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LITHOSTRATIGRAPHY AND SEDIMENTOLOGY ACROSS THE CRETACEOUS/TERTIARY BOUNDARY IN THE FLYSCHGOSAU (EASTERN ALPS, AUSTRIA)

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ABSTRACT

Detailed lithological profiles across the Cretaceous/Tertiary boundary (K/T) in the flyschoid Gosau Formation at Gosau (Elendgraben) and Gams (Knappengraben) are presented. The revised low sediment accumulation rates in the lowermost Danian correspond to those calculated by Smit & Hertogen (1980) for the Caravaca section. The estimated longer time-span for the deposition of the K/T boundary layers of 6-11 ka seems to be more realistic. The sediment at the K/T in the Gosau area was deposited under reducing conditions (Reissner *et al.* 1985). Peak levels of the siderophile elements do not coincide at Gosau and Gams. A diachronism of events is therefore assumed. The gradual decline of $CaCO_3$ and some major element oxides beginning 4 cm below the K/T boundary and also a 1 mm thin yellow clay layer 10 mm underneath the boundary clay at Gams suggest multiple events and could be the result of a period of increased volcanism.

Keywords: Cretaceous/Tertiary boundary, Gosau Formation, Northern Calcareous Alps, turbidite sequences.

RESUMEN

Se presentan dos secciones litológicas detalladas del límite Cretácico-Tertiario (K/T) de la Formación Gosau, de naturaleza flyschoide, en Gosau (Elendgraben) y Gams (Knappengraben). Los índices de acumulación sedimentaria revisados en el Daniense basal se corresponden con los calculados por Smit & Hertogen (1980) en el corte de Caravaca. Parece plausible el lapso de hasta 6-11 ka calculado para la sedimentación de la capa del límite K/T. Este sedimento, en el área de Gosau, fue depositado en un ambiente reductor (Reissner *et al.*, 1985). Los niveles de anomalías de los elementos sideróﬁlos no coinciden en Gosau y Gams, por lo que se asume un diacronismo entre los acontecimientos respectivos. El declive gradual del $CaCO_3$ y de algunos óxidos principales 4 cm bajo el límite K/T, así como la presencia de un nivel de arcilla amarilla oscura, de 1 mm de grosor, a 10 mm bajo las arcillas del límite K/T en Gams, podrían ser el resultado de un período de mayor volcanismo.

Palabras clave: Límite Cretácico-Tertiario, Formación Gosau, Alpes Calcáreos del Norte, sucesiones turbidíticas.

INTRODUCTION

Lithostratigraphical columns of the K/T transition in the areas of Gosau and Gams (Northern Calcareous Alps) are presented together with correctional remarks and new interpretations. The logs of the stratigraphic sequences will be published in full length in the Abhandlungen of the Austrian Geological Survey (Stradner, ed., in preparation).

The localities of supposed and proved K/T transitions are given in Fig. 1 within their geologic unit together with paleoflow directions during Maastrichtian and Paleocene. Attempts to fix the K/T boundary in the Eastern Alps with micropaleontological biostratigraphy began in the fifties. Ganns & Knipscheer (1954), Küpper (1956) and Wille-Janoschek (1966) could not produce fossil evidence for the Danian. Since then a sedimentary contact between Late Maastrichtian and Early Paleocene was denied for the Gosau "Basin".

Wicher & Bettenstaedt (1956) located a section in the Gosau Formation of the eastern Gams area. After resampling, this exposure turned out to be of Paleocene age (NP 2 Zone, det. H. Stradner).

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Oberhauser (1963) found K/T transition sections in the Gosau areas of Muttekopf (Rotkopf), Grünbach-Neue Welt (Zweiersdorf) and in the Giesshübl Beds (Sparbach). The Rotkopf/Seebrig-Karle section on a high crest of the Upper Sediment Complex in the Muttekopf-Gosau, Tyrol, exposes sheared marls and a calcite layer at the K/T boundary. In Sparbach, Lower Austria, two localities (Schacherweg and Saubachgraben) could be narrowed by means of nannofossil determination. At this locality several cm of a sheared yellow and blue-grey clay on top of a redbrown calcareous marl mark the K/T boundary.

In the Helvetic-Zone north of Salzburg near Waidach Gohrbandt (1963) traced Maastrichtian and Paleocene marls of the Oiching Beds over several small creeks. Resampling of these outcrops led to the discovery of the NP 1 Zone therein and of a limonitic basal Danian layer upon mylonitized darkgrey Maastrichtian marls.

The first K/T boundary clay in the Gosau Formation of the Eastern Alps was located by Herm in the Wasserfallgraben torrent of the Lattengebirge-Gosau, Bavaria (Herm *et al.* 1981 a, b). Perch-Nielsen *et al.* (1982) reported on biostratigraphical results and on geochemical anomalies. Rast & Graup (1985) measured a bulk iridium value of 4-5 ppb.

A combination of geological mapping and comparison of detailed sedimentological columns in cooperation with nannofloral analyses by H. Stradner enabled the author to find a K/T boundary clay at three Austrian sections: Elendgraben torrent (Abtenau, Salzburg), Knappengraben torrent (Gams, Styria) and Rotwandgraben torrent (Gosau, Upper Austria).

GEOLOGICAL SITUATION

K/T boundary sections that contain a "rusty layer" and an Ir anomaly have been found in the Eastern Alps only within the flyschoid Upper Campanian - Lower Eocene Upper Complex of the Gosau Beds. These sections are located in areas which were deposited above the calcite compensation level (CCD) in a more southern paleogeographical position –like the Gosau areas of Lattengebirge, Gosau and Gams (Hesse & Butt, 1976).

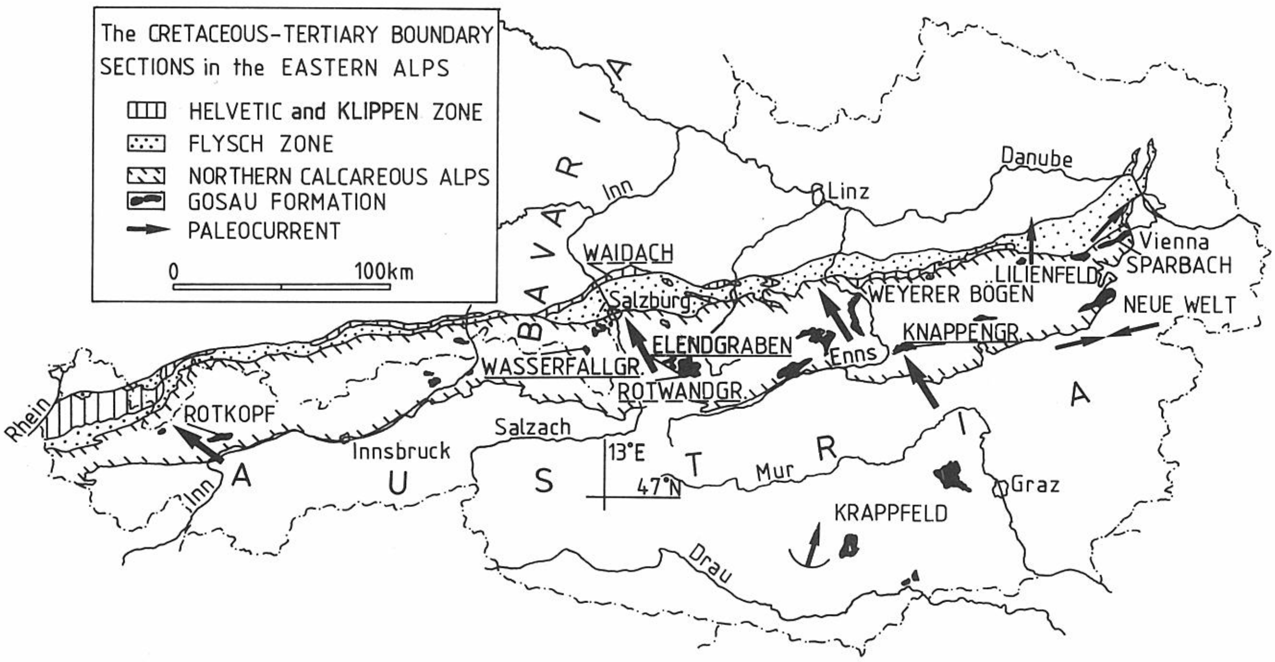


Figure 1. Location of K/T boundary sections in the Eastern Alps within their geologic unit. Localities with proved Ir-anomalies underlined (strongly assumed = dashed). Paleocurrent in northern alpine areas of the Gosau Group during Maastrichtian and Early Paleocene, in central alpine areas from Campanian to Early Maastrichtian. Data in the Gosau areas Weyerer Bögen, Lilienfeld and Neue Welt from Faupl *et al.* (1987), in the Krappfeld area from van Hinte (1963).

The Upper Complex of the Gosau Group at Gosau/Abtenau is composed of the Ressen-, Nierntal-, and Zwieselalm Formations. This succession is best exposed in the Elendgraben, which is a steep torrent south of the village of Russbach. The K/T boundary is situated north of the Zwieselalm (pasture ground) at an altitude of 1245 m within the basal part of the Zwieselalm Formation.

Eastward of the village of Gams, Styria, the Gamsbach torrent crosses the K/T transition several times. The Knappengraben section is exposed east of the Klausknechtkeusche (farm) at an altitude of 795 m, mainly along a roadcut of a forest road from Krautgraben Valley. The K/T boundary is situated within the Nierntal Formation –on the last (very detailed) geological map of that area, surveyed by Kollmann (1964), a little to the north of a narrow microfaunal zone "Danian and Paleocene I".

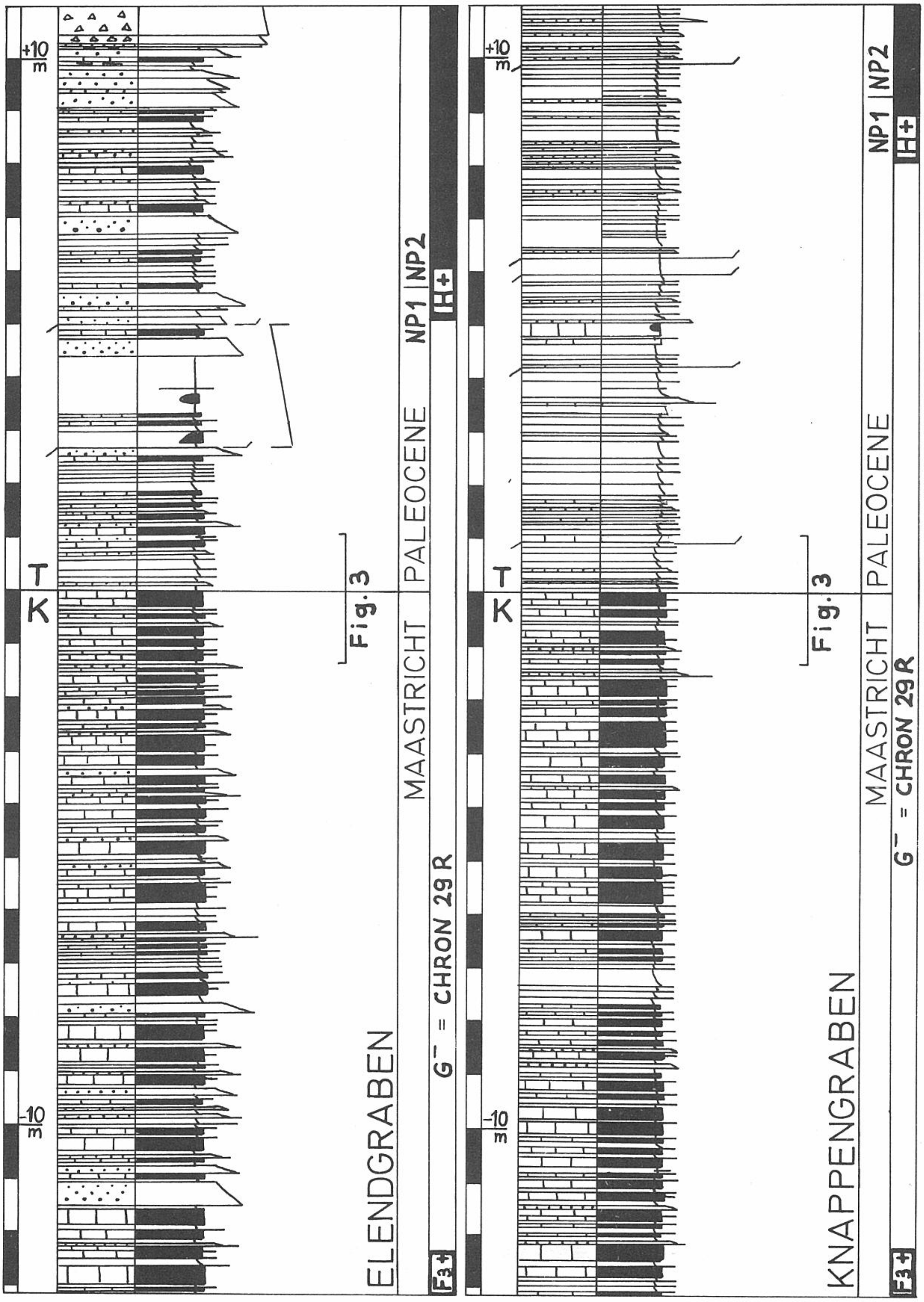
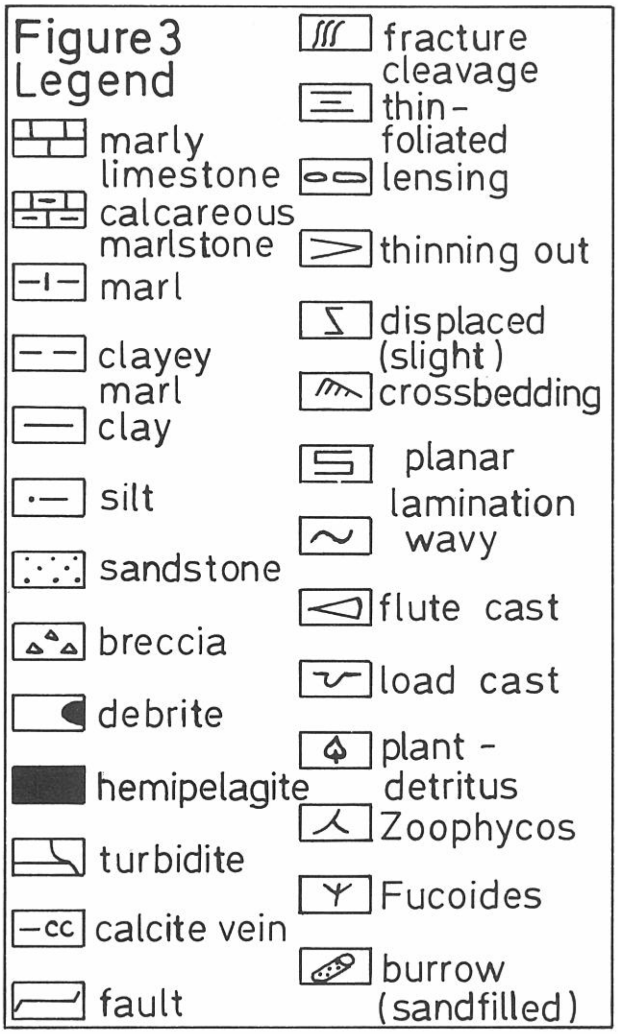


Figure 2. Lithological and sedimentological columns extending over 24 m across the K/T boundary in the Flyschgosau occurrences of Gosau (Elendgraben) and Gams (Knappengraben). Magnetostratigraphy from Mauritsch (1986) and Mauritsch & Zeissl (1987), nannoplankton zonation by Stradner (1985, 1986, pers. comm.). Legend as Fig. 3, simplified.



STRATIGRAPHY ACROSS THE K/T TRANSITION IN THE GOSAU FORMATION OF GOSAU AND GAMS

The lower part of the Zwieselalm Formation in the Elendgraben section consists of a turbidite sequence of graded breccias and sandstones with pelitic intervals for which the Bouma-cycle is applicable. Grey hemipelagic marly limestones and some chaotic deposits with synsedimentary slump folds are intercalated. Nine meters above the K/T (in the NP 2 zone) this succession of interchannel deposits passes into thickbedded and coarse grained breccias and sandstones which can be interpreted as channel-fill deposits (Fig. 2, left column). They contain phyllitic rock fragments, quartz-pebbles and bioclasts of corals and red algae.

The slope facies of the Nierntal Formation in the Knappengraben section is characterized by hemipelagic calcareous marls with intercalated turbidites and rare mass-flow deposits. During the Maastrichtian thin turbidite cycles alternate with grey hemipelagic calcareous marls. In the Paleocene thin-bedded turbidites –consisting of fine grained sandstones and grey to reddish-brown sandy marls– are disrupted by chaotic mud-flow deposits which include Maastrichtian marly limestone-olistholites (Fig. 2, right column). Breccias and sandy marls of the Zwieselalm Formation (NP 3-NP 9 zone, det. H. Stradner) occur south of the Gamsbach torrent.

The uppermost Maastrichtian calcareous beds

In the Elendgraben and Knappengraben sections the K/T boundary is marked by a lithological change: The boundary layers (clay) end a sequence of Late Maastrichtian micritic marly limestones (Elendgraben or calcareous marls (Knappengraben). Only the uppermost bed is abundant in trace fossils (*Zoophycos, Chondrites*) and has a slight wavy top surface. After a slow gradual rise there is a relative sharp but still gradual decline of the $CaCO_3$ content within the uppermost 4 cm of the marly limestone or calcareous marl just below the boundary clay (Fig. 3) –similar to the analyses of Strong *et al.* (1987). A decrease of some major element oxides (SiO_2, TiO_2, Fe_2O_3, Na_2O) was also analysed in this bed (Preisinger *et al.* 1986, Fig. 4). Iron oxide coating of joints, crack-fills and concretions were observed below the boundary clay. New observations at both localities point to an "event with a warning signal": In the Elendgraben section the uppermost 9-11 mm of the light grey marly limestone turn to greenish-grey colour and in the Knappengraben section a yellow-light brown layer of 1-2 mm appears about 10 mm below the boundary clay–probably a precursor of the main K/T event.

The boundary clay layers

The basal K/T boundary layer is a white-grey soft marly clay (2-6 mm at Elendgraben, 3-7 mm at Knappengraben) that contains well preserved micro- and nannofossils and is enriched in smectites (Fig. 3). This layer contains significant higher values of Ir, Cr, Co, Ni, MgO, Al_2O_3 and TiO_2 but not an unusual depletion of rare earth elements (Preisinger *et al.* 1986, Fig. 4b).

The grey layer passes into a thin porous light-yellow clay of 2-7mm at Knappengraben (laterally discontinous in this section) or into a dark yellow orange clay of 2-4 mm thickness at Elendgraben ("rusty layer"). Its darker colour therein is concentrated in the upper part of the layer whereas the lower one contains rust-brown spots. The rusty layer has a maximum value of expandable clay minerals and of elemental and organic carbon, and contains pyrite octahedrons. The highest Ir content within this layer is controversial (refer to iridium distribution). Some Cretaceous nannofossils are present which probably are relic species.

Generally separated from the subjacent bed by a thin layer of calcite plates, up to 8 mm, a soft micaceous dark grey kaolinitic clay with coarser pyrite crystals marks the top of the boundary layers. Its thickness ranges 3-6 mm (rarely 1 mm) at Elendgraben and 10-17 mm at Knappengraben. Further upward

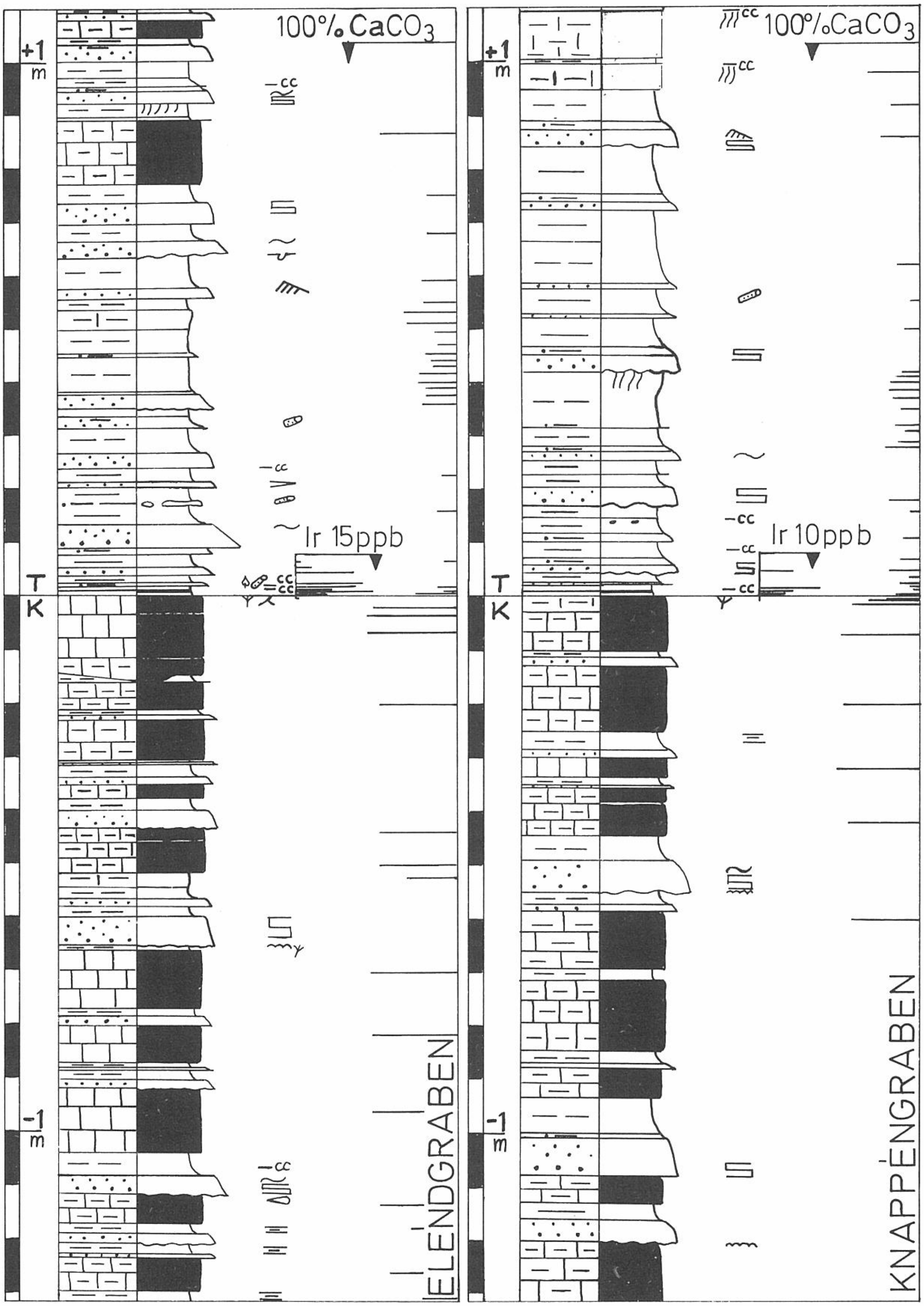


Figure 3. Enlarged sections from Fig. 2 extending over 2.4 m across the K/T boundary. Detailed sedimentological columns comparing turbidites and hemipelagites deposited before and after the K/T boundary at Gosau and Gams. Determination of Ir by Grass, of $CaCO_3$ by Frey, Lahodynsky and Zobetz (from Stradner, ed., in preparation). Interpretation of the marls in the Tertiary part of the Knappengraben section as hemipelagites is uncertain.

follows a turbidite sequence of very fine micaceous sandstones containing plant detritus and grey-brown marls.

Unconformities near the K/T boundary

Shear zones, with or without calcite plate, were observed on several levels of the stratigraphic sequence close to the K/T boundary. In both sections (Elendgraben and Knappengraben) a layer of calcite plates occurs immediately above the rusty layer. Also a mylonitized clay (dark brown in the Knappengraben section) with thin calcite plates and small slickensides is situated about 35 mm above the K/T boundary, below the second Danian sandstone layer. Another mylonitized yellow clay with calcite plates occurs 150-180 mm above the K/T boundary in the Knappengraben section, below a 40 mm thick sandstone layer.

In a Gamsbach section, less than 1 km to the west, a calcite layer and a white and yellow clay is intercalated between Maastrichtian marlstones and clayey marls of the NP 2 zone. Further westward breccias, sandstones and marls of the NP 3-5 zones (det. H. Stradner) superimpose Maastrichtian limey marlstones.

INTERPRETATION OF THE STRATIGRAPHICAL COLUMNS

Apart from the fact that flyschoid sediments do not provide the best sections for event-stratigraphy, the K/T boundary sections in the Gosau and Gams areas cannot be assessed as an evidence for an impact scenario. In contrast to Hallam's (1987) assumption, the following reasons stand against it.

Estimation of sedimentary rates

The estimation of sedimentary rates depends on the duration of the chron 29R = G^- zone (440, 600 or 830 ka?) and the absolute time scale used in the calculation. Therefore the age of the K/T bounary (range 63-67 Ma) and her position within chron 29R is of importance. Cox (in Harland *et al.*, 1982) suggested an age of 65 Ma for the K/T boundary which is used in this recalculation. Different paleomagnetic and radiometric time scales were mixed in the paper of our working group (Preisinger *et al.*, 1986).

Because of a gap of 30 ka in this paper between text on p.2 (470 ka) and Fig. 2 (500 ka) for the duration of the G^- zone the very high time resolution rate of 0.67 years for the duration of the K/T event at exactly 66.7 Ma ago is not justified.

The time structure calculation is also wrong because turbidites are not restricted to the sandstone layers but have a finer grained clayey or marly upper division. Only the calcareous marls and marly limestones can be interpreted as hemipelagites, which were deposited in an environment above the CCD. By adding the thicknesses of hemipelagic layers, and calculating with different polarity zone durations, one obtains different accumulation rates for the Cretaceous and the Tertiary part of the G^- zone (Fig. 4).

		La Brecque *et al.* (1977)	Hardenbol & Berggren (1978)	Cox (1982)
Elendgraben	Tertiary	0.51	0.24	0.29
	Cretaceous	1.83	1.5	1.72
Knappengraben	Cretaceous	1.72	1.4	1.62

Figure 4. Approximate accumulation rates for hemipelagites across the K/T boundary in the Flyschgosau (in cm/ka) calculated from different estimations of the polarity zone chron 29R.

From the estimated accumulation rates, a duration of 3-4 ka can be roughly assumed for the deposition of the characteristic grey and yellow boundary couple. 6-11 ka would be realistic values including the dark kaolinitic clay below the first sandy layer. Smit & Hertogen (1980) calculated similar rates for the Caravaca section. The result of Smit (1982) was 17 ka for the deposition of the whole 12 cm thick clay. Thierstein (1982) estimated 23 ka for deposition of the boundary clay at Gubbio.

On the other hand there is a higher terrigenous influx during the Tertiary part of the G^- zone (especially in the Knappengraben section). *Globigerina eugubina* Luterbacher & Premoli-Silva (det. F. Rögl) appears first at 0.78 m (Elendgraben) and at 0.95 m (Knappengraben) above the K/T boundary, approximately 25-45 ka after deposition of the boundary layers (using either the scale of La Breque, 1977 or Cox, 1982). This occurrence coincides with the first hemipelagic layer above the boundary clay in the Elendgraben section.

Thin-bedded turbidites

In both K/T sections the clay beds above the boundary layers are not a bulk of hemipelagic layers (as in Preisinger *et al.*, 1986; Fig. 2 —in reference to the Elendgraben section), but comprise an alternation of fine grained sandstone— and claystone layers which can be interpreted as very thin-bedded turbidites. The first sandy layer above the boundary clay is a "sandy silt" and the second one a "silty sand" (according to the size of the quartz grains in the sand-silt-clay triangle).

Very thin silt layers within some marls may not originate from several different turbidite cycles but develope in a cohesive low concentration - flow type described by Postma (1986): The turbidity current will differ from the Bouma-sequence from the point where a mixture of very fine sand, silt and clay terminates the distribution-grading due to equilibrium of tangential shear stress and yield strength of the plastic sediment. Distinct laminae of segregated clay and silt particles in the upper part of the Bouma-sequence may be caused alternatively by flocculation of clay in muddy suspensions.

Debrites

An impact of an asteroid should have triggered large scale earthquakes and tsunamis which on their part induced mass movements on submarine slopes: Yet these are missing in the sedimentary record below the geochemical anomaly. Slumping and chaotic debris-flows occur in the Gosau and Gams sections but cannot be tied to a K/T boundary event because of their deposition far below and above the K/T boundary.

A remarkable olisthostrome, 0.2-1.5 m thick, is exposed 4.2 m above the K/T boundary in the Knappengraben section (besides other thin chaotic layers) which contains clasts of Maastrichtian marly limestone and eroded clasts of a rusty layer within a Danian claystone matrix. These debrites above the K/T boundary seem to correspond to a culmination of slumping and turbidite activities shortly after the K/T boundary in the Scaglia Rossa (Chan *et al.*, 1985).

Evidence for diagenetic effects

A narrow spaced slaty cleavage proves a relative high diagenetic overprint of the turbidites in the Muttekopf - Gosau. A weaker slaty cleavage can be observed in the Campanian, Maastrichtian and Paleocene marls of the Gosau area. This is in contrast to an earlier statement by Stradner *et al.*, 1985, wherein the turbiditic sediments are supposed to show no signs of diagenetic changes. An s-shaped fracture cleavage and calcite veins (high and low dipping) are additional observations in the claystones above the K/T boundary at Gosau and Gams.

One may further assume that Ca-smectite and montmorillonite represent the diagenetical alteration product of volcanic ash beds.

Iridium distribution

Although the distribution of Ir shows a relative sharp rise to a maximum value followed by a gradual diminution this curve cannot be best interpreted as due to an impact. In the described turbiditic sections, deposited at a very low sedimentation rate, even a careful cm by cm sampling is not careful enough - especially when the layers reach a thickness of only a few mm. Besides they are inhomogenous, divided into hardly recognizable sublayers, bioturbated, thin out or lens out. Considering these attributes, the K/T boundary layers in the Gosau sections should be resampled and reanalysed in the careful manner described by Hansen (1987).

In the Elendgraben section Ir (maximum value 14.5 ppb after Preisinger *et al.*, 1986) and Cr reach their peak values within the rusty layer. In the Knappengraben section an Ir value of less than 7 ppb was measured within the yellow boundary clay (Stradner *et al.*, 1987) and an Ir peak of 11.4 ppb just above this layer (det. F. Grass 1987, reported by A. Preisinger during the K/T excursion of the Austrian Geological Society).

A second Ir peak above the boundary clay (Elendgraben: 12 ppb, Knappengraben: 9 ppb; det. F. Grass) is not the result of a late fallout within hemipelagic boundary layers (Preisinger *et al.*, 1986) but an enrichment within a turbiditic sandstone bed. A different event cannot be excluded as a cause of that peak.

In the Knappengraben section very thin yellow clay layers were observed within the brownish marls above the K/T but also within the Cretaceous calcareous marls, even few mm below the K/T boundary, which may indicate multiple metal enrichment.

Several other yellow clay layers within the two sections (and in other outcrops of Maastrichtian and Paleocene sediments in both areas) should be analysed too. Some of them occur near the base of sandy layers and are subsequently followed by a series of red-brown marls.

Winkler *et al.* (1985) analysed many Bentonite beds and ferro-manganiferous layers in the Swiss flysches. Some of these beds –interpreted as derived from volcanic sources– have the same Cr and Fe values as the rusty boundary clay at Gosau. A high resolution Ir determination was not carried out yet (U. Krähenbühl, 1987, personal communication).

Diachronous K/T boundary event

Hansen *et al.* (1986) found two distinct geochemical horizons (Ir peak $\neq$ ^{13}C anomaly) at the Danish sites which indicate diachronous extinctions. In the Elendgraben section Cr and Ir peaks coincide with the rusty layer whereas Co and Ni have their peak values in the layers below and above. Hansen (1987) found similar distributions of siderophile elements and a strong correlation of Cr and Ir at Stevns Klint, but in contrast to the Elendgraben section the Ir and Cr peaks are situated above the rusty layer.

In some other K/T boundary sections the main Ir peak levels also do not correspond to a rusty layer: The Ir peaks at the Raton Basin localities occur up to several cm below and above the K/T kaolinitic clay within carbonaceous shales and coal beds (Gilmore *et al.*, 1984; Fig. 2). In the Knappengraben section the rusty layer contains a Cr peak but the main Ir peak corresponds to the layer above. A Cr peak before the Ir (and an Ir doublepeak) is suggested a Flaxbourne River/New Zealand (Strong *et al.*, 1987; Fig. 3). The Knappengraben section might contain an Ir double-peak too but the suspicious layer below the boundary clay was not analysed yet.

Because the boundary layers may have been deposited in small depressions (Schmitz, 1985) or wedge out laterally due to gravitational gliding along this lithologic unconformity (as can be observed at Gams) the top surface of the Maastrichtian calcareous marls or marly limestones could be defined as the K/T boundary rather than an imaginary geochemical boundary in the middle of the rusty layer. In the Elendgraben section an Ir peak position just in the middle of the rusty layer was only assumed but not measured.

ALTERNATIVE EXPLANATIONS

Interpretation of stable isotope stratigraphy

Alvarez *et al.* (1980) postulated an impact of an asteroid at the K/T boundary that caused a suppression of photosynthesis. As a result the collapse of food chains led to mass extinctions. A sudden decrease of carbon 13 directly above the K/T boundary at the El Kef section (Perch-Nielsen *et al.*, 1982; Fig. 6) was assumed as a direct consequence of a reduced photosynthesis. But in general $\delta\ ^{13}C$ values begin a gradual decrease within the latest Maastrichtian that continues across the K/T boundary (Magaritz *et al.*, 1985; Figs. 2 & 3). Significant environmental changes before the boundary event are therefore suggested.

$\delta\ ^{18}O$ curves are highly controversial and possibly diachronous. Hsü *et al.* (1982) proposed a temperature increase above the K/T boundary due to a greenhouse effect which took place after a longer period of cooling represented by the boundary clay. In many sections $\delta\ ^{18}O$ records exhibit a gradual cooling prior to the K/T boundary and a subsequent temperature increase, still beginning below the boundary and continuing across the boundary (Perch-Nielsen *et al.*, 1982, Figs. 6 & 13; Hamilton, 1984, Fig. 2; Magaritz *et al.*, 1985, Figs. 3 & 4).

After Perch-Nielsen *et al.* (1982) an overall cooling in the Early Paleocene is recorded in the European sections probably related to fluctuations in surface circulation patterns. A statement of Pollack *et al.* (1976) might explain the measured drop in paleotemperature: the integrated effect over all stages following a volcanic eruption is a net cooling caused by small sized dust and sulfuric acid aerosol particles.

Enrichment of chalcophile and siderophile elements

Brooks *et al.* (1985) suggested precipitation of arsenic and other chalcophiles from sea water under very reducing conditions. Schmitz (1985) explained enrichment of chalcophiles and siderophiles in the Danish K/T sections at a redoxcline during 5 ka. Dissolved detritus (from volcanism) in the underlying chalk was suggested as a source for the metals. After Bowles (1986) platinum group elements can enter into solution at ground water temperature and high chloride concentrations under acid conditions. Rowell *et al.* (1986) studied a hydrothermal Cu-Ni sulfide occurrence wherein chalcopyrite comprises 55 % of the total sulfide mineralization and Ir is concentrated up to 28 ppb.

Hansen *et al.* (1986) proved that the Danian fish clay did not originate from dissolution of a chalk deposit. A correlation of iridum with non carbonate carbon was also analysed in the Elendgraben section (Preisinger *et al.*, 1986; Fig. 4).

Shocked quartz grains, iridium and volcanism

Some of the observed planar features in quartz grains at Gosau (Preisinger *et al.*, 1986; Fig. 5a) could be tectonically derived lamellae too. Because of microstructures and textures indicative of shock stress found in Toba ignimbrites (Carter *et al.*, 1986) and Ir concentrations reported from Kilauea airborne particles (Zoller *et al.*, 1983) eruptive volcanism is strongly suggested as a possible source of the metals. Hildebrand *et al.* (1986) favoured an impact triggered volcanism, but peak levels of Co, Ni, As and Sb before the Ir anomaly make it difficult to explain volcanism as a cause of an impact event. As and Sb suggest a mantle rather than meteoritic origin (Officer *et al.*, 1985).

Recent studies of small volcanic particles (Wohletz *et al.*, 1984) showed the presence of metallic oxide and sulfide phases in spherical volcanic ash particles formed in hydrovolcanic explosions which occur with both silicic and basaltic magmas. Their eruption plumes may exceed 50 km. Basaltic magmas may contain a distinct phase of Fe, Ni, Cr, Ti, Zn, Cu oxides prior to eruption.

The problem remains how Ir is transported. Zoller *et al.* (1983) proposed Ir transfer as a fluoride (IrF_6) or vapor transport as a chloride, Wood (1987) suggested chloroxy –carbonyl– and sulfur compounds.

CONCLUSION

Aftereffects of an hypothetical sudden event (earthquake, tsunami) have been presumed previously by Eder *et al.* (1987), based on the Elendgraben data, but there is no evidence for chaotic mass-flow deposits in the sedimentary record immediately below the K/T boundary layers. Additionally, the calculation of the size of the supposed incoming meteorite form the amount of Ir in the sediment does not consider that siderophile and chalcophile elements may be enriched in the surface and in rims of the hypothetical body (Grossman & Wasson, 1987). Therefore the estimated meteorite size must have been of an enormous volume to fit the calculations. This stands in contrast to an assumed reduced size and to smaller effects by the impact proponents (Bray, 1985).

The selective extinctions at the K/T boundary, e.g. in the Lattengebirge Gosau (Perch-Nielsen *et al.*, 1982) the gradual decline of the species stock of ammonites during the Maastrichtian of the Krappfeld Gosau (Thiedig & Wiedmann, 1976), the decrease of $CaCO_3$ (this paper, Fig. 3) and of some major element oxides (Preisinger *et al.*, 1986; Fig. 4) before the K/T boundary and different peak positions of Ir anomalies at below and above a boundary clay (Gilmore *et al.*, 1984, Hansen, 1987, and this paper), together with probable multiple Ir enrichments (Strong *et al.*, 1987), suggest a combination of diachronous events.

Close up field observations and analytical results are more in accordance with a series of events than with a sudden single impact. Because of the gradual changes below the K/T boundary a period of intense eruptive volcanism (Courtillot *et al.*, 1986, Officer *et al.*, 1987), possibly beginning several ka before the K/T boundary, seems to be a very probable explanation for the observed phenomena.

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