Mitt. Österr. Geol. Ges.	ISSN 0251-7493	**86** (1993)	S. 61–74	Wien, August 1994

Key words
Austria
Eastern Alps
Graywacke Zone
Paleogeography
Thrusting
Thick-skinned tectonics

Revised Lithostratigraphy and Structure of the Eastern Graywacke Zone (Eastern Alps)

FRANZ NEUBAUER, ROBERT HANDLER, SIEGFRIED HERMANN & GERNOT PAULUS*)

7 Text-Figures, 1 Table

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Revision der Lithostratigraphie und Struktur der östlichen Grauwackenzone (Ostalpen)

Zusammenfassung

Der oberostalpine Deckenstapel der östlichen Grauwackenzone wurde neu kartiert und petrographisch, strukturell und geochronologisch untersucht. Entgegen älteren Auffassungen besteht die östliche Grauwackenzone aus vier alpidischen Decken, die sich in Grundgebirgslithologie, jungpaläozoisch/triadischen Hüllsedimenten und präalpidischer metamorpher Überprägung unterscheiden. Wir unterscheiden vom Liegenden zum Hangenden zwischen der Veitscher Decke, der Silbersbergdecke, der Kaintaleckdecke und der Norischen Decke, zu der tektonisch auch die basalen Anteile der Nördlichen Kalkalpen gehören.

Die Veitscher Decke besteht aus karbonischen molasseähnlichen Klastika und Karbonaten und möglichen permischen Rotsedimenten. Die neu eingeführte Silbersbergdecke setzt sich aus einem quarzphyllitischen Grundgebirge (Altpaläozoikum?), einem verrucanoähnlichen Deckgebirge (Perm?) und dem alkalinen Gloggnitzer Riebeckitgneis zusammen. Die ebenfalls neu eingeführte Kaintaleckdecke besteht aus altpaläozoisch amphibolitfaziell metamorphen Grundgebirgsserien und Schuppen, die sowohl vom Hangenden wie Liegenden der Decke eingeschuppt sind. Diese Grundgebirgseinheiten stammen möglicherweise von mehreren unabhängigen tektonischen Einheiten. Wichtig sind Amphibolite mit geochemischer Affinität zu mittelozeanischen Rückenbasalten und Intraplattenbasalten, Serpentinite, migmatitische Paragneise, Glimmerschiefer, Quarzite und Marmore, sowie Pegmatit- und Aplitgneise. Die Norische Decke beinhaltet ordovizische bis unterkarbonische siliziklastische Sedimente, saure ordovizische Vulkanite, silurische Metabasite und vorwiegend devonische Karbonate.

Die Stapelung dieser Einheiten erfolgte in der Unter- bis Oberkreide unter niedriggradig metamorphen Bedingungen mit duktiler, meist west- bis nordwestgerichteter einfacher Scherung. Eine qualitative Bilanzierung des ostalpinen Deckenstapels deutet an, daß die Silbersbergdecke als Liegendeinheit der Nördlichen Kalkalpen betrachtet werden kann, die durch Bifurkation und vorlandgerichtetes Klettern des basalen, ostalpinen Abscherhorizontes von der Norischen Decke einschließlich der Nördlichen Kalkalpen getrennt wurde.

Abstract

The Upper Austroalpine Nappe Complex of the eastern Graywacke Zone has been examined by field mapping, petrographical, structural, and geochronological studies. In contrast to previous studies evidence was found of four major Alpine thrust sheets which can be subdivided by their basement lithologies, their Late Paleozoic to Triassic cover sequences, and the extent of pre-Alpine metamorphism. We distinguish between the following thrust sheets (from footwall to hangingwall): The Veitsch nappe, the Silbersberg nappe, the Kaintaleck nappe, and the Noric nappe.

*) Authors' addresses: FRANZ NEUBAUER, Institut für Geologie und Paläontologie, Paris-Lodron-Universität, Hellbrunnerstraße 34, A-5020 Salzburg; ROBERT HANDLER, SIEGFRIED HERMANN & GERNOT PAULUS, Institut für Geologie und Paläontologie, Karl-Franzens-Universität, Heinrichstraße 26, A-8010 Graz.

The Veitsch nappe includes clastic and carbonatic post-Variscan molasse-like sequences of Carboniferous and possibly even Permian age. The Silbersberg nappe (new term) is composed of a quartzphyllite basement of supposed early Paleozoic age, an "Alpine-Verrucano"-type cover of probable Permian age, and mylonitic alkaline metavolcanics (Gloggnitz Riebeckite Gneiss). The Kaintaleck nappe (new term) generally includes amphibolite facies metamorphic rocks of various lithologies imbricated with low grade metamorphic rocks from both footwall and hangingwall units. The basement lithologies are probably derived from several independent basement complexes, including various amphibolites with both MOR- and WP-basalt-like geochemical signatures, serpentinites, migmatitic paragneisses, micaschists, quartzites, and thin marbles. Some of these basement complexes are intruded by pegmatites and aplitic gneisses. The Noric nappe contains Ordovician to Carboniferous siliciclastic sediments, Ordovician acidic volcanics, Silurian metabasites, and Devonian carbonate sequences. The Noric nappe is unconformably covered by Permo-Mesozoic sequences of the Northern Calcareous Alps.

The assembling of all these units occurred during the Early to Middle Cretaceous thrusting under low grade metamorphic conditions, forming ductile, top to the W- to NW-directed fabrics. The qualitative balancing of the Austroalpine nappe pile suggests that the Silbersberg nappe may be the footwall extension of a part of the Northern Calcareous Alps. The Silbersberg nappe is believed to be separated from the Noric nappe by bifurcation and foreland-directed climbing of the decollement surface during Cretaceous thrusting.

1. Introduction

The eastern Graywacke Zone plays an important role in the evaluation of the intra-Austroalpine nappe structure within the Eastern Alps (Text-Fig. 1). The basic observation is the well-known superposition of a thrust sheet, containing an early Paleozoic basement and the Permian to Mesozoic cover sequences of the Northern Calcareous Alps, over fossil-bearing Carboniferous sediments of the Veitsch nappe along the Noric Thrust ('Noric Line') within the Graywacke Zone. This structure and its suggested extension to central and southern portions of the Austroalpine Nappe Complex, often combined with the Upper Austroalpine Nappe Complex, proves that a large amount of displacement in the scale of at least 150 kilometers occurred (TOLLMANN, 1959, 1987; FLÜGEL, 1960). Other arguments in favor of a limited displacement along the basal Upper Austroalpine thrust surface have also been proposed (FRANK, 1987). Recently the significance of the thrust is stressed because of the observation of Triassic deep sea sediments along the southern margin of the Northern Calcareous Alps (KOZUR and MOSTLER, 1992). Furthermore, investigations in the last few years suggest that the structure along the Noric Line is more complicate than previously supposed (NIEVOLL, 1984; HERMANN et al., 1992b).

Especially in the Kaintaleck complex, mainly amphibolite facies metamorphic rocks which are situated along the nappe contact, have been suggested to represent the pre-Late Ordovician basement of the Noric nappe (DAURER & SCHÖNLAUB, 1978; NEUBAUER, 1985). On the other hand, NIEVOLL (1984) suggested that clastic sequences below the Kaintaleck basement may represent Verrucano-type Permian clastics.

In this study we present new field observations and petrographical data concerned with the lithostratigraphy from several areas along strike of the Noric thrust (e.g., HERMANN, 1992; PAULUS, 1992; HANDLER, 1994) that argue for a more complicate stratigraphy and structure of the eastern Graywacke Zone. We discuss these data together with new results from geochronological and structural studies, which will be presented elsewhere (HANDLER et al., submitted; NEUBAUER et al., in prep.). The main goal in this paper is to show the significance of our new field data in conjunction with the intra-Austroalpine nappe structure.

2. Litho- and Tectonostratigraphy of the Eastern Graywacke Zone

In this study new data from the following areas are discussed: the area east of Bruck a.d. Mur (Text-Fig. 2); Kaintaleck and Oberdorf a.d. Laming (Text-Fig. 3) and Gloggnitz-Vöstenhof (Text-Fig. 4). The basic data of all tectonostratigraphic units have been compiled in Table 1. Also included are representative cross sections from all areas mentioned above (Text-Fig. 5) and a tectonostratigraphic scheme (Text-Fig. 6).

The Middle Austroalpine basement complexes (Rennfeld-Mugel and Troiseck-Floning crystalline complexes) and the Permian to Triassic cover sequences occur below the structural base of the Graywacke Zone (Text-Figs. 1, 6). The Middle Austroalpine cover consists of Verrucano-type clastic to volcanic sequences (Rannach Fm.) of supposed Permian age, rauhwackes and fossil-bearing Middle Triassic dolomites and limestones ("Triassic of Thörl"; TOLLMANN, 1963, 1968; NEUBAUER, 1988a). The geological time scale of HARLAND et al. (1989) is used for calibrations between biostratigraphy and chronostratigraphy.

2.1. Veitsch Nappe

The Veitsch nappe contains a continuous stratigraphic section that includes fossil-bearing Early and Late Carboniferous formations (RATSCHBACHER, 1987; RATSCHBACHER & NIEVOLL, 1984; KRAINER, 1992; NIEVOLL, 1983) extending into possibly Permian clastic sequences (NEUBAUER & VOZAROVÁ, 1990). We propose renaming the sequence of all these formations as the Veitsch Group.

RATSCHBACHER (1987) introduced a subdivision of the Carboniferous part of the Veitsch Group into three formations: from footwall to the hangingwall he distinguished the Steilbachgraben Fm., composed mainly of clastics and minor carbonates, the Triebenstein Fm. with carbonates and some greenschists and the Sunk Fm. with preferably quartz conglomerates, and anthracite/graphite deposits. In the eastern portions, the Veitsch Group exhibits a similar threefold subdivision with clastics which are separated by a carbonate horizon.

The hangingwall greyish clastics of the Sunk Fm. grade into the Graschnitz Fm. (NEUBAUER & VOZAROVÁ, 1990) that includes light-coloured, brownish to reddish sandstones, phyllites, and rare quartz breccias. The only major exposures occur north of the village of Frauenberg east of Bruck a.d. Mur (Text-Fig. 2; FLÜGEL et al., 1990). This section is estimated to represent approximately several tens of metres in structural thickness. The sandstones and breccias form dm-scaled intercalations within the predominant phyllites/metasiltstones. Along the basal portions of the section, 0,1 metres thick acidic tuffaceous intercalations including quartz and alkali feldspar megacrysts occur.

Text-Fig. 1.
Tectonic map of eastern portions of the northeastern Alps including the eastern Graywacke Zone.

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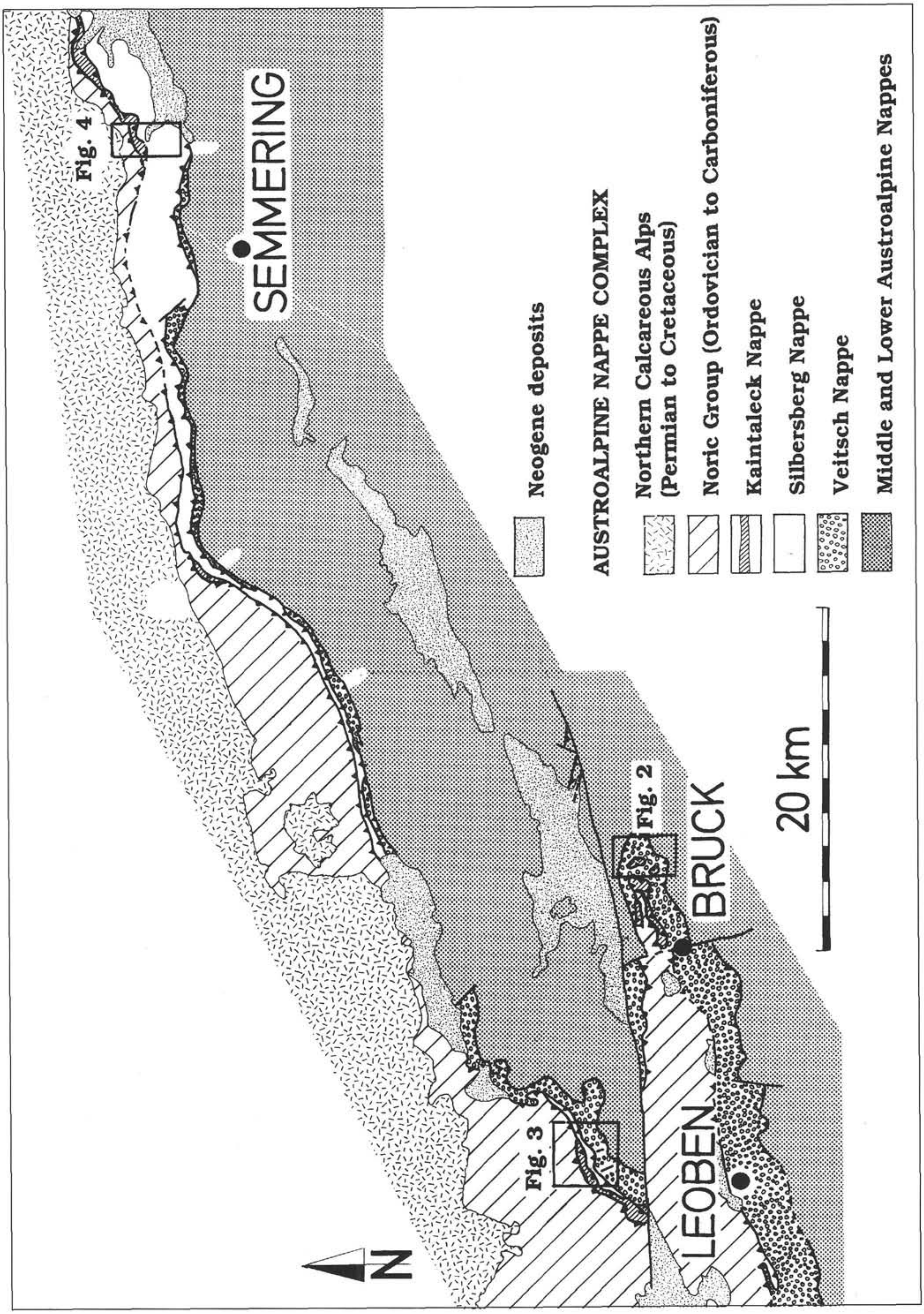
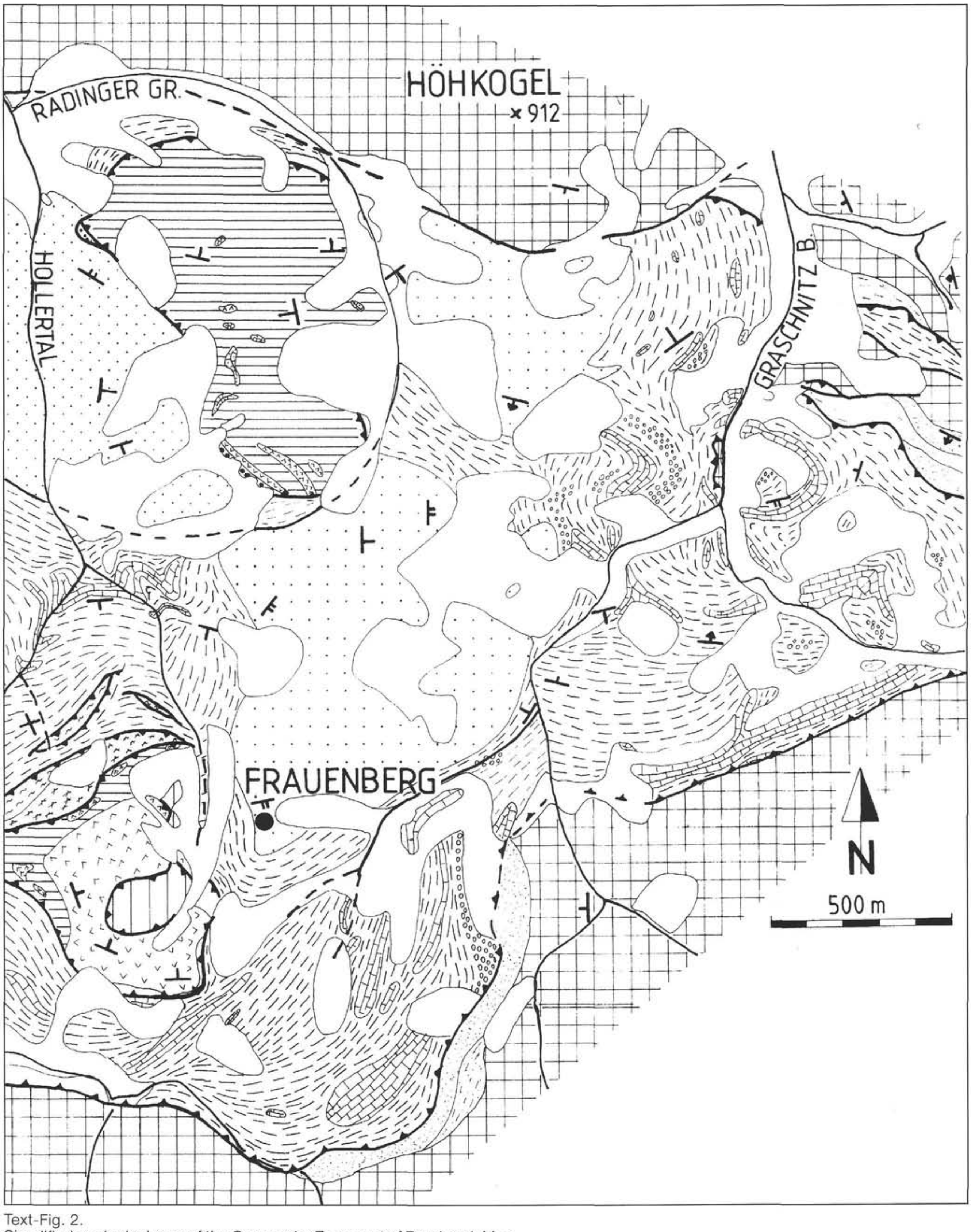


Fig. 4
SEMMERING
Fig. 2
BRUCK
20 km
Fig. 3
LEOBEN
N
Neogene deposits
AUSTROALPINE NAPPE COMPLEX
Northern Calcareous Alps (Permian to Cretaceous)
Noric Group (Ordovician to Carboniferous)
Kaintaleck Nappe
Silbersberg Nappe
Veitsch Nappe
Middle and Lower Austroalpine Nappes

2.2. Silbersberg Nappe

We introduce the Silbersberg nappe to summarize a number of formations that are clearly tectonically separated from all other footwall and hangingwall formations. These include all formations below the metamorphic Kaintaleck Complex already known from previous maps by CORNELIUS (1952), LESKO (1960) and NIEVOLL (1984).

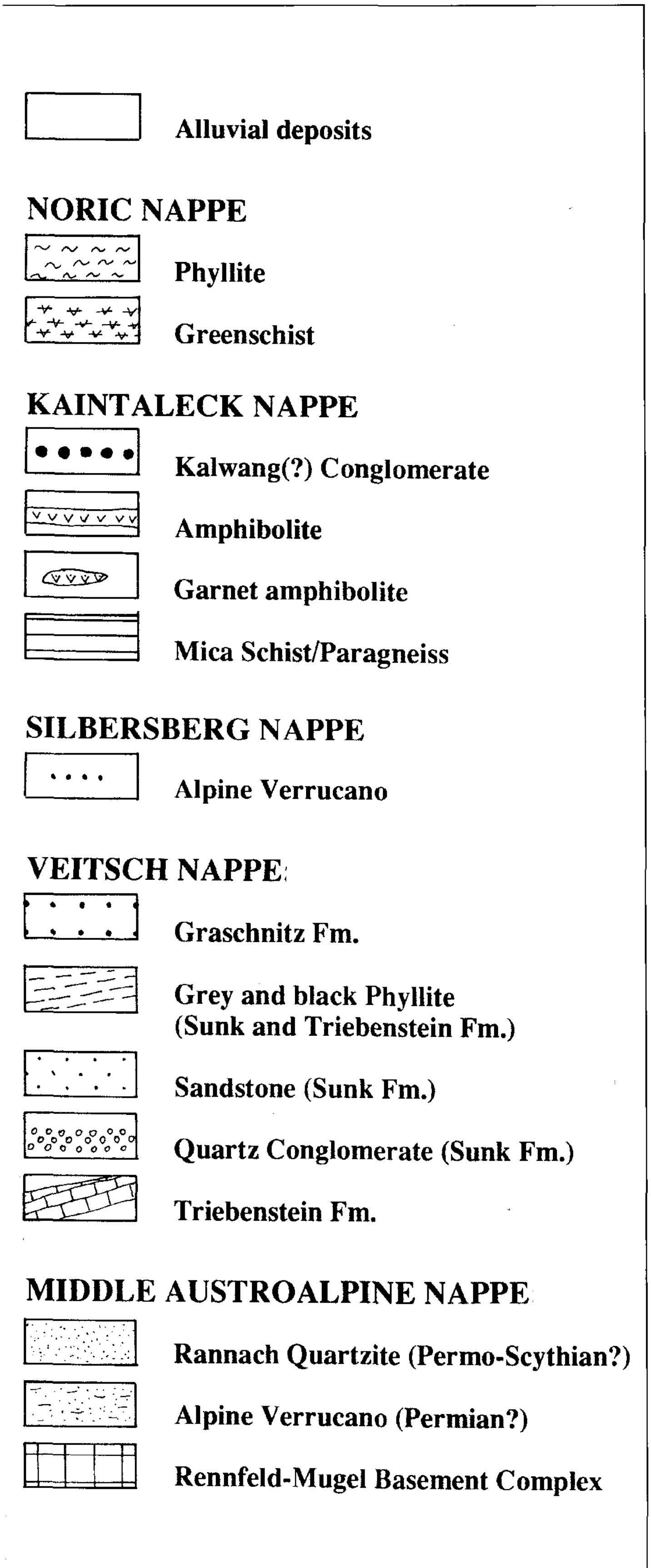
These formations include quartzphyllite and carbonate-chlorite schists which occur at the tectonic base of the



Text-Fig. 2.
Simplified geological map of the Graywacke Zone east of Bruck a.d. Mur.
For location, see Text-Fig. 1; for legend, see opposite page.

nappe, the Gloggnitz Riebeckite Gneiss and the Silbersberg Conglomerate (Text-Fig. 6).

The carbonate chlorite schists include greenish, well-foliated chlorite-carbonate schists and intercalated chlorite schists. These schists occur with a structural thickness of c. 100 metres above the Veitsch nappe in the Oberdorf area (Text-Fig. 3). The quartzphyllite occurs both SW of the Kaintaleck and the Gloggnitz area (Text-Fig. 3, 4). The thickness of the quartzphyllite including all intercalations is appr. 100 metres in the Gloggnitz area. Here, thick lenses of foliated felsic volcanics occur. These are mainly composed of feldspar and minor quartz suggesting a more intermediate composition. Other intercalations observed are greenschists with alkaline geochemical composition (PAULUS, 1992; PAULUS & NEUBAUER, in prep.). The Gloggnitz Riebeckite Gneiss occurs along the boundary between the quartzphyllite and the Silbersberg Conglomerate. The gneiss is a fine-grained mylonite which contains quartz/feldspar, riebeckite and rare clinopyroxene.



The geochemical signature of the gneiss suggests a highly fractionated volcanic protolith (KOLLER & ZEMANN, 1991; PAULUS, 1992; PAULUS & NEUBAUER, in prep.). A Rb-Sr whole rock errorchrone of ca. 132±12 Ma is interpreted to represent either a middle Cretaceous age of protolith formation or dating the age of the Cretaceous metamorphic overprint (PAULUS, 1992; PAULUS & NEUBAUER, in prep.). The quartzphyllite and carbonate chlorite schists closely resemble early Paleozoic quartzphyllite which are widespread throughout the Austroalpine units (e.g., SCHÖNLAUB, 1979; NEUBAUER & SASSI, 1993).

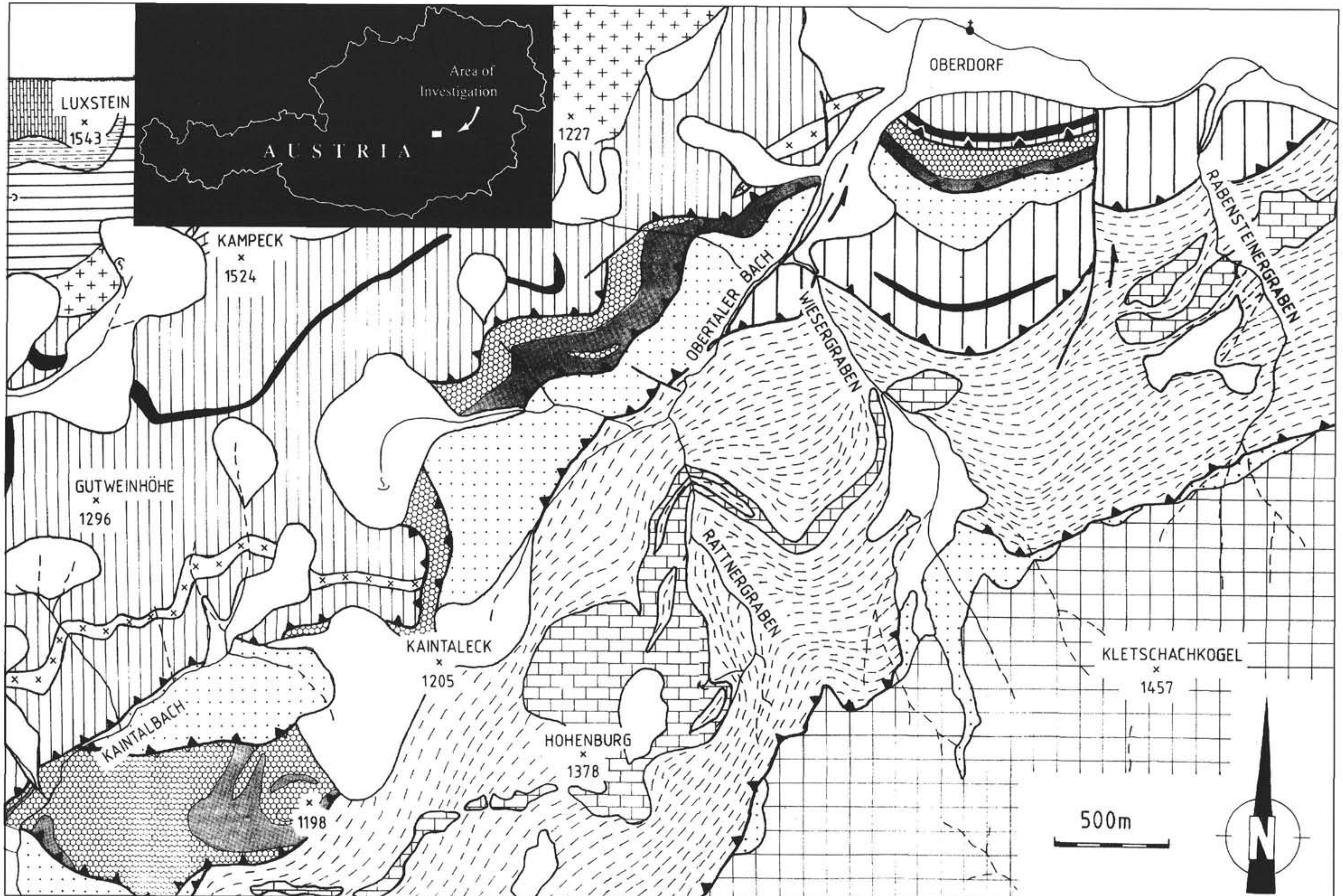
The main constituents of the Silbersberg Nappe are light-coloured greenish quartzitic phyllites, which include thin layers of acidic tuffs and quartz breccias. Here all constituents are interpreted to represent the Alpine Verrucano Fm., and the Silbersberg Conglomerate. In both formations, quartz clasts dominate and often exhibit a reddish colour. Other constituents are minor carbonate clasts, detrital white mica and some local micaschist and orthogneiss clasts were observed.

In accordance with previous suggestions (NIEVOLL, 1984) we interpret that both, the Silbersberg Conglomerate and 'Alpine Verrucano Fm.' represent deposits of Permian age supported by the following arguments:

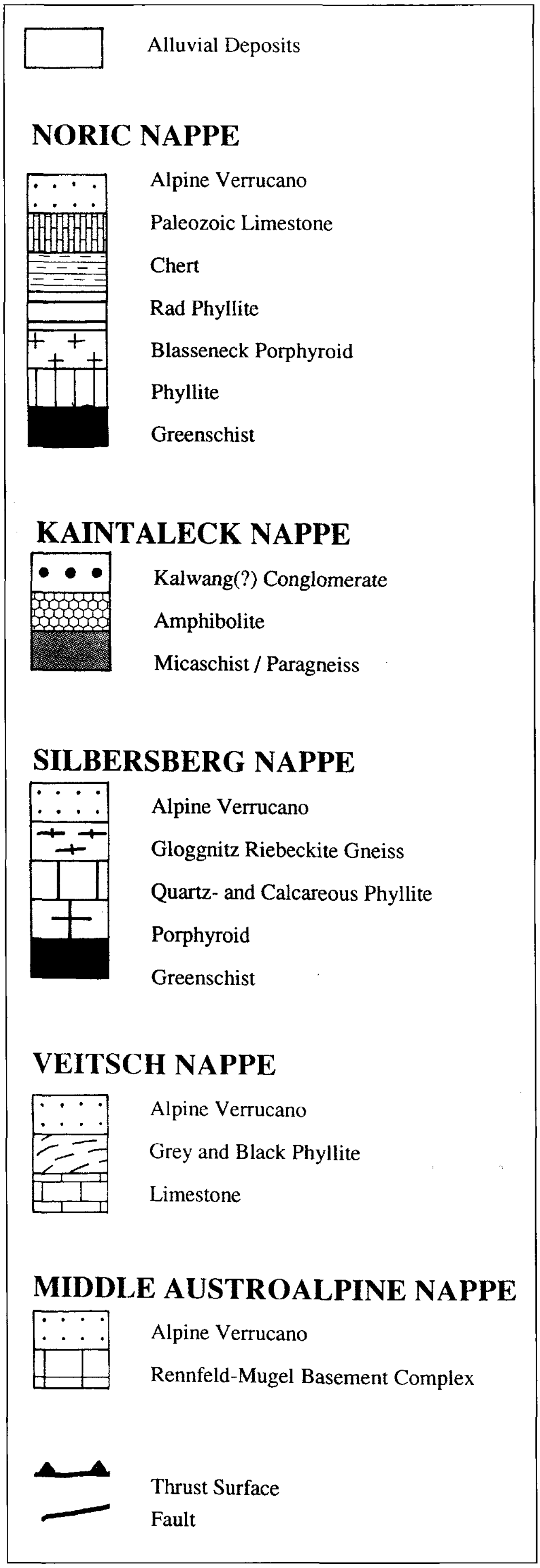
1) the general habit is similar to the 'Alpine Verrucano Fm.' in other Austroalpine units such as the Semmering-Wechsel units (e.g., TOLLMANN, 1977);
2) the general dissimilarity with early Paleozoic formations in the region;
3) the intercalations of acidic tuffs which are similar to other intercalations of this kind in the 'Alpine Verrucano Fm.' elsewhere; and
4) the inclusions of reddish quartz pebbles which are preserved although Cretaceous metamorphism. Until now such reddish pebbles were found in the Alps only in Permian deposits.

2.3. Kaintaleck Nappe

The "Kaintaleck slices" occur within the eastern Graywacke zone along 70 km of a thrust surface (HAUSER, 1938; CORNELIUS, 1941, 1952). The structural thickness of the Kaintaleck slices does not exceed two hundred metres. In some areas these slices are intensely imbricated with footwall and hangingwall rocks as in the Bruck and Kaintaleck areas (Text-Fig. 3) (NEUBAUER et al., 1987; RATSCHBACHER & NEUBAUER, 1989; HERMANN, 1992). Lithologies, geochro-



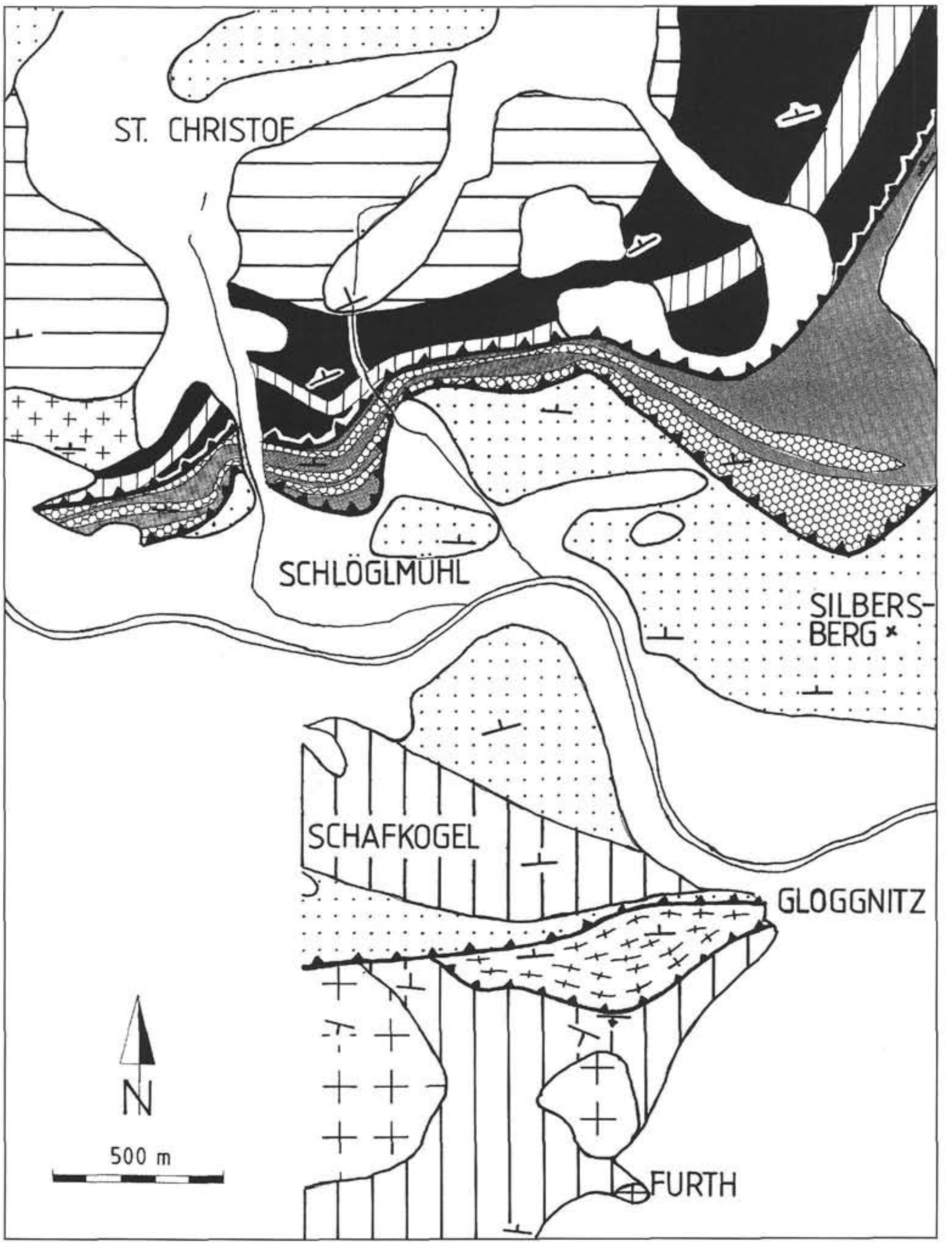
Text-Fig. 3.
Simplified geological map of the area Kaintaleck – Oberdorf a.d. Laming. For location, see Text-Fig. 1; for legend, see opposite page.



nological data, geological relationships, and the structural position suggest that the Kaintaleck slices consist of various lithotectonic units. This subdivision is mainly based on work in the area near Bruck a.d. Mur (NEUBAUER & FRISCH, 1993).

1) The Ritting complex occurs near Bruck/Mur, at the Kaintaleck, and west of Vöstenhof. It is composed of garnet-zoisite amphibolite, serpentinite, micaschist and thin marble layers. The chemistry of the amphibolites corresponds to tholeiite basalts (NEUBAUER et al., 1989b; PAULUS, 1992). At the Kaintaleck geochemical analyses point consistently to transitional within plate-basalt affinities (HERMANN, 1992; HERMANN et al., 1992a). In the Bruck area amphibolites contain a disseminated Cu mineralization. Chromite occurs in the serpentinites (NEUBAUER et al., 1989). The protolith age of the Ritting complex is uncertain.
2) The Frauenberg complex is exposed in an area near Bruck/Mur (Text-Fig. 2) and near Oberdorf (Text-Fig. 3). It is mainly composed of paragneiss containing plagioclase amphibolite and marble lenses. The petrographic characteristics are at a contrast with those of the Ritting complex. The amphibolites exhibit a mildly alkaline trend. A hornblende-garnet gneiss from the Bruck/Mur region which is included in the plagioclase amphibolite contains *numerous rounded zircons with smooth surfaces*, which are interpreted as the result of high-grade metamorphism. Pressure and temperature conditions are uncertain, but a high-pressure event is indicated by the high pyrope content in garnet (ca. 40 mole percent pyrope). The zircons yielded an U-Pb upper intercept age of ca. 2.53 Ga and a lower intercept age of 516 Ma (NEUBAUER et al., 1989b). Due to this highly discordant pattern, the upper intercept age is considered to be the protolith age, assuming an igneous source of the hornblende-garnet gneiss, and the lower intercept refers to the late Cadomian age of metamorphism (NEUBAUER et al., 1989b). Brown colored, metamict zircons yield an upper intercept age of approximately 2.8 Ga. These zircons are interpreted to represent crustal contamination of the igneous source rock (NEUBAUER et al., in prep.).
3) The Prieselbauer complex is exposed near Bruck/Mur, Oberdorf, and west of Vöstenhof. It is composed of migmatitic augen paragneiss and micaschists including minor occurrences of amphibolite as well as concordant and discordant aplites. Zircons from the paragneiss yielded a lower intercept U-Pb zircon age of ca. 391 Ma which is interpreted as being the approximate age of metamorphism. A discordant aplitic vein yielded an upper intercept zircon age of 363 Ma which reflects the zircon crystallization within the protolith (NEUBAUER et al., 1987; in prep.). The Prieselbauer complex has been interpreted as the basement of the Carboniferous sediments of the Veitsch nappe (NEUBAUER & FRISCH, 1993).

The Ritting and Frauenberg complexes are transgressively covered by equivalents of the Kalwang (Gneiss) Conglomerate that has been interpreted to represent the stratigraphic base of the fossiliferous Late Ordovician sequences of the Noric Group (DAURER & SCHÖNLAUB, 1978; NEUBAUER, 1985; LOESCHKE et al., 1990). Apart from various basement fragments, such as amphibolites and serpentinites, trondhjemitic orthogneiss components dominate the conglomerate. The orthogneiss is interpreted to be derived from a plutonic source in a supra-subduction zone environment because of its geochemical patterns, especially those of the REEs. The U-Pb zircon upper intercept ages of two boulders from different localities are approximately 500 Ma



Text-Fig. 4.
Simplified geological map of the Gloggnitz area.
For location, see Text-Fig. 1; for legend, see Text-Fig. 3.

(NEUBAUER et al., 1987). The dominance of the orthogneiss clasts suggests the presence of a major pluton in the hinterland of the conglomerates. This orthogneiss is not known to occur in the Kaintaleck slices.

Previously it was argued that the Kalwang (Gneiss) Conglomerate might be the stratigraphic base of the Noric Group (DAURER & SCHÖNLAUB, 1978; NEUBAUER, 1985). The conglomerate at the locality Frauenberg (Text-Fig. 2) follows the Kaintaleck Complex along a sedimentary contact (NEUBAUER, 1985). Age data for metamorphism and magmatism ranging from 520 to 360 Ma preclude that interpretation. Furthermore, detailed mapping by LOESCHKE et al. (1990) showed thrust surfaces separating the Kalwang Conglomerate from the equivalents of the Ordovician Gerichtsgraben Formation.

Recent mineral ages (Rb/Sr and $^{40}Ar/^{39}Ar$ muscovite and amphibole) of all three complexes of the Kaintaleck nappe resulted in ages ranging between 420 and 360 Ma with no significant difference between these three complexes (DALLMEYER et al., 1992; HANDLER et al., 1993, submitted). Therefore, a major Mid-Paleozoic tectonothermal event affected major portions of the "Kaintaleck slices".

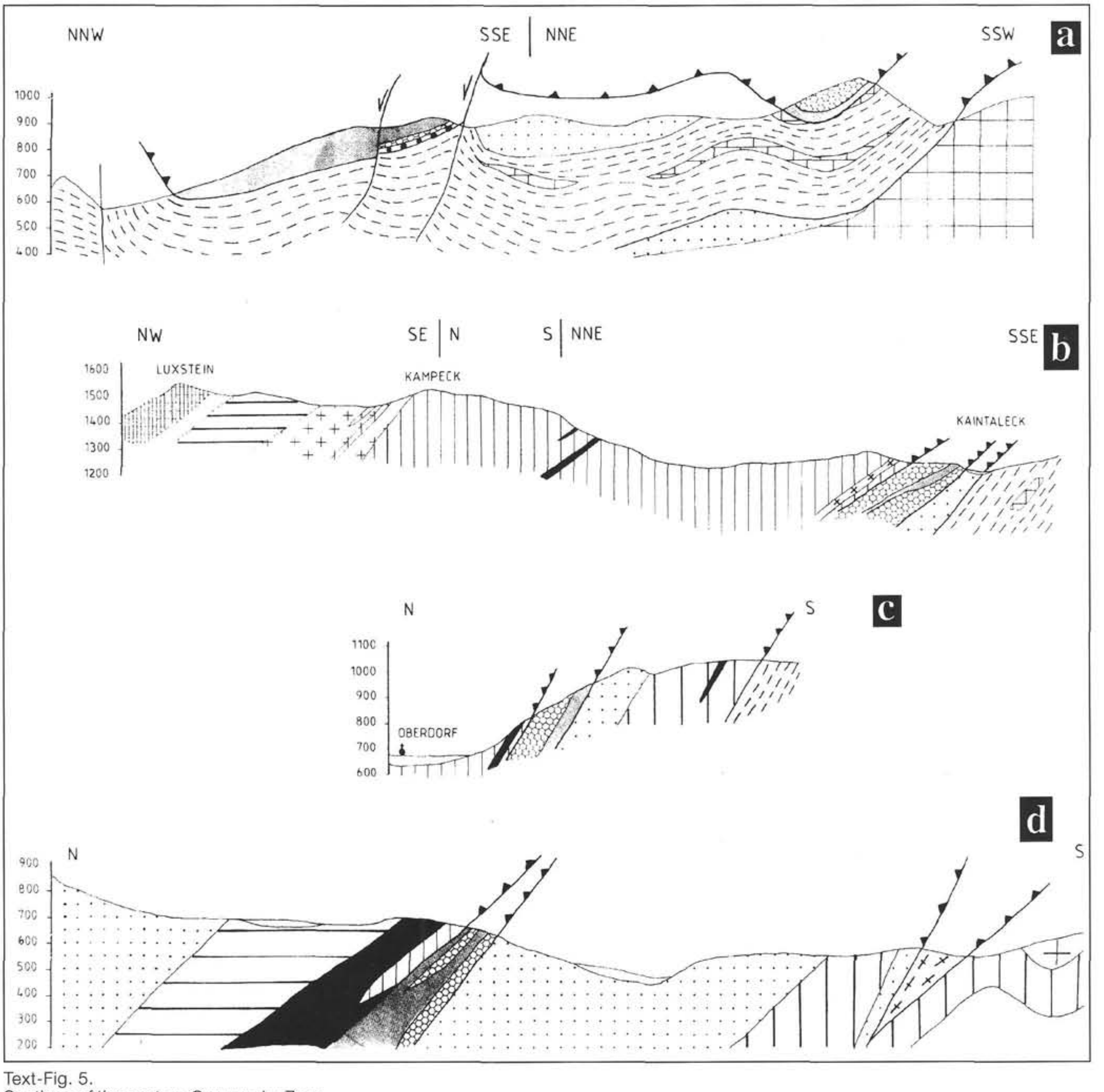
In nearly all areas the ductile shear zones separate the Kaintaleck lithologies from other adjacent units. Similar ductile shear zones in the scale of one to ten metres also occur within the Kaintaleck complex sometimes forming "pseudoconglomerates" with boudins of competent lithologies within a ductilely deformed mica-rich matrix.

2.4. Noric Nappe

The Noric Nappe consists of a thick continuous sequence of clastic, volcanic, and carbonate-dominated formations for which we have introduced here the term Noric Group. In the study area, the Noric Group includes sequences from Late Ordovician to the Visean-Namurian boundary (SCHÖNLAUB et al., 1980; SCHÖNLAUB, 1982; NIEVOLL, 1987) and a fossil-free portion below the fossil-bearing Late Ordovician rocks. Internal stratigraphy of the Noric Group has yet to be completely resolved in the study area.

Besides the Late Ordovician to Devonian carbonate-dominated sections in the central portions, the eastern Graywacke zone contains wide regions of siltstone and phyllite, and minor mafic volcanic rocks. The phyllite is related to sections occurring with thin Devonian pelagic limestones (NIEVOLL, 1987; SCHÖNLAUB, 1982).

The structural base of the Noric Group is dominated by up to ca. 1000 metre thick, partly arkosic phyllite (Gerichtsgraben Fm.) which contains thin greenstone layers, acidic tuffs, and metasandstones (DAURER & SCHÖNLAUB, 1978; LOESCHKE, 1989; LOESCHKE et al., 1990; SCHÖNLAUB, 1982; HERMANN, 1992). Especially in the Kaintaleck area, the up to 30 metres thick Kaintalgraben Porphyroid (Text-Fig. 3; HAUSER, 1938; HERMANN, 1992) forms a continuous volcanogenic layer several hundreds metres below the Blasseneck Porphyroid. This horizon may be correlated with



Text-Fig. 5.
Sections of the eastern Graywacke Zone.
For locations, see Text-Fig. 1. For legend, see Text-Fig. 3. Location of sections: a – Text-Fig. 2; b,c – Text-Fig. 3; d – Text-Fig. 4.

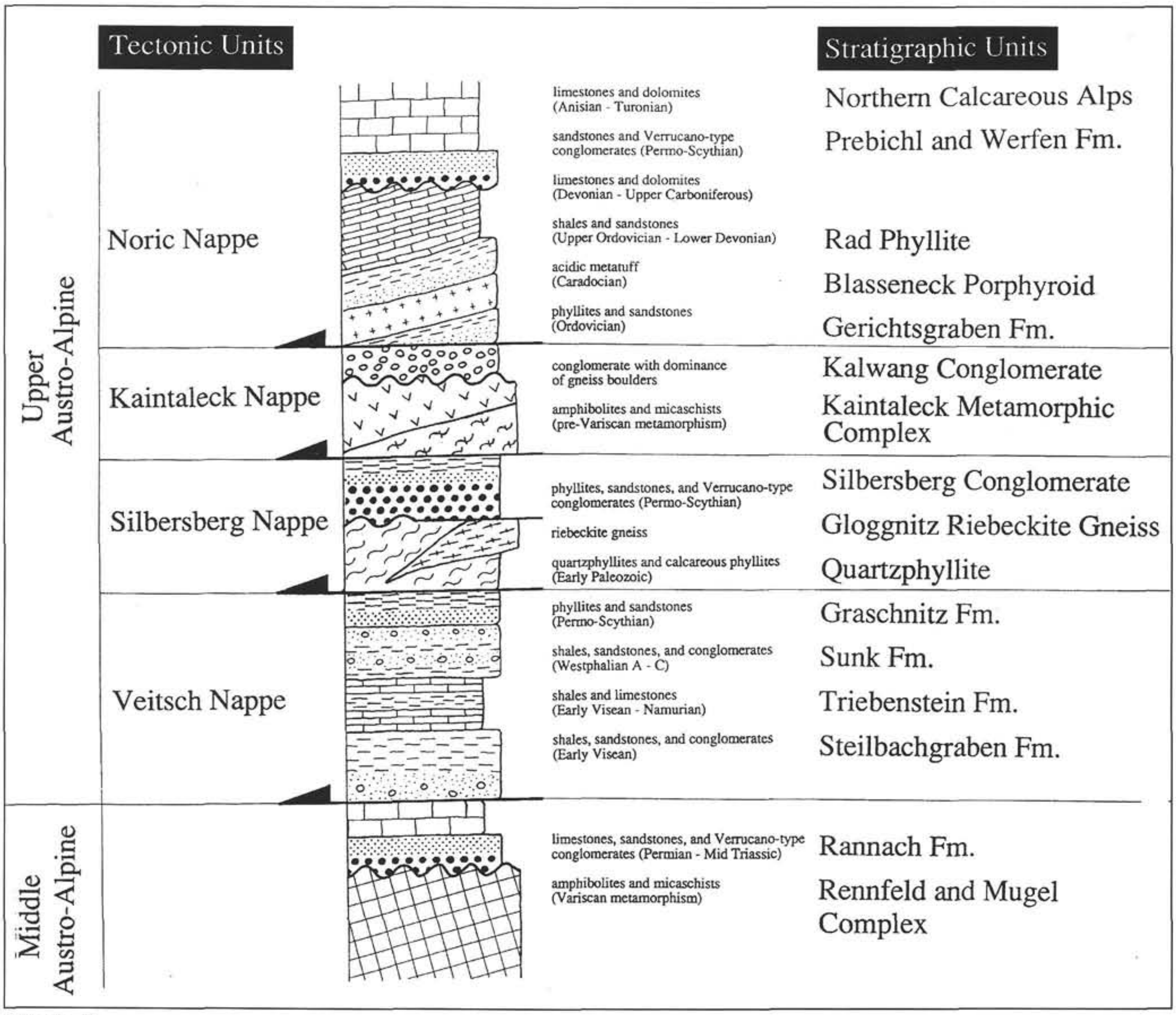
acid tuffs immediately above the Kalwang Conglomerate at the locality Kalwang/Teichgraben (SCHÄFFER & TARKIAN, 1984; LOESCHKE et al., 1990).

At high levels of these basal phyllites conodonts of Caradocian age occur (FLAJS & SCHÖNLAUB, 1976). Recently, REITZ & HÖLL (1989) described palynomorpha of early Ordovician age within slates of a comparable section of the western Graywacke zone.

The Blasseneck porphyroid is of ignimbritic origin (HEINISCH, 1981; LOESCHKE et al., 1990) and is locally overlain by the Petersbauerngraben Fm., a metaconglomerate which may extend to the west into the Polster Quartzite (FLAJS & SCHÖNLAUB, 1976; STATTEGGER, 1982) and further continues into black slates and cherts (HERMANN, 1992). Laterally, thick slates and phyllites occur (Rad Phyllite: CORNELIUS, 1952) containing another acidic tuff layer of late Silurian or early Devonian age, greywackes and lydites (NIEVOLL, 1987). The slates grade into middle and late Devonian pelagic limestones and mid-Carboniferous shales.

The Silurian and early Devonian mafic volcanics that dominate the westerly adjacent areas (SCHÖNLAUB, 1982; HEINISCH et al., 1988; SCHLAEGEL-BLAUT, 1990) apparently do not occur within the area of investigation. The age of deformation is younger than Namurian A (latest sediments in a Carboniferous crinoidal breccia) and older than the supposed early Permian age of the transgressive Prebichl formation. The angular unconformity prove some (two or three) Variscan nappes as well as semiductile folding and faulting (SCHÖNLAUB, 1982; NEUBAUER, 1989).

A Rb-Sr thin slab isochrone of the Carboniferous slates yielded an age of 246 Ma (JUNG, 1980). Detrital white micas yield a maximum model age of approximately 320 Ma that falls within reasonable proximity to the supposed age of the Variscan metamorphism in the source region.



Text-Fig. 6.
Tectonostratigraphy of the eastern Graywacke Zone.

3. Alpidic vs. Pre-Alpidic Metamorphism

The eastern Graywacke Zone is believed to have been penetratively overprinted by Alpidic greenschist facies metamorphism. The basic observations supporting that, are the complete penetrative ductile deformation of the Veitsch nappe, which apparently does not exhibit pre-Alpidic ductile fabrics (RATSCHBACHER, 1986), Cretaceous K-Ar muscovite ages from the western portions of the eastern Graywacke Zone (RATSCHBACHER, 1984), and mineral parageneses which are formed within greenschist facies conditions. Temperature conditions have been estimated as high as 500°C immediately to the west of the area of investigation (RATSCHBACHER & KLIMA, 1985).

Mineral parageneses in post-Variscan sediments from the Veitsch nappe include:

1) actinolitic amphibole + chlorite + green biotite + albite + quartz + sphene in mafic rocks; and
2) quartz + white mica (muscovite) +/- albite +/- chlorite in metapelites and metasandstones.

On the other hand, recent Rb-Sr and mineral ages from the basement rocks, especially those of the Kaintaleck Complex, clearly show the presence of pre-Alpine mineral ages ranging from 413 to 355 Ma (DALLMEYER et al., 1992; HANDLER et al., 1992, submitted; HERMANN, 1992). The $^{40}Ar/^{39}Ar$ muscovite spectra indicate no loss of radiogenic argon due to Alpine overprint. We conclude therefore, that Alpidic metamorphism did not significantly exceed 400°C in the area of investigation.

4. Alpidic Ductile Deformation

Late Paleozoic and early Triassic cover sediments, especially the Veitsch Group and the Silbersberg Conglomerate, exhibit a penetrative foliation including a mineral or stretching lineation, respectively. The foliation generally dips towards NNW, the stretching lineation is generally subhorizontal and trends W to NW in the area Bruck a.d. Mur towards Trofaiach and SW in the sectors between Trofaiach and Vöstenhof. In accordance with previous investigations in the westerly adjacent areas general displacement during nappe stacking is top to the W or NW, respectively, due to shear sense indicators that have been formed during penetrative ductile deformation in cover sediments (NIEVOLL, 1983; RATSCHBACHER, 1986; RATSCHBACHER & OERTEL, 1987; NEUBAUER et al., 1987; RATSCHBACHER & NEUBAUER, 1989). The presence of these fabrics in the Permo-Triassic cover sequences clearly proves the Alpine age of the penetrative deformation.

5. Discussion

From a lithological point of view, the stratigraphy presented here has been basically well known for a long time (for summary, see TOLLMANN, 1977). Especially, the stratigraphic succession between the Veitsch nappe and the Kaintaleck Complex in the easternmost portions of the Graywacke Zone near Gloggnitz has been completely patched up to the Noric nappe (TOLLMANN, 1977; DAURER & SCHÖNLAUB, 1978; SCHÖNLAUB, 1979). Metamorphic rocks of the Kaintaleck Complex were believed to be included with those of the Noric nappe, although the successions below and above the Kaintaleck Complex are completely different from each other. Consequently, the Gloggnitz Riebeckite Gneiss have been compared with the Blasseneck Porphyroid and an Ordovician age was suggested (e.g., CORNELIUS, 1941; KOLLER & ZEMANN, 1991).

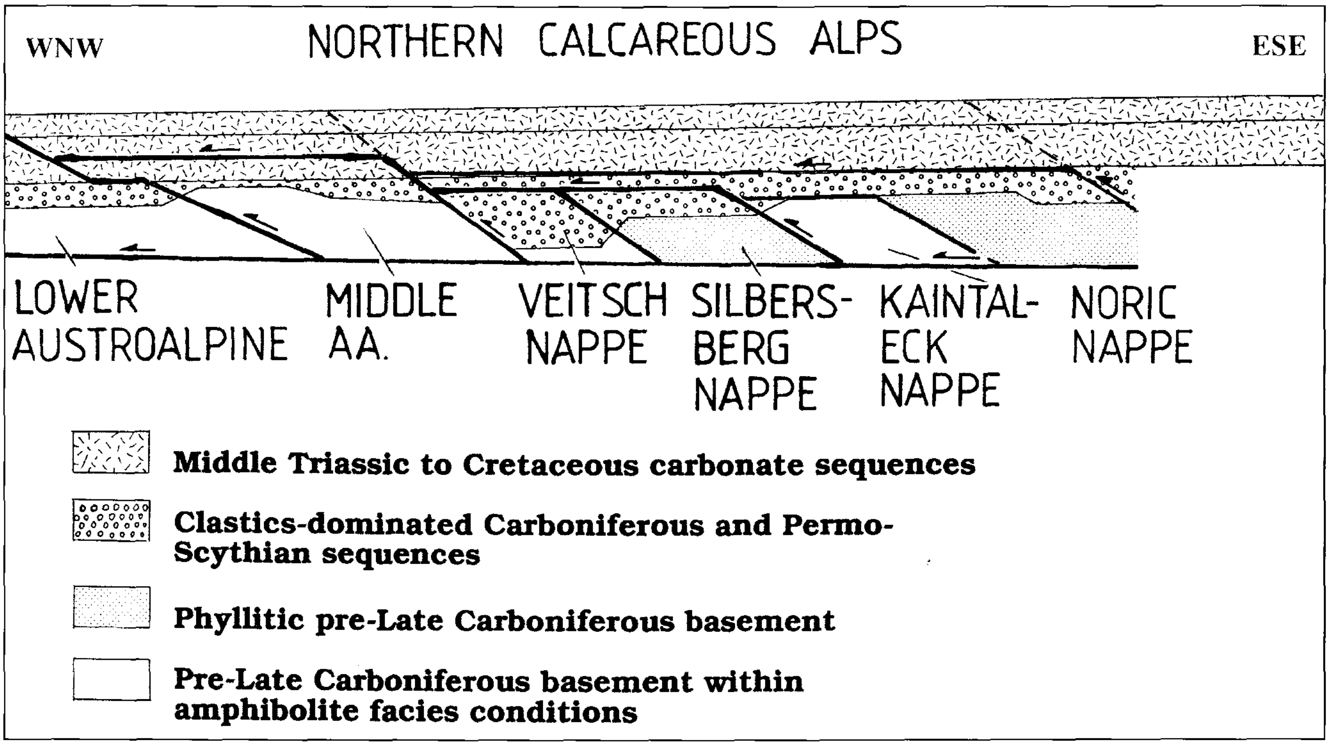
The age data (Tab. 1) from the Kaintaleck Complex (HANDLER et al., submitted; NEUBAUER & FRISCH, 1993) indicate that this Complex was not subjected to any major Variscan metamorphic overprint. This fact contrasts with the Variscan metamorphic overprint of the adjacent Rennfeld-Mugel Complex to the south (part of the Muriden units; NEUBAUER, 1988b; FRISCH & NEUBAUER, 1989; NEUBAUER & FRISCH, 1993). This difference underlines the importance of the Noric Thrust along which the Kaintaleck Complex has been emplaced. On the other hand, primary relationships between portions of the Kaintaleck Complex and the Veitsch nappe cannot be ruled out.

The new stratigraphic and tectonic divisions bear some importance to the Alpine paleogeography which we discuss here in a qualitative way. It is obvious from many sections, that the cover sequences of the Middle Austroalpine nappe, the Veitsch nappe and the Silbersberg nappe only include basal Permian and Triassic portions (Text-Fig. 7). Restoring in a qualitative way (for basic methods, see BOYER & ELLIOT, 1982), assuming a general NW transport during Alpine thrusting (e.g., RATSCHBACHER, 1986), the pre-thrusting arrangement of the Permian and Triassic sequences from present NW to SE is as follows: the Middle Austroalpine unit, Veitsch nappe, Silbersberg nappe, Kaintaleck nappe and Noric nappe as well as other nappes of the Northern Calcareous Alps. In this arrangement it is obvious that within northern portions of the Northern Calcareous Alps the basal stratigraphic portions are missing suggesting preservation within the other three nappes.

Our new data suggest a further aspect for large-scale regional correlation, namely the presence of two nappes con-

Tectonostratigraphic unit	Protolith ages	Extent and age (Ma) of pre-Alpine metamorphic overprint	Age of Alpine metamorphic overprint (Ma)
NORIC NAPPE:			
Basal Northern Calcareous Alps	Permian to Cenomanian		140 - 120
Noric Group	Late Ordovician to Visean(?)	greenschist facies 320 - 310	?
KAINTALECK NAPPE:			
Kalwang(?) Conglomerate	post-Middle Devonian	?	140 - 120
Kaintaleck Complex	pre-Devonian	polyphase amphibolite f. 520 - 380	140 - 90(?)
SILBERSBERG NAPPE:			
Silbersberg Conglomerate	Permian		?
Gloggnitz Riebeckite Gneiss	?		140 - 110(?)
"Quartzphyllite" Basement	Ordovician to Devonian (?)	greenschist	?
VEITSCH NAPPE:			
Veitsch Group	Early Carboniferous to Early Permian	--	100 - 80
MIDDLE AUSTROALPINE NAPPE:			
Liesing-Thörl Groups	Permian - Middle Triassic		100 - 80
Rennfeld-Mugel Complex	L. Proterozoic to E.Carboniferous	polyphase amphibolite f. 360 - 330	100 - 80

Table 1.
Summary of stratigraphic and geochronological data of the Eastern Graywacke Zone.
Geochronological data are based on compilations and data in FRANK et al. (1987), NEUBAUER et al. (1987), NEUBAUER (1988a), DALLMEYER et al. (1992), HANDLER (1994), HANDLER et al. (1992, submitted) and NEUBAUER & FRISCH (1993).



Text-Fig. 7.
Suggested restored paleogeography of eastern sectors of the Austroalpine units.

taining early Paleozoic phyllitic basement rocks with possibly early Paleozoic quartzphyllites in the Silbersberg Nappe and early Paleozoic, mostly pelagic sediments in the Noric Nappe. This relationship closely resembles the internal structure of the Upper Austroalpine units in the Central Alps, i.e. those of the Graz and Gurktal Nappe Complexes. In the Gurktal Nappe Complex, the basement lithologies (mainly quartzphyllites, greenschist and marbles) of the Murau Nappe could be largely compared with the Silbersberg Nappe and those of the Stolzalpe Nappe with those of the Noric Group. In the Graz Nappe Complex, lithologies of the Schöckl-Anger Groups are similar to the quartzphyllites of the Silbersberg Nappe, the Noric Group has main equivalents in the pelagic Laufnitz Group within the Graz Nappe Complex. These relationships argue for a major uniform Upper Austroalpine nappe system that covers the entire Middle Austroalpine unit of the Central Alps.

6. Conclusions

From the data presented above and discussions we conclude:

1. The eastern Graywacke Zone is composed of four Alpine thrust sheets.
2. Major portions of the Kaintaleck Complex do not represent the basement of the early Paleozoic Noric Group.
3. The metamorphic Kaintaleck complex strongly contrasts in time the Variscan metamorphism within the Middle Austroalpine basement.
4. The Silbersberg nappe between Veitsch and Kaintaleck nappes includes both a quartzphyllitic basement and a Permian (?) cover sequence.
5. The Alpine metamorphic overprint in the eastern Graywacke Zone did not significantly exceed 350–400°C.
6. The pre-Alpine tectonothermal overprint is, therefore, well preserved in the eastern Graywacke Zone.

Acknowledgements

We acknowledge valuable suggestions by formal reviews from Helmut HEINISCH (Gießen) and Hans-Peter SCHÖNLAUB (Vienna). The work has been supported by the Austrian Science Funds (grants P7405-GEO and P8652-GEO).

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Manuscript received: 28. 12. 1992
Revised version received: 21. 07. 1993
Manuscript accepted: 06. 10. 1993