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"Rare Events in Geology"

Abstracts of Lectures
Excursion Guide

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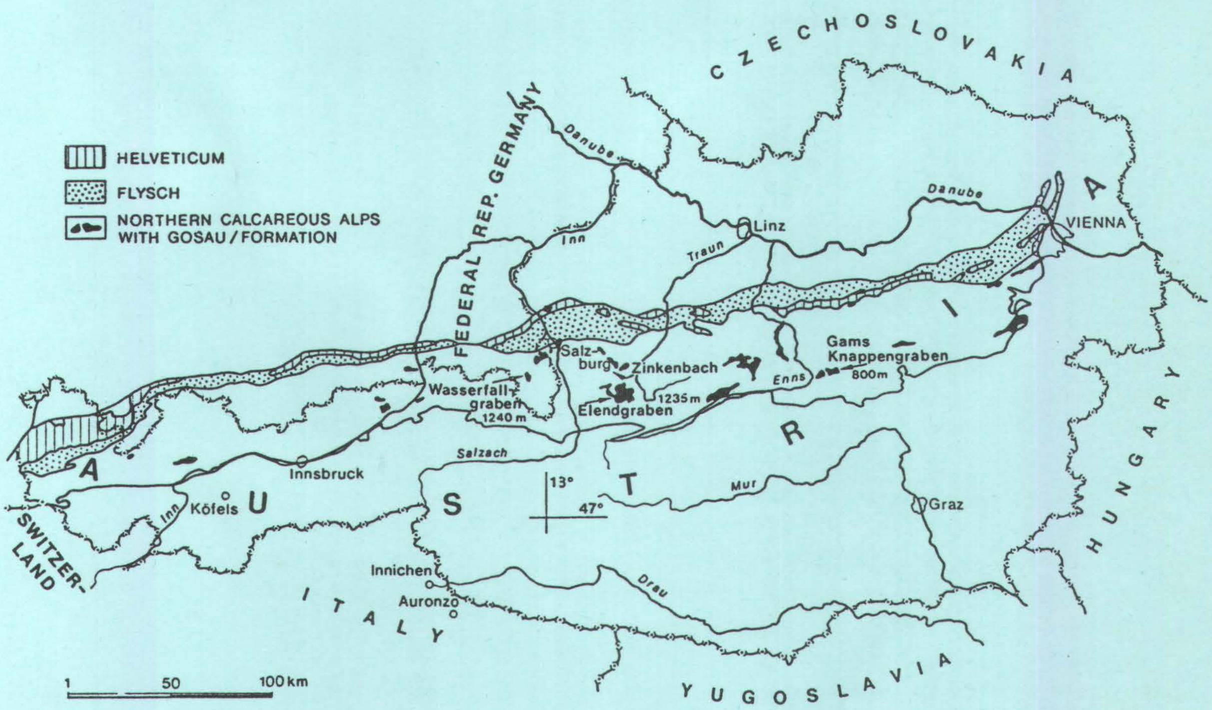
A Cordial Welcome
to all participants in our IGCP-Workshop on "Rare Events in Geology"



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IGCP-Project 199: "Rare Events in Geology"

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Sept. 12 – 14, 1988
VIENNA

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Element Concentrations at the Triassic-Jurassic Boundary in the Kendlbachgraben Section (Austria)

D. D. Badjukov, L. D. Barsukova, G. M. Kolesov, I. V. Nizhegorodova, M. A. Nazarov
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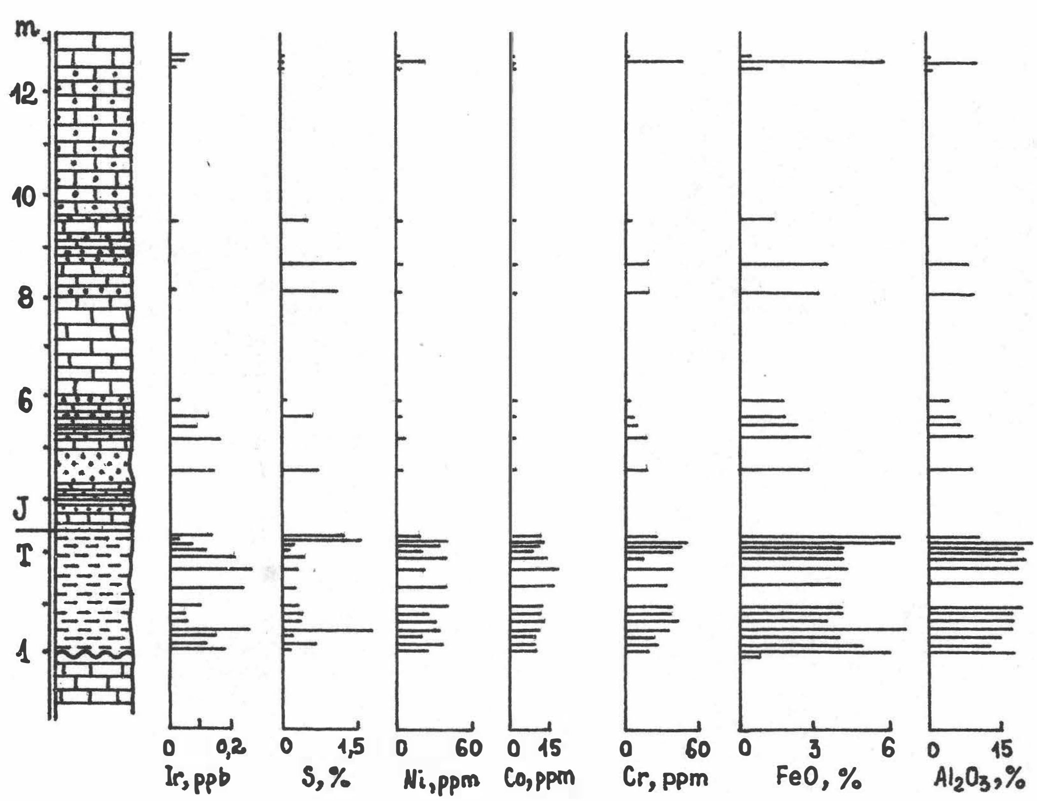
H. Lobitzer
(Geologische Bundesanstalt, Vienna, Austria)

Badjukov et al. (1) reported an occurence of shocked quartz grains (SQG) at the Triassic-Jurassic (T/J) boundary in the Kendelbachgraben sections, Northern Limestone Alps, Austria. SQR were found in the grey clay layer at the top of the Triassic. These grains are very different from the tectonically deformed quartz grains which are present in the clay also. Concentrations of SQR in the clay seem to be higher than the estimated background abundance of SQR. It suggests that an impact event could have taken place at the T/J boundary. In order to study the possibility we analysed the Kendlbachgraben T/J sediments for Ir and other elements.
Ir contents in the T/J sediments are in the range of 0.02-0.29 ppb. The highest Ir concentrations were found in the grey clay layer where SQR were identified (Fig.). The Ir contents in this layer are higher than the average crust abundance of Ir, but they are comparable with those reported in deep sea sediments (2,3). However the grey clay is different in lithology from deep sea sediments and, hence, the T/J erichment in Ir could not be due to a very low rate of sedimentation of the grey clay. It is also difficult to explain the Ir enhancement by deposition of the clay under reducing environment because there is no correlation between Ir and S (Fig.). Ir is also not correlated with with Cr, Ni and Co (Fig.). Concentrations of the



elements in the clay are close to the crust abundance of the elements. Therefore a mantle source for Ir at the T/J boundary seems to be impossible if, of course, there was no element fractionation during sedimentation of the clay. In contrast, an extraterrestrial reason for the Ir enrichment can be more plausible because the cosmic Ni/Ir, Cr/Ir and Co/Ir ratios are signifficatly lower than those in the mantle, and, hence, Ni, Cr and Co concentrations cannot be enriched at the observed Ir enhancement. Thus the Ir data support probably an impact scenario for the T/J transition, proposed (1) from the SQR occurence in the section. However other T/J sections must be studied in detail to establish exactly the nature of the T/J transition.

(1) Badjukov D. D., et al. (1987), LPS XVIII, p. 38; (2) Crocket and Kuo H. Y. (1979) GCA, v. 43, p. 831; (3) Nazarov et al., (1984) LPS XV, p. 595.

Carbon Isotope Profile in the Permian-Triassic of the Central Tethys: The Kashmir Sections (India)

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Mordeckai MAGARITZ
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New Carbon isotope profiles have been measured in late Permian - early Triassic marine sediments of the famous Guryul Ravine and Palgham localities in the Central tethyan Kashmir region. Compared to other tethyan sections, the great interest of these localities is the full development of the basal Triassic Otoceras zone with the zonal fossil, not yet known in the Tethys outside the Himalayan province. For the basal part of the Triassic, the very good age calibration of these profiles has to be noted.
As we have shown previously the Permian-Triassic boundary is marked by a large delta 13C depletion in the the Tethys.
The main characteristics of these new measured profiles with complete and fossiliferous Griesbachian (early Triassic) pelagic sediments are indicated below.

1- In comparaison with other P/T shallow water tethyan sections, the whole delta 13C curve is shifted toward low values of about 2‰ .

2- From positive values within the main part of the Late Permian Zewan Formation, the delta 13C become negative 3m below the end of the Formation and the main drop to -2‰ occurs just at the top. A similar evolution is observed in the upper part of the late Permian Chhidru Formation of the Salt Ranges (Pakistan).

3- At the base of the overlying member E1 (topmost Permian?) of the Khunamuh Formation (Guryul Ravine profile) the delta 13C values change during a short interval from negative to positive ones. In the Nammal Gorge section of the Salt Ranges, the correlative lower Khatwai member shows the same trend.

4- Within the basal Triassic Otoceras zone (member E2 of the Khunamuh Formation), the downward slope of delta 13C is gradual and low values (-4‰) are reached in the overlying Ophiceras zone (member E3) at the rate of 0,4‰m-1. We have measured a similar trend in the correlative part of the Tesero profile (S Alps, Italy), but the rate there is half (0,2‰m-1).

5- After the low delta 13C values in the late Griesbachian Ophiceras zone, we note a progressive rise at the base of the overlying Vishnuites zone (Nammalian).

Plate Tectonics and Fluctuation of Sea Level and Climate at the Permian-Triassic Boundary

Rainer BRANDNER
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Results of comparative research in P/Tr boundary sections show widely differing changes in relative sea levels.

Whereas the Western Tethys is dominated by a transgressive trend comparable to the curve described by Haq et al. in 1987, regressions of varying amplitude and a hiatus are to be found in the Eastern Tethys.

One answer as to the origins might lie in tectonic elevations of crustal segments as a result of decreasing subduction of Permian Oceanic crust in marginal areas of the Pacific Plate.

In the Southern Alps, a generally transgressive depositional sequence of the post Mid Tatarian indicates the existence of parasequences.

A significant amplitudinal increase of these parasequences relates to the uppermost Bellerophon beds. There is an abrupt change from aggradational to retrogradational parasequence sets. A parallel phenomenon occurs in the hydrodynamic conditions of the shallow shelf. The stagnant Bellerophon Sea gives way to a well-ventilated Werfen Sea.

Early meteoric diageneses and euryhaline faunas offer evidence of fresh-water influx in the shallow shelf area. This is attributable to increasingly humid climates with strong monsoon rains.

The phenomena listed above are connected with the disappearance of numerous Permian biogenes, and the transformation of types of facies.

As to the origins of these phenomena - rapid sea-level elevation, increasing currents and precipitation, destruction of life - we have to depend on mere speculation. It reads like this: The phenomena listed above are to be attributed to drastic increases of global surface temperatures which created a greenhouse atmosphere through drastic CO_2 outgassing by massive basalt eruptions, probably the "Siberian Traps".

Dinosaur Extinction: A Rare Palaeontological Event with a Rare Geological Cause

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Dinosaur extinction at the Cretaceous-Tertiary boundary can be considered as a major palaeontological event which drastically altered the composition and evolution of continental communities. In this regard, its consequences probably reached farther than those of any other mass extinction in vertebrate history, including the Permian-Triassic crisis. As already pointed out by other authors, none of the large purely terrestrial vertebrates survived the Cretaceous-Tertiary transition.

It has been suggested that dinosaur extinction at the end of the Cretaceous may have been the result of "normal" geological events, such as orogenic activity or a marine regression. All such explanations are inadequate, either because they involve merely local events, whereas dinosaur extinction was a world-wide phenomenon, or because similar events in the course of dinosaur history (from Late Triassic to Late Cretaceous) failed to cause large-scale extinctions among dinosaurs. Important climatic deterioration on a world-wide scale over a long period of time is unlikely, too. because of lack of material evidence for such an event. and because of the survival of animals known to be sensitive to temperature changes. such as crocodilians.

There is now compelling evidence for a relatively brief crisis in the plant world at the Cretaceous-Tertiary boundary, with, notably. a sharp temporary decline of angiosperm abundance, and this event may have been sufficient to cause a severe disruption of terrestrial food chains, leading to the extinction of dinosaurs (just as the phytoplankton crisis of the Cretaceous-Tertiary boundary may have triggered a chain reaction of extinctions among marine organisms). This crisis in the plant world, possibly due to acid rain, seems to be linked to iridium enrichment, and the ultimate cause of dinosaur extinction could then be traced back to the rare extra-terrestrial or internal event which caused this enrichment. The pattern of dinosaur extinction is not known with sufficient accuracy to be used as decisive evidence in favour of either the impact or the volcanic hypothesis. Data suggesting a decline of dinosaur diversity prior to final extinction would, however, support unusually high volcanic activity rather than asteroid or comet collision.

First Report on Palynological Analyses of Upper Maastrichtian and Danian Samples Collected at Two Austrian K/T Boundary Sites

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Austrian Science Foundation Project 6734

33 samples were collected from three K/T boundary sections, at the Knappengraben and Grenzgraben near Gams (Styria) and the Elendgraben near Russbach (Salzburg) and were prepared for palynological investigation.

In most of the samples palynomorphs, predominantly Dinoflagellate cysts, are present.

Pollen and spores are nearly absent in the Maastrichtian part of the sections. Only Dinoflagellate cysts could be found there. The grey marl below the yellowish "Iridium-layer" (K/T boundary) is characterized by Thallisophora pelagica (EISENACK) EISENACK & GOCHT.

The "Iridium-layer" itself is void of palynomorphs, both at Elendgraben and Knappengraben. In the grey clay overlying the Iridium layer at Knappengraben trilete spores of fern plants are found beside the Dinoflagellate cysts. Twenty centimeters higher in Danian sediments angiosperm pollen (Extratriporopollenites pertrudens PFLUG) could be recognized. At 90 cm above the K/T boundary, again only marine Dinoflagellate cysts are present.

Reef Biotopes Near the Permian/Triassic Boundary (Skyros, Greece and Sichuan, China) – Environmental Trends in Extinction?

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Late Permian reefs are represented by Calcisponge Buildups and Algal Crust/Tubiphytes/Carbonate Cement Buildups. Uppermost Permian (Dorashamian, late Djulfian, Palaeofusulina zone) reefs are rare. Two case studies (Skyros Island/Sporaden, Greece: Skiathos Group, Palaeofusulina zone; Sichuan/ SW China: Uppermost Changxing Formation, Palaeofusulina sinensis subzone) reveal major similarities with regard to reef types and biota:

(1) Stratigraphic reefs (reef mounds), no ecological reefs. (2) Stacked biostromes. (3) Small dimensions (thickness of the total reef facies up to about 100 m, thickness of individual reef mounds about 10 m). (4) Predominance of "calcisponges" ("sphinctozoans", "sclerosponges", inozoans). (5) Lack of framework cavities. (6) Lack of coarse-grained reef detritus. (7) Bioclastic inter-reef sedimentation.

Differences occur with regard to the paleogeographical position (Skyros: near-coast inner shelf of the Paleotethys; Sichuan: margin of an intracontinental platform), sedimentary environment (Skyros: predominantly siliciclastic; Sichuan: carbonates), bathymetrical development of the reef facies (Skyros: uniform, shallow subtidal; Sichuan: shallowing-upwards trend), and synecology (differences in biogenic encrustation patterns and in population densities).

Both reefs have been formed within shallow-marine, low-energetic environments.

Diversity of reef biota increases in both reefs towards the top of the reef sequence.

The development of the last Permian reefs terminated not at the P/Tr boundary but during the Late Permian with a change in the sedimentary facies (Skyros: reef carbonates are overlain by siliciclastics or algal carbonates; Sichuan: reef carbonates are overlain by lagoonal algal carbonates).

Changes in the paleobathymetry and salinity might have been responsible for the termination of reef development in Sichuan but can not be postulated for the Skyros reef.

High (and increasing) diversity, similarities in the biotic composition as well as differences in the reef types (as compared with early Upper Permian reefs, e.g. Djebel Tebaga, Tunisia) are difficult to explain by models of marine deprovincialization or a reduction in the diversity of reef biota.

The Frasnian-Famennian Extinction Event(s) and Anoxic Sedimentation: Are They Related?

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Our knowledge of the Frasnian-Famennian (F-F) extinction event has greatly increased over the last few years and even though the F-F boundary does not have the glamorous attributes of the Cretaceous/Tertiary event, the devastating effects on the marine biota were probably of comparable severity.

Evidence for a catastrophic event or events at the F-F boundary includes: mass killing (all shallow-water settings); drastic faunal change (all environments); pyrite concentrations (slope and deep-water settings); positive δS^{34} anomaly (Alberta, Canada); short-lived algal bloom, mostly oncolites (Alberta, Canada; NW Australia; southern Spain); iridium anomaly (NW Australia); absence of glacial activity.

Evidence against a catastrophic cause includes: a general lack of trace element anomalies; absence of widespread volcanism; absence of shocked quartz; temporary survival of Frasnian brachiopods (southern China); common association with abrupt facies change.

A synthesis of the above evidence suggests flooding of shelves and epicontinental seas by an anoxic water mass causing a mass killing event of the marine biota. Anoxic sedimentation occurred repeatedly during the late Middle and Late Devonian, represented by black shales or lime-mudstones. These sediments are generally associated with extensive, often craton-wide transgressions. It must be assumed that the transgressing water was oceanic in origin regardless whether the water was oxic or anoxic. The repeated influx of anoxic water implies pronounced stratification of oceanic and marginal basins, the result of continued warm climatic conditions during the Middle and Late Devonian. The pycnocline may have risen to levels that a strong eustatic rise of sealevel, regional subsidence, or a strong tectonic pulse caused mildly anoxic water from the uppermost dysaerobic levels below the pycnocline to flood shallow-water environments.

Black euxinic sediments were deposited over wide regions but they are not associated with faunal extinctions. The flooding process was too slow and consequently, the biota was able to retreat to unaffected areas. However, such periods of pronounced ocean stratification were ideal settings for the occurrence of catastrophic events such as meteorite impacts. The massive energy release would have triggered sudden oceanic overturns, flooding of shelves and epicontinental seas with 'deep', highly anoxic water and mass killing on a global scale. Reef communities would have been especially affected due to their narrow tolerance limits with respect to changes of salinity, Eh and pH.

There is evidence for at least two large impacts, the Siljan Crater in Sweden (368 ± 1 ma) and the Charlevoix Crater in Quebec, Canada (360 ± 25 ma). Both are located in continental crust and could have been simultaneous events; if so it is likely that additional impacts occurred in oceanic areas that have long since been subducted. In summary, the available data suggest that a meteorite shower was the ultimate cause of the Frasnian-Famennian mass killing event(s).

A Triassic-Jurassic Boundary Section in the Northern Calcareous Alps (Austria)

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Austrian Science Foundation Project 6734

The development of the Triassic/Jurassic boundary sections in the Tethys realms of the Northern Calcareous Alps depends on the condition of the Uppermost Triassic relief.

At that time sea-level fluctuations caused a hiatus in the deposition of shallow water Upper Triassic carbonate platforms (Dachstein Limestone, Steinplatte Limestone) in large areas. Only in intraplatform basins (like Kössen Formation - Kössen facies) sedimentation occurs and thus research about the boundary is possible.

Two localities, Kendlbachgraben and Tiefengraben, in the area of the Zinkenbachgraben, Osterhorngruppe, Salzburg, were investigated. Both sections consist of Kössen beds (Rhaetian) and Grauer Liasbasiskalk (Hettangian, Lowermost Jurassic). The Triassic/Jurassic boundary section between the Kössen Formation (Choristoceras marshi zone) and the Grauer Liasbasiskalk (Psiloceras planorbis zone) was studied using biofacial and lithological methods.

As an equivalent to the northwestern Europe "Preplanorbis Beds", this newly investigated sequence represents a restricted subtidal area with increasing terrigenous influence. It was determined to be of Liassic age by means of bivalves (Cardinia-community) and nannofossils (Annulithus arkelli zone). Additional fossil groups, as foraminifera, ostracods, brachiopods and echinoderms document a biofacial change from the Kössen Formation to the directly overlying "Preplanorbis Beds".

Opposite to the underlying beds the boundary layer reveals restricted sedimentation, reduced carbonate content and terrigenous quartz grains.
This boundary layer demonstrates the extinction of the Kössen type fauna and the shift to new Jurassic biofacial communities.

Good News from Köfels (Austria): Abundant Lamellae in Quartz

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Austrian Science Foundation Project 5879

Since the discovery of a foamy glassy rock ("Bimsstein") near Köfels, Ötztal, Austria, there has been a considerable debate over its origin and the origin of associated geomorphological features, a semi-circular niche in the mountains and a natural dam in the valley. An early volcanic theory (1) was challenged by an impact theory (2) and more recently a landslide theory (3). The weight of petrologic evidence, unfortunately neglected in many discussions (see 4), indicates an impact origin. This evidence includes the presence of diaplectic quartz, maskelynite, planar features in quartz and feldspar, lechatelierite, feldspar glasses, olivine, and FeNi metal (5-9). We report here on initial results of a re-investigation of samples previously described (9), this time using an universal stage to study deformation features.

Our studies confirm the results of (7) and (8) who reported the presence of lamellae in quartz. These features are present in quartz in gneiss samples and are particularly abundant in a sample of ignimbritic tuff (Nat.Hist.Mus. Inv.Nr. L 2530, thinsection L 4675). This rock consists predominantly of glass with abundant crystalline fragments apparently derived from a crystalline rock with a perthite-quartz-plagioclase-muscovite assemblage. All minerals are strongly deformed with highly undulatory, often patchy extinctions and ubiquitous recrystallization. Quartz contains abundant sets of multiple lamellae almost uniquely in the $\{10\bar{1}3\}/\{0113\}$ forms. Perthite is dominated by deformation bands and irregular grain boundaries or twins. Plagioclase is polysynthetically twinned with the twins extending only part way across grains, terminating irregularly. Micas show extreme kink-banding. The fragments are highly fractured, with abundant long, intergranular fractures.

The observed features are characteristic of shock and strongly suggest an impact origin of the Köfels structure. We are now in the process of verifying the nature of the quartz lamellae using TEM methods (10, 11). Should they prove to be shock lamellae, there can be no doubt that the Köfels structure is a crypto-explosion structure.

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Magnetostratigraphy of Permotriassic Boundary Sections in China and Pakistan

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A few hundred samples have been drilled for magnetostratigraphic analysis and correlation in late Permian to early Triassic sections in China and Pakistan which are characterized by continuous marine sedimentation. The Permotriassic (P/T) boundary section at Shangsi (Sichuan province: 32°N, 105.5°E) consists of nearly 200 m thick, well bedded micritic and sparitic limestones intercalated with clays and mudstones which belong to the Wuchiapingian and Changxingian (Uppermost Permian) and Feixiangian (Lower Triassic) stages. The P/T boundary is formed by a clay horizon. Lithology and stratigraphy of the 400 m thick section at Liangshan near Hanzhong (Shaanxi province: 33.1°N, 107°E) and at Heshan (Guangxi province: 23.5°N, 108.2°E) are similar to that at Shangsi, but the lower part of the Upper Permian of the Hanzhong section and the whole Upper Permian of the 200 m thick Heshan section is extremely cherty. The P/T boundary is formed by volcanic deposits.

The sections in Pakistan belong to the Upper Permian Chhidru and Wargal Formation and to the Kathwai member (Lowermost Triassic). The lithology of the sections in the Nammal gorge and in Zaluch Nala (Salt Range) is variable. In the Nammal gorge, white to red sandstones, nodular limestones, bioclastic wackestones and marlstones are exposed. The P/T boundary is marked by a black clay.

Stratigraphic correlation between the sections in China and Pakistan is not straightforward because the Uppermost Permian seems to be missing in Pakistan. Rockmagnetic problems with intensity and stability of natural remanent magnetization (NRM) also hinder the development of reliable magnetostratigraphies. The initial NRM intensity is very low, averaging 0.25 mA/m in the China sections and 0.10 mA/m in Pakistan. Magnetic cleaning shows about 40% of the samples to be overprinted heavily by secondary magnetization (along the present earth magnetic field). After removal of this component the magnetization intensity often is getting too weak for accurate measurement. This results in unforeseen gaps of the magnetostratigraphic columns.

Nevertheless a magnetization component which is considered to be of early origin, has been established in many samples. Normal and reversed polarity of this characteristic magnetization make up a distinct pattern of magnetozones in most sections. The P/T boundary of the Pakistan sections being situated in the upper part of a negative polarity zone confirms the already published Shangsi results. Magnetostratigraphic analysis of the other Chinese sections mentioned is in progress with the aim of getting further evidence of the magnetostratigraphic position of the P/T boundary and dating the beginning of the reversals of Illawarra mixed polarity hyperzone.

New Insights on the Permian-Triassic Boundary Event from Core Gartnerkofel-1 (Carnic Alps, Austria)

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A 330-m core was cut through the marine Permian/Triassic (P/Tr) boundary in the Carnic Alps of Austria, and studied in closely correlated geochemistry, petrography and paleontology. The decrease of $\delta^{13}C$ from its late Paleozoic high began at least 50 m below the P/Tr boundary, accelerated across the boundary, and bottomed in a complex 50-m minimum zone in a Lower Triassic section with *Hindeodus* parvus. Each of two carbonisotope minima within this zone is characterized by an oxicanoxic transition with high Ce*/La*, pyrite and concentrations of Ir, Co and other metals. Metallic ratios are unlike those of chondrites and Cretaceous/Tertiary (K/T) spikes. Both the carbon isotope and chemical shifts may have causes related to regressions and transgressions of the sea.

Paleomagnetism of the Meishan Permian-Triassic Section at Changxing of Zheijang Province

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Meishan section D is located at 31.1° N,119.7° E,near Meishan Town of Changxing County of Zhejiang Province. The section containing Changxing Formation of Upper Permian and Qinglong Formation of Lower Triassic is a set of continueous marine sediments. A 5 cm-thick layer of gray illitemontmorillonite clay which is taken as the boundary between Permian and Triassic in the section lies at the bottom of Qinglong Formation. An iridium anomalous content of 8.0 ppb was detected by Shun Yiying et.al. in the clay layer in 1984. 111 oriented samples were collected from the section and Samples 1-66 among them came from Changxing Formation,Samples 67-111 were derived from Qinglong Formation. The natural remanent magnetizations(NRM) of the samples were measured with a 3-axis crygenic magnetometer. The NRM directions of most of the specimens measured are grouped around the direction of the present geomagnetic field at Meishan area that suggests that a strong overprint of the primary magnetization by secondary components. In order to test the NRM stability, 24 samples were selected as pilot samples and each of them was cut into two specimens for progressive alternating field and thermal demagnetization,respectively. The test proved thermal demagnetization to be superior to the alternating field cleaning in removing secondary magnetization conponents. Therefore, all samples of the section were subjected to progressive thermal cleaning at 50-100° C intervals up to 700° C. After each step susceptibilities also were measured to monitor any mineralogical changes at elevated temperature. The characteristic remanent magnetization(ChRM) components of rocks were distinquished in the light of the progressive demagnetic orthogonal projections. 88 of 111 samples can show thier ChRM mixed some secondary components after magnetic cleaning. The polarities of them can be difinitely or fairly defined. Depending on the data from 88 samples, six normal and reversed polarity zones from bottom to the top of the section were emerged. They are Normal Zone I, Reversed Zone II, Normal Zone III and Reversed Zone IV in the Upper Permian and Normal Zone V and Reversed Zone VI in the Lower Triassic. The P/T boundary of Meishan section lies near the bottom of Normal Zone V,i.e. located at the transition zone from Reversed Zone IV to Normal Zone V. The polarity period recorded in Meishan section could be compared with the lower part of well known Illawrra mixed polarity interval.Isothermal remanent magnetization(IRM) acquisition and its thermal demagnetization experiments suggest that the dominant ferrimagnetic minerals are goethite and titaniferous megnetite in limestones of the lower part of Changxing Formation while the mainly titaniferous magnetite, magnetite and titaniferous magnetite(or pyrrhotite, maghemitite) are contained in the rocks of upper part of the Formation. In limestones and mudstones of Qinglong Formation the magnetic minerals are magntite and heamatite. The paleopole position of early Triassic is at 51.1° N, 230.3° E with A_{95}=7.4° and the paleolatitude of the sampling site is 12.3° N.

Carbon Isotope Event at the Permian-Triassic Boundary

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In 1984, the carbon isotope abrupt shift in the marine carbonate boundary sequence between the Permian and the Triassic in South China has been published in my paper (Chen et al., 1984). This discovery has drawn the attention of many geologists and geochemists and provided an important signature to confirm the possibility of another abrupt carbon isotope shift event in the geologic history in addition to the Cretaceous-Tertiary boundary. Since then, the study of carbon isotope stratigraphy and the boundary event at the P-TR boundary has been conducted for four years and many new and valuable data have been obtained which are the basis of the present paper.

In South China, three sections located in Changxing, Zejing province, Langshan, Shanxi prov. and Zuny, Guizhou prov. have been studied for carbon and oxygen isotopes. These sections are characterized by succesive sequences, abundant fossils and similar lithofacies and the position of the boundary between the Permian and the Triassic is well defined by Chinese paleontologists and stratigraphers.

From the three sections, samples have been collected closely and systematically, average spacing of which is 80 cm, and 10 cm near the P-TR boundary. 183 carbon and oxygen isotope analyses for marine carbonates of the P-TR boundary sequence have been completed. These data show;

i) The δ^{13}C values of the three sections vary from 5.5 ‰ to -8.1 ‰ and lie within a range of 13.6 ‰, which is much greater than usually accepted.

2) δ^{13}C values of three sections constitute cyclic variation and the cyclic carbon isotope variation of marine carbonates is consistent with certain stratigraphic units.

3) δ^{13}C values appear positive below the P-TR boundary and negative above it.

4) δ^{13}C values of marine carbonates show an abrupt shift from positive to negative precisely at the P-TR boundary.

5) The range of δ^{13}C value shift near the P-TR boundary is 3.7 ‰ for Changxing section, 5.4 ‰ for Langshan section and 2.8 ‰ for Zunyi section.

6) The thickness of marine carbonate strata showing the δ^{13}C value abrupt shift near the boundary is 10 cm for Changxing section and Zunyi section and 60 cm for Langshan section. It is difficult to estimate the geologic time duration of the δ^{13}C value abrupt shift.

7) The abrupt shift of marine carbonate δ^{13}C value at the P-TR boundary is at least an extensive phenomenon because the three sections studied are located far from each other in distance (more than 1000 km). Perhaps it is a world-wide phenomenon.

Finally, it is concluded that the δ^{13}C value excursion of marine carbonates may be used as a tool for stratigraphic classification and the abrupt shift of marine carbonate δ^{13}C values at the stratigraphic boundary would be mainly caused by great dying of biomass.

K/T Boundary Mass Extinction Pattern not Consistent with Single Impact Level

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The Cretaceous/Tertiary (K/T) boundary mass extinction has been widely recognized as a nearly instantaneous catastrophy in marine plankton such as foraminifera caused by a large extraterrestrial bolide impact. High resolution quantitative foraminiferal analysis of the stratigraphically most complete K/T boundary sections known to date, El Kef, Tunisia and Brazos River, Texas, show that this mass extinction event spans an extended period of time. Major species extinctions begin in the upper part of Anomaly 30 about 0.8 to 1.0 m.y. before the hypothesized K/T boundary impact event. Species extinctions appear to be non-random with large complex species going extinct earlier than smaller more primitive morphologies. In general, the early disappearance of large biserial and multiserial forms is followed by large globotruncanid species and subsequently by the smaller robust rugoglobigerinids and finally by the simple biserial pseudotextularids. The small heterohelicids as well as some small globigerinellids, hedbergellids and guembelitrids survived into the early Paleocene Zone P1a. This pattern of extinction is unlikely due to random extinctions, but implies a progressive disruption of the marine habitat unrelated to the K/T boundary event.

In contrast, lithological and geochemical signatures such as minima in $CaCO_3$, $\delta^{13}C$, maximum in TOC and Ir anomaly point towards a geologically instantaneous event at the K/T boundary. This event (extraterrestrial impact?) hastened the demise of an already declining Maastrichtian fauna. Carbon-13 data indicate a crash in surface water productivity at this time and recovery was delayed for several 100,000 years (Zone P1b). The reason for this prolonged crash in surface productivity is unclear.

About 10 Cretaceous species survived the K/T boundary event and became extinct by the end of Zone P1a in both El Kef and Brazos River sections. All survivors (Heterohelicids, guembelitrids, globigerinellids, pseudotextularids) are small and of simple morphology; their size in Danian sediments is dwarfed and stressed as compared with Maastrichtian forms. Relative population abundances of these species are relatively unaffected by the K/T boundary event. However their population decline begins soon after the boundary in Zone P0. Their demise near the end of Zone P1a appears to be a result of niche competition as the early Tertiary fauna succeeds in establishing itself with the return of more normal surface water productivity.

Faunal and geochemical data from El Kef and Brazos River thus indicate an extended period of mass extinction beginning 0.8 to 1.0 m.y. before the K/T boundary, a geologically instantaneous event (impact?) at the K/T boundary that hastened the demise of the declining Maastrichtian fauna, and survivorship of small species with simple morphologies into the Danian when the new early Tertiary fauna is established. The extended period of mass extinction in the late Maastrichtian prior to the K/T boundary event appears to be related to global climatic changes.

On the Geology of the Cretaceous-Tertiary Transition in Austria

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Until now East Alpine K/T sections that expose a boundary clay were found only within the deep sea fan sequences of the Flyschgosau, a group of formations ranging from Lower Campanian to Lower Eocene. The boundary clay layers are intercalated between Late Maastrichtian hemipelagic marly limestones or calcareous marls and thin Early Paleocene overbank turbidites. Detailed lithostratigraphic logs of several sections will be presented, as well as transparencies of several sections.

The K/T boundary clay-triplet in the Gosau sections consists of a basal light brown or ligth-grey clayey marl, a yellow or light orange clay ("rusty layer") and a dark grey marly clay on top. Turbidite cycles comprising siltstones, fine sandstones and marly clays are superimposed in the Early Danian. Shear zones parallel to bedding close to the K/T boundary disturb the succession of beds at Gosau and Gams. These fractured zones with small slickensides and calcite plates are a common feature of the Austrian K/T transition sections - whether a characteristic boundary clay is exposed (as in the Elendgraben and Knappengraben sections) or not (as at Waidach, Sparbach and Rotkopf). They occur mostly in and above the "rusty layer" and also below the first Danian fine-grained sandstone bed.

Geomarkers as Indicators of Global Rare Events Exemplified at the K/T Boundary

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In modern geology geomarkers are generally defined as trace-elements, allowing a characterization of the rock-types in question. Platinum-group elements, siderophile and chalcophile metals, rare earth elements, as well as other trace-metals, such as actinides, range among these elements. Furthermore, biogenic elements and stable isotope ratios of organic and inorganic carbon, oxygen and nitrogen may be used as geomarkers. In our studies we have used the following elements: Ir, Cr, Co, Ni, Zn, As, Sb, REE, Th, C_{org} and $\delta^{13}C$. They allow a clear characterization and distinction of certain materials, like Cl-chondrites, crust, upper mantle, mid ocean ridge basalts and C_{org} rich marine sediments. As representatives of a global distribution the concentrations of these geomarkers are shown in the following hemipelagic and pelagic K/T boundary sections: Caravaca (Spain), Gosau and Gams (Austria) and DSDP Site 465 A (North Pacific).
The composition and concentration of the original "fall-out" [material rain including reworked and redeposited fall-out] is similar at these localities. It is shown that quantitative analysis of these geomarkers represents a measure for characterizing the source of this fall-out.

Magnetostratigraphic Studies across "Rare Event" Boundaries in the Southern and Eastern Alps

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In the Southern Alps, two P/Tr boundaries were studied in detail. Whereas in the Nassfeld region a 300 m long continuous core was studied, near Auronzo just a 3 m boundary sequence was investigated. From the main core, paleomagnetic samples were drilled and oriented by the bedding planes. The strike direction was extrapolated from nearby outcrops. The rockmagnetic experiments established the carrier minerals, pyrrhotite and magnetite in the Bellerophon beds, magnetite and haematite in the Werfen beds. Petrographic investigations proved a strong overprint of the primary lithology, by dolomitisation, stylolitisation synchronous with intensive tectonism during alpine orogeny. These changes altered the original orientation of the natural magnetisation more or less depending on mineralogy and lithology. Except for a few short sequences, the whole profile shows quite obviously a dominating cretaceous overprint.

In the Kendlbachgraben section, Northern Calcareous Alps, a magnetostratigraphy across the Triassic-Jurassic boundary was carried out. The dominating carrier mineral is magnetite, minor haematite and pyrrhotite. Whereas the Triassic shows a complete overprint, in the Lower Liassic a reversal was found.

The K-Ar Age of Kara Impact Structure: Its Link with the K/T Boundary Event

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It was suggested (1,2) that the Kara impact structure could be formed by fragments of the main K/T body disrupted before the collision. If the suggestion is correct, then a physical nature and a trajectory of the K/T bolide can be constrained from geological and geochemical data on the Kara structure. In 1987 a Soviet expedition studied the structure and collected samples for isotopic and element analysis. The samples are currently analyzed in USSR (our group), Austria (C. Koeberl), and USA (A. V. Murali, V. L. Sharpton, K. Burke). In the paper we report results of K-Ar dating of the structure.

The Kara structure (USSR, Polar Ural) consists of two adjacent craters, the Kara crater (60 km diameter) and the Ust-Kara crater (25 km diameter). The target is mainly composed from Permian sandstones and shales. Samples of impact melts and glasses formed in different environment were chosen for K-Ar dating. It was shawn that all of studied samples contain an excress of radiogenic argon. Concentration of the trapped 40 Ar depends of thermal history of the samples. Glasses are usually poorer in trapped 40 Ar than crystalline samples. Regression analysis of the K-Ar data showed that the most part of the studied samples forms of an isochron line indicating an age of 66.4 ± 1.0 (16) Myr and the 40 Ar excess of $(0.41 \pm 0.07)\ 10^{-6}$ cm³/g. The glasses mainly dont belong to the regression line. An isochrone for glasses shows an age of 65.5 ± 1.1 Myr and a trapped 40 Ar content of (0.12 ± 0.07) 10^{-6} cm³/g.

On the basis of the data the K-Ar age of the Kara structure was computed to be 66.1 ± 0.8 Myr that exactly coincides with the K/T boundary age (65-67 Myr). A probability of formation of two continental craters different in their age and bigger than 60 km during 3.2 Myr (.2 = error of the age) can be found to be only 2 % at the usual rate of cratering (3). Hence there should not have been another continental crater bigger than the Kara structure in the interval of 64.5-67.7 Myr, if the rate of cratering was not increased during the time. However, in any cases the obtained K-Ar data give us a new strong evidence for an impact cause for the K/T event. The Kara structure should be studied in detail to constrain the nature of this event.

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The Permian-Triassic Boundary in the Southern Alps – A Study of Foraminiferal Evolution

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The marine Upper Permian and Lower Triassic deposits of the Southern Alps (northern Italy and northern Yugoslavia) consist of shallow marine sediments which were deposited in a marginal basin of the Tethys on an eastward dipping homoclinal ramp. The Upper Permian sediments exhibit a transgressive trend from the base of the top: evaporites are overlain by dolomites of a restricted environment . These are followed by limestones which were deposited under changing low and high energy conditions. The Upper Permian transgression culminates in oolitic sheets which overlap the continental red beds in the west. The following short-time regression is indicated by an algal-mat sedimentation. The base of these deposits marks the Permian-Triassic boundary. A new eustatic transgression initiates the widespread uniform conditions of a shallow sea: carbonates of quiet-water origin and a few tempestite-layers alternate with evaporitic horizons of a supratidal environment (Scythian)

The distributional pattern and evolution of the foraminifera is strongly facies-controlled: diversity and abundance increase in the course of the Upper Permian transgression and the development of open-marine conditions in the uppermost part of the Permian. Here a rich fauna of stenohaline forms (e.g., Fusulinidae, Biseriamminidae) occurs.

The Permian-Triassic boundary is characterized by the extinction of most Paleozoic foraminifera. The extinction might be caused mainly by a climatic change to more humid conditions which is indicated by an extensive fresh-water diagenesis in the shallow-marine carbonates.
A small-sized euryhaline fauna of Miliolidae and Textulariidae survived the extinction event and formed the basis for the radiation in the Middle Triassic.

Evidence for Early Mesozoic Mass Extinctions In Eastern North American Rift Deposits (Late Triassic–Early Jurassic, Newark Supergroup)

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Newark Supergroup rocks provide an unprecedented fine scale record of continental faunal and floral change spanning all of the Late Triassic and most of the Early Jurassic (Carnian-?Toarcian). Sedimentary cycles produced by rift lake level changes were apparently controlled by orbitally induced climate changes and potentially permit calibration of faunal and floral change at a less than 21,000 year level of resolution over a 40 million year span.

Taxonomic faunal and floral turnover is concentrated in two episodes: 1) an older episode dated by palynostratigraphy as Middle Carnian marking the transition from a still poorly known South American-like assemblage dominated by mammal-like reptiles and archosauromorph reptiles to a typical North American Late Triassic assemblage strongly dominated by "primitive" archosaurs, especially phytosaurs; and 2) a younger episode dated by palynostratigraphy as at the Triassic-Jurassic boundary marking the transition from the latter to a dinosaur and crocodile-dominated assemblage. The Carnian episode is characterized by the **replacement** of one assemblage of terrestrial vertebrates with another while the Triassic-Jurassic episode represents a large number of extinctions **without** replacement: the succeeding assemblage consists of survivors. In palynomorphs, the Carnian episode is characterized by the replacement of a diverse spore-rich assemblage by a diverse pollen-rich one. In contrast, the Triassic-Jurassic episode is marked by the dramatic and seemingly sudden elimination of a relatively high diversity Triassic pollen assemblage with the survivors constituting a Jurassic assemblage of very low diversity overwhelmingly dominated by *Corollina.* Within the Newark the palynoflora never recovers its previous levels of diversity.

No interval of concentrated taxonomic turnover is apparent in strata dated by palynostratigraphy as straddling the Carnian-Norian boundary in the Newark Supergroup, either in terrestrial vertebrates or palynomorphs. This is a significant difference from literature tabulations by others which have suggested an episode of high extinction in marine organisms at that boundary. Either the Newark Carnian episode is misdated or the marine and terrestrial transitions are not synchronous.

In contrast, the Triassic-Jurassic Newark faunal and floral transition does seem synchronous with massive marine extinctions. Preliminary data suggest the Newark pollen and spore transition took place in less than 40,000 years, while available bone and footprint data suggest the extinction of ecologically dominant Late Triassic terrestrial vertebrates over a maximum duration of less than 850,000 years.

Within the Newark Supergroup, available evidence does not suggest a catastrophic mass extinction event at the Carnian-Norian boundary, or anywhere early in the Triassic. Although we are still in the early stages of investigation, everything known about the Newark Triassic-Jurassic episode is consistent with a very large and abrupt mass extinction event, synchronous in both terrestrial and marine environments.

Late Maastrichtian Planktonic Foraminifera Extinctions in Central Poland: Patterns and Causal Mechanism

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Quantitative population analysis of planktonic foraminifera from Late Maastrichtian successions in Central Poland indicates that the final Cretaceous extinction event was preceded by stepwise extinction. Three steps of extinction of planktonic foraminifera can be distinguished:

1. The extinction in the Late Belemnitella junior Zone of all species of Globotruncana
2. The extinction in the Late Hoploscaphites constrictus crassus Zone of all species of Rugoglobigerina, shortly followed by
3. the extinction of the last planktonic species of the genera Heterohelix, Globigerinelloides and Guembelitria.

Late Maastrichtian worldwide regression which coincided with the tectonic activity in the Polish-Danish Trough and cooling of climate following the regression were most probably responsible for the extinction of planktonic foraminifera in area studied during latest Maastrichtian.

Event Stratigraphy Exemplified at the K/T Boundary

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Determining the time sequence of geological events is of decisive importance for the understanding of the evolution. Since an absolute age determination by means of radio nuclide dating only permits an accuracy of approximately 1 per cent, relative methods must be used to date the time sequence of geological events. So far the two independent methods, i.e. magneto-stratigraphy of pole reversal and the biostratigraphy of micro-fossils have been used for this purpose. With the methods of pole reversal, the accuracy is of an order of magnitude of a thousand years, with the development and establishment of new species between 100 and 1000 generations, i.e. for microfossils of an order of magnitude of some hundred years. Neither method, however, gives clear information on the time sequence of short-term events such as volcano eruptions or meteoritic impacts, since the pole reversal is triggered by events in the interior of the earth and the development of species by mutations.

However, geomarker - changes in the geochemical element- and isotope composition as well as changes of mineral phases - permit statements on the time structure of geological events (event stratigraphy). By means of this events stratigraphy, global geological events and their consequences can be proved. For the reconstruction of a geological event it is necessary to consider all relevant data synoptically.

By means of element enrichement and depletion, isotope conditions, mineral phase changes at deep-sea sediments of the K/T boundary it can be shown that this is a short-term event.

An Iridium-Enriched Level in the Late Maastrichtian of the Aix-en-Provence Continental Basin (Southern France)

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In the continental Aix-en-Provence basin, the K-T boundary (KTB) is situated in a sedimentary sequence rather poor in fossils. In the absence of reliable stratigraphical and paleontological data, the KTB is assigned to lie in an uncertainty zone centered on a prominent conglomerate, the "Poudingue de la Galante". Conventionally, the lower limit of the uncertainty zone is defined in coincidence with the last occurrence of in-situ dinosaur eggs, about 10 meters below the "Poudingue de la Galante". The upper limit, rather badly defined, is the limestone bar of Vitrolles which is said to contain Physa montensis, a fossil considered as tertiary. The uncertainty zone is the terminal part of a red clay/silt sequence, 50-150 meter thick, overlying the Rognac limestone bar, another easily identifiable stratigraphical milestone of the basin.

During an intensive search for the iridium enriched level, characterizing the KTB in marine sections, we have carefully sampled the uncertainty zone in four sites located in very different parts of the Aix basin. Samples were analysed by neutron activation. Iridium concentrations were measured with a 2D-spectrometer. No significant amount of iridium was found; in any case 3σ upper limits do not exceed 50 pg/g.

Lately, we have extended our investigation downward in the Rognacian and Begudian, local subdivisions of the continental Maastrichtian. Anomalous iridium concentrations were found in samples from the upper part of the Rognac limestone bar. The anomaly is rather diffuse and extends over at least half a meter with concentrations fluctuating around 80 pg/g. It includes three marly-lignitic beds which, by their iridium concentration, do not significantly differ from the adjacent limestone layers. Concentrations are low but well significant (5 to 10 σ).

This finding is rather surprising because the anomalous level is situated well inside the Maastrichtian. It can be understood in three ways:

1- The iridium anomaly is a component of the very KTB event which means that the position of the KTB assumed so far was wrong. This is in total disagreement with the close coincidence of the dinosaur extinction and the iridium event observed in the north american continental sites. Indeed, in the Aix basin, the position of the last in-situ dinosaur eggs and ultimate representatives of Clavatoraceae (charophytes), found 60-90 meters above the iridium anomaly, indicates a delay of about one million years.

2- Low sedimentation rates prevailed for a while in this area resulting in the accumulation of the cosmic material permanently accreted by the Earth. A concentration of 50-100 $pg.g^{-1}$ could be accounted for by a deposition rate of 0.25-0.5 $m.Ma^{-1}$(1), about two orders of magnitude lower than the average rate in the basin. A detailed paleomagnetic study of the section could help to clarify that point but, a priori, this explanation is not good.

3- The anomaly is not directly linked with the KTB but is the relic of some precursory event which occured in the Maastrichtian. This possibility is consistent with the hypothesis of a comet shower (2) or the occurence of volcanic eruptions (responsible, for instance, for the formation of the Deccan traps (3,4) at about the same time (5)). Such complex phenomena are sometimes alleged to explain the stepwise character of the end of Cretaceous biological extinctions. Although iridium enrichments have not been observed yet in marine sections in coincidence with precursory extinction steps (ammonites, rudists, inoceramids, etc.), this hypothesis seems to be the most appropriate to explain our observations in the Aix basin.

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The D-C Boundary Event (360 Ma) in the Carnic Alps (Austria)

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(Los Alamos, USA)

The D-C boundary event, also known as "Hangenberg Event" has been widely recognized for a long time.It represents a major extinction event that effected many pelagic organisms such as conodonts, ammonoids,trilobites and tentaculitids. Whether Earth originated - eustatic and volcanic - or extraterrestrial causes can be held responsible for this turnover has been variously speculated in recent times.

In the Carnic Alps the Devonian/Carboniferous boundary beds are excellently exposed. Moreover, the stratigraphic control seems to be much better there than in any other place of the world.Particularly the section Grüne Schneid (GS) exhibits a continuous limestone succession across the boundary consisting of a uniform lithology with abundant fossils,e.g.,goniatites,clymeniids,conodonts and trilobites.

In contrast to this locality in the corresponding Kronhofgraben (K) section a shale unit is intercalated in the pelagic limestone sequence. The 0.50m thick black sulfide-rich shale is equivalent to the so-called Hangenberg Shale known from many places in Europe,Iran,North America and Southern China at the D-C boundary.

Biostratigraphical,lithological and analytical results in both sections suggest Earth originated causes for the faunal changes at this boundary in the Carnic Alps. There is no indication of significantly enhanced amounts of siderophile elements at the boundary, nor did we find micro-spherules, shocked mineral grains or volcanic debris. Furthermore, the C and O isotopes show no exciting changes throughout the boundary beds. However, there is a weak signal of excess Ir in the shales over a local background of 0.023 to 0.034ppb in the over-and underlying limestones. When normalizing to the clay (Al) content,the Ir/Al ratio is lower in the shales than in the limestones. This relationship suggests that the two-to three-fold increase in Ir was carried into the sea with detrital material from an hitherto unknown source area.

Based on our available data from the Carnic Alps and elsewhere the faunal changes at the D-C boundary are briefly discussed.Oceanographic changes, i.e. sea level fluctuations are the most likely cause for most if not all evolutionary developments at that time.Overturn conditions are reflected in the Kronhofgraben section but not at Grüne Schneid. The effects of the global modifications in the ocean,however, are in both sections the same.

Microfauna and Nannoflora of the Knappengraben Section (Austria) across the Cretaceous/Tertiary Boundary

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Fred RÖGL
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Austrian Science Foundation Projects 2659, 5879, 6734

After the discovery of a K/T boundary section in the Gosau formation of the Elendgraben in Salzburg, Austria (1, 2, 3, 4, 5) the search for more sections of identical age was extended over other areas of Austria, where the Gosau formation had been mapped before (6, 7, 8). After intensive geologic mapping accompanied by instant methods of nannopaleontological age determination the second Austrian K/T boundary site could be excavated in the Knappengraben, in the eastern part of the Gosau basin of Gams, Styria, by Lahodynsky and Stradner in 1986. In addition to the proof of an Ir peak (9) and a very detailed geochemical and sedimentological research campaign on a large number of samples (Preisinger, this meeting) the great turnover in the biota (planktonic foraminifera and calcareous nannoplankton) gives evidence of a drastic event marking the Maastrichtian- Danian boundary. Contrary to other Austrian sites, only here in the Knappengraben as well as in the Elendgraben the sequence of the turnover can be studied in detail also with micropaleontological methods. At the other sites either missing strata, barren intervals over several of meters or heavy reworking are blurring the picture.

In the uppermost Maastrichtian sediment of the Knappengraben Abathomphalus mayaroensis and Globotruncana contusa, together with a rich nannoflora of the Micula murus nannoplankton zone are present. A few millimeters higher, still underneath the yellow Iridium layer and co-occurring with shocked quartz grains, which are marking the K/T event, also Micula prinsii, the very last Maastrichtian

GAMS KNAPPENGRABEN Box sample across K/T Boundary Clay		Heterohelix/Pseudoguemb.	Pseudotextularia elegans	Ventilabrella eggeri	Racemiguemb. fructicosa	Globigerinelloides spp.	Rugoglobigerina spp.	Globotruncanella spp.	Abathomphalus mayaroensis	Gt. (Rosita) contusa	Gt. (Gt.) arca	Gt. (Gt.) falsostuarti	Globotruncana stuarti	Eoglobigerina fringa	Chiloguembelina taurica	Chiloguembelina spp.	Guembelitria sp.	Globoconusa? sp.	Eoglobigerina trifolia	Eoglobigerina praeedita	Globorotalia ex gr. pseudobulloides	Micula murus	Micula prinsii	Thoracosphaera operculata	Biantholithus sparsus	Markalius inversus
10 - 15	103	●	●			●								●	●	●	●	●	●	●	●			▮	●	●
8 - 10	7											●												▮		●
7 - 8	6																							▮		●
4 - 7	5						●																	●		
3 - 4	4																							▮		●
2 - 3	3																									
0,5 - 2	2	●																								
0,3 - 0,5	1 B	●	●			●						●														
0 - 0,3	1 A	●	●		●	●		●	●		●	●										●	●	•		
-0 - -8	100	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	●	▮									●		•		
cm	sample	FORAMINIFERA																				NANNOPL				

micro-marker fossil could be encountered. The yellow Ir-layer and the overlying compact boundary clay are barren of nannofossils (except reworked ones in worm tracks). At 3 cm above the boundary, we find calcareous nannoplankton developed again, with the typical bloom of Thoracosphaera operculata (frequency at least ten times that of the Maastrichtian) and plenty reworked cretaceous nannofossils (not only Maastrichtian, but also Campanian species). At 10 cm above the boundary the earliest Danian planktonic foraminifera with Globigerina fringa are definitely established. G. edita appears at 50 cm above the boundary. Above 80 cm the planktonic foraminifera show a distinct increase with massive occurrences of Chiloguembelinas and the FAD of Globorotalia pseudobulloides. In calcareous nannoplankton Markalius inversus marks the NP 1 zone together with common Thoracosphaera operculata.

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Structural Features and Microanalyses of Pumice from Köfels (Tyrol, Austria)

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The pumice of Koefels in the Oetz Valley, Tyrol, has a foamy, porous structure. The non-homogenous matrix consists mainly of glass rich in Si, Al, K, Na, Ca and Fe. In the more compact portion the majority of the cavities are measuring from 5 to 50 µm in diameter, single pores may reach up to 400 µm. In the coarser portion of the pumice the cavities vary between 100 to 400 µm, some may even have diameters of several millimeters. The cavities are sphercal, ovoidal or streched and are irregularly distributed in the matrix. The walls between the cavities are of varying thickness (down to 1 µm) and may themselves enclose minute cavities. In the more compact portion of the pumice one often can observe burst bubbles mainly about 5 µm in diameter. The vents are irregular or starshaped and are surrounded by radially arranged fissures. In the coarser portion of the pumice mainly longitudinal fissures (about 50 µm in length) are found. This seems to indicate a more vigorous emission of the gas in the coarser portion of the sample.

On etching with hydrofluoric acid the following phases became visible: fragmented and heavily altered grains of quartz and feldspars (in one case with planar features) and other minerals (at present under investigation) measuring from 5 to 100 µm in diameter, lumps of quartz glass (lechatelierit), some micas and also euhedral crystals with elemental composition and crystal habits typical for feldspars and feldspathoids (10 - 40 µm in diameter) which could be precipitates from a vapor phase.

A sample of gneiss from which the pumice probably originated is granitic in composition and shows ubiquitous effects of strain: Sets of planar and undulatory lamellae and fissures in quartz, displaced and undulated feldspar lamellae, kink banding in micas and extensive fracturing.

A comparison sample of shocked gneiss from the Ries crater at Nördlingen, Bavaria, shows shock lamellae more often and more pronounced than shocked gneiss from Köfels.

Mineralogical and Geochemical Features of the Barranco del Gredero Sequence (Caravaca, South-Eastern Spain) at the C/T Boundary

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A mineralogical, petrographical and geochemical study have been made of sediments from the Jorquera Formation in the Barranco del Gredero sequence (Caravaca, south-eastern Spain).

Once the C-T boundary had been identified, 58 samples were chosen from four separate stratigraphic intervals between the Upper Cretaceous and Lower Eocene.

The main mineral assemblage is indicative of a carbonate sequence, evolving from pelagic (Cretaceous) conditions towards hemipelagic (Paleocene) conditions until it assumes a distincly turbiditic character (Eocene).

In the clay C-T layer, about 12 cm thick, is evident a thin red argillitic basal layer, about 0.3 cm in thickness, containing 85% phyllosilicates, and entirely different from the rest of the layer, which consists of clayely marl and marl.

The mineralogical composition of the < 0.004 mm fraction of the carbonatic sequences is mainly made up of smectite and illite-smectite, with subordinate amounts of hydrated-illite, kaolinite, chlorite, and chlorite-vermiculite.

In the basal part of the C-T layer, smectite is the predominant mineral (90%), alone with 10% kaolinite, whereas the upper part is characterized by an assemblage of smectitic minerals with subordinate kaolinite and rare chlorite and chlorite-vermiculite.

Analysis by SEM of various types of grains, selected at the stereomicroscope from the > 0.063 mm fraction of the C-T layer, led to the identification of: 1) single quartz crystals of about 0.10 mm, idiomorphic, bipyramidal; 2) prismatic tabular equidimensional crystals (0.15-0.20 mm) of celestine; 3) ankerite (?) twinnings (0.15-0.20 mm); and 4) aggregates of roughly 0.5 mm of 0.01 mm spherulites consisting essentially of Fe.

The study of the distribution of the analyzed elements (Fe, Mn, Cr, Co, Ni, Cu, Pb, Zn, Li, C, and S) has indicated an enrichment of Cr, Co, Ni, Cu, Pb, and Zn in the red basal C-T thin layer.

The ratios of Cr, Co, and Ni with Fe and between them in the samples from the studied C-T layer have been compared with ratios in samples from other C-T layers and from other terrestrial and extraterrestrial materials.

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Grain Size Distribution Analyses of Hemipelagic Deposits and Turbidity Current Flows Exemplified at the K/T Boundary

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Austrian Science Foundation Projects 5879, 6734 and Austrian Academy of Science

Grain size analyses were carried out to obtain information on Upper Maastrichtian and Danian deposition processes.

Grain size distributions ranging from sand, silt to clay fractions required different, overlapping methods in order to get accurate results: Sieves were used for particles >63 µm, ultrasonic sieves for particles in the range 100 µm to 20 µm and a particle size analyzer by X-ray (Sedigraph 5000 ET) for 40 µm to 0.2 µm.
Results are presented as frequency and cumulative curves on Φ-scale. Parameters as mode, mean grain size, median grain size, sorting and skewness were deduced from graphic presentations of the data as well as calculated directly from the size data. Furthermore frequency grain size curves were split into three normal i.e. Gaussian distribution curves (coarse - middle - fine), which correspond best to sand, silt and clay fractions.

The grain size distribution analyses carried out cm by cm on decalcified Upper Maastrichtian samples of Elendgraben show sequences of turbiditic layers regularly alternating with hemipelagic marly limestones, whereas hemipelagic intervals in early Danian (from K/T up to 70 cm) are almost missing.

Beside textural characteristics the turbiditic sequences show decreasing mean grain size and increasing portions of fine fraction from base to top. The terrigenous part of hemipelagic deposits is made up to almost homogenous clay-sized sediment grains.

Distinction between turbiditic and hemipelagic portions of sedimentary deposition was necessary in order to estimate accurate sedimentation rates.

The Latest Results of Permian-Triassic and Frasnian-Famennian Boundary Events in China and Permian-Triassic Boundary Event in Pakistan

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1. Iridium Since 1982 a number of workers have studied the geochemistry of Permian-Triassic boundary at Meishan, Changxing County, Zhejiang Province, China. The analytical results of a number of elements from various labs agree well except iridium and some platinum group metals. The iridium results from various labs exhibit a difference of one to two factors (see Table). Possible deviation will be discussed in the presentation.

P-Tr bondary of Meishan section was resampled detailedly in 1987 and 6 samples were collected in the grayish black boundary mudstone of AG 92 of 6cm in thickness in which the highest spike of Ir anomaly was discovered in the past. The mean Ir content of these 6 samples is 0.4ppb among which 2.1ppb was detected in the uppermost sample CG672f of 1cm in thickness by a method of preconcentrated RNAA.

P-Tr boundary samples of Nammal, Chhidru, Pakistan and Serlung, Tibet and Wuxi, Jiangsu Province, China are being analysed. Hopefully, by the time of the Austria meeting encouraging Ir results can be published.

2. δ13C Notable negative perturbation of -7‰ of δ13C is reconfirmed in the 20cm thick layer above the P-Tr boundary clay in Changxing.

In Chhidru, Pakistan δ 13C negative perturbation of -0.66‰ is found in a 10cm thick layer at the Triassic base right above the P-Tr boundary. Further up in the Triassic δ 13C values are all positive. In the Permian beds underlying the P-Tr boundary δ13C values show also positive.

In Xiantian section, Luoxiu County, Guangxi Autonomous Region, δ 13C values change abruptly from positive to negative across the Frasnian-Famennian boundary i.e. the boundary between the upper part of Xiangtian Member and the lower part of Wuzhishan Formation. The perturbational amplitude of δ13C values may reach 6‰ (PDB) and greater.

Table Comparison of Ir abundance of Permian-Triassic boundary of Meishan and Shangsi sections by various authors

Section	Sample	Ir(ppb)	Analysed by	Runs	Labs	Reference
Meishan	AG92	5	INAA	2	A	Sun Yi-Yin et al.,(1984)
China	AG92	0.60+0.	RNAA	10	A	Chai Zhi-Fang et al.,(1986)
		0.046	RNAA	-	C	F. Asaro et al., (1986)
	B4	0.034	RNAA	1	D	Clark et al., (1986)
	MBS-3	0.0414	RNAA	1	D	Mao Xue-Ying et al.(1986)
		0.050	RNAA	1	E	Zhou Lei et al., (1986)
	CG672f	2.1	RNAA	1	F	Zhou Shu-Qing et al.,(1987)#
Shangsi	AG253	2.0	INAA	2	A	Xu Dao-Yi et al., (1985)
China	AG786	2.7	RNAA	2	B	Jin Li-Yun et al., (1987)
	AG253	0.054	RNAA	-	C	F. Asaro et al., (1986)
	AG787	0.027	RNAA	1	D	Mao Xue-Ying et al., (1986)
Aronzo Italy	-	3+1	RNAA	1	G	Brandner et al., (1986)
Nammal Pakistan	NB	0.7	RNAA	-	H	B. Haq et al., (1986)

Notes: A. Institute of High Energy, Academia Sinica; B. Atomic Energy Academy of China; C. Lawrence Berkeley Lab, USA; D. Los Alamos Lab, USA; E. Institute of Geophysics & Geology, University of California; F. Ministry of Energy Resources; #Preconcentrated RNAA; G. Institute of Geochemistry, USSR; H. Nuclear Activation Service of Hamilton, Canada;

Magnetostratigraphy of a New K/T Boundary in the Gosau Beds of Austria

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Austrian Science Foundation Project 5879

In the Knappengraben. E of Gams, Styria, a section ranging from Upper Maastrichtian to the Paleocene was sampled for paleomagnetic investigations. The aim of this work was to get informations of the magnetic polarity pattern, especially within the range of the Cretaceous/Tertiary boundary.

The results of the first measurements gave evidence that the G^{-}-zone (chron 29-R) can be found within this outcrop. Consequently 520 specimens were taken in very small distances down to 0.1 m. The characteristic remanent magnetization (CARM) mostly was obscured by chemical secondary components aligned to the recent Earth's magnetic field. Therefore more than 80 demagnetization experiments had to be done. In order to isolate the characteristic component of natural remanence, the behaviour of the RM-vectors during thermal demagnetization can be described by three different types of demagnetization curves.

As carrier of the secondary component the rapid drop of intensity, after heating up to 100°C, indicates goethite. The carrier minerals of the normal and reversed paleofield direction are magnetite as well as hematite.

According to the different sedimentary accumulation rates the preserved polarity pattern of the Knappengraben section corresponds very well with the polarity records of other sections.

Carbon Isotopic Event near the Frasnian-Famennian Boundary at Xiantian Section (Luoxiu County, Guangxi Autonomous Region, China)

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HOU HONG-FEI
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SUN YI-LIN
(Institute of Geology, Academia Sinica)

The Upper Devonian is well developed in the south of South China Platform. Late Devonian sediments of deeper water basin facies in South China are generallly subdivided into two formations, the lower one (D_3^1) Liujiang Formation consisting of siliceous rocks with pelagic fauna mainly ammonoids and tentaculites in Guangxi. The upper one (D_3^2) Wuzhishan Formation consisting of nodular or banded limestone, containing abundant conodonts of Palmatolepid and a few ammonoids. The boundary between these two formations is correlated to nearby the boundary between the Frasnian and the Famennian. Between the two formations mentioned above there is a layer named Xiangtian Member. The first appearance of Palmatolepis delicatula occurs at the base of Bed F and coincides with the occurrence of the nodular limestone.

About 70 samples near the boundary have been analysed for carbon isotope research. The results of isotopic analysis indicate that the $\delta^{13}C$ values across the boundary between the upper part of Xiangtian Member and the lower part of Wuzhishan Formation shift notably. $\delta^{13}C$ values in Xiangtian Member show positive, but above the boundary, e.g. in the strata at the bottom of Wuzhishan Formation display negative, so the $\delta^{13}C$ values change abruptly from positive to negative across the Frasnian and Famennian boundary. The perturbational amplitude of $\delta^{13}C$ values may be greater than 6 ‰ (PDB) and the perturbation terminates within a thin layer of 20 cm in thickness, then $\delta^{13}C$ values return from negative to positive. This negative anomaly of $\delta^{13}C$ near the Fr-Fa boundary is quite similar to other perturbations of negative $\delta^{13}C$ value near the Permian-Triassic boundary, which seems that a carbon isotope event had occurred between Frasnian and Famennian.

& This paper supported by National Natural Science Foundation of China

"Strangelove Effect" at the Permian-Triassic Boundary of Meishan Section-A (Zhejiang Province, China)

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(Institute of Geology, Academia Sinica)

About 100 samples were collected from Meishan section-A, Zhejiang Province, China, in May, 1987 of 1 to 2 cm intervals in a distance of one metre across the P-Tr boundary. $\delta^{13}C$ values at site A are similar to those at site B of the Meishan section.

$\delta^{13}C$ values below the P-Tr boundary in the Upper Permian (Changxingian Formation) all display positive and within the range of 1 to 3 ‰ (PDB), but the samples at the P-Tr boundary from the top of Changxingian Formation, a sharp spike perturbation with a minimum values of -6 ‰ occurs abruptly. The thickness of the interval depleted in ^{13}C is only 10-20 cm. Thence upward the $\delta^{13}C$ values in the Lower Triassic layer shift back to positive and sway around the zero per mil (PDB).

These negative $\delta^{13}C$ values have also been found at several other P-Tr boundary sections, and are considered to be the result of a " Strangelove effect " by K. Hsü. At Meishan section-A $\delta^{13}C$ values decrease suddenly up to -6 ‰ (PDB), which is interpreted as reflecting the extinction of biomass.

& This paper supported by National Natural Science Foundation of China

BERICHTE DER GEOLOGISCHEN BUNDESANSTALT

Excursion Guide

to the Geologic Sites of

"Rare Events in Geology"

Work Shop and Field-Trip sponsored by
the IGCP Project 199
and the Austrian Ministry of Science and Research

Organized by
H. STRADNER (Chairman)
P. FAUPL
F. GRASS
H. J. MAURITSCH
A. PREISINGER
C. SCHWARZ
E. ZOBETZ

Vienna, Austria
Sept. 12 - 17, 1988

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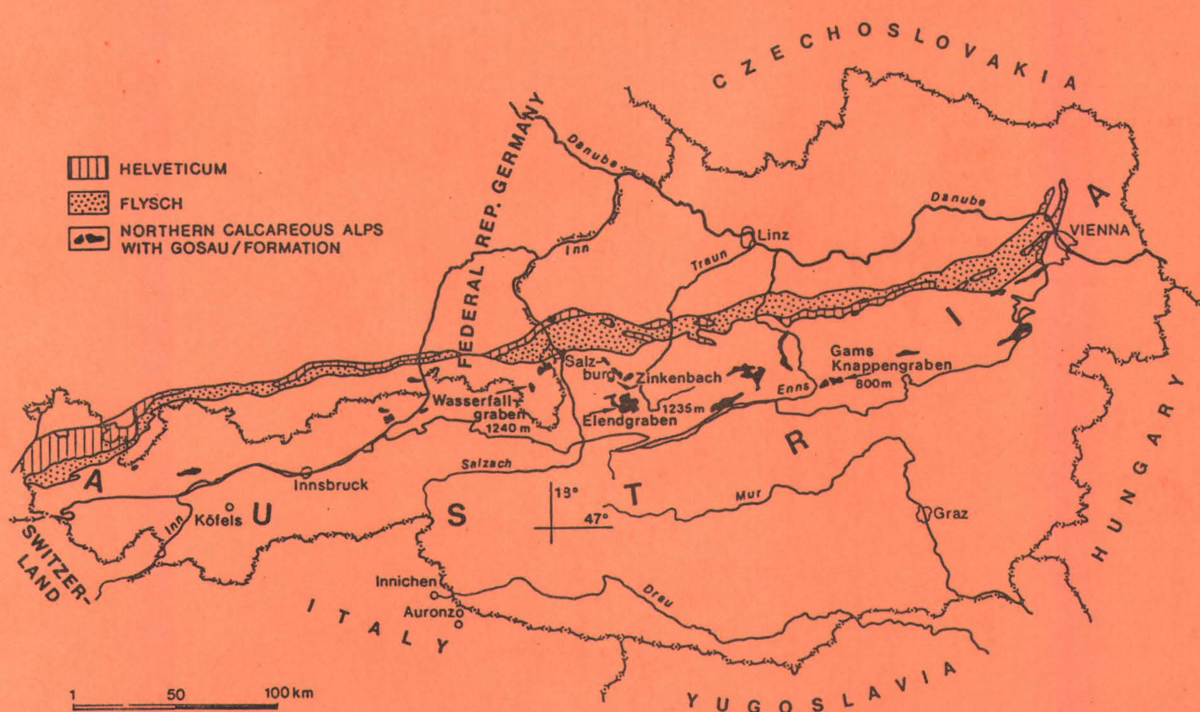
Project Managers: Univ.-Prof. Dr. A. PREISINGER, FWF Projects 5879, 6734
ao. Prof. Dr. H. STRADNER, FWF Project 2659

A Cordial Welcome

to all participants in our field-trip to geologic sites of "rare events"



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IGCP-Project 199: "Rare Events in Geology"

Field-Trip through Austria and Northern Italy Sept. 15 – 17, 1988

Contents

Field-Trip Itinerary

STOP 1: The K/T Boundary of the Knappengraben at GAMS, Styria, Austria.

STOP 2: The Tr/J Boundary of the Kendlbachgraben and Tiefengraben at ZINKENBACH, Upper Austria.

STOP 3: The P/Tr Boundary at AURONZO, Southern Tyrol, Northern Italy.

STOP 4: Shocked Quartzes at KÖFELS, Ötztal (Oetz Valley), Tyrol, Austria.

Field-Trip Time Table

Thursday, September 15:

Departure from Technical University Gußhausstraße 27-29	8.00
Excursion STOP 1: Knappengraben, Gams (K/T)	11.00 - 14.00
Lunch at Mooswirt, Mooslandl, Styria	14.30 - 16.00
Transfer to Hotel Carossa Zinkenbach, Upper Austria	16.00 - 18.00
Supper and Lodging at Hotel Carossa	

Friday, September 16:

Breakfast	7.00 - 8.00
Departure from Hotel Carossa, Zinkenbach	8.00
Transfer to Excursion STOP 2 in shuttle buses	8.00 - 9.00
Kendlbachgraben and Tiefengraben (Tr/J)	9.00 - 12.00
Lunch at Hotel Carossa, Zinkenbach	12.30 - 14.00
Transfer from Zinkenbach to Innichen, Hotel Grauer Bär (Orso Grigio), Southern Tyrol, Northern Italy	14.00 - 19.00
Supper and Lodging at Hotel Grauer Bär	

Saturday, September 17:

Breakfast	7.00 - 8.00
Departure from Hotel Grauer Bär	8.00
Transfer from Innichen to Auronzo	8.00 - 9.00
STOP 3: Auronzo (P/Tr)	9.00 - 11.00
Transfer from Auronzo to Misurina	11.00 - 12.00
Lunch at Misurina, Lake Misurina	12.00 - 13.00
Departure for Innsbruck, Tyrol	13.00
Arrival at Innsbruck (with stops at the Central Railway Station and at the Air Terminal Innsbruck, Kranebitten)	17.30
Transfer to STOP 4 at Köfels, Ötztal "Shocked quartzes"	17.00 - 18.00
Departure for Innsbruck	19.30
End of Excursion at Innsbruck	20.30

There are chances for free rides back to Vienna during night or early next morning.

Geology of the K/T Boundary Site at Knappengraben Creek (Gams, Styria)

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Austrian Science Foundation Project 5879

Regional features

The largely fault bounded basin of Gams, Styria, is situated in the eastern part of the Northern Calcareous Alps close to the marked bend of the Enns river. The area comprises more than 2000 m thick rock sequences ranging from Santonian conglomerates, sandstones and marls to sandstones and marls of the Upper Paleocene. The Gams basin was an important area for earlier attempts to locate the Cretaceous-Tertiary boundary, based on microfaunal investigations (Wicher & Bettenstaedt, 1956 and Kollmann, 1964). A detailed geological mapping by Kollmann (1964) allowed a limited litho- and nanno-stratigraphical investigation of several boundary sections. At last, in 1986, a K/T boundary clay could be found in the Knappengraben section. (Stradner et al. 1987).

Excursion route

The occurrence of the Gosau Formation at Gams was dealt with in two recently published excursion guides (Kollmann, 1984 and Kollmann & Summesberger, 1982).

Near the post office of the small village of Gams a minor road branches of the federal highway no 25. Since the narrow picturesque road through the Noth-canyon (cave with gypsum crystals) is not open to public traffic we use the bypass road via Gamsforst (a minor settlement). Sandstones, conglomerates, sandy and clayey marls of the Concavata zone are exposed along the road and a small squeezed out and overthrust zone of the Lower Triassic base of the Unterberg nappe is crossed, which splits the Gams Basin into two parts.

The narrowing of the Eastern Gams Basin towards the Torsattelpass and its overthrust by the Göller nappe in the south is well visible from Gamsforst.

The excursion traverses breccias, sandstones and marls of the Zwieselalm-Formation (NP3-NP9 zone in the Gams area, det. H. Stradner) along a small torrent down to Krautgraben valley. After crossing the Gamsbach river east of a small saw mill we drive over Zwieselalm Beds to the first ascend of the Saugraben forest road. Further eastward road scarps expose grey Maastrichtian marls of the Nierntal Formation. South of the forest road the Gamsbach river runs along the K/T transition and scours the softer Danian marls. Lowermost Paleocene wedges out more and more in westward direction.

K/T boundary section

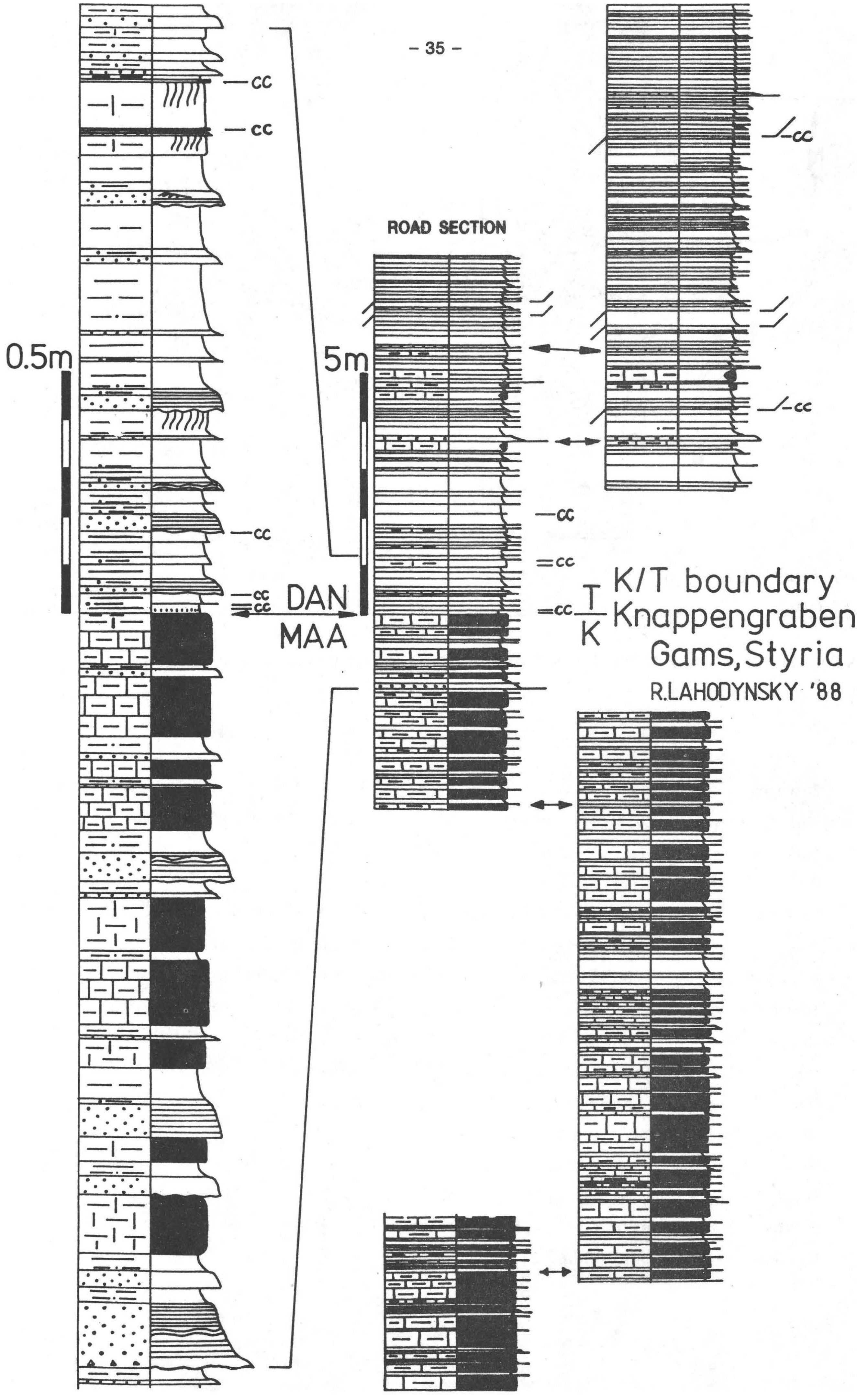
The Knappengraben boundary site is situated east of the Hafneralm (a farm), south of Beilstein mountain, at an altitude of 795 meters above sea level and comprises a series of artificial exposures along a small creek and a scarp of a forest road. The K/T boundary layers mark the end of a cyclic alternation of thin turbidites with interbedded hemipelagic calcareous marl beds, deposited above the CCD-level.

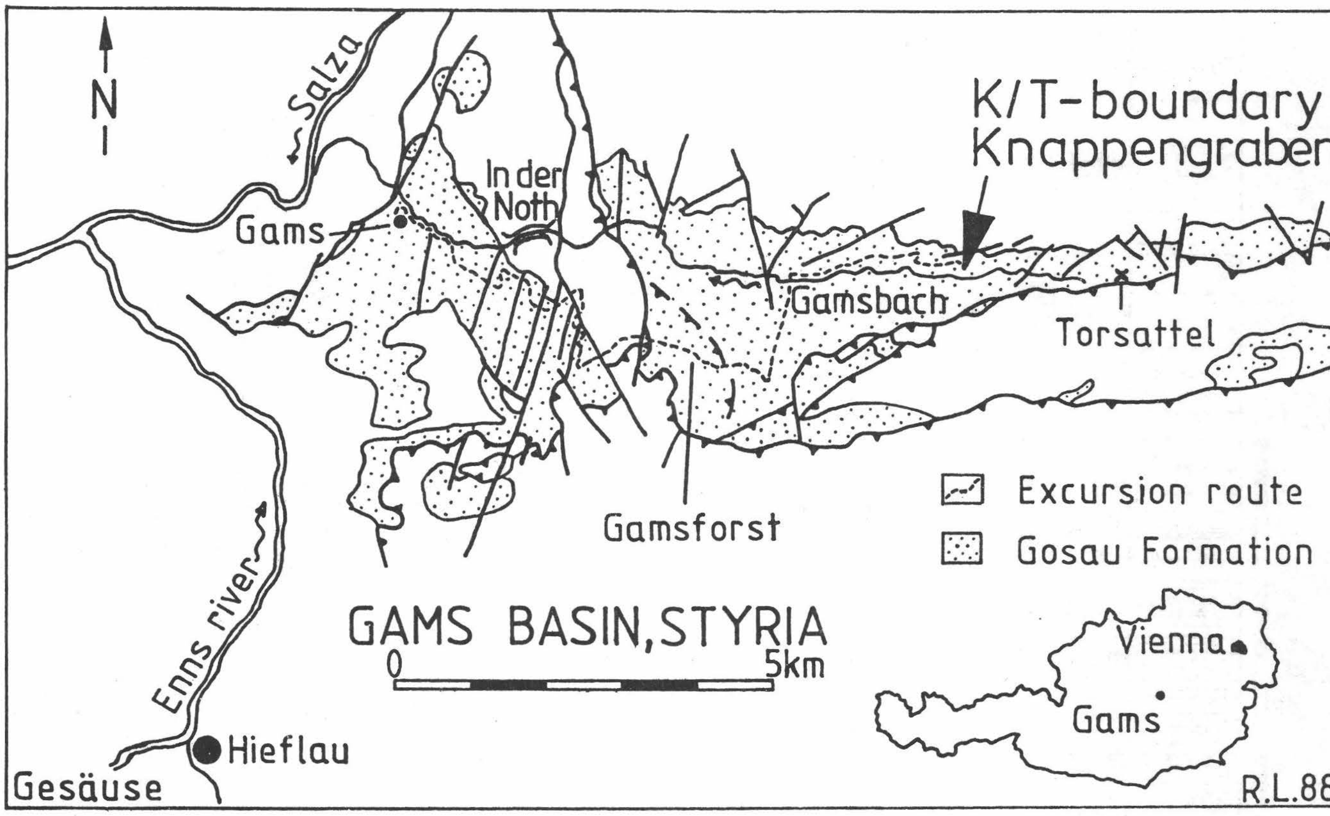
The slightly tectonized boundary sequence consists of a white, yellow and dark grey clay triplet with layers of calcite plates and slickensides. The bright yellow or "rusty layer" may thin out laterally. The slope facies association of the Nierntal Beds above the K/T is mainly composed of sandstones and sandy grey-brown or red-brown turbiditic marls.

Some chaotic beds containing Maastrichtian limestone olistholites are intercalated in the lowermost Tertiary.

Legend of the lithostratigraphic logs 1 : 10 and 1 : 100 at the Knappengraben boundary site, Gams, Styria

- calcareous marl
- marl
- clayey marl
- clay
- sandy pelite
- silt
- sandstone
- breccia
- "rusty layer"
- calcite layer
- hemipelagite
- turbidite
- debrite
- cross bedding
- wavy lamination
- planar lamination
- fracture cleavage
- fault


ROAD SECTION
0.5m
5m
cc
DAN
MAA
T
K
K/T boundary
Knappengraben
Gams, Styria
R.LAHODYNSKY '88



Geological sketch map of the Gams Basin, Styria (after KOLLMANN, 1964; modified)

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Magnetostratigraphy of the K/T Boundary in the Knappengraben

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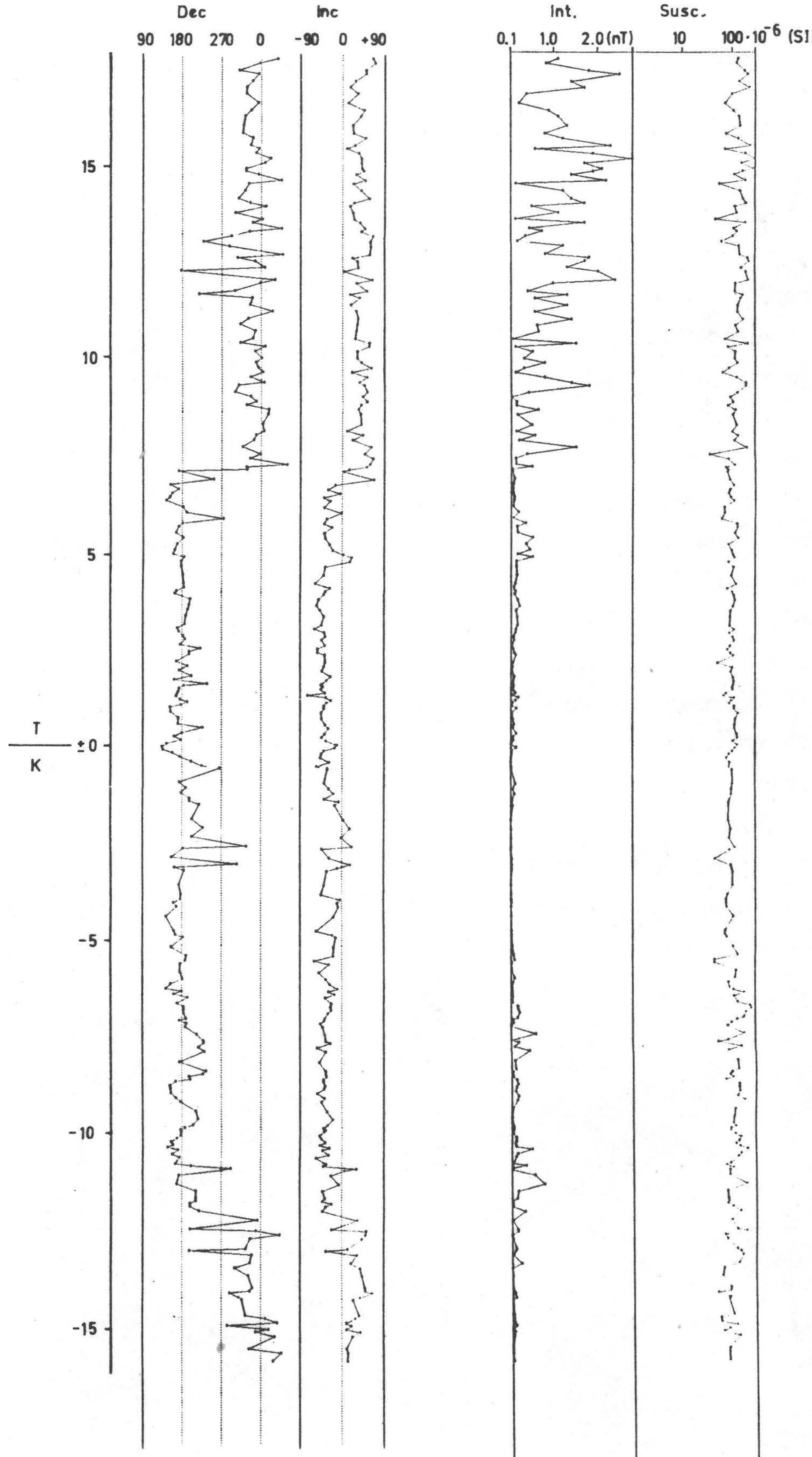
In the Knappengraben, E of Gams near Hieflau (Styria) a complete K/T boundary section, ranging from F^{+3} to H^{+} was discovered. The well preserved boundary clay occurs at 12,8 m above the top of chron 30-N (F^{+3}) and 6,8 m below the bottom of chron 29-N (H^{+}). A cretaceous slump, strongly varying in thickness, can be seen between 4,0 and 5,5 m above the C/T boundary causing a rough estimation of the real thickness of the Tertiary (6,8m). The mean direction computed for the G^{-} zone is about 184/-38, while the normal polarities (F^{+3}, H^{+})are at about 340/+43. Comparing these data to the Elendgraben section (Zwieselalm-Gosau) remarkable 60° counterclockwise rotation is indicated. This seems to be plausible in respect to the local tectonic.
In the Cretaceous, magnetite was found to be the carrier mineral of the normal and reversed paleofield directions while in the Tertiary magnetite as well as hematite were identified.
In most cases the intensity and bulk susceptibility seems to be lithologically controlled. The anisotropy of the susceptibility is indicating primary magnetic fabric with q values less than 0,67 and K_{min} axis perpendicular to the bedding plane. The correlation seems less accurate for the Tertiary.

Knappengraben - T 470



A Triassic/Jurassic Boundary Section in the Northern Calcareous Alps (Austria)

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INTRODUCTION

The development of the lowermost Jurassic sediments in the Tethys realm of the Northern Calcareous Alps is dependant upon the Upper Triasic relief. Due to sea-level fluctuations, the Triassic/Jurassic boundary is characterized by a hiatus in large areas. Only in the intraplatform basin of the Kössen Formation (Kössen facies) sedimentation occurs during this time and makes research possible.

Although the Kössen Formation and the Liassic Cephalopod Limestones (Enzesfelder Kalk) at the Kendlbachgraben were extensively studied by SUESS and MOJSISOVICS (1868), BLIND (1962), PEARSON (1970), MORBEY (1975) and KUSS (1983) the boundary section itself remained undiscovered. Using conodonts KRYSTYN (1980) classified the uppermost bedss of the Kössen Formation, previously defined as Jurassic, as being of Triassic age. PLÖCHINGER (1982) named the sequence between the Kössen Formation and the Liassic Cephalopod Limestones the "Kendlbachschichten". Investigating the paleogeographic distribution of carbonate platforms and intraplatform basins of Rhaetian age it became possible to search for the Triassic/Jurassic boundary sections in areas which were not affected by the sedimentary hiatus.

Further localities were studied and successfully correlated besides the two sections, Kendlbachgraben and Tiefenbach: in the Karwendelgebirge near the Fonsjoch at the Achensee; in the Hinterrisstal, in the Eiberg Quarry near Kufstein (Tyrol), as well as near Grossraming in the Enns valley (Upper Austria, Frankenfelser Decke). Though these sections are situated in different tectonic units and are geographically separated by nearly 300 km, all of them show a strong lithological and biofacial similarity and thus allow us to describe the Triassic/Jurassic boundary in a more precise way.

LOCALITIES

Both localities, Kendlbachgraben (STOP 1) and Tiefengraben, (STOP 2, see Fig. 1) are situated in the Northern Calcareous Alps in the area of the Zinkenbachgraben (altitude 900 m) in the Osterhorngruppe W of the Wolfgangsee in the Salzkammergut, 30km SE of the city of Salzburg.
Kendlbachgraben:47 41 15/13 21 30, Tiefengraben: 47 41 45/13 21 00 Österreich Karte, Blatt nr.95, St. Wolfgang, 1:50.000; Geologische Karte, Blatt nr. 95, GBA 1982, 1:50.000).

TECTONICS

Oberostalpine Staufen-Höllengebirgsdecke, Osterhornmulde

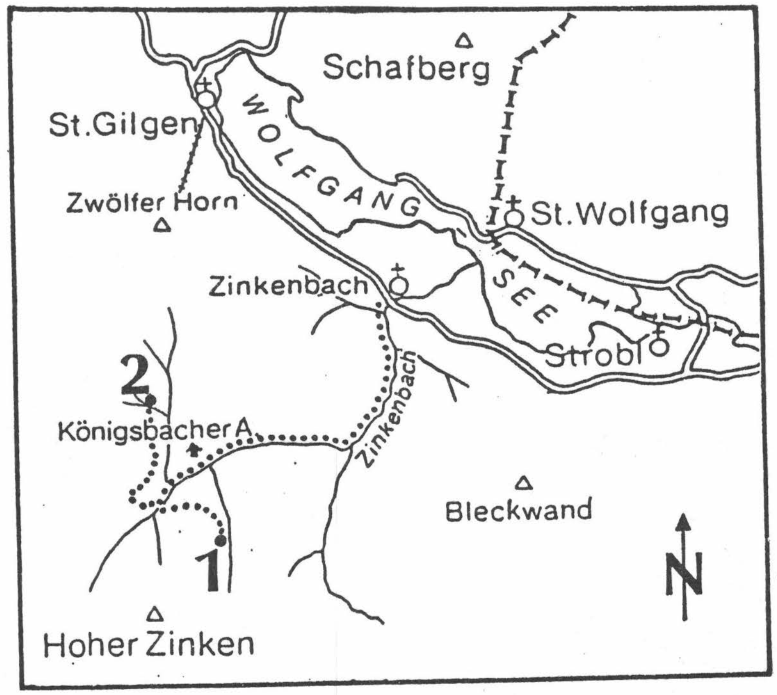


Fig. 1.
Excursion route to the Tr/J sites Kendlbachgraben (1) and Tiefengraben (2).

PROFILES

Basal part:

The underlying beds of both boundary sections are formed by the Kössen Formation, developed in the Kössen facies. The bioclastic peloidal wackestones with a characteristic fauna of ammonites (Choristoceras marshi HAUER), bivalves (Oxytoma-community), brachiopods (Oxycolpella-community), numerous echinoderm fragments and conodonts (Misikella posthernsteini-assemblage) (GOLEBIOWSKI, 1986) represent a full-marin basin facies. This intraplatform basin of moderate water depths was bordered to the N and S by shallow water platforms ("Oberrhätkalk", Steinplattekalk).

Upper part:

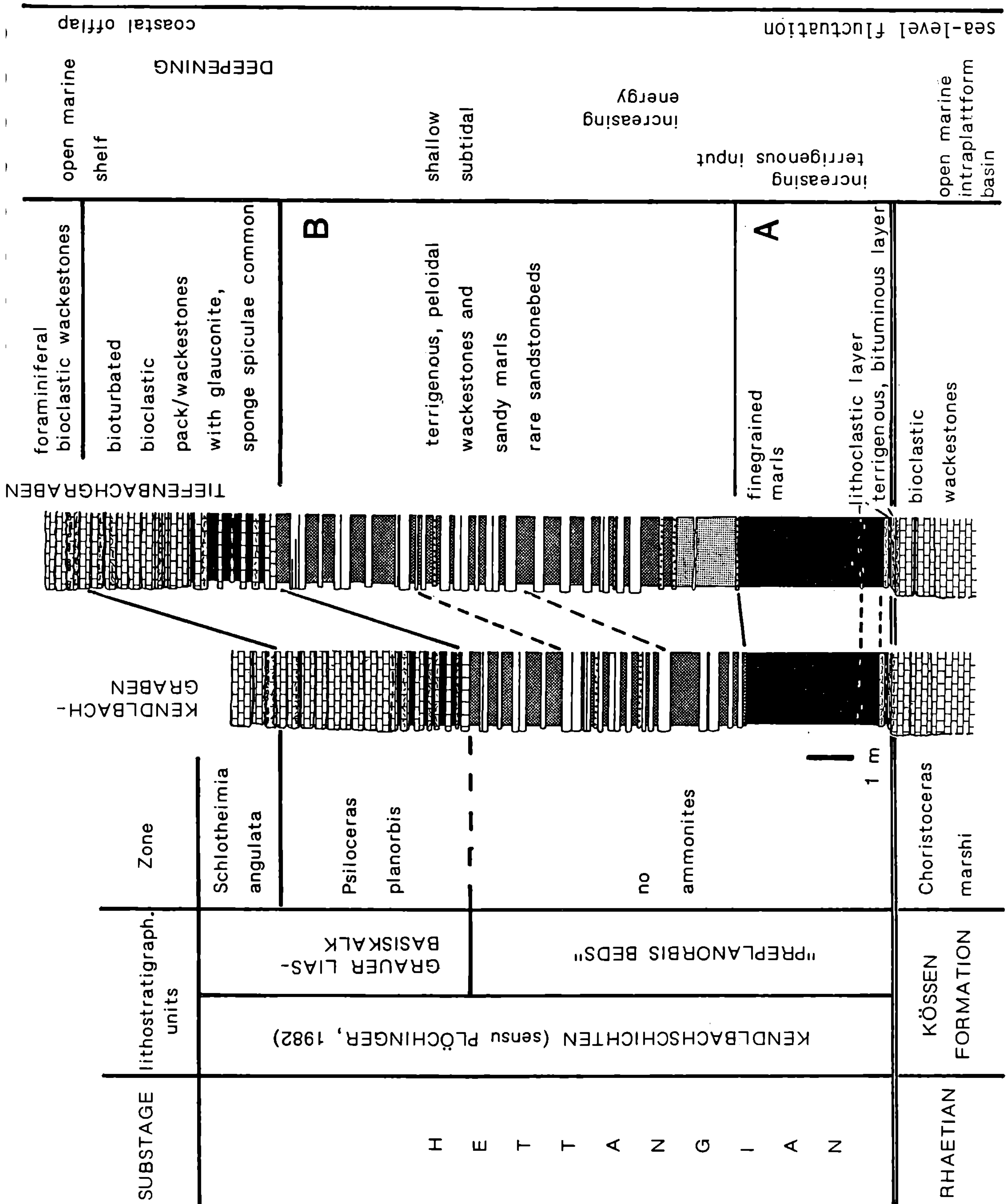
The upper part is built up of the "Grauer Liasbasiskalk" (FABRICIUS, 1966) with intercalations of marls in the basal part. These bioturbated, bioclastic wackestones with glauconite and numerous sponge spicules are characterized by a bivalve fauna:

Plagiostoma punctata (SOW.),	Oxytoma inaequivalva (SOW.)
Antiquilima succineta (SCHLOTH.)	Camptonectes sp.
Chlamys textorius (SCHLOTH.)	Liostraea hisingeri NILSSON
"Ostrea" ariaetis (QUENST.)	Pinna sp.
Lobothyris ovatissima (QUENST.)	Spiriferina walcotti (SOW.)

and the first Liassic ammonites (Psiloceras planorbis (SOW.) (found at Breitenberg, SUESS and MOJSISOVICS, 1868).
The uppermost sequence of these beds (thickness:1 m) consists of foraminiferal bioclastic wackestones (Involutina liassica, Trocholina sp.) and contains a condensed ammonite fauna (Schlotheimia angulata (SCHLOTH.), etc). Contrary to the underlying sequence the Liasbasiskalk represents sediments of an open marine shelf area with progressive deepening.

Fig. 2.

Lithostratigraphy and facies development of the Triassic/Jurassic boundary beds in the Zinkenbach area.



BOUNDARY SECTION and "PREPLANORBIS BEDS"

In both sections, Kendlbach (Fig.4) and Tiefengraben (Fig.3), an additional sequence, called Preplanorbis Beds, was discovered and determined as the sediment package between the Kössen Formation and the Liasbasiskalk (Zone of Psiloceras planorbis). The Liassic age of the beds is confirmed by bivalves, brachiopods and nannofossils and besides representing an interval barren of ammonites these beds are stratigraphically comparable with the Preplanorbis Beds of western Europe (England, DONOVAN 1961) and of northwestern Germany (HOFFMANN 1960).
Both sections have a uniform, corresponding, lithological sequence. The middle part of the Tiefengraben section however has a greater thickness (Fig 2). The sequence can be differentiated in a basal, fine grained, marly part (A) and an upper part with sandy marls, limestones and rare sandstone layers (B).

The lowermost horizon of the fine grained sequence is represented by a 10 cm brown, bituminous, compact marly layer with a high content of terrigenous rounded quartz grains (Ti 22, Kb 1/1). This layer, directly overlying the uppermost limestone bed of the Kössen Formation, contains numerous Liassic bivalves:

Cardinia hybrida (SOW.)
Chlamys textorius (SCHLOTH.)
Pseudolima hettangiensis (TERQUEM)

Contrary to the Kössen beds, this layer reveals restricted sedimentation and a reduced carbonate content and can be determined as the T/J-boundary layer sensu stricto.

This boundary layer is overlain by a 3 m sequence of soft, dark grey, fine grained marls. At its base an intercalation of a 20 cm, solid, light grey marly horizon is marked with pyrite conglomeration (Kb 2/1, Ti 20). The marls underneath (thickness 7 cm) have a higher content of quartz and mica. (K 1/2 and Ti 21)
The lowermost meter of the marl sequence is characterized by reworked lithoclasts of bioclastic pack- to grainstones containing shallow water foraminifera (Triasina hantkeni, Aulotortus sp., Auloconus sp.) from an adjoining carbonat plattform.

Fossil content of the fine grained marly layer (determined by HOHENEGGER and KRISTAN-TOLLMANN):

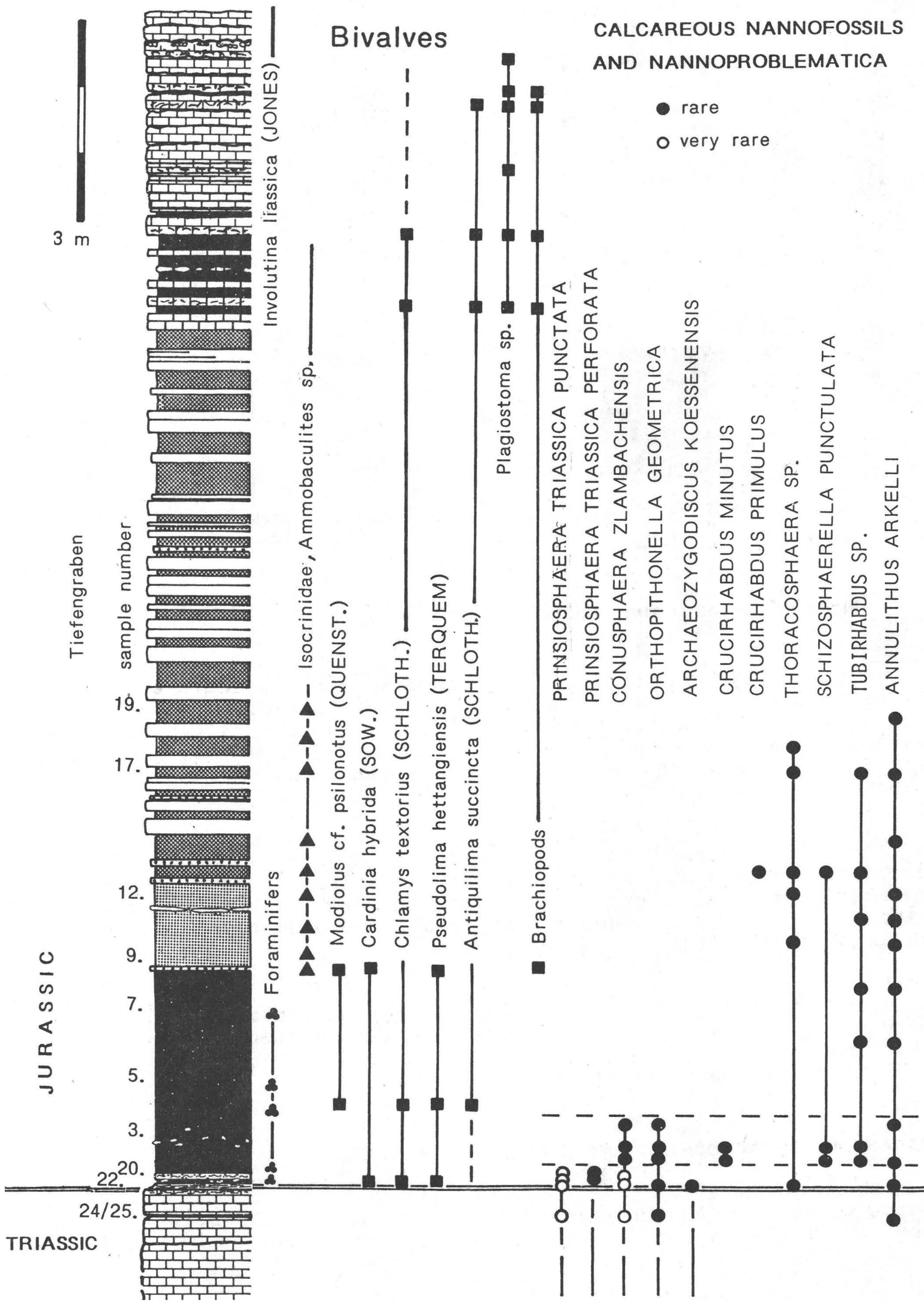
Foraminifera: Hyperammina stabilis KRISTAN-TOLLMANN, Trochammina alpina KRISTAN-TOLLMANN, Nodosaria sp., Astacolus primus (D'ORB.), A. varians (BORNEMANN), A. matutinus (D'ORB.), Dentalina pseudocommunis FRANKE, D. vetusissima (D'ORB.), Ichtyolaria nov. sp., Vaginulinopsis protracta (BORNEMANN), V. deformis (BORNEMANN), Trocholina sp.

Ostracods: Lobobairalia sp., Triadohealdia sp., Ogmoconchella sp., Trimirasevia sp.

The morphological difference of Ichtyolaria densicostata HOHENEGGER (planorbis zone) and the occurence in the Preplanorbis Beds allows the assumption that Ichtyolaria nov. spec. could be of stratigraphical value for the lowermost Hettangian (pers.comm. HOHENEGGER)

The spectrum of faunal elements in Kössen facies of the Kössen Formation of Salzburg and Tyrol is common and it also occurs in the lowermost, epicontinental, marly sediments of the southern German Jurassic (Planorbis beds, Beta-Tone of Schwäbische Alb, HOHENEGGER, pers. comm.). Therefore this fauna is of no stratigraphic importance with respect to the boundary.

Fig. 3 (for legend compare fig. 2).



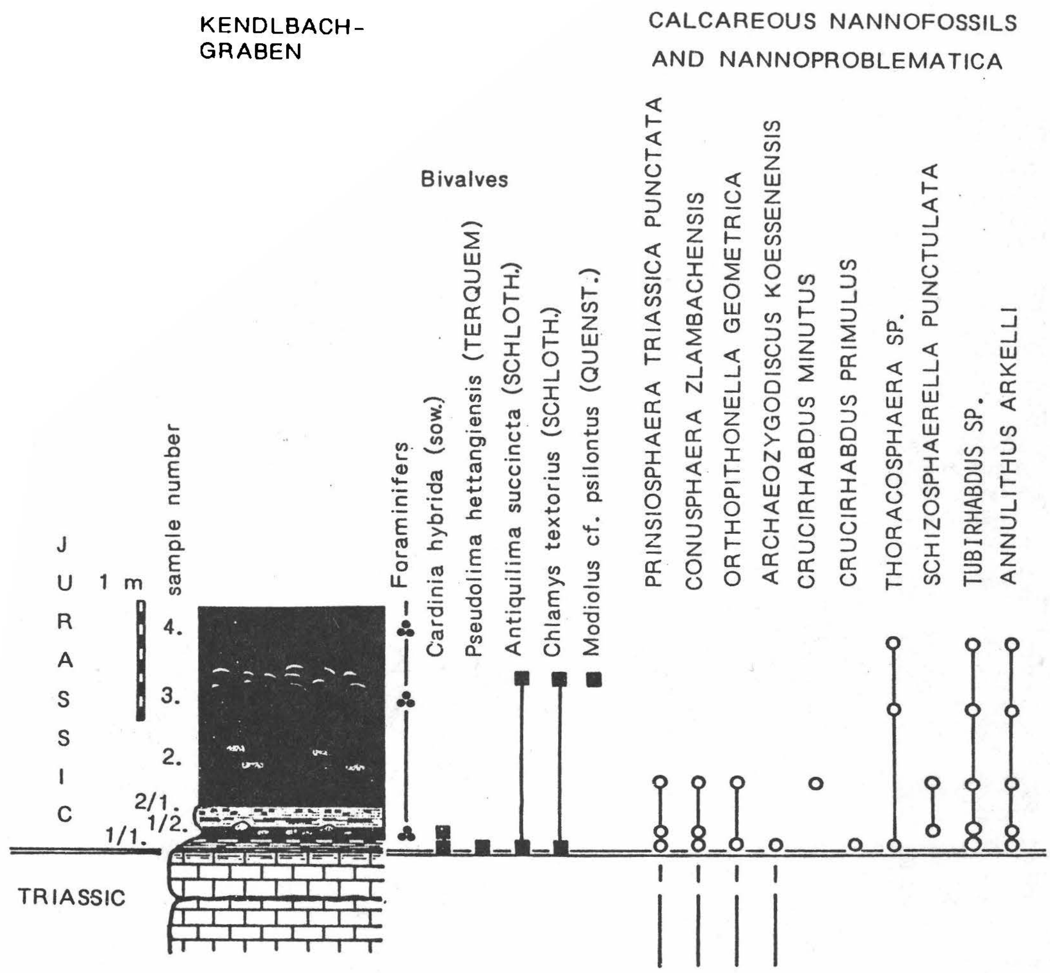


Fig. 4 (for legend compare fig. 2).

The upper part (B) of the Preplanorbis Beds is indicated by a change of facies. Pelodial wackestones banks alternate with brownish weathering arenitic marls with increasing grain size and rare calcareous sandstone beds. The thickness of the lower sequence of part B in the Tiefengraben section is larger, the upper part corresponds with the Kendlbach section. (Fig. 2)
Fossil content:

Contrary to part A the arenitic marls, rich in mica, contain no other foraminifera than Ammobaculites sp. and rare ostracods (Healdidae). But this facies is characterized by numerous elements of Isocrinides (?Cladocrinus sp.) and Procidaris spines. Exclusively in Ti 9, calcitic shelled bivalves and brachiopods are observed in thin-sections.

Bivalves:
Chlamys textorius (SCHLOTH.), Pseudolima hettangiensis (TERQUEM)
Modiolus sp., Cardinia sp., Liostrea hisingeri (NILSON)
Brachiopods:
Lobothyris sp., Spiriferina walcotti (SOW.)

CALCAREOUS NANNOFOSSILS AND NANNOPROBLEMATICA

The examination of all samples (Fig. 3, 4) characterizes a sparse nannoflora assemblage with low frequence and poor preservation in the Kössen Formation as well as in the Preplanorbis Beds.

Prinsiosphaera triassica JAFAR 1983, an enigmatic nannofossil, and Conusphaera zlambachensis MOSHKOVITZ 1982, occur more abundantly in the Rhaetian stage (Ti 24/25). The variety of five subspecies of the Prinsiosphaera (JAFAR, 1983) could not be recognized in the present study, two of these could be morphologically distinguished in the LM. P. triassica hyalina JAFAR 1983 is considered to be a synonym of Orthopithonella geometrica JAFAR 1983 (JANOFSKE, 1987).
Schizosphaerella punctulata DEFLANDRE and DANGEARD 1938 (Hettangian-early Kimmeridgian), an organism which shows affinities to the dinoflagellates within the Thoracosphaerales (BOWN, 1987) is too rare to be used as a stratigraphical marker.

Beside this group of incertae sedis taxa also the calcareous nannofossils show a change straddling of the Triassic/Jurassic boundary.

Archaeozygodiscus koessenensis BOWN 1985 and Crucirhabdus minutus JAFAR 1983, after BOWN (1987) of Rhaetian age only, could also be observed above the boundary section (Ti 22, Kb 1/1). Annulithus arkelli ROOD, HAY and BARNARD 1973 (Rhaetian - mid Hettangien), a zonal marker (Annulithus arkelli zone, BARNARD, T. & HAY,W.W., 1974) for the lowermost Jurassic, was found of most significant stratigraphical value. Crucirhabdus primulus PRINS 1969 (Rhaetian to Lower Torarcian) is so rare that only a single specimen was encountered (TI 12, Kb 1/2).

A. arkelli is a small and simply constructed ring of irregularly shaped calcite crystals (3-4µ) and occurs consistently in all samples of the entire sections (fig. 3, 4).
Its appearance could be recorded for the first time in Austria. Sparse in the Rhaetian, it becomes more common in the Hettangian in the upper part of the studied sections (Ti 13).

CONCLUSION:

The Triassic/Jurassic boundary in the Northern Calcareous Alps marked by a lithological change happens during an interval of sea-level fluctuations (SCHÖLL & WENDT, 1971, RUMPF, 1986; HAQ et al., 1987) and a lowering of the seawater temperature (FABRICIUS et al., 1970).

Due to changing sedimentolo-gical and ecological conditions, the formation of carbonate platforms (SCHLAGER & SCHÖLLNBERGER, 1974) ends and the intraplatform basins transformed to restricted, subtidal areas with increased terrigenous influence ("Preplanorbis Beds").

By means of bivalves (Cardinia-community) and nannofossils (Annulithus arkelli) the entire sequence above the Kössen Formation could be determined to be of Liassic age. With the boundary layer the extinction of Kössen type fauna and the shift to new Jurassic biofacial communities is demonstrated (Fig. 5).

Over the northern (Bajuvaricum), as well as over the central (Tyrolicum) units of the Northern Calcareous Alps the boundary section shows a constant facial development and a striking similarity in their geodynamic evolution. Since the studied sections are distributed over a distance of at least 300 km distance, one can assume a more than regional cause for this change.

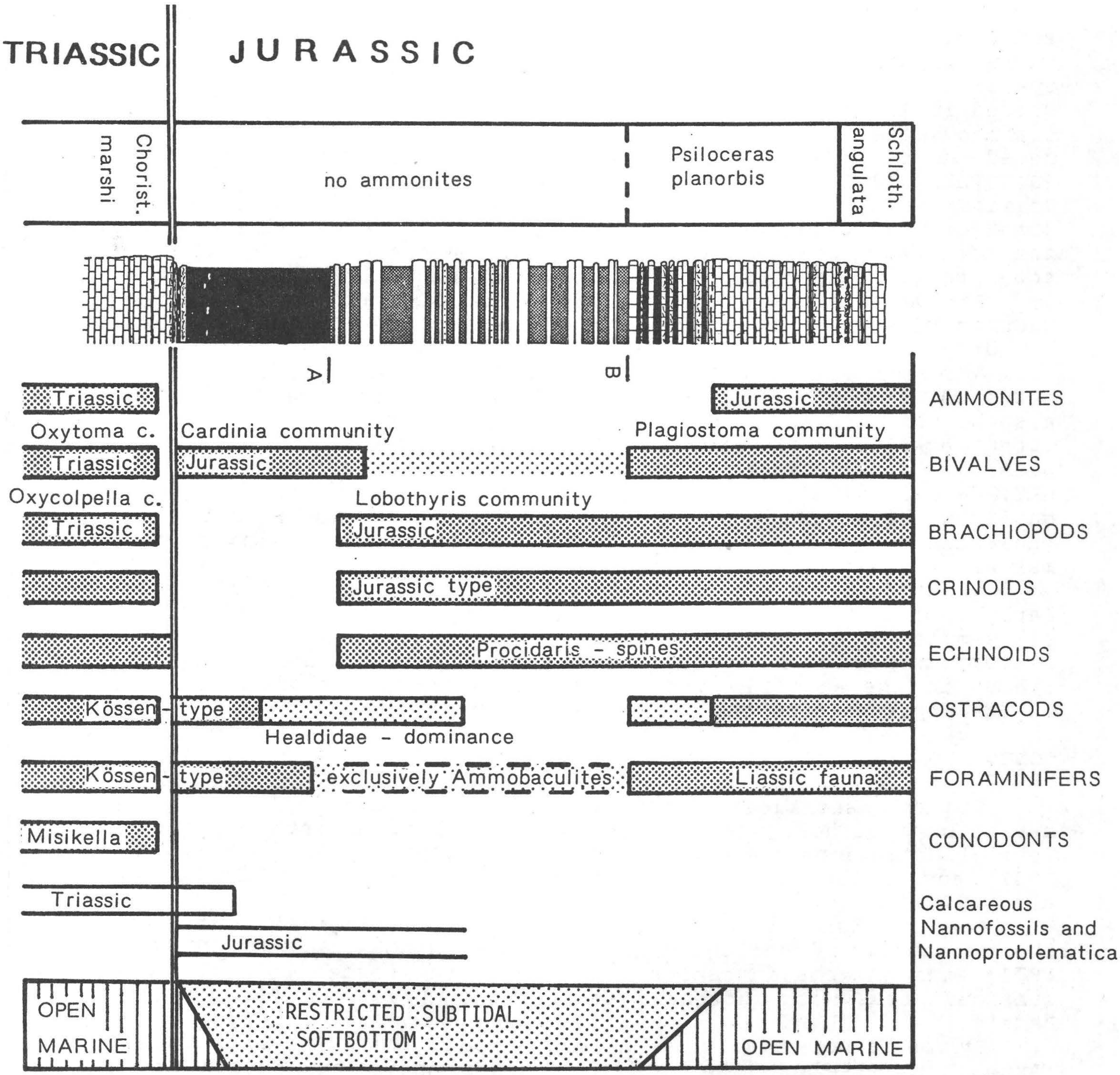


Fig. 5.
Biotic development across the Triassic/Jurassic boundary.

Magnetostratigraphy of the Tr/J Boundary in the Kendlbachgraben

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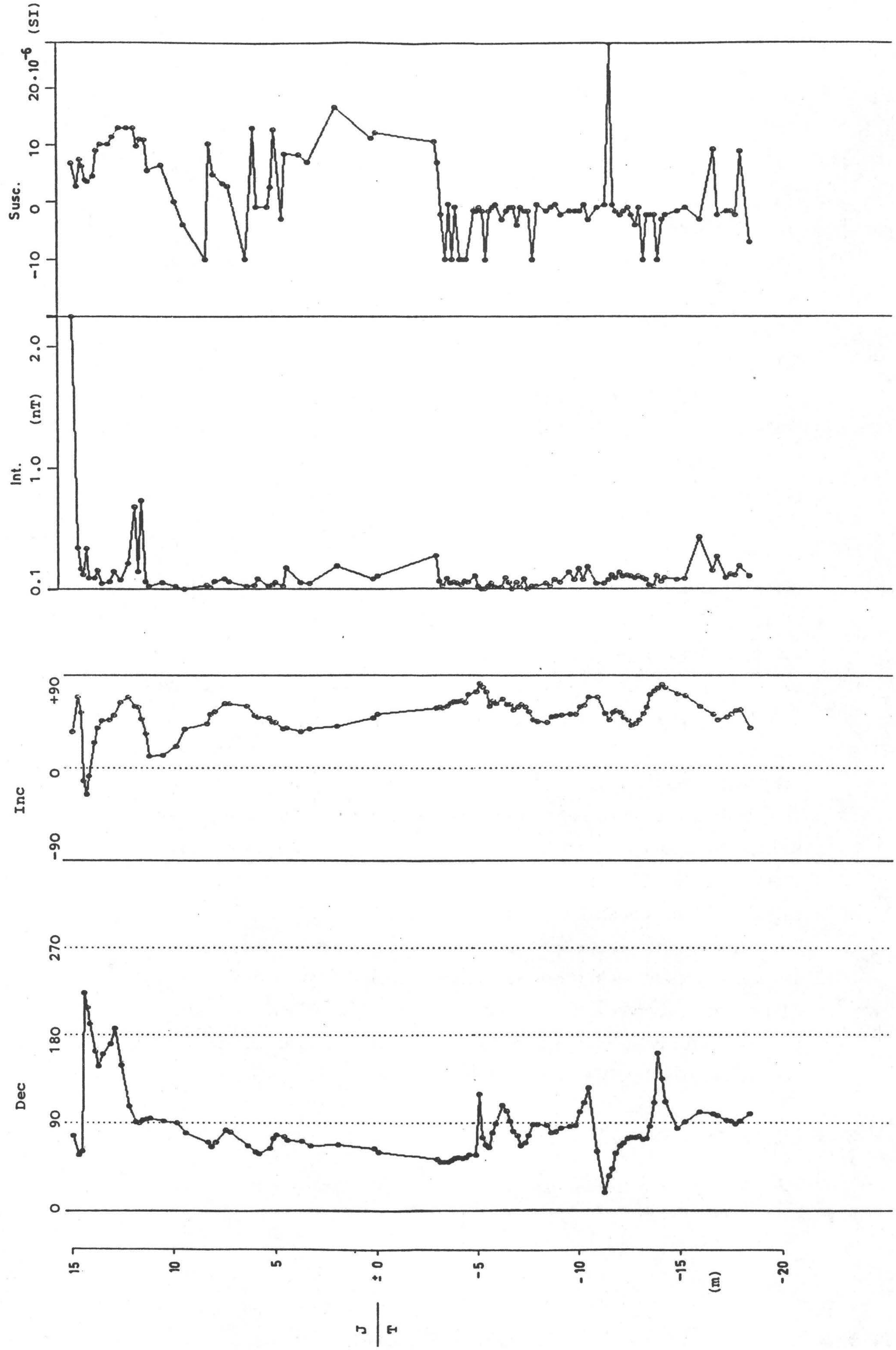
Austrian Science Foundation Project 5879

In the Kendlbachgraben, near St. Gilgen, a section ranging from Upper Rhaet to the Lias was sampled for paleomagnetic investigations.
Mostly the NRM-directions (Natural Remanence) were aligned to the recent Earth's magnetic field obscuring the characteristic remanent magnetization (ChRM) which indicates the ancient Earth's magnetic field direction during deposition. To determine the paleofield direction excessive demagnetization experiments were necessary.
Some improvement in the grouping of the remanent magnetization vector was obtained by means of stepwise AF (Alternating Field) demagnetization, carried out on a pilot set of samples, but much better grouping was attained by thermal cleaning. Therefore samples from each site were subjected to thermal demagnetization, usually in 10 or 12 steps up to 700°C. During demagnetization the intensity diminishes more or less (30%-95%) at 100°C which indicates goethite as the carrier of this secondary magnetic component mostly aligned to the recent Earth's magnetic field. The remaining component especially in the Lias unit (Adneter Kalk) follows the normal or reversed direction of the paleofield. The carriers of this primary component are magnetite and hematite pigment (Adneter Kalk).
The intensity and especially the bulk susceptibility of the Triassic limestones (Kössener Schichten) are very low, indicating diamagnetic behaviour of these rocks. Therefore in particular primary information about the ancient Earth's magnetic field is given only by the upper part of the section.

Kendlbachgraben - T 300 (5)



The Permian-Triassic Boundary in the Dolomites (Southern Alps, Italy), San Antonio Section

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Topographic map:	Freytag-Berndt Tourist Map 17, Eastern Dolomites, 1:100 000
Geological maps:	Carta Geologica d'Italia, 1:100 000, F. 4–13, Monte Cavallino-Ampezzo P. Casati et al., 1981: Carta Geologica della Valle d.F. Ansiei e dei Gruppi M. Popera - Tre Cime di Lavaredo, 1:25 000. - Riv. Ital. Paleont., v. 87, 3, 1982
Route:	San Candido (Innichen) - Monte Croce - (Kreuzberg) - Padola - Passo Zovo - San Antonio Section (Stop) - Auronzo - Misurina (lunch) - Innsbruck

Foreword:

The complex subject of the "Permian and Permian-Triassic Boundary has been dealt with extensively at a memorable Field Conference hosted by "IGCP 203 Group" in Brescia, in July 1986. Our Italian colleagues presented us with an excellent field-book compilation of their research activities.

The Institute of Geology of Innsbruck University has been conducting research on the same subject. Thus ist follows that the paper on the "San Antonio Section" combines yet unpublished results of our own work with some of those of our Italien friends.

The **biostratigraphic P/Tr boundary** runs somewhere in a zone of transition a few meters thick along the basis of the Werfen Formation within the Tesero Horizon. This puts it beyond precise definition. **Physical** and **chemical events** have been traced in the uppermost Bellerophon beds, i.e. uppermost Permian.

Research in the Dolomites has produced a series of rather complete boundary sections positioned in the inner-shelf area of a basin opening eastwards. This basin had a coastline ca. 100 kilometers west of Auronzo (see Fig. 1). The Werfen Sea reached beyond this area westwards.

In the Southern Alps the P/Tr boundary is to be located within a **depositional sequence** (in the sense of van Wagoner et al.) bounded by unconformities of Mid Permian and Mid Triassic age. The "Sexten Conglomerate"* and the Tarvis Breccia* p.p. form the basis of the sequence which rests by an unconformity on crystalline basement and Lower Permian volcanics ("Bozener Quarzporphyr").

The Sexten Conglomerate and Tarvis Breccia are overlain by Gröden Sandstone Fm, Bellerophon Fm., Werfen Fm. and some lower Mid Triassic formations. The entire depositional sequence shows onlapping toward the west.

The boundaries between Gröden Fm. and Bellerophon Fm. are significantly diachronous.

The basin development is characterized by transcurrent movements in the Lower and Middle Permian, and Mid Triassic (Venturini, 1983, and Brandner, 1984). Along the P/Tr interval predominates tectonic quiescence and a constant subsidence rate.

According to Farabegoli et al., 1986, the basal sequence can be subdivided into three tectonically controlled **sedimentary cycles** with members of sandstone, gypsum, dolomite and limestone. The cycles are of third-order ranging in thickness from 50 to 200 meters. However, a significant regression in the upper part of the Bellerophon Fm. (Tatarian?) could be attributed to a eustatic sea-level change, described by Haq et al., 1987.

* both visible along the highway between San Candido/Innichen and Padola

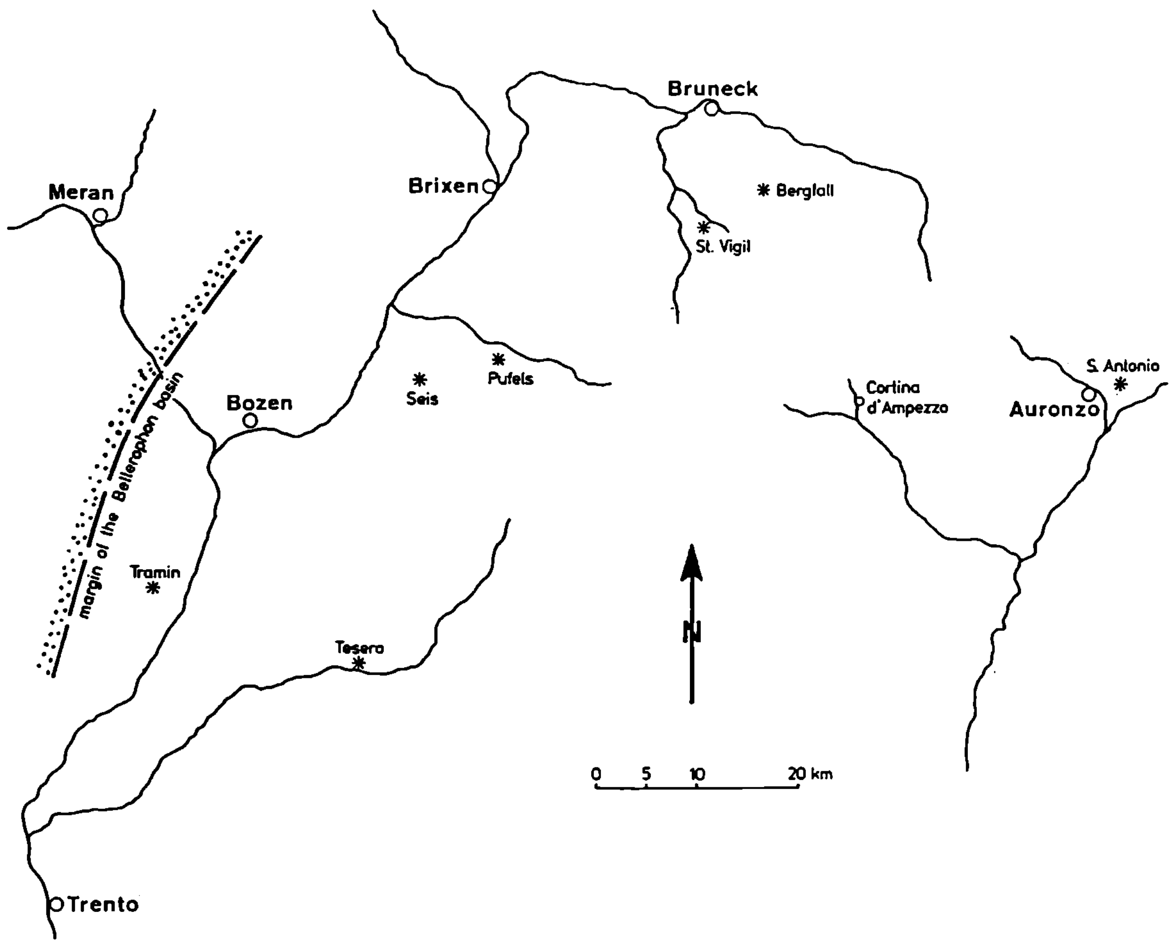

Fig. 1.
Map of distribution of P/Tr Boundary sections (for details compare fig. 2).

The only chronological datum available in the clastic sediments relates to the paleomagnetic Illawara event (Mauritsch & Becke, 1983).

These third-order cycles continue into the Werfen Fm., creating a sequence of stratigraphic members with an articulate alternation of carbonatic and terrigenous deposits.

The third-order cycles consist of minor **shallowing-up cycles** or **parasequences** (in the sense of van Wagoner et al.), a few meters thick and clearly recognizable in the upper Bellerophon beds. Broglio Loriga et al., 1986, describe the following lithofacies members:

- subtidal limestone units with dark gray and black packstones and wackstones with predominantly foraminifers, algae and skeletal fragments of bivalves, echinoderms etc. Sedimentary structures are destroyed by strong bioturbation.
- black marl-limestone alternations
- vuggy dolomite, gray with rootled beds (Skolithos-like burrows of Broglio Loriga et al.)

The shallowing-up cycles proceed well into the Werfen Fm. A striking decrease of biogenes and bioturbation, light-gray, well-washed oolithic grainstones, gray, silty marls and mudstones as well as a significant increase of tempestites: These factors contribute to basic alterations in the lithofacies.

In addition, cycles along the P/Tr boundary indicate a sharp **increase of amplitudes**. A detailed sequence stratigraphic analysis shows amplitudes of sea-level changes around 10 meters, with an increase from cycle A to cycle B (see fig. 2). The aggradational parasequences of the upper Bellerophon Fm. shift abruptly to retrogradational parasequences of the lower Werfen Fm.

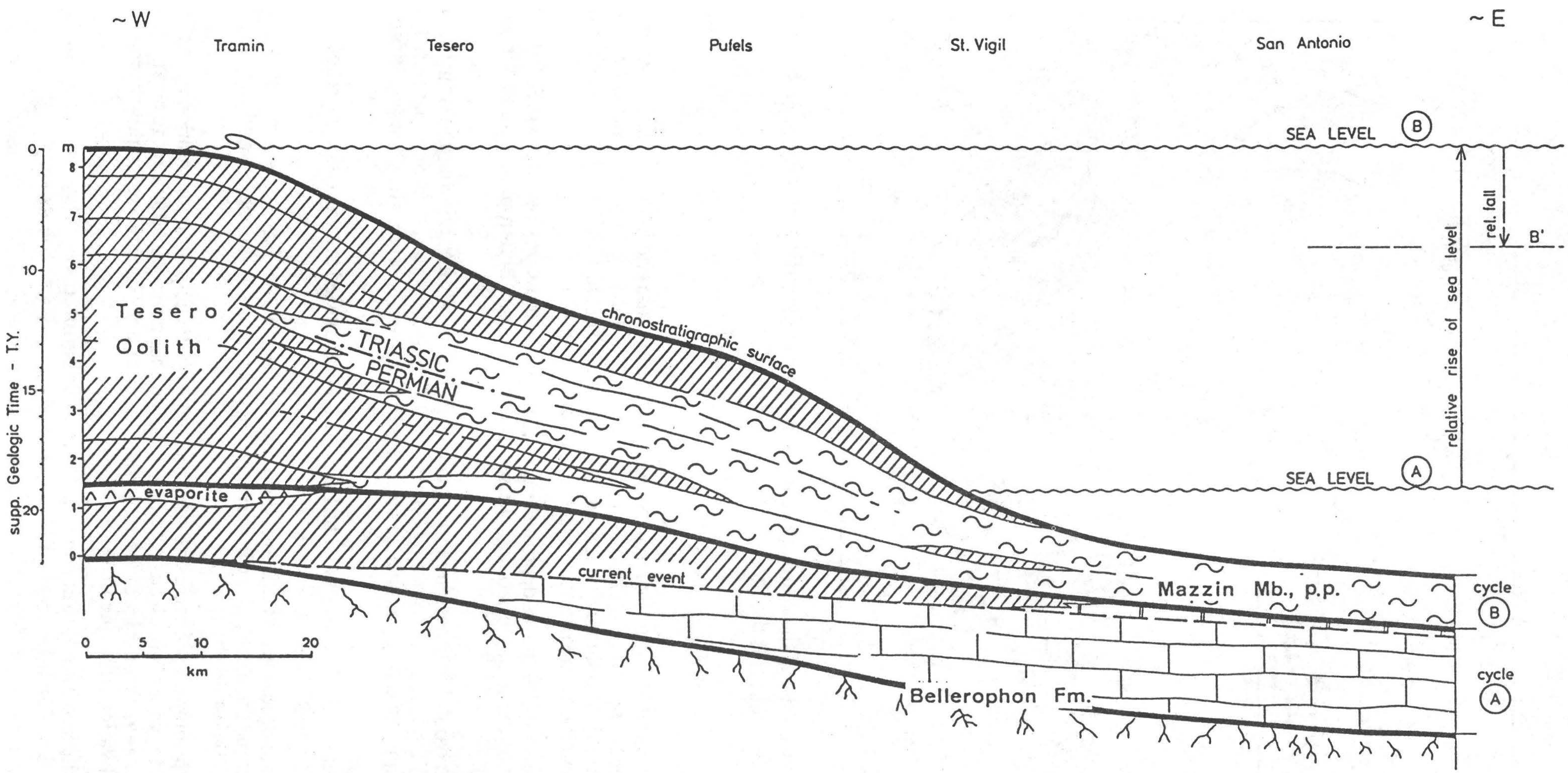

Fig. 2: Paleogeographic section at the end of cycle B, based on sequence-stratigraphic investigation. For geographical position of P/Tr sections see fig. 1

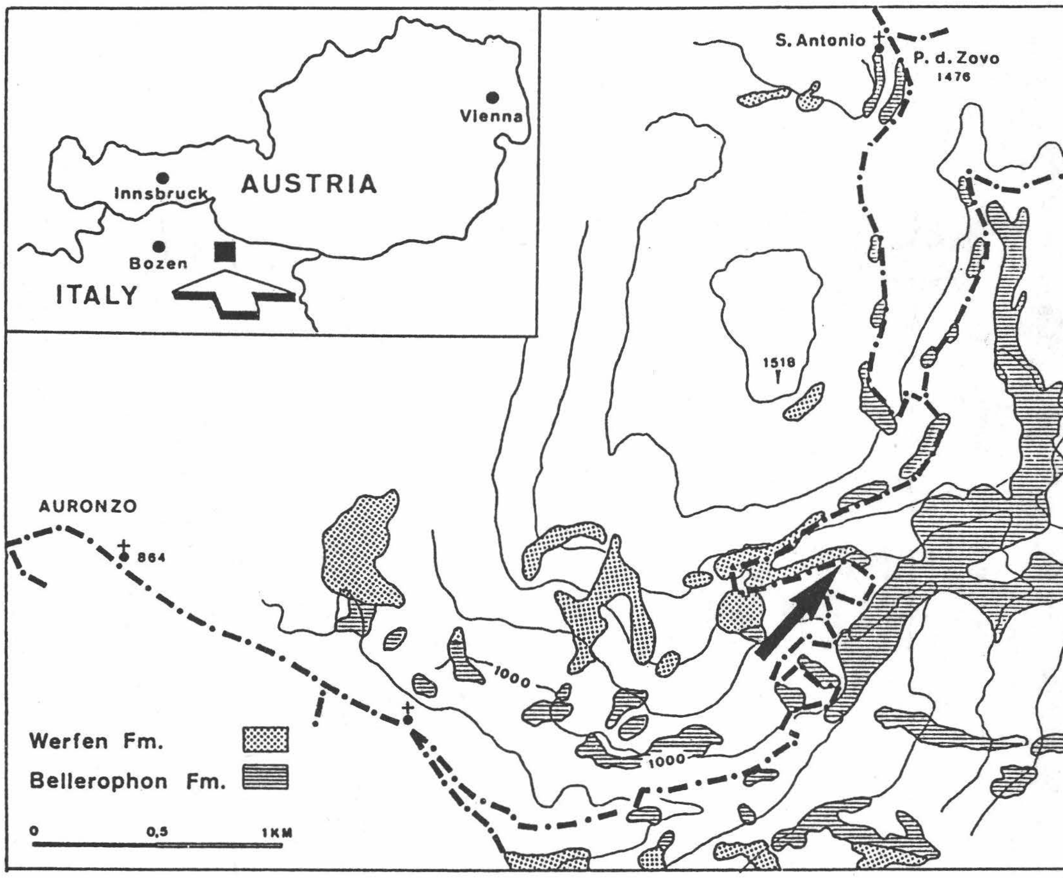

Fig. 3: Geological map of the Auronzo-San Antonio area (simplified after P. Casati et al., 1982). The arrow indicates the San Antonio P/Tr boundary section

Within cycle A there is a significant **growth of hydrodynamic energy** in the entire Dolomite region ("Current event", fig. 2). This causes an out-wash of the fossiliferous *Fusulina* packstones and sedimentation of oolithical grainstones, i.e. base of Tesero Horizon. The evaporites of the coastal facies in the west correspond to the regressive part of cycle A.

The mass of Tesero Oolith was deposited during the speedy transgression of cycle B. In the lower basin (Auronzo) the transgression comprises the switch from Bellerophon Fm. to Werfen Fm. (Mazzin Mb.).

Grainstones and oolithic limestone show growing influence of **meteoric diagenesis** in the coastal area. Oomoldic porosity, dolomitization and de-dolomitization are common features. Furthermore, the disappearance of stenohaline biogenes emphasizes the **strong fresh-water influx** in the Mazzin Sea.

Facies analyses conducted in continental P/Tr sediments have led to corresponding results (Krainer, 1987, Stingl, in press).

Following more or less arid conditions during the Upper Gröden Fm., a persistent hydrographic network has come into being in the Lower Alpine Buntsandstein. A concise stratigraphic correlation has yet to be established.

Estimates of the duration of cycles can be achieved with the help of sedimentation rates of carbonates in shallow water. This leads to the conclusion that a few 10 000 years formed one cycle. Thus, like so many other cycles of the geological record, our P/Tr cycles are within the range of the earth's orbital variation frequencies.

As shown in the San Antonio Section (fig. 4), **all P/Tr boundary events** occurred within the T-R cycles A and B within **a few tens of thousands of years**. These events are:

- the disappearance of numerous paleozoic organisms and a significant decrease of bioturbation,
- increase of hydrodynamic energy,
- increase of humidity
- shifts in $\delta^{13}C$ and $\delta^{34}S$

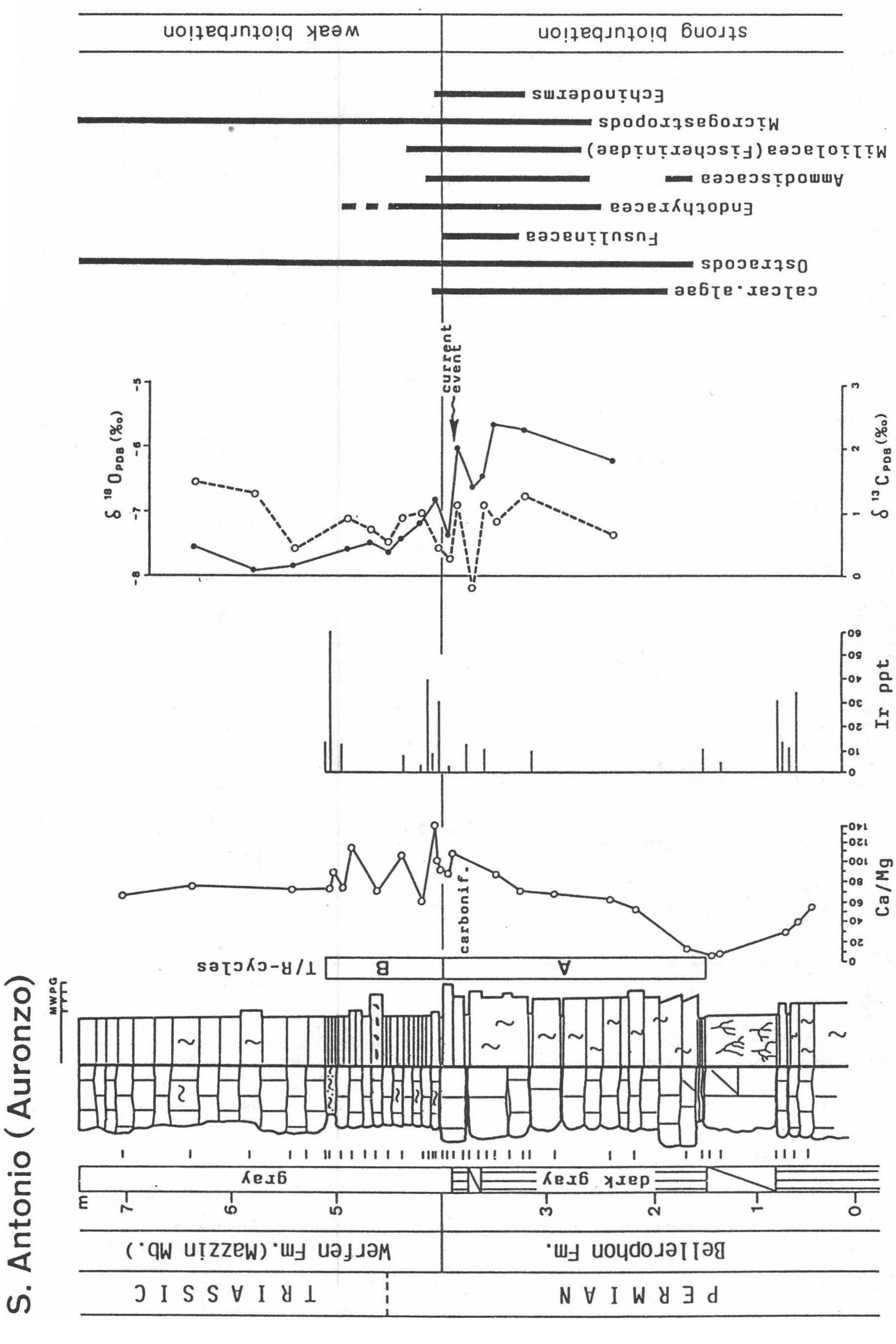

Fig. 4: San Antonio section. Ir-data: Nazarow, Moscow; $\delta^{13}C$, $\delta^{18}O$: Oberhänsli & Weissert, Zürich; micropaleontology: Resch, Innsbruck

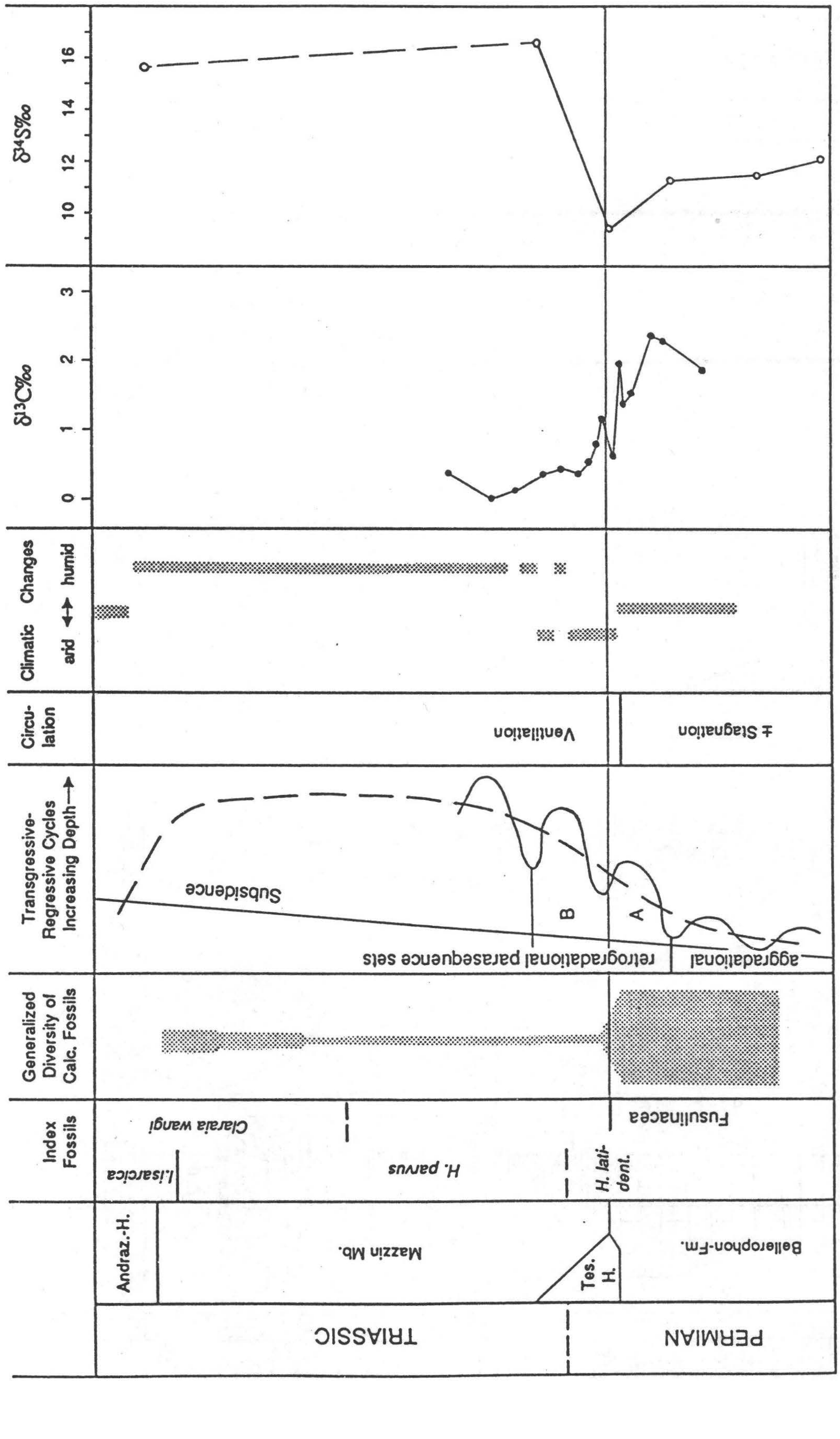

Fig. 5: Summary of stepwise events near the P/Tr boundary in the Dolomites

The **C-isotope** curve (analysts: Weissert & Oberhänsli, ETH Zürich) shows, within a generally negative trend, first drops still in the uppermost Bellerophon beds. Margaritz et al. in 1988 published a similar curve of the Tesero Section. Detailed sediment-petrographic investigation in the San Antonio Section show that the first $\delta^{13}C$ drops are correlated directly with grainstones and poorly-washed packstones of the "Current Event". There are two interpretations:

(1) the $\delta^{13}C$ drop was caused by ventilation of the Bellerophon and (?) Ocean Basin;
(2) the $\delta^{13}C$ drop was caused by meteoric diageneses in the grainstones.

The general depletion within several tens of thousands of years probably reflects a reduction in the transfer of organic matter from the oceanic to the sedimentary reservoir (Oberhänsli et al., in press).

Data on the **sulphur isotopes** of marine evaporites along the P/Tr boundary are rare (Holser & Margaritz, 1987). Figure 5 represents a sulphur isotope curve (analyst E. Pak, Inst. f. Radiumforschung u. Kernphysik, Vienna) based on marine evaporites along the rim of the Bellerophon and Werfen basin in the Western Dolomites. The known anti-correlation between $\delta^{13}C$ and $\delta^{34}S$ in the long-term (see Veizer et al., 1980) can be made evident there as a short-term event. The increase of sulphur isotope ratio takes place within cycle B and can be correlated to sea-level changes as well as to the ventilation- and climatic event.

There could be a link between biological, physical and chemical events in the step-by-step pattern and a **drastic rise in global surface temperatures.**

Loper et al. report in 1988 that massive effusions of CO_2 and sulphates occur mostly in hot-spot or kimberlitic volcanoes. Thus, the giant Siberian Trap is seen to have been the ultimate forcing factor. Its exact age is yet unknown. Ms. Dobruskina (oral com.) places it in the Upper Permian or Lower Triassic (see also Holser & Margaritz, 1987). Model simulations conducted by Barron & Washington, 1985, lead to the assumption that CO_2 warming (sea level rise by melting inland ice?) also intensified the hydrological cycle. This applies particularly to monsoonal circulation systems. Parrish et al. (1982) suggested a monsoonal system for the earliest Triassic Pangea.

Analyses proved that Brandner et al., 1986, quoted erronous **Ir-data** in the San Antonio Section (analyst Nazarow, Vernadsky Institute, Moscow). For correct data see fig. 4. There is no distinct impact related to Ir-peak, higher values are clearly correlated to clay intercalations.

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Magnetostratigraphy of the P/Tr Boundary near Passo San Antonio

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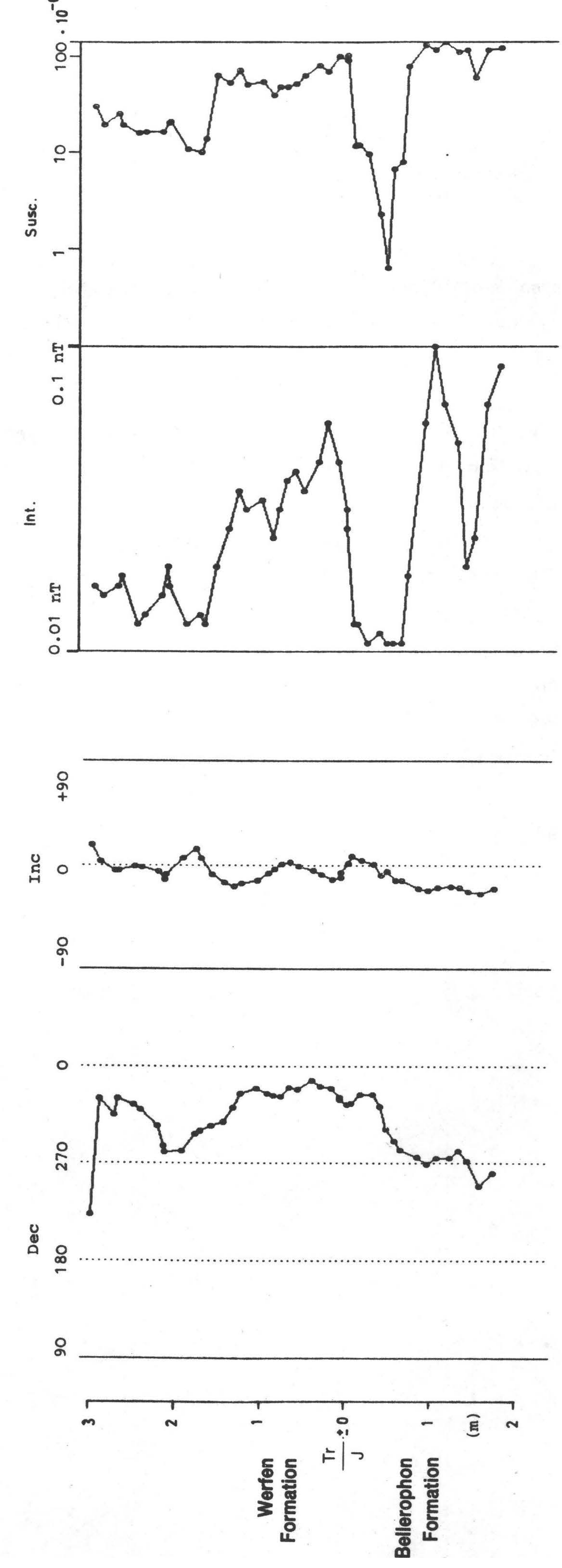
In the area of Passo San Antonio, near Auronzo, northern Italy, a magnetostratigraphy section ranging from Upper Permian to Lower Triassic was covered by 43 specimens. The distances were down to 0,10 m.

The aim of this investigation was to get information about the magnetic polarity pattern, especially within the range of the Permian/Triassic boundary. The demagnetization- and saturation experiments established magnetite and iron sulfide to be the main carrier minerals. In some samples a strong influence by iron-hydroxide was identified. NRM-intensity and susceptibility prove a strong lithological control of the magnetic properties. Above the section, a foldtest in the Triassic was tried and a clear negative result observed. As the anisotropy pattern shows random distribution of the axis of the anisotropy ellipsoid, a diagenetic magnetization direction has to be assumed. Geological evidences point to an early diagenetic process. The magnetic directions are supporting these evidences, as the paleo-inclinations are very shallow, swinging around the equator. The paleo-declinations show insignificant distributions. A polarity change near the P/Tr boundary was not found.

San Antonio - T 200 (5)



Excursion to the Shocked Quartzes of Köfels (Tyrol, Austria)

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H. STRADNER
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The village of Köfels is situated on the western slope of the Fundus mountain crest at an altitude of about 1400 m and is famous for the occurence of a foamy glassy rock called "Bimsstein" or pumice. For this rare type of rock, the new term of KÖFELSITE was created by F. E. SUESS in 1936. The area of the visible landslide deposits is about 11,5 square kilometers. ABELE in 1974 calculated the volume of the debris to be 2,1 cubic kilometers. Based upon its volume the landslide of Köfels is one of the largest of the Alps, and the largest involving crystalline rock. The age of the failure was determined by dating wood remnants in the gravel and landslide debris. The radiocarbon age is 8,710 $\pm$ 150 yrs B. P. according to MÜNNICH (1957). So this event took place in the Holocene, whereas most of the other big landslides in the Alps occurred in the late-glacial period.

The main Ötz Valley and its tributary, the Horlach Valley, have been blocked by the giant mass of landslide deposits. The classification as a landslide is undoubtful since a gallery was cut into the Taufenberg some 1,200 m above sea level in connection with a power scheme. The gallery showed that the whole barrier had resulted from a landslide because the boundary between severely shattered landslide debris and normal solid rock was clearly evident (HEUBERGER et al. 1984).

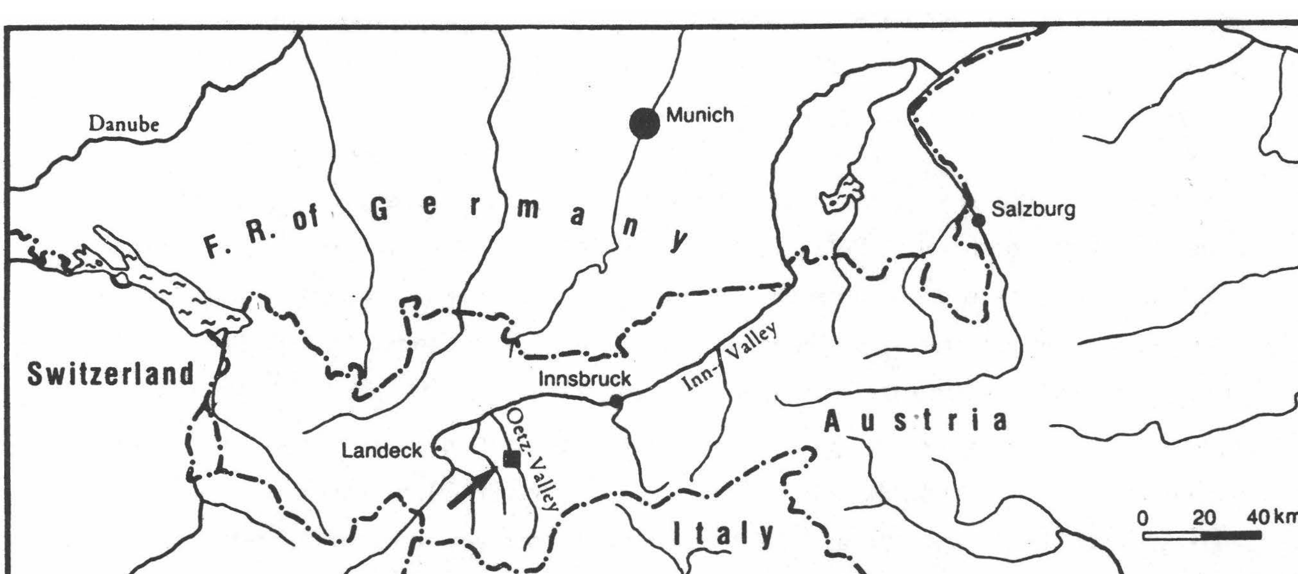

Fig. 1: Map showing the location of Köfels, Ötz Valley, Tyrol.

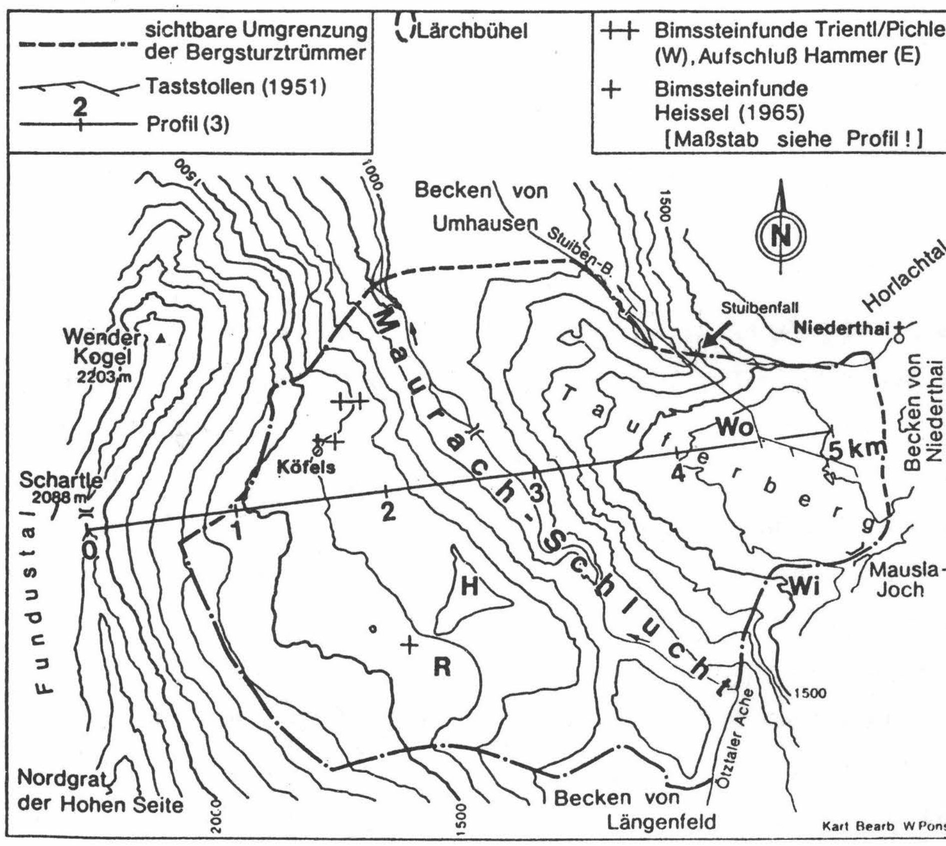

Fig. 2: Geographical sketch of the Köfels site.

The slipway of the landslide is visible over large areas on the eastern slope of the Funduns crest above Köfels. Directly above Köfels, these areas are inclined at 25 - 30°, while at other areas they exhibit gradients of up to 45°.

Köfels pumice or Köfelsite is a usually brown, though occasionally black, porous glass rock corresponding chemically to augengneiss and gneiss. Much of the famous pumice within the landslide masses was carried off as trophies by mineral collectors after PICHLER had published his results in 1863. So it is hard to find it in situ today.

The pumice originated through rapid heating, fusion, and quenching of the melt under surface conditions. PREUSS (1971, 1974) was the first to realize that the pumice, if not developed through volcanism or meteoritic impact, could have been generated by frictional heat at the base of the landslide. ERISMANN 1977 concluded that the energy produced was of the order of 1,65. 10^{16} joules. This is equivalent to the energy which would be produced by the impact of an iron meteorite of more than 85,000 tons (diameter about 30 meters) travelling at 20 km/sec (ERISMANN et al 1977). The whole process of sliding only took one minute, during which a velocity of up to 200 km/h (125 m. p. h.) was reached.

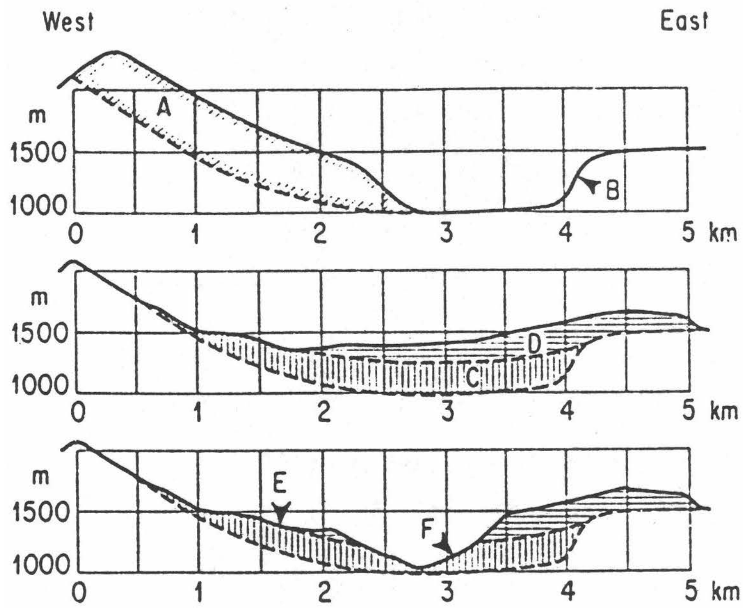

Fig. 3.
Example for the separation of the mass into two parts by collision with an obstacle: section of Köfels landslide (partly completed by estimation).
From top to bottom: Situation before landslide, immediately after landslide, at present.
A = rock in initial position; B = vertical lip; C = lower part; D = upper part; E = secondary gliding surface (where pumice stones are found); F = shattered rock in gorge retaining its original fabric.

The formation of "frictionite", a name introduced by ERISMANN 1977 for glassy rocks generated by large-landslides, is in no way related to the cause of the landslide: rather it is a result of the landslide. The existence of frictionite has produced no clue as to the cause, which triggered off the landslide.

Some evidence in favour of an impact as possible trigger force for initiating such a gigantic landslide is given by the presence of lechatelierite, feldspar glasses, maskelynite, diaplectic quartz and planar features in quartz, olivine and rare FeNi metal (GRATZ & KURAT, SURENIAN, this meeting). Up to present no larger lump of the presumed meteorite itself could be unearthed.

(In large parts excerpted from quoted literature.)

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