Structural analysis of the Late Cretaceous Gosau Group of Rigaus, Fahrenberg and Nussensee (Northern Calcareous Alps, Salzburg – Upper Austria): Tertiary deformation during lateral extrusion illustrated

Die tertiäre Deformation der Gosaugruppe von Rigaus, Fahrenberg und Nussensee (Oberkreide – Eozän) während der ostgerichteten Extrusion der Ostalpen (Nördliche Kalkalpen, Salzburg – Oberösterreich)

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mit 8 Abbildungen und 1 Tabelle

Keywords:
Northern Calcareous Alps
Salzburg
Upper Austria
Gosau Group
Tertiary Deformation
Strike-slip faulting

Schlüsselwörter:
Nördliche Kalkalpen
Salzburg
Oberösterreich
Gosau Schichtgruppe
Tertiäre Tektonik
Blattverschiebung

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Mitt. Ges. Geol. Bergbaustud. Österr.	**38**	S. 93–106	Wien, 1992

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Zusammenfassung

Strukturanalysen im Bereich der Gosauvorkommen von Rigaus, Fahrenberg und Nussensee erlauben die Charakterisierung folgender Deformationen: (1) einer N–S gerichteten Verkürzung mit Ausbildung von Blattverschiebungen und einer anschließenden E–W orientierten subhorizontalen Extension. Diese Deformationen werden der Oligozänen-Miozänen, ostwärts gerichteten Ausweichbewegung der Ostalpen unter fortschreitender N–S Einengung zugeordnet (RATSCHBACHER et al., 1991); (2) eines jüngeren Ereignisses mit E–W gerichteter Kompression.

(1) Im Zuge der ostgerichteten Ausweichbewegung der Kalkalpen werden (W)SW–(E)NE streichende sinistrale Blattverschiebungen angelegt, die die Grenze der Rigauser Gosau zum Osterhorntirolikum und zur Dachsteindecke bilden. Diese Blattverschiebungen setzen sich in der NE-gerichteten Überschiebung der Fahrenberg Gosau auf die Nussensee Gosau fort. Die Überschiebung bildet die kinematische Verbindung des Rigauser Störungssystemes mit der sinistralen Traunsee Blattverschiebung. Der Mindestversatz an beiden Störungssystemen beträgt 3 km. Vor allem kleinmaßstäbliche Blattverschiebungen werden während der nachfolgenden E–W gerichteten Dehnung als Abschiebungen reaktiviert. Vertikale N–S streichende fasergefüllte Zerrspalten, die lokal bis zu 6% Dehnung anzeigen, werden ebenfalls der E–W gerichteten Streckung zugeordnet. Deviatorische Stresstensoren definieren ein älteres Stressfeld mit N–S orientiertem σ_1 und subhorizontalem E–W gerichtetem σ_3, sowie eine jüngere Tensorgruppe mit subvertikalem σ_1 und horizontalem, E–W gerichtetem σ_3.

(2) Ein Ereignis E–W gerichteter Kompression läßt sich aus der Überprägung von Kleinstrukturen sowie von dextralen Bewegungen an verschiedenen Abschnitten des Rigauser Störungssystemes und der Traunseestörung ableiten. Dieses Ereignis ist somit jünger als das ostwärts gerichtete Ausweichen der Nördlichen Kalkalpen. Die ermittelten Paläostressrichtungen (σ_1 E–W, σ_3 meist annähernd vertikal) können gut mit Ergebnissen aus anderen Abschnitten der Kalkalpen verglichen werden.

Abstract

Deformational structures of the Late Cretaceous Rigaus, Fahrenberg and Nussensee Gosau deposits record a Tertiary deformation history encompassing: (1) N–S shortening and subsequent E–W directed subhorizontal extension. Deformations are related to the eastward extrusion of the Eastern Alps during the Oligocene/Miocene (RATSCHBACHER et al., 1991). (2) E–W directed compression postdating extrusion.

(1) Large-scale structures that formed due to N–S shortening during eastward extrusion include (W)SW–(E)NE trending sinistral strike-slip faults separating the Rigaus Gosau from the Osterhorn Unit and the Dachstein Nappe, and the thrust stacking the Fahrenberg Gosau group onto the Nussensee Gosau formations. Motion of the hanging wall along this thrust parallels the direction of the strike-slip faults and kinematically links the Rigaus fault system to the Traunsee fault. A minimum offset of 3 km along this thrust compares well to the offset estimated for the Traunsee fault. Strike-slip faults are reactivated whith oblique-normal slip during subsequent subhorizontal E–W oriented extension. Extension is also accomodated by N–S trending subvertical tension gashes that locally account for up to 6% extension. Deviatoric stress tensors related to eastward extrusion are computed from meso-scale faults and indicate an older stress field with σ_1 oriented N–S, σ_3 subhorizontal E–W, and a younger one with σ_1 subvertical and σ_3 subhorizontal E–W.

(2) E–W directed compression postdating extrusion resulted in dextral slip along several segments of the Rigaus fault system and the Traunsee fault. Paleostress analysis of minor faults gives tensors with σ_1 directed E–W and σ_3 oriented subvertical.

1. Introduction

The Late Cretaceous Gosau deposits of Rigaus, Fahrenberg and Nussensee in the Salzkammergut area cover tectonic positions along major tectonic lines that separate the Tirolic Osterhorn and Staufen-Höllengebirge Nappe from the Juvavic Lammertal and Dachstein Nappe (Fig. 1). We will show, that the contacts of the Rigaus Gosau to the Tirolic and Juvavic nappes are sinistral strike-slip faults here termed Einberg and Rigaus fault (Fig. 1). The earliest description of this fault system we are aware of comes from LEBLING (1911). These faults form the southern continuation of the sinistral Traunsee strike-slip fault. The kinematical linkage of the Traunsee and Rigaus faults is formed by the thrust of the Fahrenberg Gosau group onto the Nussensee Gosau deposits.

The Traunsee fault as well as a series of equally oriented sinistral strike-slip faults formed during the eastward lateral extrusion of the Eastern Alps (Fig. 2; LINZER et al., 1990; RATSCHBACHER et al., 1991). Part of the eastward motion of the Central Alps has been transferred to the northern units by faults that branch off from the SEMP strike-slip fault (LINZER et al., 1992). Strike-slip faulting and extension in the northern Eastern Alps including the Calcareous Alps started during the Miocene (DECKER et al., in press). The faults in the Rigaus and Fahrenberg area as well as most of the small-

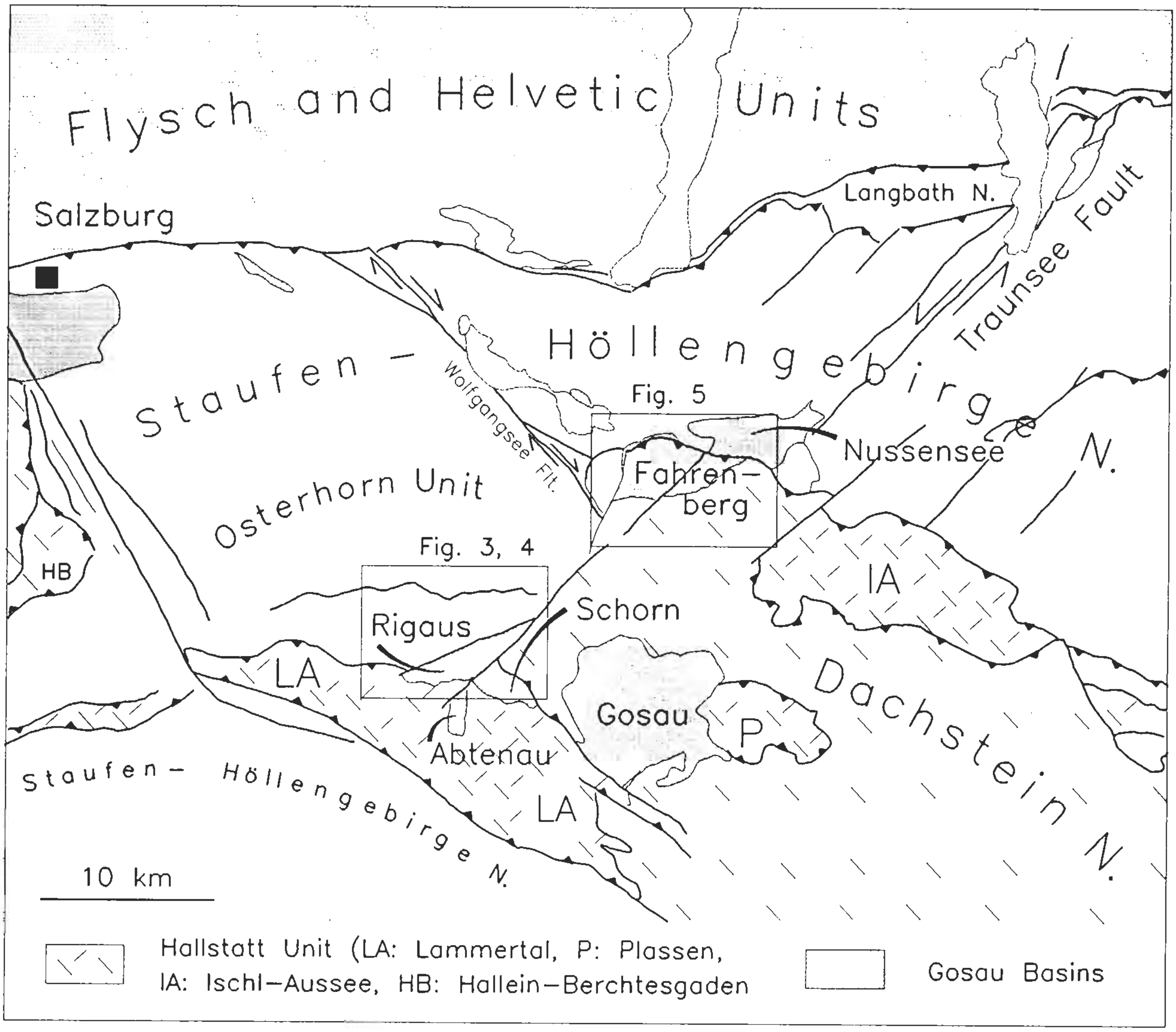

Fig. 1. Tectonic map of the Salzkammergut area. Synthesized from Tollmann (1976), the Geological Maps of Austria (1:50.000, No. 94 and 95) and Germany (1:200.000, Bad Reichenhall). The Tirolic nappes are the Staufen-Höllengebirge and Tennengebirge Nappe; Juvavic units (hatched) include the Berchtesgaden, Dachstein and Hallstatt nappes. Boxes refer to location of maps given in Fig. 3 and Fig. 5.

scale deformation structures recorded in the Gosau sediments formed during N–S compression and E–W extension during eastward extrusion. Structural analysis of these Gosau deposits and adjacent areas allow a detailed illustration of the kinematics and deformations related to lateral extrusion in this part of the Northern Calcareous Alps.

Stratigraphic and tectonic overview

The Early Santonian to Paleocene sediments of the Gosau Group at the Rigaus locality (Fig. 1) overlie Permian Haselgebirge of the Lammertal Unit (JARNIK, in prep.; WILLE-JANOSCHEK, 1966). They cover a tectonic position at the contact of the Osterhorn Unit, the Lammertal Unit and the Dachstein Nappe (Fig. 1) and therefore have been considered to disconformably overly the prae-gosauan thrust of the Juvavic nappes onto the Osterhorn unit (WILLE-JANOSCHEK, 1966; SPENGLER, 1951). The steeply NNW or SSE dipping Late Cretaceous sequences are tightly folded and dismembered by faulting. Detailed descriptions of the sedimentary sequences and geological maps are given by JARNIK (in prep.) and WILLE-JANOSCHEK (1966).

The Gosau group of the Fahrenberg consists of basal conglomerates and Conjacian to Santonian sandstones and marls unconformably overlying Late Triassic Dachsteinkalk Fm. of the Dachstein Nappe (PLÖCHINGER, 1973; 1982; SUMMESBERGER, 1985). These sequences form a WNW–ESE trending syncline at the northern tip of the Dachstein

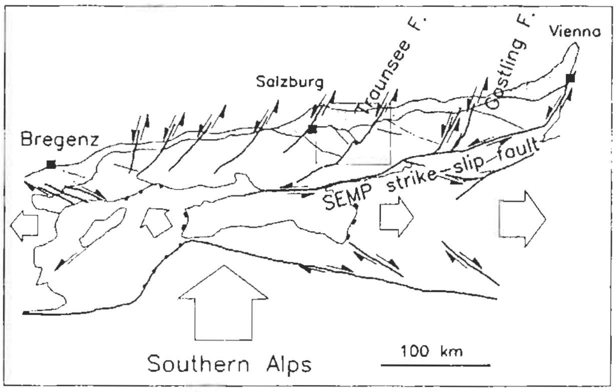

Fig. 2. Strike-slip faulting in the Eastern Alps during lateral extrusion of the Central Alps (dotted). Eastward displacement of the Central Alps is transferred to the Northern Calcareous Alps (white) by sinistral strike-slip faults branching off from the SEMP-strike-slip fault (e.g., the Traunsee fault). Tectonic sketch map after LINZER et al., 1990; RATSCHBACHER et al., 1991.

Nappe (Fig. 1) and have been thrust over Late Cretaceous deposits of the Nussensee Gosau resting on the Staufen-Höllengebirge Nappe. According to recent basin and facies analysis (WAGREICH, in prep.), the Fahrenberg and Nussensee sequences can be interpreted as the proximal and distal depositional sequences of the same sedimentary basin. The northern part of the Dachstein Nappe has also been thrust over the Wolfgangsee strike-slip fault and over Flysch and Helvetic sediments that occur in the flower structure of the Wolfgangsee tectonic window along this fault (PERESSON, 1992). Helvetic Eocene marls (Buntmergel Fm.; PLÖCHINGER, 1982; PERESSON, 1991) displaced from this flower structure along the fault bounding the Dachstein Nappe and the Fahrenberg Gosau to the west give a minimum offset of about 3 km and prove post-Eocene age of thrusting (Fig. 5).

Methods

We applied the methods of brittle microtectonics (e.g., HANCOCK, 1985) that include the analysis of brittle faults (PETIT, 1987), extension gashes (RAMSAY and HUBER, 1983), and joints (HANCOCK, 1985). In addition, paleostress analysis using the direct inversion method (ANGELIER, 1979;ANGELIER and GOGUEL, 1979; SPERNER, 1991; SPERNER et al., submitted) was carried out wherever a sufficient number of slickensides could be measured in a narrow outcrop. The direct inversion method computes the best-fitting deviatoric paleostress tensor for a homogenous group of slickensides. The tensor is defined by the orientations of the three

Table 1: Deviatoric stress tensors computed by the direct inversion method (ANGELIER, 1979; program by SPERNER, 1991). Tensors are defined by the orientation and the relative magnitude of principle stresses given by R ($\sigma_1 > \sigma_2 > \sigma_3$; $R = (\sigma_2 - \sigma_3)/(\sigma_1 - \sigma_3)$). Also given are the numbers of measurements and the mean deviation of the computed and the measured slickenlines. 1: Tensors related to N-S compression and strike-slip faulting; 1*: Tensors computed from the thrust of the Fahrenberg Gosau group onto the Nussensee Gosau formations. 2: Tensors related to subhorizontal E-W-oriented extension; 3: Tensors defining E-W-directed compression. See Figs. 4 to 8 for location of sites.

Rigaus					
AB-1 Dachstein limestone, 14 measurements					
1	σ_1 171/13	σ_2 277/49	σ_3 70/38	R = 0.19	F = 8°
AB-2 Dachstein limestone, 24 meas.					
1	σ_1 2/6	σ_2 111/70	σ_3 270/18	R = 0.56	F = 6°
3	σ_1 70/7	σ_2 336/26	σ_3 174/63	R = 0.45	F = 8°
AB-4-2 Dachstein limestone, 24 meas.					
1	σ_1 356/13	σ_2 232/67	σ_3 90/18	R = 0.70	F = 9°
AB-5-2 Gosau/Biebereck Fm., 9 meas.					
1	σ_1 193/22	σ_2 48/64	σ_3 289/14	R = 0.29	F = 5°
AB-7-2 Dachstein limestone, 8 meas.					
1	σ_1 10/0	σ_2 132/89	σ_3 280/1	R = 0.39	F = 6°
AB-9 Gosau/Zwieselalm Fm., 58 meas.					
1	σ_1 5/19	σ_2 191/71	σ_3 96/2	R = 0.81	F = 9°
2	σ_1 92/76	σ_2 2/0	σ_3 272/14	R = 0.92	F = 5°
3	σ_1 279/21	σ_2 24/34	σ_3 164/49	R = 0.11	F = 7°
AB-10 Gosau/Nierental Fm., 16 meas.					
1	σ_1 11/9	σ_2 116/57	σ_3 275/31	R = 0.25	F = 9°
3	σ_1 63/2	σ_2 154/19	σ_3 327/71	R = 0.12	F = 5°
Fahrenberg					
95-1 Gosau/Kreuzgraben Fm., 41 meas.					
1*	σ_1 199/8	σ_2 104/34	σ_3 301/55	R = 0.24	F = 5°
1	σ_1 9/5	σ_2 104/47	σ_3 274/42	R = 0.48	F = 12°
2	σ_1 93/64	σ_2 342/10	σ_3 247/23	R = 0.88	F = 3°
95-13-1 Gosau/Grabenbach Fm., 8 meas.					
3	σ_1 102/31	σ_2 324/51	σ_3 206/21	R = 0.15	F = 2°
95-21-1 Dachsteinkalk Fm., 11 meas.					
1	σ_1 224/5	σ_2 2/83	σ_3 134/4	R = 0.59	F = 12°
95-22-2 Dachsteinkalk Fm., 13 meas.					
1	σ_1 357/1	σ_2 95/85	σ_3 267/5	R = 0.03	F = 4°
95-23 Gosau/Grabenbach Fm., 11 meas.					
1*	σ_1 20/18	σ_2 114/13	σ_3 239/67	R = 0.78	F = 11°
Nussensee					
95-16 Gosau/Kreuzgraben Fm., 19 meas.					
1*	σ_1 206/2	σ_2 296/14	σ_3 108/76	R = 0.20	F = 12°
2	σ_1 2/50	σ_2 182/40	σ_3 272/0	R = 0.74	F = 3°
95-20-1 Gosau/Reef Complex, 14 meas.					
1	σ_1 175/4	σ_2 65/78	σ_3 266/11	R = 0.56	F = 11°

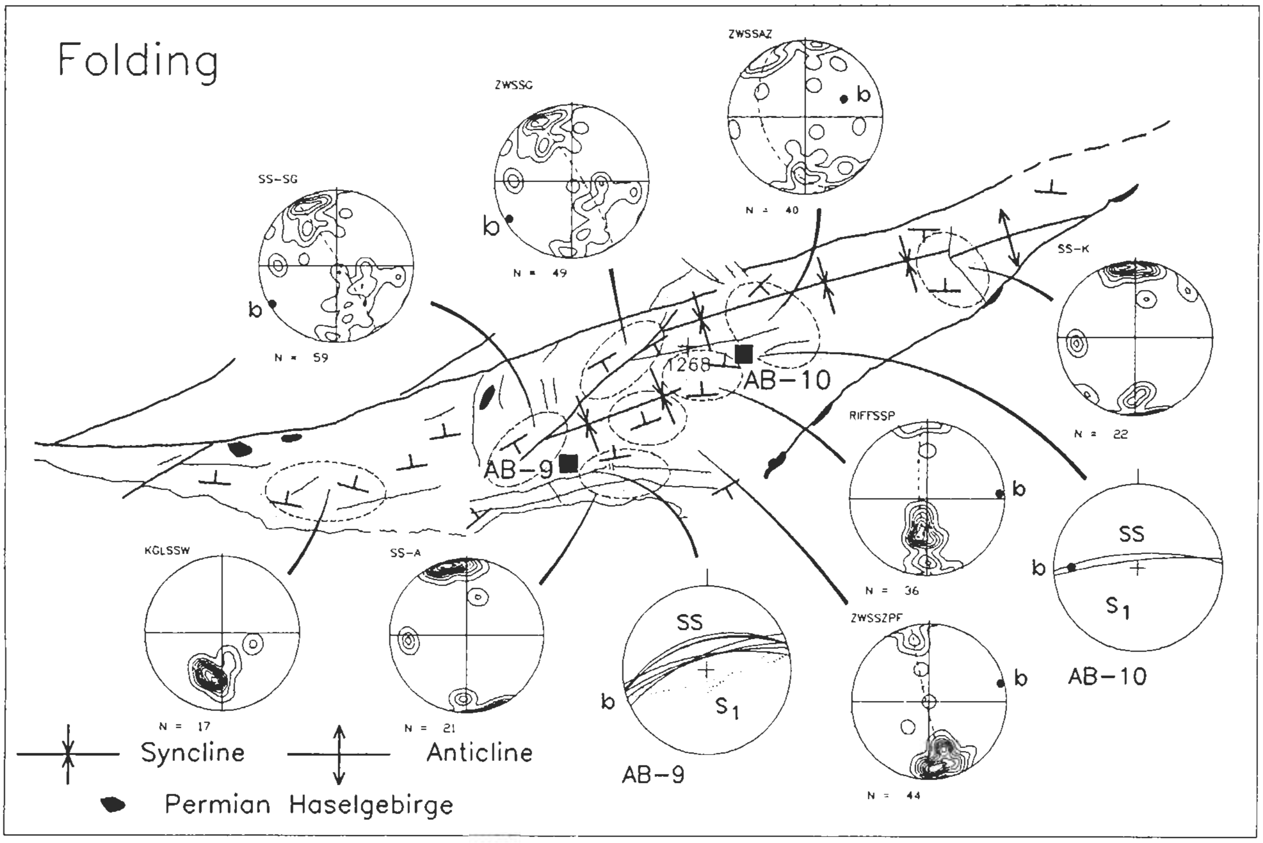

Fig. 3. Folding of the Rigaus Gosau group (dotted; after Jarnik, in prep.). Insets: Contoured stereographic plots (Schmidt's projection, lower hemisphere) of poles to bedding planes. Great circles represent the best-fitting plane through data points, the minimum eigenvectors normal to this plane give the best-fitting fold axes. Insets to stations AB-9 and AB-10: intersections of bedding and axial plane cleavage. Data support ENE-WSW trending fold axes. Location of map given in Fig. 1.

principle stresses $\sigma_1 > \sigma_2 > \sigma_3$ and by the relative magnitudes of these stresses $R = (\sigma_2 - \sigma_3)/(\sigma_1 - \sigma_3)$. The best-fit tensor is found by minimization of the deviation angles between the measured slickenlines and the orientations of the maximum shear stresses in the fault planes for the computed tensor (BOTT, 1959). Planes with unknown sense of movement are considered in this calculation. More detailed descriptions of the separation and computation procedure and discussions of the limitations of this method are given by CAREY (1979), DECKER et al. (in press), ETCHECOPAR et al. (1981) and ONCKEN (1988). The kinematic analysis of large-scale faults was aided by map interpretations (JARNIK, in prep.; PLÖCHINGER, 1982, 1987) and by the use of aerial photographs. Density contouring of poles to bedding planes after the method of ROBIN and JOWETT (1986) and computation of minimum eigenvectors for the reconstruction of large-scale fold axes was done with the program SpheriStat 1.1 at the University of Tübingen.

2. Results

Structural analysis reveals four major Tertiary deformations of the Gosau deposits. The following relative chronology has been deduced from cross-cutting relationships of structures observed in the field (from old to young): (1) folding of the Rigaus Gosau group; (2) strike-slip faulting related to N-S oriented compression together with the formation of major SW-NE trending sinistral strike-slip faults; (3) E-W oriented subhorizontal extension; and (4) E-W oriented compression.

2.1. Folding of the Rigaus Gosau

The oldest deformational structures recorded in the Rigaus Gosau are map-scale and mesoscale folds with horizontal E-W to ENE-WSW orientated fold axes. Orientations of fold axes are derived from analyzing dips of bedding planes, intersection lines of bedding and axial plane cleavage (Fig. 3), and from the orientation of slip along bedding planes related to flexural slip folding.

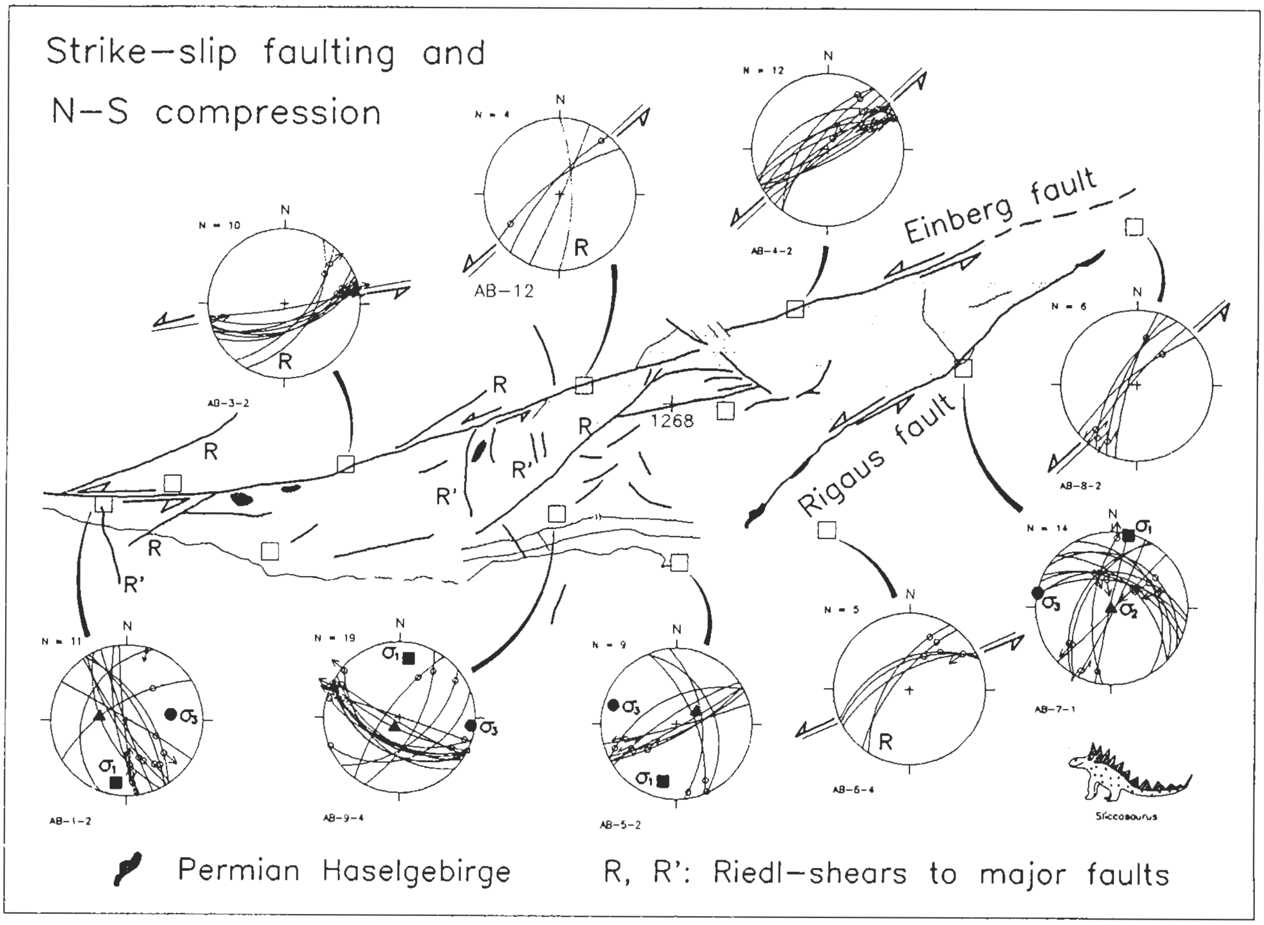

Fig. 4. Strike-slip faulting in the Rigaus area. Sinistral movement along the Einberg and Rigaus faults bounding the Gosau deposits are inferred from mapped slickensides (inserted stereographic plots) and from faults joining the major faults that are interpreted as synthetic (R) and antithetic Riedl shears (R'). Stereographic plots AB-1-2, AB-9-4, AB-5-2 and AB-7-1 show the orientations of the main principal stresses ($\sigma_1 > \sigma_2 > \sigma_3$) computed from the fault planes (comp. Tab. 1). Lower hemisphere Schmidt's projection with great circles representing fault planes, slickenlines marked by dots and arrows indicating senses of movements.

2.2 Strike-slip faulting and N–S shortening

Map-scale faults

Kinematical analysis of the major faults bounding the Rigaus Gosau to the north in the slope of the Einberg and to the south in the Rigaus valley shows that both faults are steeply dipping sinistral strike-slip faults. Senses of movement are inferred from sinistral slickensides with large offset in outcrops along the Einberg and Rigaus faults and from faults that include angles of about 20° with the master faults (Fig. 4). The latter are interpreted as Riedl shears. The Einberg fault is clearly cut by the younger Rigaus fault (Fig. 1). The Rigaus fault can be traced to the northeast for at least some 15 km to the Ischl Valley where it forms the western boundary of the Fahrenberg Gosau (Fig. 5). Sinistral shear bands and fiber-coated faults with significant offsets prove sinistral sense of shear. Eocene Helvetic marls displaced from the Wolfgangsee flower structure to the NE give the minimum offset along this fault segment of about 3 km (Fig. 5; PERESSON, 1992).

The Rigaus strike-slip fault shows a marked change of dip from subvertical in the SW (Rigaus valley) to a dip of about 45° towards SE (E of the Postalm; compare plots AB-8-2 and 95-24-1 in Fig. 8) causing the curved outcrop trace of the fault depicted in Fig. 8. To the NE, the Rigaus fault is kinematically linked to the thrust of the Fahrenberg Gosau group of the Dachstein Nappe over the Nussensee Gosau deposits (Fig. 5). Thrusting along this segment is directed towards the NE, paralleling the slip along the Rigaus fault. The direction of main shortening of the Fahrenberg Gosau formations is about NE–SW as inferred from the axes of the map-scale syncline formed by the Gosau deposits (PLÖCHINGER, 1982) and from axial plane cleavage-bedding intersections (Fig. 5). SE-dipping and conjugate NW-dipping reverse faults from both the overriding Fahrenberg and the Nussensee Gosau sequences in the footwall (plots 95-

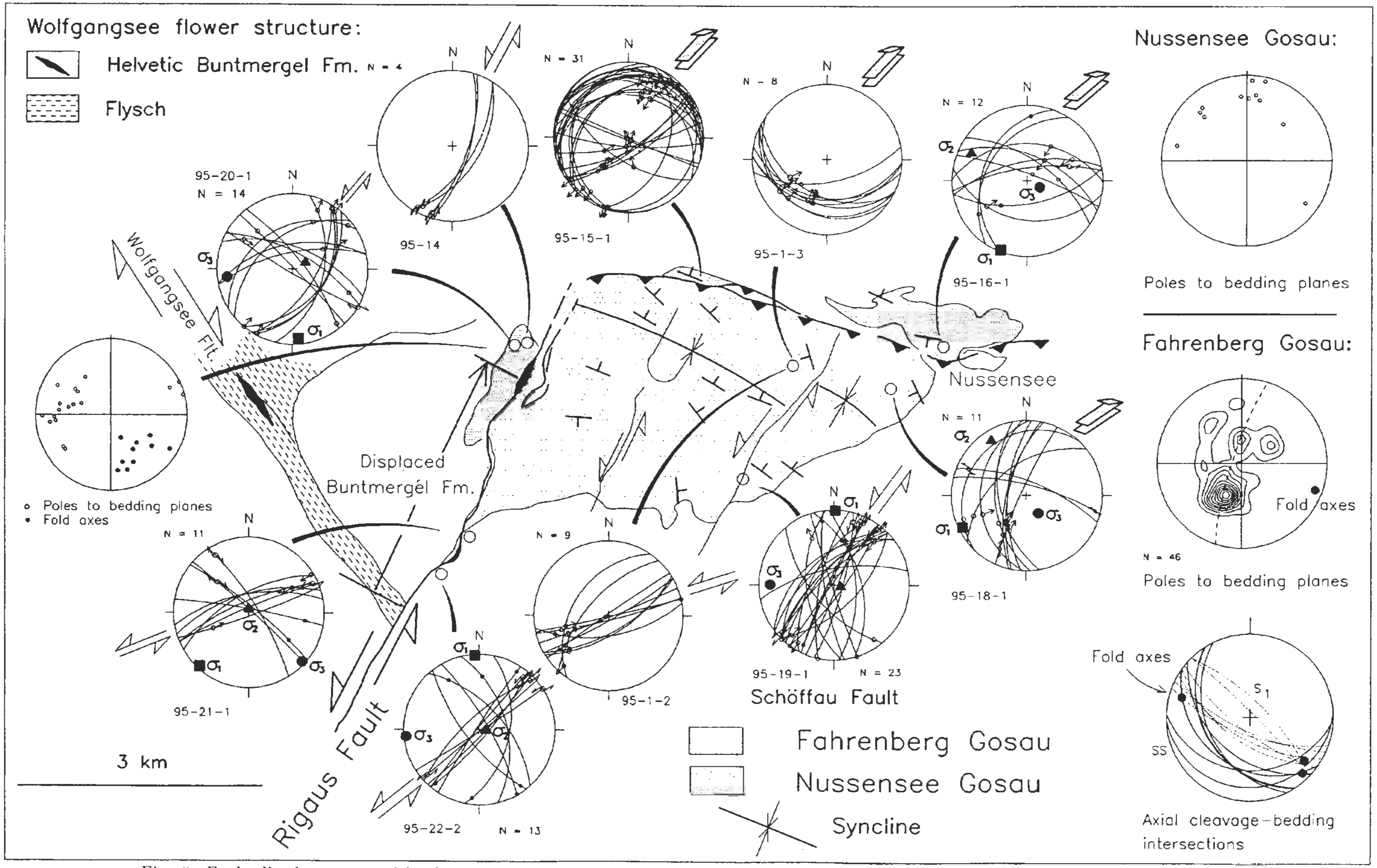

Fig. 5. Fault-slip data mapped in the area of the Fahrenberg. Sinistral offset along the Rigaus fault is inferred from slickensides plotted in insets 95-14, 95-21-1 and 95-22-2. The fault is linked to the top-to-NE thrust of the Fahrenberg onto the Nussensee Gosau formations. Slip along reverse faults parallels the strike-slip fault (plots 95-1-3, 95-15-1). Right column: fold axes determined from bedding planes and cleavage-bedding-intersections in Fahrenberg Gosau deposits. Fold axes are oriented perpendicular to the slip direction along the footwall thrust of the Fahrenberg Gosau group. Location of map shown in Fig. 1.

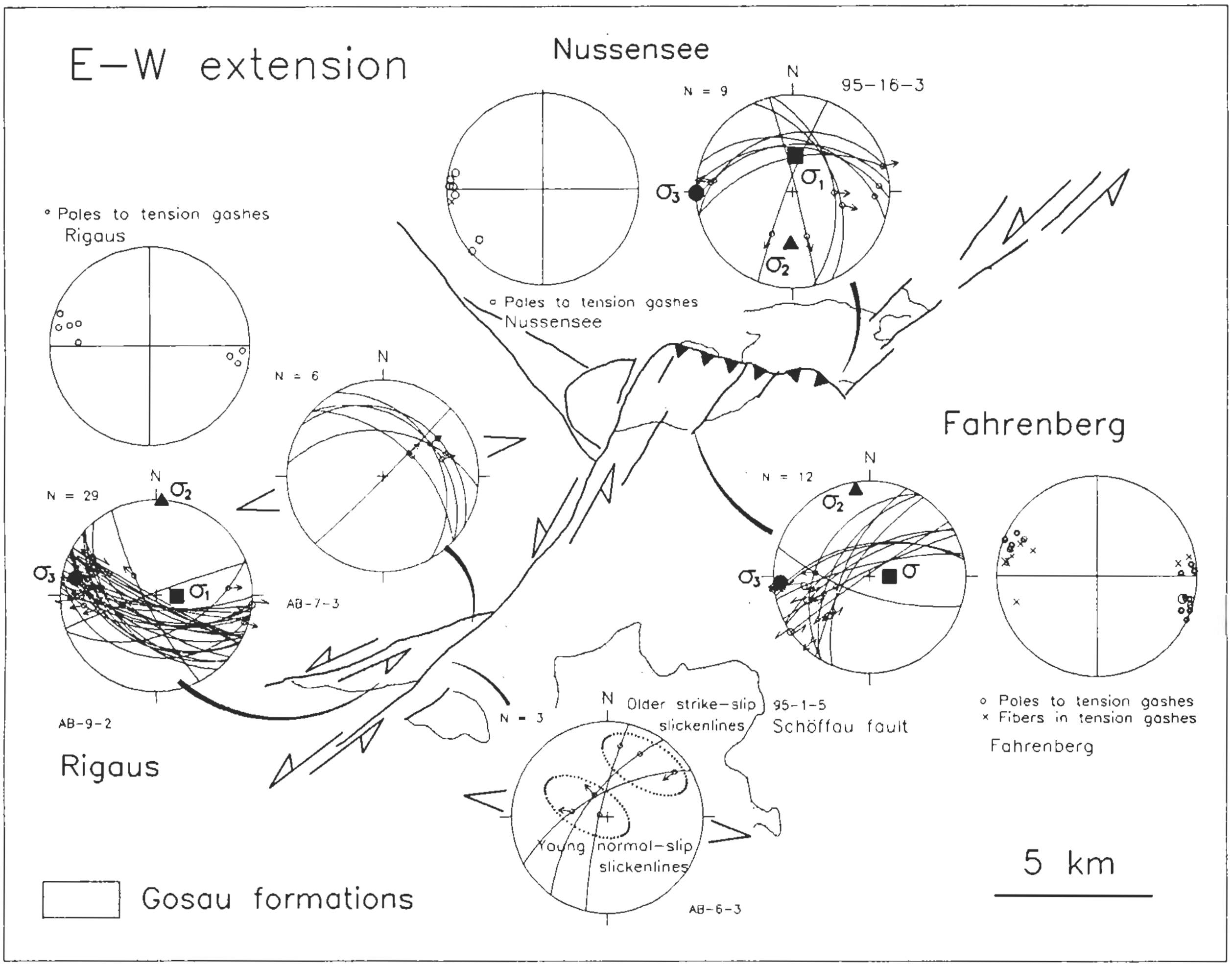

Fig. 6. Subhorizontal E–W directed extension. Extension is mainly achieved by oblique-normal reactivation of former strike-slip faults that formed during N–S compression (plot AB-6-3). Tension gashes and growth directions of calcite fibers in the gashes from the Nussensee, Fahrenberg and Rigaus Gosau deposits also indicate E–W oriented extension.

1-3, 95-15-1, 95-16-1 in Fig. 5) indicate thrusting towards the NE in a local stress field with σ_1 directed horizontally NE–SW and subvertical σ_3. Plot 95-15-1 indicates rotation of the former synthetic NE-directed reverse faults into near-vertical orientation during subsequent folding. Fold-and-thrust structures of the Fahrenberg Gosau deposits are cut by younger sinistral strike-slip faults (e.g., the Schöffau fault, Fig. 5) that indicate continued N–S shortening.

Meso-scale structures related to N–S shortening

N–S orientated compression in the Rigaus, Fahrenberg and Nussensee Gosau is evidenced by conjugate fibre-coated faults (Fig. 4, plots AB-9-4 and AB-10-2). Meso-scale faults cutting axial plane cleavage and map-scale faults cutting folds show that strike-slip faulting postdates folding of the Rigaus Gosau. Paleostress analysis of homogenous fault sets off the large strike-slip faults reveals deviatoric stress tensors with N–S orientated σ_1, vertical σ_2 and E–W dircected σ_3 (Tab. 1 and Fig. 4). Tensor orientations are consistent throughout the study area.

2.3. E–W directed subhorizontal extension

Conjugate meso-scale strike-slip faults that formed during N–S oriented compression are subsequently reactivated as oblique-normal faults. Paleostress analysis from such fault populations reveal deviatoric tensors with subvertical σ_1 and σ_3 orientated subhorizontally E–W (Tab. 1; Fig. 6, plots 95-1-2, 95-1-5). E–W extension is also indicated by vertical N–S trending tension gashes that are very prominent both within Gosau deposits and within Triassic rocks of the Osterhorn and Dachstein unit. Estimating strain from stretched pebbles in conglomerates of the Fahrenberg Gosau reveals about 3–6% extension compensated by such tension gashes.

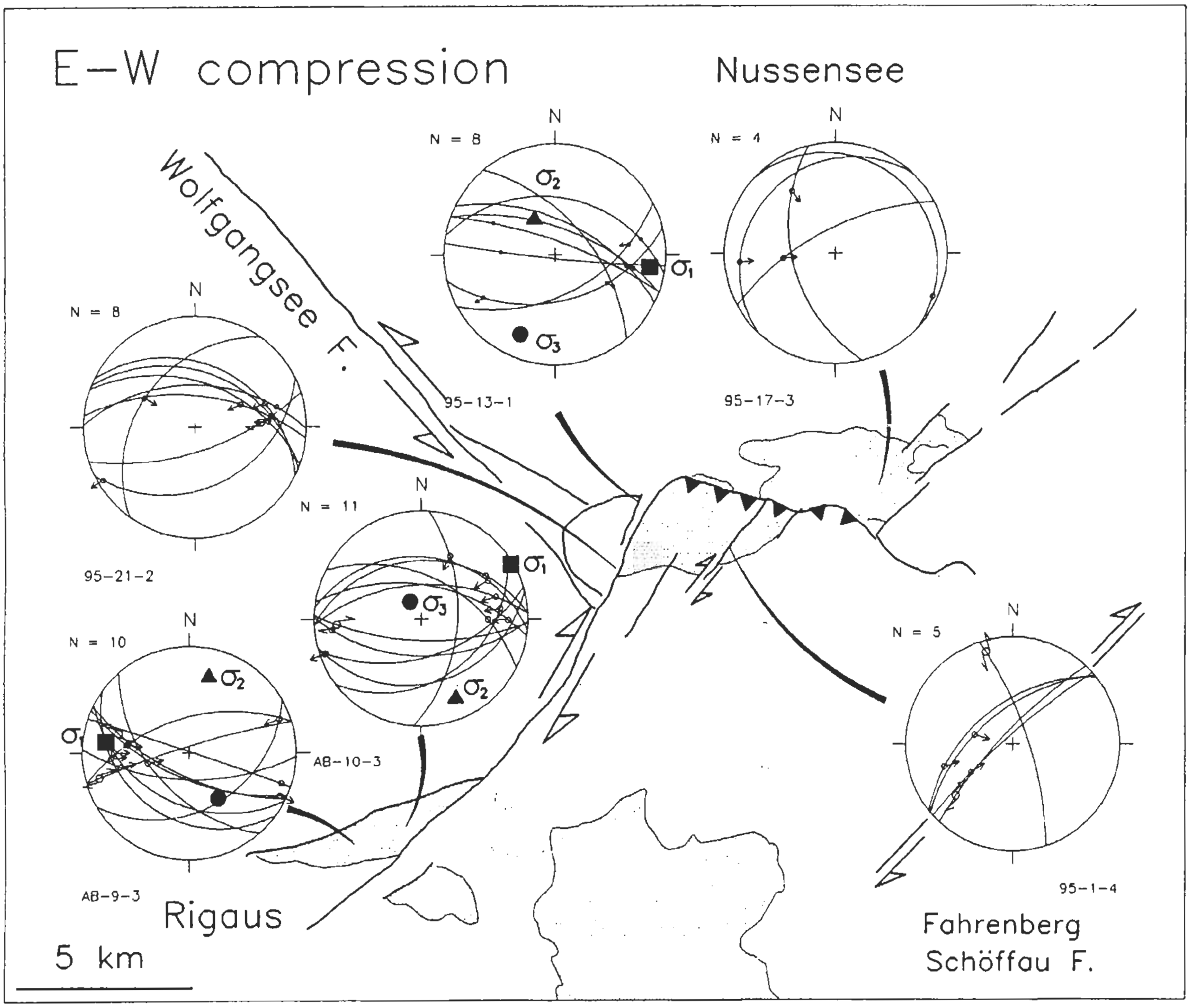

Fig. 7. E–W oriented compression. Dextral reactivation of former sinistral faults (e.g., plot 95-1-4) indicates that E–W compression postdates N–S oriented compression. Stress tensors computed from reactivated faults show E–W oriented subhorizontal σ_1 while the orientation of σ_3 varies from near-vertical to subhorizontal. Sinistral movement along the Wolfgangsee fault has been described by Peresson (1992).

2.4. E–W directed compression

An event of E–W directed compression postdating N–S compression and E–W oriented extension is indicated by reactivation of variably oriented faults including conjugate strike-slip faults that formed during N–S compression (Fig. 7). Observations along the Rigaus fault (sites 95-21 and 95-22) indicate dextral movements of this major fault during this tectonic event. Similar results come from the Traunsee fault NE of the study area (GEISER, in prep.). In the Fahrenberg Gosau, dextral slip occured along the previously sinistral strike-slip fault that cuts the Gosau in the Schöffau valley (Fig. 7; plot 95-1-4). The deviatoric stress tensors computed from several fault sets, though constrained by comparably few data, show very similar orientations with ENE–WSW trending σ_1 and near vertical σ_3.

3. Discussion

Folding of the Rigaus Gosau Group

Folding of the Rigaus Gosau formations may either be related to an earlier deformation or to transpression resulting from interaction of sinistral shearing and horizontal shortening of the Gosau deposits between the Einberg and Rigaus fault (e.g., SANDERSON and MARCHINI, 1984).

Cross-cutting relationships show that folding of the Rigaus Gosau predates subsequent strike-slip faulting. No evidence has been found for folded fault planes or faults rotated during folding. Extension directions (trending 80° to 100°; Fig. 6) deduced from

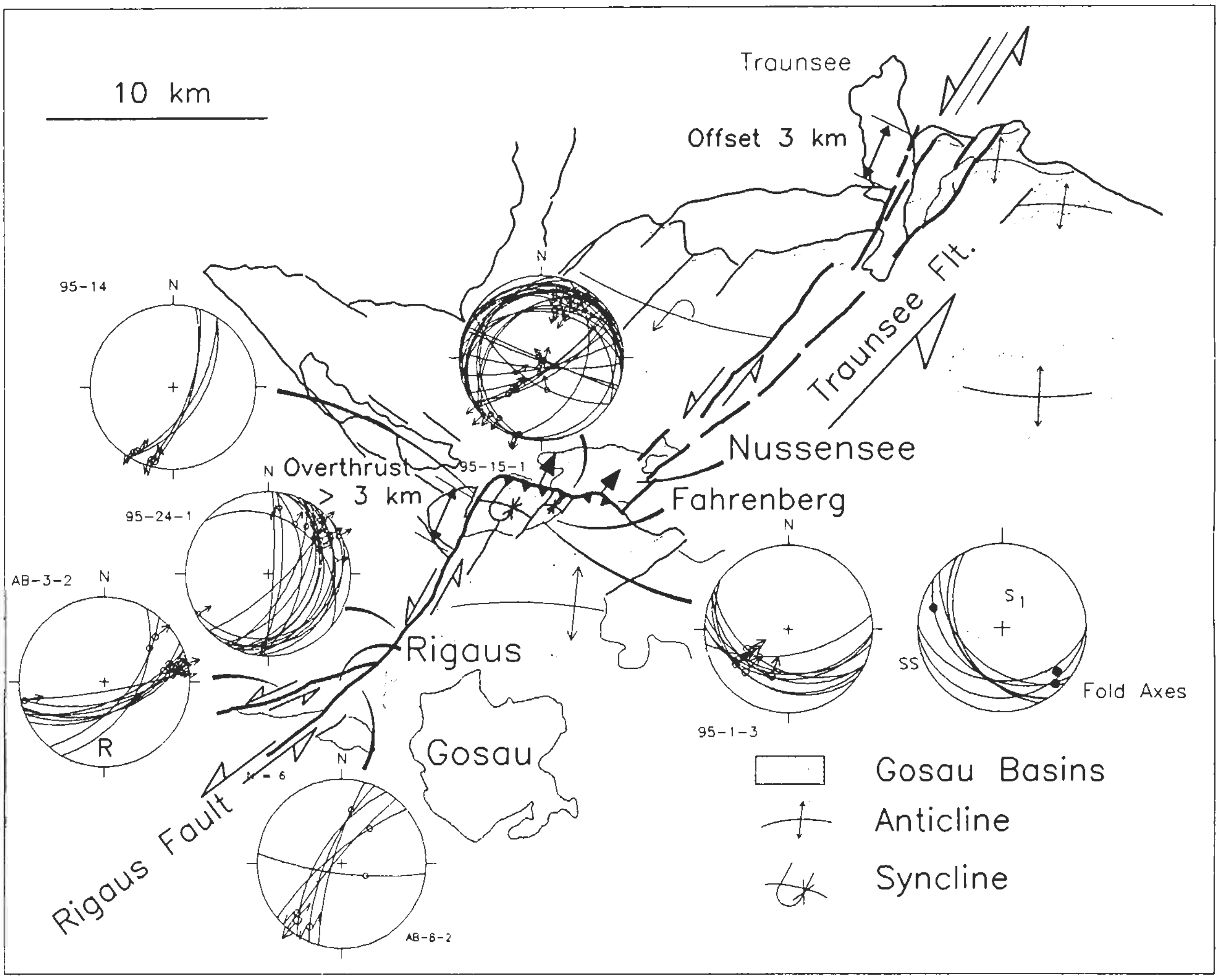

Fig. 8. Kinematics of the Rigaus-Traunsee strike-slip fault system. The Rigaus fault is linked to the Traunsee fault system by the thrust of the Fahrenberg Gosau group onto the Nussensee Gosau group. The minimum offset estimated for the northern part of the Rigaus fault (3 km) compares well to the offset of the northern margin of the Calcareous Alps by the Traunsee fault. Dots delineate the eastern NE-moving block bounded by the Traunsee-Rigaus System.

oblique-normal faults and tension gashes approximately match orientations of fold axes that trend 60° to 90° (Fig. 3) as expected for transpressional settings (e.g., BÜRGMANN, 1991; RATSCHBACHER, 1986). However, extension directions are consistent with data from the Fahrenberg and Nussensee area suggesting coaxial E–W extension on a larger regional scale. This indicates that extension in the Rigaus area occured during a distinct tectonic event rather than in a local transpressional regime along a short segment of the Rigaus strike-slip fault system.

Fold axes in the Rigaus Gosau compare well to the orientation of ENE–WSW trending fold axes and to compressional structures like SSE-dipping ramps in the Gosau of the type locality 5 km to the east (Fig. 1). These structures are related to Eocene thrusting within the Northern Calcareous Alps (compare DECKER et al., in press) predating deformations related to eastward extrusion.

Strike-slip faulting during N–S compression and east-west directed subhorizontal extension

Sinistral movement along the SW–NE trending Rigaus fault system kinematically results in about N–S oriented shortening and E–W directed extension. Paleostress analysis in the blocks bound by these faults reveals tensors with horizontal N–S trending σ_1 and σ_3 oriented horizontal E–W. Such tensors have been found all over the northern margin of the Eastern Alps defining a fairly homogenous stress field (DECKER et al., in press). We assume that the Rigaus and Einberg fault were active in this stress field. The locally deviating stresses along the thrust of the Fahrenberg onto the Nussensee Gosau formations result from geometrical constraints. The direction of reverse slip along this SW-dipping fault is determined by slip direction of the Rigaus and Traunsee fault system performing a "guided movement" (CASAS-SAINZ and SIMÓN-GÓMEZ, 1992). This thrust kinematically links the Rigaus fault to the Traunsee fault in the NE. 3 km offset along the Rigaus fault east of the Fahrenberg compare well to the offset estimated for the northernmost part of the Traunsee Fault (Fig. 8).

The Traunsee strike-slip fault has been interpreted as a major fault branching off from the SEMP strike-slip fault and transferring a part of the eastward motion of the Central Alps into the Northern Calcareous Alps (Fig. 2; LINZER et al., 1992). Overall E--W extension and eastward motion within the Northern Calcareous Alps is also accomodated by minor conjugate strike-slip faults, normal faults and extension gashes that sum up to significant strain values within the blocks bounded by major faults. Deformation within these blocks was coaxial. This can be shown by regionally consistent orientations of tension gashes and by fault slip analysis that gives no hint for rotation of stress axes relative to the blocks. The stresses recorded for strike-slip faulting and subsequent extension (older tensors with σ_1 N-S, σ_3 E-W; younger tensors with σ_1 vertical and σ_3 E-W) show very consistent orientations and can be correlated to tensor groups encountered along the northern margin of the Eastern Alps (tensor group S_3 and E_4 of DECKER etal., in press).

East-west compression

Young east-west compression postdating the lateral extrusion of the Eastern Alps has already been described from the northern part of the Eastern Alps (DECKER et al., 1992; PERESSON, 1992). In the Rigaus and Fahrenberg area, E-W directed compression caused reactivation not only of minor fractures but also of parts of the Rigaus fault and the Wolfgangsee fault (PERESSON, 1992). Reversed movement has also been documented for the Traunsee fault (GEISER, in prep.). Paleostresses computed from three homogenous fault sets reveal tensors with near-vertical σ_3. Comparison with data from other sites in the eastern NCA (DECKER et al., 1992) shows that the regional stress field corresponding to E-W compression is inhomogenous. Deviatoric tensors are characterized by either vertical σ_2 or vertical σ_3 while σ_1 is orientated E-W rather constantly.

4. Conclusions

(1) Structures that formed during Miocene eastward extrusion of the Calcareous Alps encompass the SW-NE striking sinistral Einberg and Rigaus strike-slip faults as well as the northeastward thrust of the Dachstein Nappe onto the Nussensee Gosau which is kinematically linked to these faults. In the meso-scale, N-S compression and E-W extension is accomodated by conjugate strike-slip faults, (oblique)normal faults, and subvertical N-S trending fibrous extension gashes.

(2) The paleostresses related to these deformations in the study area show a clear relative chronology. Strike-slip faulting predates subhorizontal extension. Strike-slip faulting occured in a stress field with horizontal σ_1 oriented N-S and horizontal σ_3 oriented E-W. These tensors are older than tensors with subvertical σ_1 and σ_3 subhorizontal E-W. These orientations of tensors are homogenous on a large scale within the eastern part of the Northern Calcareous Alps and the underlying units (Rhenodanubic Flysch and Helvetic Nappes; DECKER et al., in press). Locally deviating stresses as those related to northeastward thrusting of the Fahrenberg Gosau result from the guided movement along this thrust determined by the orientation of slip along the Traunsee and Rigaus fault.

(3) Strain accomodated by meso-scale structures in the Northern Calcareous Alps due to extrusion tectonics is significant. Locally, extension gashes account for up to 6% E-W extension. It is, however, difficult to estimate strains accomodated by minor strike-slip and normal faults.

Acknowledgements

We appreciate the discussions with Gert Linzer (Univ. Tübingen) who also critically reviewed this text. We thank Prof. Peter Faupl, Meinrad Geiser, Herwig Peresson and Michael Wagreich for fruitful discussions. Financial support of field work by the FWF projects P 8123 Geo for Kurt Decker and P 7462-Geo for Marion Jarnik is gratefully acknowledged.

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