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The geological structure of the Late Cretaceous Graden normal fault (Eastern Alps)

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With 4 figures

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Zusammenfassung: Die geologische Struktur der Graden Abschiebung (Ostalpen). – Der Südwest-Rand des Kainacher Gosau Beckens bildet eine spätkretazische Abschiebung (Graden Abschiebung). Die durch Daten von Explorationsbohrungen ergänzte geologische Kartierung rekonstruiert eine listrische Form der Graden Abschiebung. Tektonische Strukturen belegen die Absenkung des Kainacher Gosau Beckens während SW-NE orientierter krustaler Extension.

Summary: Based on field mapping and underground information from exploration drill holes, the south-western margin of the Kainach Gosau Basin is described as a Late Cretaceous listric normal fault (Graden normal fault). Tectonic structures evidence subsidence of the Kainach Gosau Basin due to SW-NE-directed crustal extension.

1. Introduction

The Graden normal fault (Fig. 1) has been described as a Late Cretaceous extensional detachment by Neubauer & al. (1995). Although timing and kinematic of this fault is generally accepted (Krohe 1987; Ratschbacher & al. 1991; Neubauer & al. 1995; Kurz & al. 2002; Tenczer & Stüwe 2003; Kurz & Fritz 2003), the detailed geological structure of this prominent fault has never been described before. Therefore, we present here a structural model of the Graden fault which is based on field mapping and underground information from exploration drill holes.

2. General geological setting

Following Early Cretaceous nappe stacking, the Eastern Alps were affected by late-orogenic extension during the Late Cretaceous. In the eastern segment of this range the Graden normal fault exposes a very low- to low-grade metamorphic cover (Graz Paleozoic Nappe Complex, GPNC) above a low- to high grade metamorphic basement (Koralm and Gleinalm crystalline complex). Synchronously, a collapse basin (Kainach Gosau Basin, KGB) subsided on top of the section (Fig. 1).

The Austroalpine crystalline basement is composed of low- to high-grade metamorphic rocks (Tenczer & Stüwe 2003; Kurz & Fritz 2003) which were incorporated into the Austroalpine nappe stack during the Early Cretaceous. The tectonically overlying very low- to low-grade metamorphic GPNC (e.g. Ebner & al. 2000) consists of Silurian to Carboniferous carbonates and pelitic-marly metasediments of a carbonate platform which was influenced by intensive Silurian volcanism. Early Cretaceous northwest-directed thrusting (Fritz 1988, Fig. 1) and subsequent Late Cretaceous crustal extension (Neubauer & al. 1995, Fig. 1) determined the present tectonic structure of

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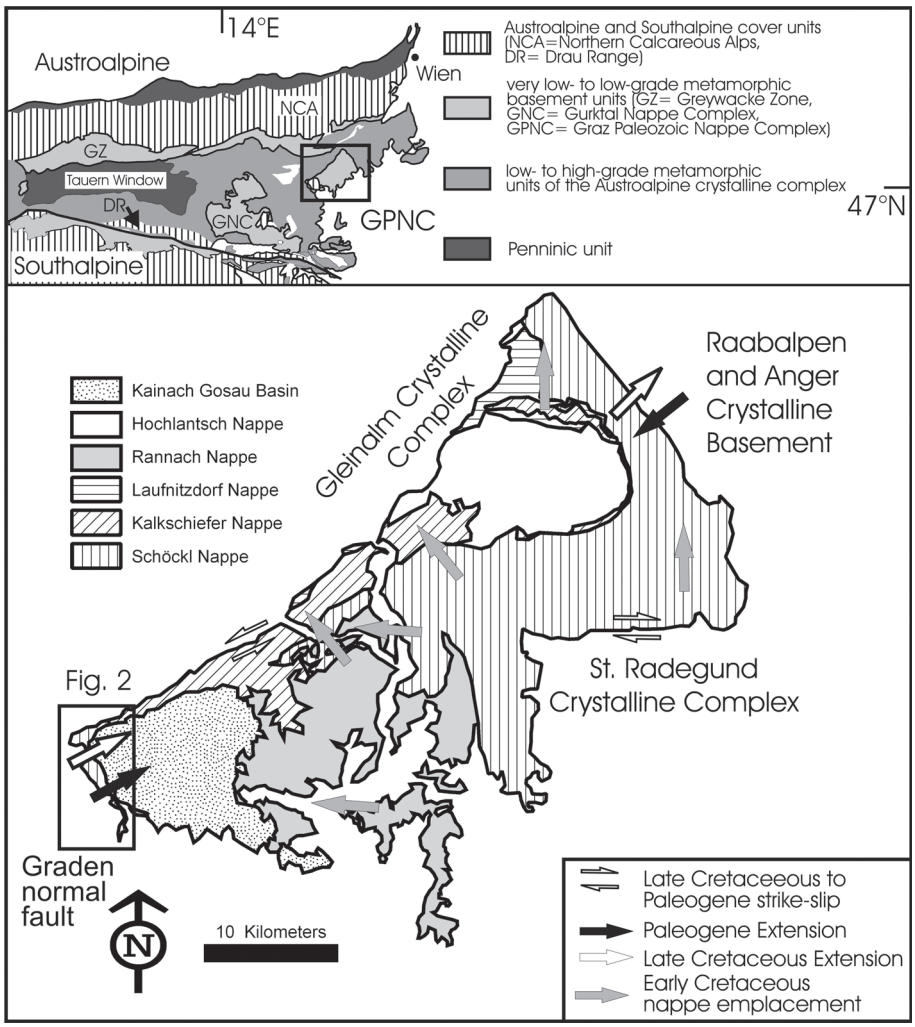

Fig. 1: Location and tectonic structure of the study area within the Eastern Alps. Arrows indicate the direction of Early Cretaceous nappe emplacement (compiled from Fritz 1991 and Neubauer & al. 1992) and subsequent extension (Ratschbacher & al. 1991; Krenn 2001).
Lage und tektonische Struktur des Arbeitsgebietes. Die Pfeile symbolisieren die Richtung der frühkretazischen Deckenüberschiebung (nach Fritz 1991 und Neubauer & al. 1992) und der nachfolgenden Extension (Ratschbacher & al. 1991; Krenn 2001).

the GPNC. This unit is subdivided into three nappe groups. From bottom to top, the lower nappe group is represented by the Schöckel Nappe, the intermediate nappe complex involves the Kalkschiefer nappe, the Laufnitzdorf nappe, and Gschwendt nappe, whereas the upper nappe complex comprises the Rannach and Hochlantsch nappes (e.g. Ebner & al. 2000, Fig. 1). The Late Cretaceous (Santonian to Maastrichtian) KGB is filled with alluvial, shallow marine and fan-delta sediments, several hundred meters thick (Neubauer & al. 1995; Ebner & Rantitsch 2000). The sediments overly different nappes transgressively of the GPNC and thus indicate a pre-Late Cretaceous nappe stacking.

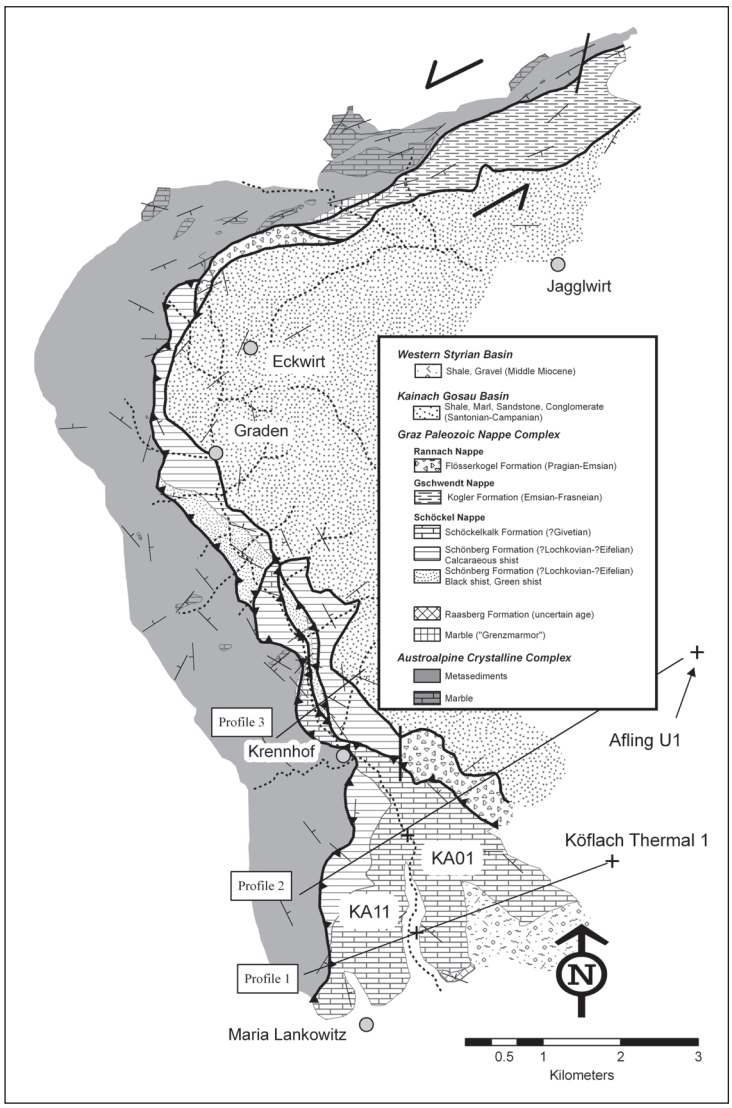

Fig. 2: Geological map of the study area. Cross symbols indicate exploration drill holes.
Geologische Karte des Arbeitsgebietes. Kreuze zeigen die Lage der Explorationsbohrungen an.

3. Methods

The area between Maria Lankowitz and Jagglwirt (Western Styria, Fig. 1, 2) was mapped at the scale of 1:10.000. Subsurface information is derived from four exploration drill holes (Kröll & Heller 1978; Gutsche 1989; Geoteam, unpublished).

4. Stratigraphy

In the geological map of Fig. 2 the GPNC rims narrowly the crystalline basement. It is overlain transgressively by the KGB. In the southern segment of the study area, Middle

Miocene conglomerates and siltstones of the Western Styrian Basin (Sachsenhofer & al. 2000; Stingl 2003) rest upon this sequence.

In the study area the crystalline basement comprises metasedimentary rocks (garnet- and staurolith-micashist, gneiss, quartzite, phyllite, and black slate) and calcite marble. Locally they are intruded by a tourmaline-bearing pegmatite. The tectonic contact between the crystalline complex and GPNC is outlined locally (NW Jagglwirt, N Krennhof) by a calcite marble layer ("Grenzmarmor") with a thickness of few meters.

The GPNC is mainly represented by the tectonically low Schöckel nappe which comprises clastic metasediments (black slate, metavolcanics) and calcareous slate of the Silurian to Lower Devonian Schönberg Formation (Ebner 1998; Flügel 2000) and slightly metamorphosed Devonian limestones of the Schöckelkalk Formation (Ebner 1998; Flügel 2000). In the south of the study area the chronostratigraphically uncertain Raasberg Formation (Flügel 2000) forms the base of the Schöckel nappe. Locally, the Rannach nappe is exposed on top of the Schöckel nappe. It is represented by dolomites and sandstones (with *Scalarituba* ichnofossils) of the Devonian Flösserkogel Formation (Ebner 1998; Flügel 2000). At the northern margin of the study area the GPNC is represented by limestones of the Devonian Kogler Formation of the Gschwendt nappe (Ebner 1998).

These units are overlain transgressively by the sedimentary filling of the KGB which is composed of conglomerates, sandstones and shales. Reddish conglomerates of the Late Santonian to Early Campanian (Ebner & Rantitsch 2000) Geistthal Formation crop out at the northern margin of the KGB. At the south-western basin margin the basin filling is represented by the Early Campanian (Ebner & Rantitsch 2000) Afling Formation.

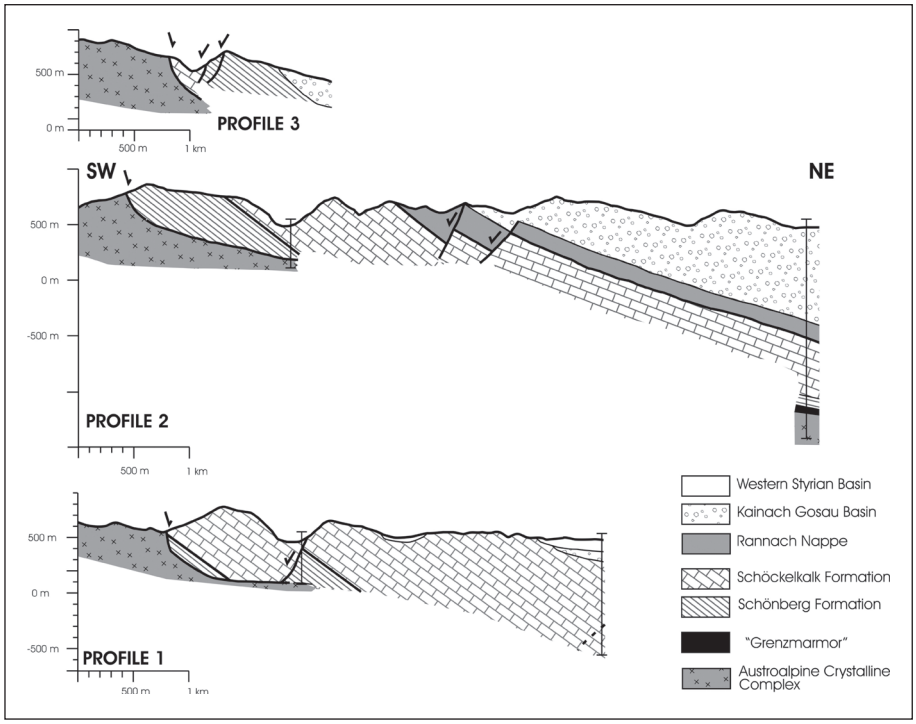

Fig. 3: Geological profiles through the Graden normal fault. The profile lines are indicated in Fig. 2.
Geologische Profile durch die Graden Abschiebung. Die Profillinien sind in Fig. 2 dargestellt.

5. Tectonic structure

The tectonostratigraphic analysis of the study area (Fig. 2) evidences the presence of antithetic normal faults within the GPNC which trend roughly parallel to the mapped contact between GPNC and crystalline basement (Fig. 2). Subsurface information from drill holes allows the reconstruction of a listric fault geometry (Fig. 3). The detachment has an eastward dip of 60 ° in the uppermost 100–300 m. Below this depth, it flattens to an angle of 20 °, reaching a minimum depth of 1630 m in the Afling U1 well.

6. Kinematics

Normal faulting along the Graden fault is evidenced by NE-trending ductile shear folds in the Schöckelkalk Formation (Fig. 4a), by an E-trending normal fault which cuts through the tectonic contact of the Austroalpine crystalline complex and the GPNC (Fig. 4c), and by the local presence of flat (058/12) lineations in bedding planes of the Gosau conglomerates

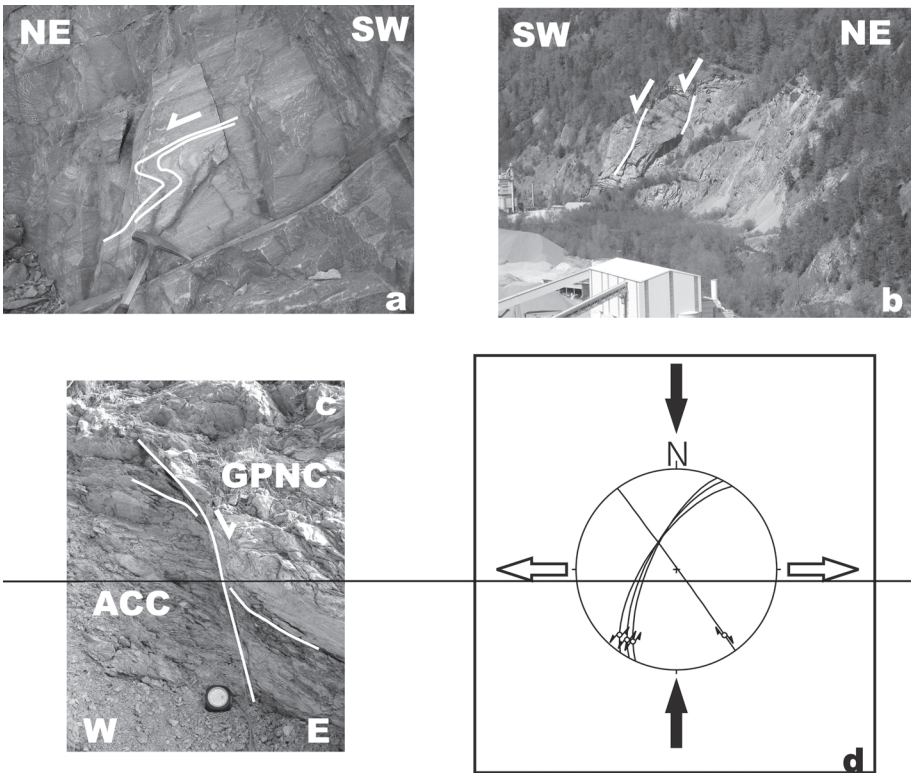

Fig. 4: Kinematic indicators in the study area: (a) Ductile shear folds in the Schöckelkalk Formation of the Gradenberg quarry. (b) Antithetic normal faults in the Schöckelkalk Formation of the quarry south of Krennhof. (c) Normal fault cutting through the contact between Austroalpine Crystalline Complex (ACC) and Graz Paleozoic Nappe Complex (GPNC) in the Randlwagner ditch west of Graden. (d) Fault set and inferred paleostress pattern in the area of Eckwirt.
Kinematikindikatoren im Arbeitsgebiet: (a) Duktile Scherfalten in der Schöckelkalk Formation des Graden Steinbruches. (b) Antithetische Abschiebungen in der Schöckelkalk Formation am Kontakt zwischen ostalpinem Kristallin (ACC) und Grazer Paläozoikum (GPNC) im Randlwagner Graben westlich von Graden. (d) Störungen und der daraus ermittelte Paläostress im Gebiet des Eckwirts.

at the tectonic base of the KGB. The presence of SW-dipping (antithetic) normal faults in the Schöckelkalk Formation (Fig. 4b) supports the tectonic interpretation of Fig. 3. At the northwestern margin of the KGB the NE-directed extension is accommodated by sinistral strike-slip tectonics during basin subsidence. Clear evidence for this kinematic is given by slickensides within the sediments of the KGB (Fig. 4d) and sinistral sheared marble layers of the Austroalpine crystalline complex (Fig. 2).

7. Conclusions

The area between Maria Lankowitz and Jagglwirt (Western Styria, Fig. 2) exposes a section through a Late Cretaceous detachment which is composed from bottom to top by the Austroalpine Crystalline Basement (Kor- and Gleinalm Range), the Graz Paleozoic Nappe Complex (Schöckel-, Gschwendt and Rannach nappe) and the Kainach Gosau Basin. The Kainach Gosau Basin subsided due to Late Cretaceous crustal extension. Whereas the south-western basin margin is formed by a normal fault (Graden normal fault), the north-western margin is a sinistral strike-slip fault (Neubauer & al. 1995). Based on field mapping and underground information from exploration drill holes, the Graden normal fault can be described by a listric geometry. Antithetic normal faults dissect the Graz Paleozoic Nappe Complex parallel to the master fault. A marble layer ("Grenzmarmor") within the Graden normal fault, ductile shear folds in the Graz Paleozoic Nappe Complex and the presence of lineation in bedding planes of the Gosau sediments suggest elevated temperatures along the fault plane during shearing (see also Rantitsch & al. in press).

Acknowledgements

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Buchbesprechung / Book Review

PAULITSCH Peter 2004. Schätze der Erde. Kristalle und Kulturen. – 252 Seiten, 32 Abbildungen. Verlag G. Preuß Darmstadt. Format 29 x 32 cm. ISBN 3-928746-19-7.

Ein sehr persönliches Buch ist erschienen von einem unserer Mineralogen der 2. Hälfte des 20. Jahrhunderts. Peter Paulitsch (Jahrgang 1922) fasziniert viele Freunde der Mineralogie, wenn er erzählt von der Freude am Sammeln, der Lust am Reisen, der Bedeutung des Reisens und was Kristalle uns erzählen. Unterwegs zu Kristallen und Kulturen in Europa, Asien und Afrika berichtet PP über Minerale und vieles mehr in 31 Ländern aus eigener Erfahrung und eigenem Erleben. Ja, der Verfasser erlebt Minerale, Erze und Gesteine als Teile der Kultur einzelner Länder und der Menschheit. Fachmineralogisches ist eng verwoben mit kulturhistorischem und persönlich Reflektiertem in bester humanistischer Tradition, doch verpflichtet dem naturwissenschaftlichen Fortschritt.

Es ist ein Buch, das man irgendwo aufschlägt und sogleich versetzt ist in ein fernes oder nahes, bekanntes oder unbekanntes Land, und doch sich zu Hause fühlt durch bekannte Minerale in neuer Umgebung. Über beides erfährt und lernt man leicht lesend interessantes und wissenswertes Neues oder auch Bekanntes in neuen Verknüpfungen. Der Verfasser muss seit Jahrzehnten auf unzähligen Reisen eigene Beobachtungen und Gedanken stets höchst diszipliniert notiert, und nun im 9. Lebensjahrzehnt noch ausgearbeitet haben. Eine ganz beachtliche Leistung, vielen Jüngeren ein Maßstab und Vorbild.

Ein unvergleichliches, seltenes Buch hat uns der Verfasser geschenkt, ein wahres Geschenk für wahre Freunde der Kristalle und Kulturen, Schätze der Erde und der eigenen Bibliothek. Wer mag bei einer schönen Mineralstufe, einer vielfarbigen, schön kristallisierten, seltenen Paragenese nicht mal wegschauen bei ihrem Preis, und diese eine, die man nicht vergessen kann, erwerben, statt vier Allerweltsstücken.

Henning von PHILIPSBORN, Regensburg