The Grabenbach Formation (Gosau Group, Santonian – Lower Campanian) in the Lattengebirge (Germany): lithostratigraphy, biostratigraphy and strontium isotope stratigraphy

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Abstract: The Gosau Group of Salzburg – Bad Reichenhall comprises basal red conglomerates (Kreuzgraben Formation), sandstones and sandy marls of the "Glanegger Schichten", detrital carbonates of the "Untersberg Formation", marls with tempestites of the Grabenbach Formation and deep-water marls and sandstones of the Nierental Formation. The Dalsenalm section within the Grabenbach Formation of the Lattengebirge was investigated in detail. The lithofacies is characterized by shelf marls and minor tempestite sandstones. Biostratigraphic data indicate the *asymetrica* planktonic foraminiferal Zone, and CC16 and CC17 nannofossil standard zones of the Santonian to the earliest Campanian. Strontium isotope ratios can be compared to the standard strontium isotope curve and allow a detailed correlation of the Santonian – Campanian boundary to standard sections in Germany and England.

Zusammenfassung: Die Gosau-Gruppe von Salzburg – Bad Reichenhall zeigt eine Abfolge von basalen roten Konglomeraten (Kreuzgraben-Formation), Sandsteinen und sandigen Mergeln der „Glanegger Schichten", detritäre Karbonate der „Untersberg-Formation", Mergel mit Tempestiten der Grabenbach-Formation und Tiefwassersedimenten der Nierental-Formation. Ein Profil innerhalb der Grabenbach-Formation nahe der Dalsenalm im Lattengebirge wurde genauer untersucht. Die Lithofazies wird durch Schelfmergel mit seltenen Sandsteintempestiten gebildet. Biostratigraphische Daten zeigen die *asymetrica* Planktonforaminiferen-Zone und die Nannofossil-Standardzonen CC16 und CC17 des Santoniums bis frühen Campaniums. Strontiumisotopenverhältnisse können gut mit der Standard-Strontiumisotopenkurve verglichen werden und erlauben eine genaue Korrelation der Santonium-Campanium Grenze zu Standardprofilen in Deutschland und England.

Keywords: Gosau Group, Grabenbach Formation, Salzburg, Bad Reichenhall, Lithostratigraphy, Strontium Isotope Stratigraphy

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Contents

1. INTRODUCTION

Sediments of the Upper Cretaceous part of the Gosau Group in the area of Salzburg – Bad Reichenhall are known since the works of GÜMBEL (1861). Together with several isolated outcrops near Salzburg and along the northern slope of the Untersberg (Fig. 1), the Gosau Group of the Lattengebirge south of Bad Reichenhall forms an Upper Cretaceous – Paleogene outcrop belt. More recent investigations in this area cover aspects of biostratigraphy and micropaleontology (e.g., HERM, 1962a, b; BUTT, 1981; RISCH, 1988; EGGER, 1990; WAGREICH & KRENMAYR, 1993; JAFAR, 1994) and sedimentology (LEISS, 1988; KRENMAYR, 1999), including a detailed investigation at the Cretaceous-Paleogene boundary in the Lattengebirge (HERM et al., 1981).

The lithostratigraphic subdivision of the Gosau Group in this area is not yet formally defined, although it includes one of the oldest lithostratigraphic terms of the Gosau Group, the "Glanegger Schichten" (GÜMBEL, 1861:163). In their detailed survey on the Gosau Group of this area HERM (1962a, b) and HILLEBRANDT (1962) used only lithological terms without formal definitions of formations, although a discussion on the facies of the "Nierentaler Schichten" (Nierental Formation) was included by HERM (1962b; for a revised definition and complete reference list see KRENMAYR, 1999).

This paper gives a short overview on the lithostratigraphy of the area, followed by a detailed investigation of one of the key sections in the shallow-marine part of the Gosau Group, the Dalsenalm section in the Lattengebirge (e.g., HERM, 1962a, b, 1981; BUTT, 1981; WAGREICH & KRENMAYR, 1993). The assignment of this section to the formally defined Grabenbach Formation is discussed and comparisons to the type area of the Gosau Group are given. The biostratigraphy of the section is based on nannofossils and planktonic foraminifera, and some data on strontium isotope stratigraphy are included.

2. LITHOSTRATIGRAPHIC OVERVIEW OF THE GOSAU GROUP OF SALZBURG – BAD REICHENHALL

The Gosau Group of Salzburg – Bad Reichenhall can be divided into a terrestrial to shallow marine lower part and a deep-marine, marly upper part. Basal sediments include a succession of coarse red conglomerates up to several hundred meters thick of the Gaisberg – Glasenbach area ("Glasenbach conglomerate" of NEUBAUER, 2002; see Fig. 1), which are very similar to the alluvial fan conglomerates of the Kreuzgraben Formation of

the type area of the Gosau Group, the Gosau valley (KOLLMANN, in PLÖCHINGER, 1982; WAGREICH, 1988, 1998). More to the west, especially along the northern slope of the Untersberg, the "Untersberger Marmor" ("Untersberg Formation", e.g. near Veitlbruch, see Fig. 1) unconformably overlies Jurassic limestones. No intercalations of red conglomerates are known, although rare bauxites infilling karst caverns are present at the base of the "Untersberg Formation". This formation is made up of a several tens of meters thick succession of mainly detrital carbonates (WAGREICH et al., 1996; see also SANDERS, 1998). It has been used extensively as a buidling stone for several hundreds of years (e.g., KIESLINGER, 1964). Above the conglomerates in the Gaisberg – Gersbach area, grey and red marls of Santonian age (OBERHAUSER, 1963; EGGER, 1990) crop out, whereas within the city and west of Salzburg, several isolated outcrops of the Gosau Group indicate a more complex facies development, including grey conglomerates and grey

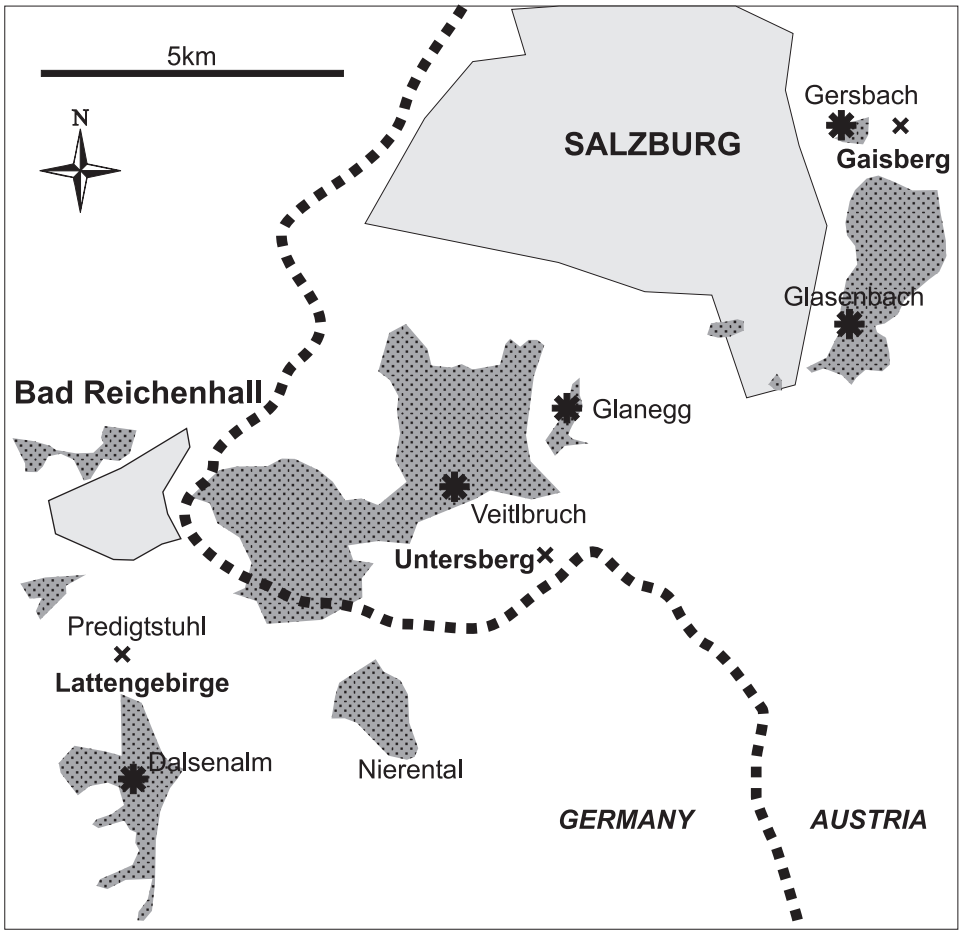

Fig. 1: Sketch map indicating the position of mentioned outcrops within the Gosau Group of Salzburg – Bad Reichenhall (dotted).

sandstones and sandy marls (PREY, 1980). Outcrops at the type locality of the "Glanegger Schichten" at the Schloßberg Glanegg west of Salzburg display mainly grey, carbonate-rich fine-grained sandstones and sandy marls, which yielded an ammonite fauna of Middle to Late Coniacian age (IMMEL, 1987). Sedimentation of these sandstones coeval to the "Untersberg Formation" is probable, although the age of the "Untersberg Formation" is poorly constrained only by the superposition of Santonian marls. The top of the "Untersberg Formation" in the Lattengebirge is characterized by marly to sandy limestones, which are overlain by a marly succession including rare sandstone beds (Phase I of BUTT, 1981). Above these grey marls, red and grey marly limestones with various amounts of sandy to marly turbidite intercalations are typical for the Nierental Formation (KRENMAYR, 1999), which ranges up into the Eocene. Olistostromes and bentonites are reported from the Paleogene of the Untersberg area (MOUSSAVIAN et al., 1990; EGGER et al., 1996). During the Eocene the occurrence of shallow water carbonates and a rearrangement of facies zones indicates a new stage of basin development (WAGREICH, 2001).

3. THE GRABENBACH FORMATION OF THE DALSENALM SECTION

3.1. Lithostratigraphy

The Dalsenalm section at the eastern bank of the Röthelbach (coordinates: UTM WGS84 east 340350, north 5281440) displays one of the key sections of the Gosau Group in the Lattengebirge area (HERM, 1962a, b, 1981; BUTT, 1981; WAGREICH & KRENMAYR, 1993). The section covers the interval from the topmost parts of the "Untersberg Formation" to the transition into the Nierental Formation. A general lithological section was given by HERM (1962b: units 1 – 15), and the transition into the Nierental Formation was described in detail by KRENMAYR (1999:417). Based on the similarities in lithofacies and biofacies, the marl-dominated interval below the Nierental Formation can be assigned to the Grabenbach Formation (Figs. 2 and 3), which has been defined in the Gosau type locality, the Gosau Valley (WEIGEL, 1937; KOLLMANN, in PLÖCHINGER, 1982; WAGREICH, 1988, 1998).

The Grabenbach Formation at the Dalsenalm section (Fig. 2) comprises soft, medium grey marls with a low sand to silt content, and carbonate contents of 35 to 50 %. The marls are rich in planktonic foraminifera, yielding planktonic/planktonic+benthic ratios of 40 to 75 (see also BUTT, 1981). The benthic foraminiferal assemblage is highly diverse, and suggests an upward deepening trend in the section (BUTT, 1981:54). Macrofossils are rare and include some bivalves, gastropods and solitary corals. A marly interval 110 cm thick that is situated about 15.5 m above the base displays slump folds.

Intercalations of sandstones are typically only a few centimeters thick up to a maximum of 35 cm. The sandstones are fine to very fine-grained sandstones to coarse siltstones, and can be classified as mixed siliciclastic-carbonate arenites. Most of the sandstone beds show only a faint horizontal lamination, sometimes with a wavy appearance. Only a single bed 24 cm thick (19 m above the base of the section) displays large low-angle hummocky cross stratification at the base, grading into horizontal lamination at the top. No distinct grain-size trend was recognized in these sandstone beds. Sole marks are common, including rill marks, drag casts and rare flat flute casts. Three measured flute casts indicate transport directions from south to north.

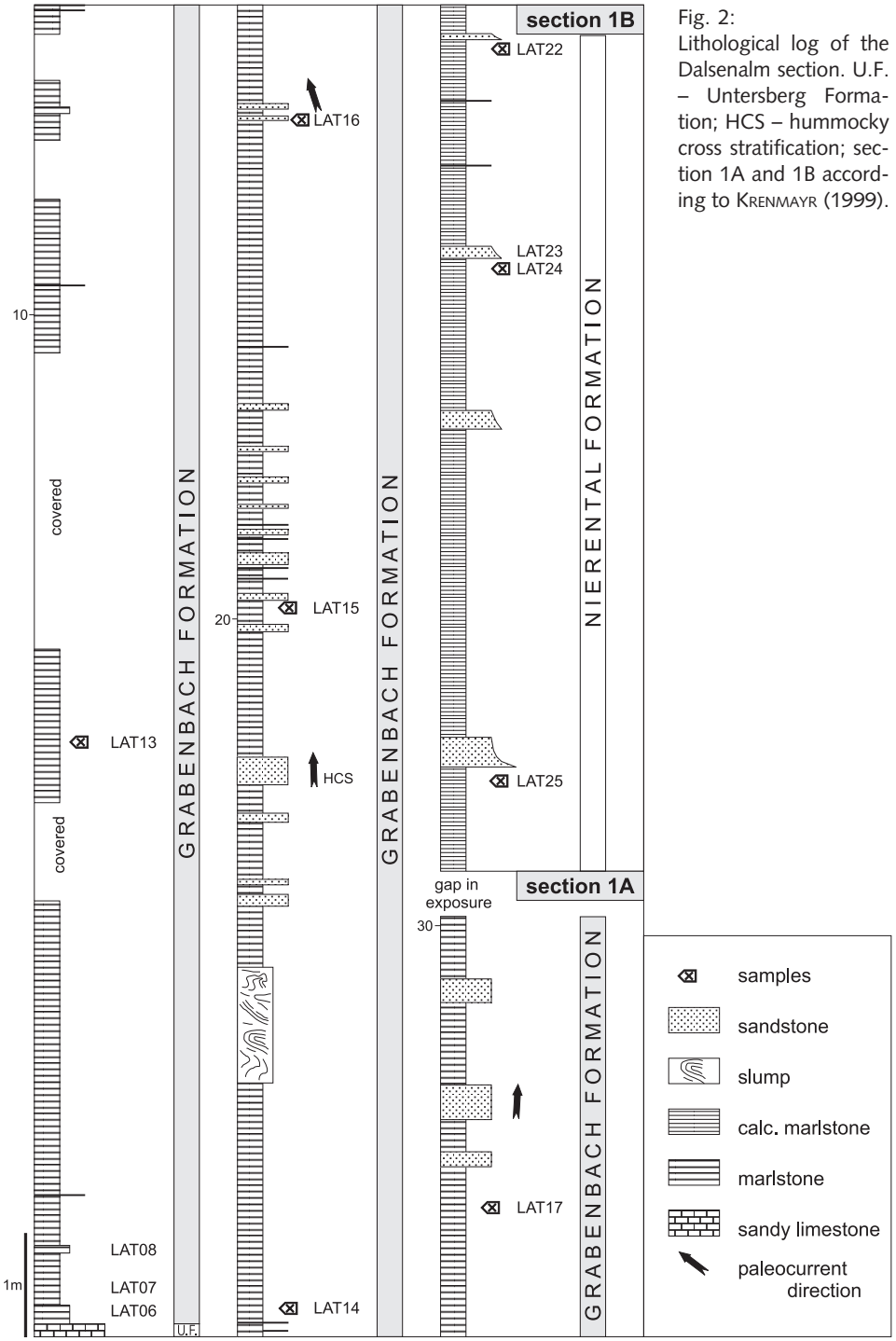

Fig. 2:
Lithological log of the Dalsenalm section. U.F. – Untersberg Formation; HCS – hummocky cross stratification; section 1A and 1B according to KRENMAYR (1999).

The lower boundary of the Grabenbach Formation displays a sharp contact of soft, grey to brownish marls on top of a massive, sandy to marly limestone of the "Untersberg Formation", which crops out within the bed of the Röthelbach (1188 m above sea level). The following lower part of the section is partly covered. Sandstone beds are rare in this interval.

The upper boundary of the Grabenbach Formation is defined by the first occurrence of graded beds of fine-grained breccia to sandstone. The marls of this basal interval of the Nierental Formation are harder, as a consequence of higher carbonate contents of 52–65 % (KRENMAYR, 1999). Foraminiferal assemblages are dominated by planktonic foraminifera which display percentages above 90 % of the total foraminiferal assemblage (BUTT, 1981).

3.2. Biostratigraphy

A Santonian age of the Grabenbach Formation in the Dalsenalm section is indicated by nannofossils of the nannofossil standard zones CC16 (defined by the first occurrence of *Lucianorhabdus cayeuxii*) and CC17 (defined by the first occurrence of *Calculites obscurus*). According to the zonation of BURNETT (1998) this corresponds to the UC11c

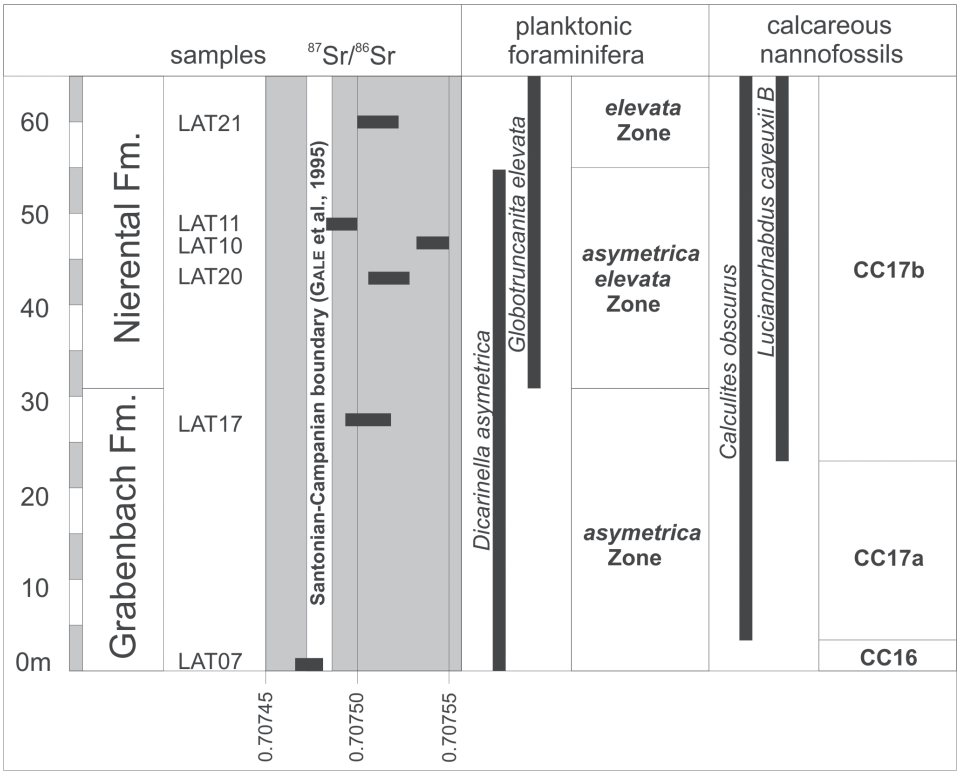

Fig. 3: $^{87}Sr/^{86}Sr$ ratios, planktonic foraminiferal zonation and nannofossil standard zones according to PERCH-NIELSEN (1985) of the composite Dalsenalm section. The error range of the $^{87}Sr/^{86}Sr$ ratio of the Santonian-Campanian boundary given by GALE et al. (1995) is indicated.

	zircon	tourmaline	rutile	apatite	garnet	chloritoid	staurolite	epidote	chrome sp.	blue amph.	others
Grabenbach Formation, Dalsenalm/Lattengebirge											
LAT2/4	6	13	3	11	7	19	0	2	34	3	1
LAT02	14	8	4	10	8	6	0	1	47	2	1
Grabenbach Formation, Gaisberg/Gersbachgraben											
GAIS8	6	13	1	1	9	19	0	0	50	1	0
GAIS9	4	15	1	8	11	11	0,5	0	49	1	0
GAIS1	2	12	1	6	10	21	0,5	2	43	1	0
GAIS5	6	5	1	4	12	15	0	2	55	0,5	0
„Glanegg Formation", Glanegg											
GLAN	8	21	1	6	11	0	0	0	53	0	0
Nierental Formation, Dalsenalm											
LAT05	11	38	4	6	14	7	3	1	15	1	1
LAT19,	8	54	3	11	5	3	2	1	12	0	2
LAT09	13	39	8	37	2	0	1	0	0	0	1
LAT11	10	33	4	39	6	0	0	0	8	1	0

Tab. 1: Heavy mineral data from sandstones of the Grabenbach Formation and the basal Nierental Formation. Numbers refer to grain percentages of the grain size interval 0.063 – 0.4 mm; at least 250 grains per sample were counted. Chrome sp. – chrome spinell, blue amph. – blue amphibole.

and UC12 zones. The planktonic foraminifer *Dicarinella asymetrica* and *Sigalia carpatica* are present from near the base of the section, thus indicating the Santonian *asymetrica* Zone of the planktonic foraminiferal zonation (e.g., CARON, 1985). *Sigalia decoratissima* is present in the topmost part of the section (see also BUTT, 1981). The FO of the planktonic foraminifer *Globotruncanita elevata*, still associated with *Dicarinella asymetrica*, is recognized in grey marls about 35 m above the base of the section, at the boundary of the Grabenbach Formation and the Nierental Formation (Fig. 3). This indicates the *asymetrica-elevata* Zone, a narrow concurrent range zone, which is either placed into the Late Santonian or into the earlymost Campanian (e.g., ROBASZYNSKI et al., 1984; WAGREICH, 1992). The first occurrence of *G. elevata* is recognized within the nannofossil subzone CC17b, a few meters above the first occurrence of curved morphotypes of *Lucianorhabdus cayeuxii* (ssp. B after WAGREICH, 1992). The following Campanian part of the section was described by WAGREICH & KRENMAYR (1993) and KRENMAYR (1999).

3.3. Heavy mineral data

Heavy mineral samples were taken from the Dalsenalm section (2 samples from the Grabenbach Formation, 4 samples from the lowermost part of the Nierental Formation) and from the Gersbach section (4 samples) at the Gaisberg, which can also be attributed to the Grabenbach Formation. Samples indicate a rather uniform heavy mineral assemblage (Tab. 1) typical of the terrestrial to shallow-marine part of the Gosau Subgroup, dominated by chrome spinell (34 – 55 %). Metamorphic minerals like chloritoid (6 – 21 %), garnet (7 – 12 %), and stable minerals such as zircon (2 – 14%) and tourmaline (8 – 15 %) are present in more or less equal amounts. The general assemblage, the presence of chloritoid and the presence of rare but significant amounts of blue amphiboles (0.5 – 3 %) are closely similar to heavy mineral assemblages reported from the Grabenbach Formation of the Gosau valley (WAGREICH, 1988) and Bad Ischl (WAGREICH, 1998). This supports the interpretation of a common source area for these Santonian sandstones and indicates a close connection of these depositional areas during the Late Cretaceous.

3.4. Strontium isotope stratigraphy

$^{87}Sr/^{86}Sr$ ratios have been measured from the calcite tests of planktonic foraminifera to apply the strontium isotope stratigraphy method (SIS, e.g., MCARTHUR, 1994). Sample preparation included washing and dissolving of the foraminiferal samples (about 10 – 30 mg) with acetic acid. Sr was separated by standard methods of ion-exchange chromatography. Samples have been measured on a Finnigan MAT262 at the Geochronological Laboratory of the Institute of Geology, University of Vienna. The results (comp. Fig. 3) are compared with the standard Sr-isotope curve (LOWESS-fit curve of HOWARTH & MCARTHUR, 1997, electronic version 1999). A larger range in Sr-isotope ratios from the standard values given by HOWARTH & MCARTHUR (1997) may be introduced by diagenetic overprint or by small clay particles which could not be removed during sample preparation. All in all, the results correspond well to the strontium isotope curve of the Late Santonian – Early Campanian given by HOWARTH & MCARTHUR (1997). The values for the Santonian – Campanian boundary indicated by GALE et al. (1995: 0.707479 ± 5 for England) and SCHÖNFELD et al. (1996: 0.707472 ± 12 for northern Germany) for the last occurrence of

the marker fossil, the crinoid *Marsupites testudinarius,* correspond to a level well below the first occurrence of *G. elevata*, thus indicating a position of the Santonian – Campanian boundary already within the Grabenbach Formation.

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