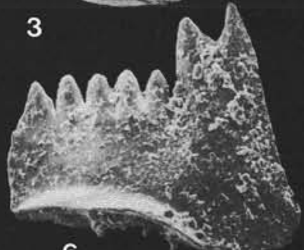

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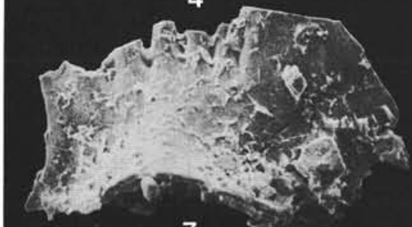

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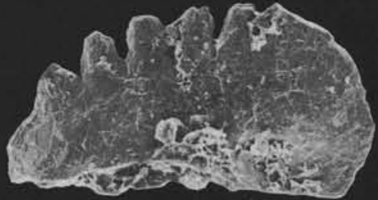

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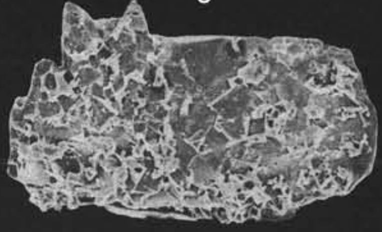

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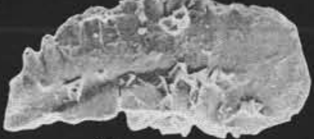

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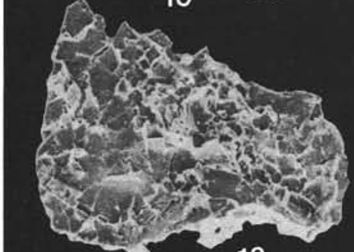

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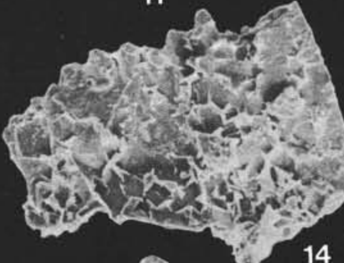

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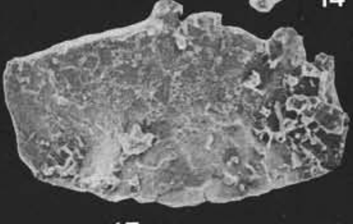

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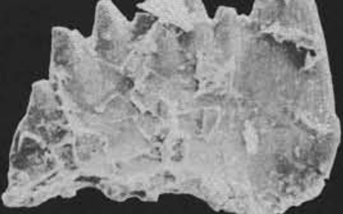

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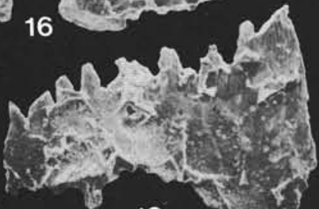

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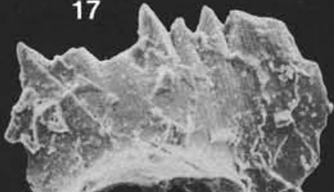

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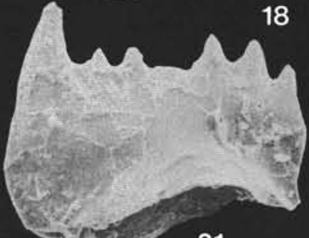

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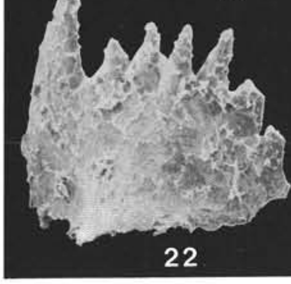

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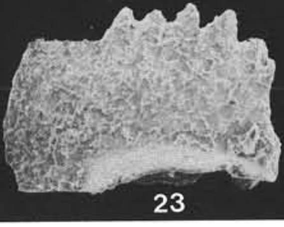

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Plate 2

Figs. 1–28: Reppwand outcrop section (B')

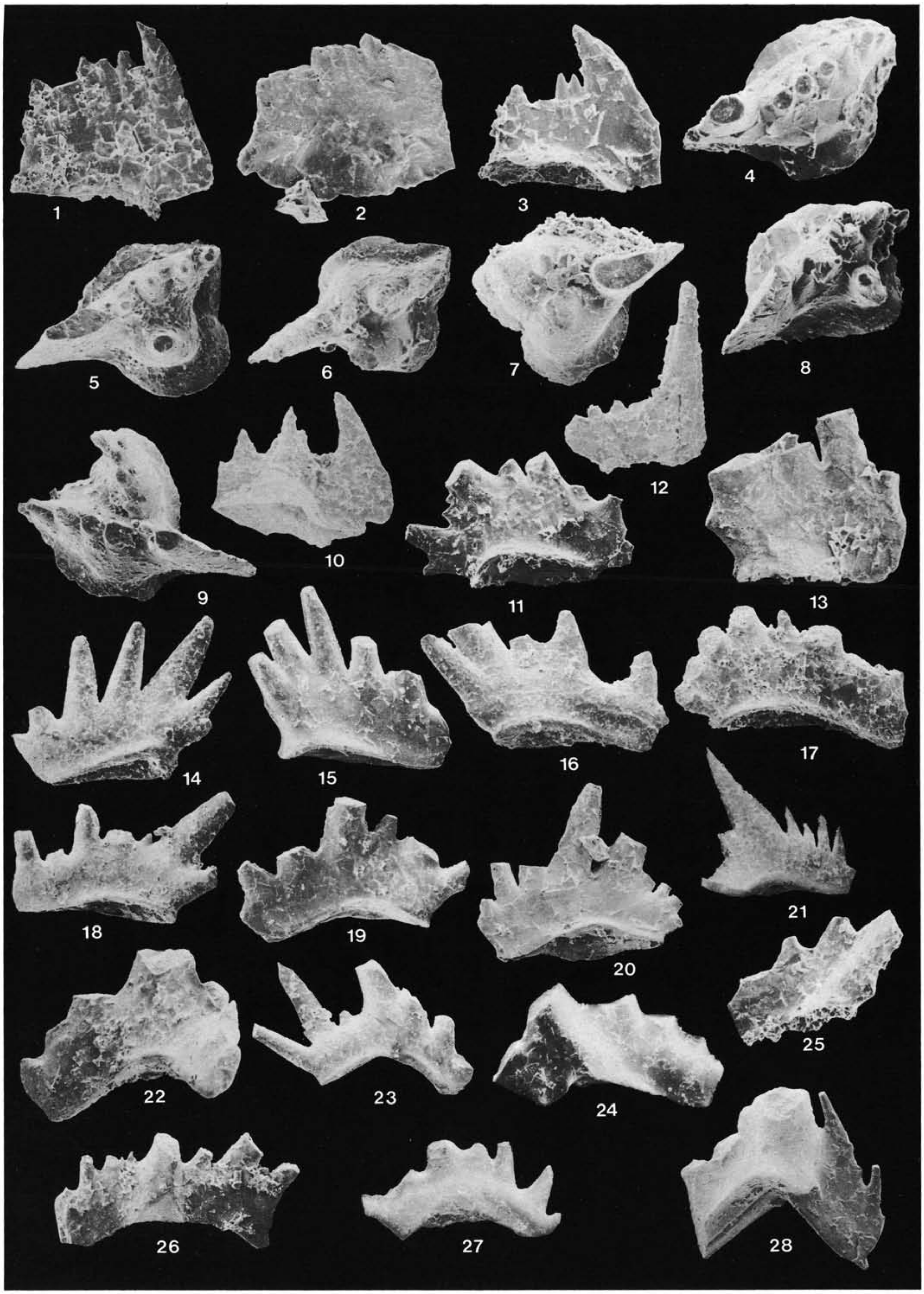
Figs. 1–3: ***Hindeodus* n.sp., Pa elements.**
Fig. 1: Reppwand outcrop section, sample no. 13, 0.19 m above base of Tesero Horizon – ×58.
Fig. 2: Reppwand outcrop section, sample no. 29, 4.10 m above base of Tesero Horizon – ×88.
Fig. 3: Reppwand outcrop section, sample no. 63, 31.20 m above base of Tesero Horizon – ×91.

Fig. 4: ***Hindeodus turgidus* (Kozur, Mostler & Rahimi-Yazd 1975), Pa element.**
Transition form between representatives of the Genus *Hindeodus* and the Genus *Isarcicella* with platform-like basal cavity.
Reppwand outcrop section, sample no. 64, 32.70 m above base of Tesero Horizon – ×83.

Figs. 5–10,12: ***Isarcicella isarcica* (Huckriede 1958).**
Fig. 5: Reppwand outcrop section, sample no. 66, 35.70 m above base of Tesero Horizon – Pa element, ×66.
Fig. 6: Reppwand outcrop section, sample no. 67, 37.20 m above base of Tesero Horizon – Pa element, ×71.
Fig. 7: Reppwand outcrop section, sample no. 65, 34.20 m above base of Tesero Horizon – Pa element, ×63.
Fig. 8: Reppwand outcrop section, sample no. 67, 37.20 m above base of Tesero Horizon – Pa element, ×58.
Fig. 9: Reppwand outcrop section, sample no. 67, 37.20 m above base of Tesero Horizon – Pa element, ×58.
Fig. 10: Reppwand outcrop section, sample no. 65, 34.20 m above base of Tesero Horizon – Pa element, ×66.
Fig. 12: Reppwand outcrop section, sample no. 65, 34.20 m above base of measured section – M element, ×65.
All specimens in upper view except Figs. 10,12 = lateral view.

Figs. 11,13–20,22,23,26,28: ***Ellisonia aequabilis* (Staesche 1964).**
Fig. 11: Reppwand outcrop section, sample no. 81, 51.80 m above base of Tesero Horizon – Pa element, ×51.
Fig. 13: Reppwand outcrop section, sample no. 81, 51.80 m above base of Tesero Horizon – Pa element, ×86.
Fig. 14: Reppwand outcrop section, sample no. 84, 54.40 m above base of Tesero Horizon – Pa element, ×41.
Fig. 15: Reppwand outcrop section, sample no. 84, 54.40 m above base of Tesero Horizon – Pa element, ×56.
Fig. 16: Reppwand outcrop section, sample no. 84, 54.40 m above base of Tesero Horizon – Pa element, ×42.
Fig. 17: Reppwand outcrop section, sample no. 84, 54.40 m above base of Tesero Horizon – Pa element, ×51.
Fig. 18: Reppwand outcrop section, sample no. 85, 55.50 m above base of Tesero Horizon – Pa element, ×44.
Fig. 19: Reppwand outcrop section, sample no. 85, 55.50 m above base of Tesero Horizon – Pa element, ×53.
Fig. 20: Reppwand outcrop section, sample no. 83, 53.40 m above base of Tesero Horizon – Pb element, ×53.
Fig. 22: Reppwand outcrop section, sample no. 81, 51.80 m above base of Tesero Horizon – Sb element, ×65.
Fig. 23: Reppwand outcrop section, sample no. 85, 55.50 m above base of Tesero Horizon – Sb element, ×33.
Fig. 26: Reppwand outcrop section, sample no. 80, 50.60 m above base of Tesero Horizon – Sb element, ×40.
Fig. 28: Reppwand outcrop section, sample no. 83, 53.40 m above base of Tesero Horizon – M element, ×40.

Figs. 21,24,25,27: **Pb, M and Sb elements of unknown apparatus.**
Fig. 21: Reppwand outcrop section, sample no. 65, 34.20 m above base of Tesero Horizon – ×46.
Fig. 24: Reppwand outcrop section, sample no. 83, 53.40 m above base of Tesero Horizon – ×43.
Fig. 25: Reppwand outcrop section, sample no. 81, 51.80 m above base of Tesero Horizon – ×58.
Fig. 27: Reppwand outcrop section, sample no. 83, 53.40 m above base of Tesero Horizon – ×38.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