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From extension to compression: Late Miocene stress inversion in the Alpine-Carpathian-Pannonian transition area

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ABSTRACT

Structural data from the Calcareous Alps, from the Vienna- and Styrian Basin and from the Bakony mountains support a Late Miocene E-W compressional event which affected the entire Alpine-Carpathian-Pannonian system after 9 Ma (Maeotian) and prior to 5.6 Ma (Pliocene). Compression terminated Early to Middle Miocene eastward lateral extrusion of the Eastern Alps and reverted the shear sense on strike-slip faults which bounded earlier extruded wedges such as the Salzachtal-Ennstal fault and the Mur-Mürz-Vienna Basin fault system. E-W directed compression terminated upper plate extension in the Pannonian area and tectonic subsidence in the Vienna- and Styrian Basin. In the Pannonian Basin, the change from extension to Late Miocene compression during the postrift phase could explain the pronounced postrift subsidence by stress-induced downward flexure of the loaded lithosphere.

Late Miocene E-W compression occurred coeval with the youngest E-directed thrusts in the Eastern Carpathians during final soft collisional convergence. Up to the Middle Miocene, slab pull during subduction of the European plate below the Eastern Carpathians caused subduction roll back and upper plate extension of the Pannonian area. Subduction retreat was replaced by soft collision after up to 60 km thick continental crust entered the subduction zone. During the period of collisional convergence E-W-directed compressive stress was transmitted across the subduction boundary into the upper plate. Compressive stress was transferred through the uppermost brittle crust of the earlier extended Pannonian region far into the Eastern Alps. E-W compression terminated during the Pliocene when the Pliocene to recent NNW-SSE compressive stress field was established in Central Europe.

Key words: stress inversion, paleostress, fault kinematics, fault reactivation, Late Miocene

Introduction

Tertiary tectonics of the Alpine-Carpathian-Pannonian system was controlled by N-S shortening between the Adriatic and European plates; by the extensional collapse of thickened Alpine crust which commenced in the Early Miocene (Ratschbacher et al., 1991); and by the retreat of the plate boundary in the Outer Carpathians where oceanic and thin continental lithosphere were subducted (Royden, 1993). All this occurred under generally N-S directed compression and E-W directed extension (Bergerat, 1987; 1989; Csontos et al., 1991; Fodor, 1995; Peresson and Decker, this vol.).

From about 20 Ma until 9 Ma, the northward indentation of the Adriatic plate together with the E-directed extensional collapse caused the eastward lateral movement of crustal wedges from the Eastern Alps into the Pannonian region (Royden et al., 1983; Ratschbacher et al., 1991). These wedges were displaced along (E)NE-striking sinistral and (E)SE-striking dextral transform faults which linked with Early to Middle Miocene thrusts in the Outer Carpathians at the leading edge of the wedges (Fig. 1; Decker and Peresson, 1996). Orogen-parallel E-W directed extension, detachment faulting, and the exhumation of metamorphic domes in the central Eastern Alps led to tectonic unroofing of the Tauern dome between the Brenner- and the Tauernostrand-detachment faults and of the Rechnitz core which began in the Early Miocene (Selverstone, 1988; von Blankenburg et al., 1989; Cliff et al., 1985; Genser & Neubauer, 1989; Ratschbacher et al., 1990; Tari et al., 1992; Mancktelow et al, 1995; Tari, this vol.). Eastward extrusion was intimately related to the eastward retreat of the subduction boundary in the outer Central and Eastern Carpathians where oceanic and thinned European continental crust were subducted westwards (Royden and Burchfiel, 1989; Royden, 1993). Subduction roll back also caused upper plate extension in the Pannonian area which resulted in Early to Middle Miocene subsidence of sedimentary basins and in the formation of shallow-dipping detachment faults (Bergerat, 1989; Tari et al., 1992; Horváth, 1993; Royden, 1993; Dunkl & Horváth, 1995; Tari, this vol.).

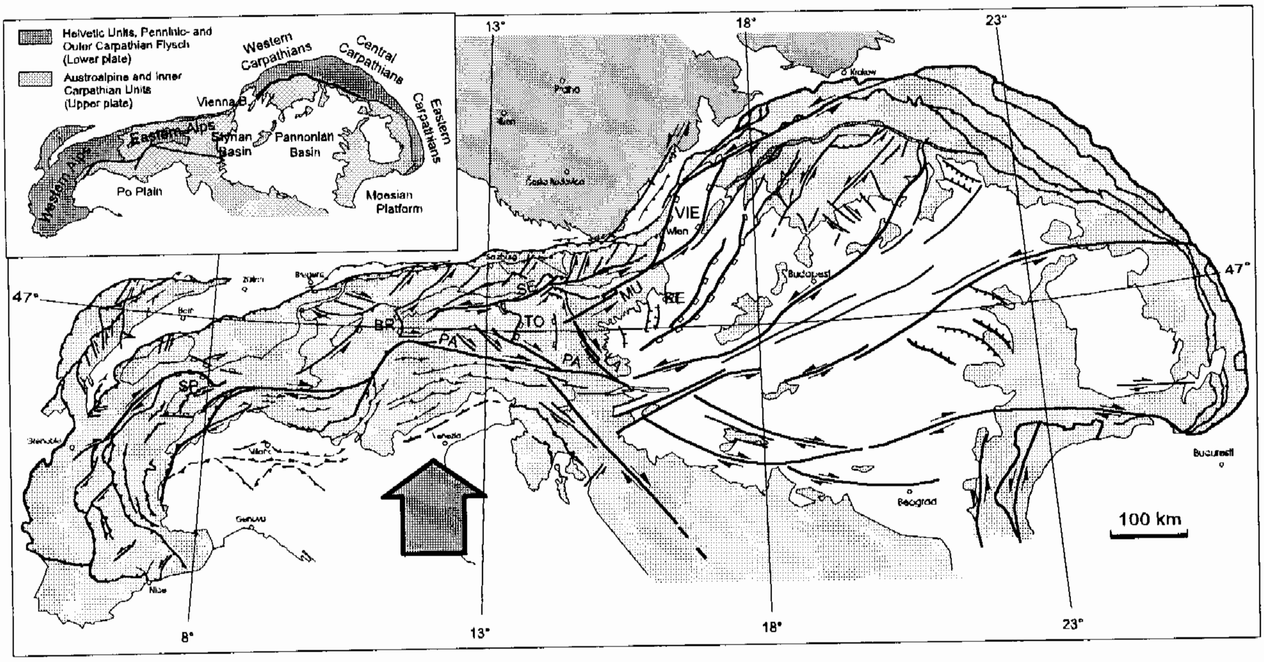

Fig. 1. Early- to Middle Miocene kinematics in the Alpine-Carpathian-Pannonian area. Synthesized from maps by Doglioni and Siorpaes, 1990; Ratschbacher et al., 1991; Mancktelow, 1992; Horváth, 1993; Decker at. al., 1994; Steck and Hunziker, 1994. BR: Brenner normal fault; La: Lavanttal fault; MU: Mur-Mürz Fault; PA: Periadriatic Line; RE: Rechnitz detachment fault; SE: Salzachtal-Ennstal fault; SP: Simplon normal fault; TO: Tauernostrand normal fault; VIE: Vienna Basin.

In this paper we review structural data from the Northern Calcareous Alps, the Vienna- and Styrian Basin, and from the Bakony mountains which proof a reorganization of the kinematics and dynamics. Kinematic and paleostress data indicate a transient E-W compressive event in the Late Miocene . Compression terminated orogen-parallel extension in the Eastern Alps, lateral extrusion, and upper plate extension in the Pannonian area and led to the inversion of Early and Middle Miocene structures (Peresson and Decker, 1996a).

Structural evidence for E-W compression

The Northern Calcareous Alps

The Northern Calcareous Alps comprise two major strike-slip fault systems which originated during Paleogene to Middle Miocene N-S shortening. These are Eocene to Early Miocene NW-striking dextral faults and Early to Middle Miocene NE-trending sinistral faults. Faults of both systems were reactivated with reverted sense of shear in the Late Miocene (Fig. 2). Paleostresses computed from stations outside the shear zones show that reactivation of both sets occurred under E-W compression (Fig. 2). The mean azimuths of all computed σ_1-directions trend 083° (E-W) in the Calcareous Alps. The orientations of the paleostress tensors with σ_2 subvertical and σ_3 N-S indicates predominance of strike-slip deformation. The amount of strain which accumulated during fault reactivation was low compared with the earlier events.

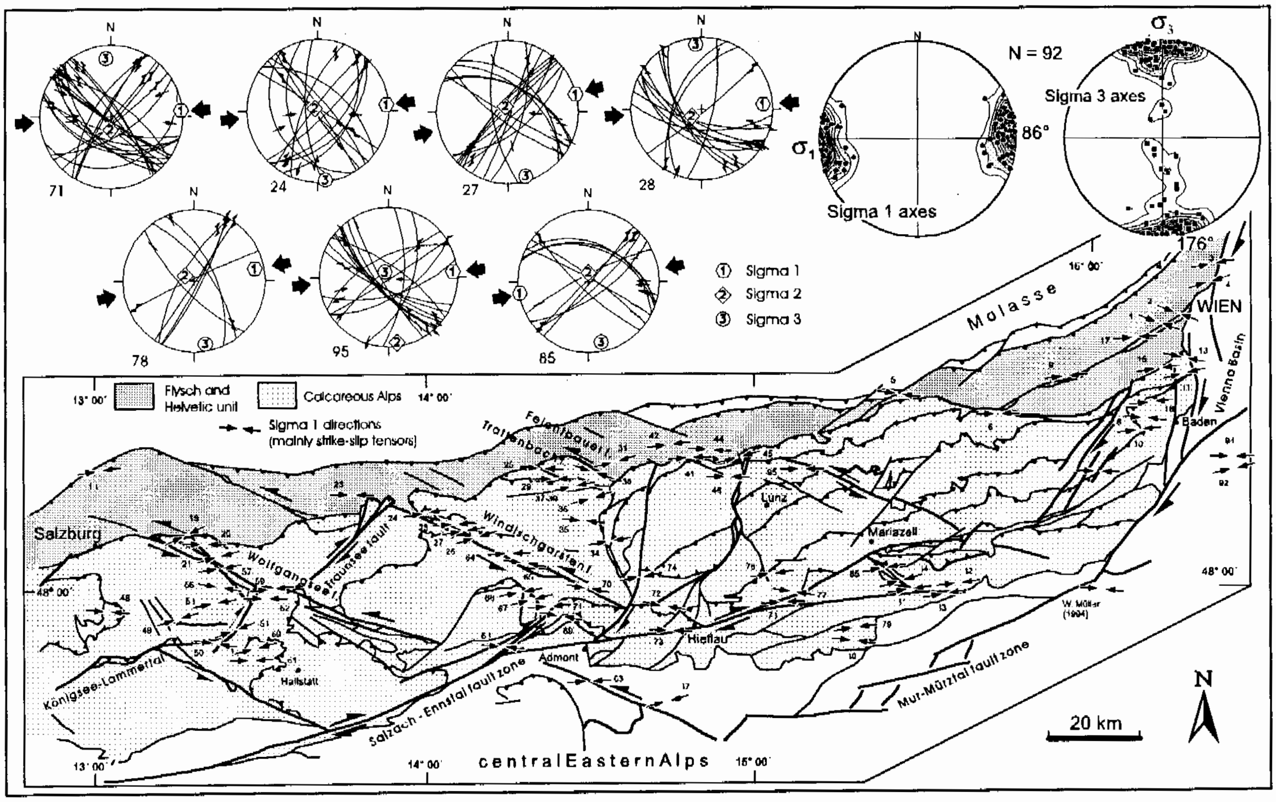

Fig. 2. E-W compressive paleostress data from the eastern part of the Northern Calcareous Alps. Arrows indicate directions of the maximum compressive stress (σ_1). Plots on top are examples of fault-slip data used for paleostress computation (lower hemisphere Schmidt diagrams). Plots on right corner represent computed directions of σ_1 and σ_3 of all sites.

Examples of previous dextral WNW-trending strike-slip faults which were reactivated with sinistral shear sense are the Wolfgangsee-, Windischgarsten-, Trattenbach- and Feichtbauern fault in the Northern Calcareous Alps (see Fig. 2 for location). The Wolfgangsee- and Windischgarsten faults extend for 75 and 100 km through the Northern Calcareous Alps and the Penninic Flysch nappes. From fault plane analysis, two deformational stages could be distinguished (Fig. 3a): Older slickensides within the shear zones show subhorizontal dextral to dextral-reverse movement related to the formation of flower structures and convergent strike-slip duplexes during Late Eocene to Early Miocene (Peresson, 1992). This deformation was associated with high strain and dextral offsets up to 20 km (Peresson and Decker, 1996b). Reversal of the Wolfgangsee and Windischgarsten fault zones is indicated by overprinting lineations (Fig. 3a). Calcite fibers overstepping older dextral Riedel shears and stylolitic solution of older dextral fibers give proof of younger sinistral shear. Similar overprinting and cross-cutting relationships also indicate reversal along the Trattenbach- and Feichtbauern fault.

The 300 km long Miocene (EN)E-trending Salzachtal-Ennstal shear zone formed the northern boundary of the eastward extruded central Eastern Alps (Fig. 1). Sinistral offset reached about 60 km (Ratschbacher et al., 1991) and is dated by deformed conglomerates of Karpatian age (17 Ma; Steininger et al., 1989), which were deposited along the fault zone. Left lateral displacement along the Salzachtal-Ennstal system was accommodated by ENE- to E-trending major faults. Simple shear within the fault zone is indicated by NE-shortening and NW-extension which include 45° and 135° with the shear zone, respectively (Peresson and Decker, this vol.). Structures include thrusts, conjugate syn- and antithetic Riedel shears, and NE-striking subvertical tension gashes. Post-Middle Miocene dextral reactivation of the fault system during E-W compression resulted in the formation of mesoscale conjugate NE-trending dextral and (W)NW-striking sinistral faults. Fractured pebbles in conglomerates of Karpatian age were sheared dextrally along NE-striking and sinistrally along NW-striking sets of microshears (Hieflau locality, Fig. 3b). Further evidence for slip reversal on ENE-trending, former sinistral major faults comes from large-scale slickensides which are overgrown by dextral calcite fibers. E-W shortening also caused the dextral reactivation of numerous NE-oriented formerly sinistral faults which branched off from the Salzachtal-Ennstal fault.

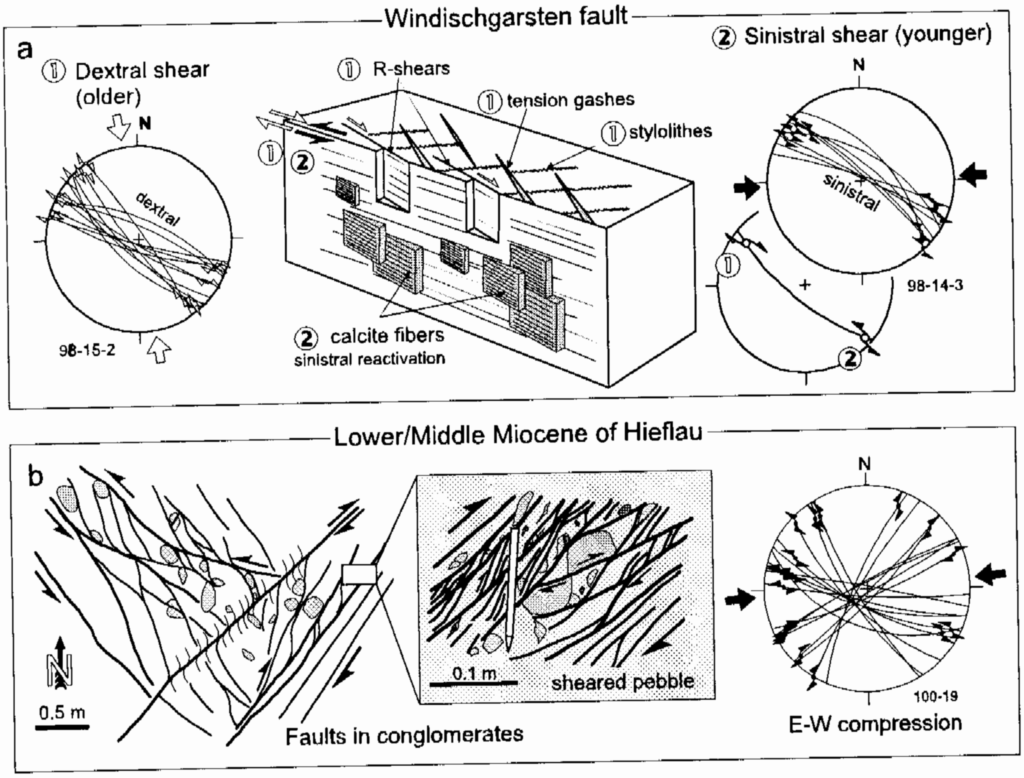

Fig. 3. (a) Structural overprint and shear sense reversal of NW-trending strike-slip faults in the Northern Calcareous Alps. (Windischgarsten Fault). Lower hemisphere plot (Schmidt net) on the left side present data confirming Late Eocene to Early Miocene dextral slip along the main fault under NW-SE to N-S compression (labeled 1). Shear sense criteria due to dextral movement are shown. Plot on the right side presents sinistral reactivation due to E-W compression (labeled 2). Shear sense indicated by calcite fibers is incompatible to the older structures. (b) Conjugate shear fractures of Karpatian age (17 Ma) conglomerates near the Salzach-Ennstal fault zone (Hieflau). Data confirm E-W compression and suggest dextral slip along the Salzach-Ennstal fault zone.

The Vienna Basin

The Vienna Basin formed between left-stepping NE-trending sinistral transform faults (Royden et al., 1982; Royden, 1985; Fodor, 1995; Decker, this vol.) which bounded a major extruding wedge during the Early and Middle Miocene (Ratschbacher et al., 1991). Subsidence of up to 5 km occurred during variable oriented oblique-sinistral extension since the Karpatian stage (17 Ma; Royden, 1985; Lankreijer et al., 1995). Structural analysis revealed a complex kinematic evolution of the basin during the Miocene extensional phase (Fodor, 1995).

In the Vienna Basin striking evidence exists for a change from E-W extension to E-W directed compression in the Late Miocene. NE-trending faults which accommodated normal-sinistral shear during the Middle Miocene were reactivated with dextral slip. An example is presented from the eastern basin margin (Großhöflein close to Eisenstadt, Fig. 4). NE-trending strike-slip faults which originated under N-S compression show an oldest horizontal sinistral striation (Fig. 4a). The sinistral slickenlines were overprinted by a younger dextral lineation marked with calcite fibers (Fig. 4b).

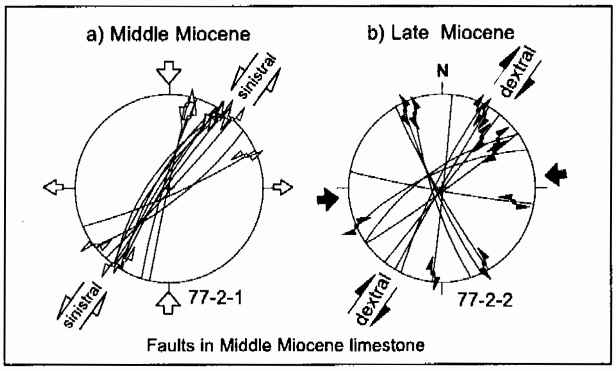

Fig. 4. Faults in Badenian (16.5 - 13.6 Ma) limestone near Eisenstadt. (a) Data plot shows sinistral NE-SW striking faults due to N-S compression and E-W extension. (b) Younger dextral shear sense on NE-SW striking faults indicates their reactivation during E-W compression.

Fault reactivation and the change from E-W extension to E-W directed compression correlated to folding of late Early Pannonian strata of the basin fill near Eisenstadt (Steinbrunn, Fig. 5; Sauer et al., 1992). The oldest structures are conjugate normal faults and shear fractures which originated during horizontal ENE-directed extension indicating the final stage of extension in the basin (Fig. 5a). The extensional structures were cut by conjugate strike-slip faults which formed during subsequent E-W compression (Fig. 5b). Both normal and strike-slip faults were folded around a N-S striking axis and were cut by minor W-directed thrusts (Fig. 5c). The youngest structures are NE-trending dextral strike-slip faults which cut through the fold (Fig. 5d). ENE-WSW compression was also described by Fodor et al. (1990) from sediments of Badenian age (16-13 Ma) and dated as Late Sarmatian.

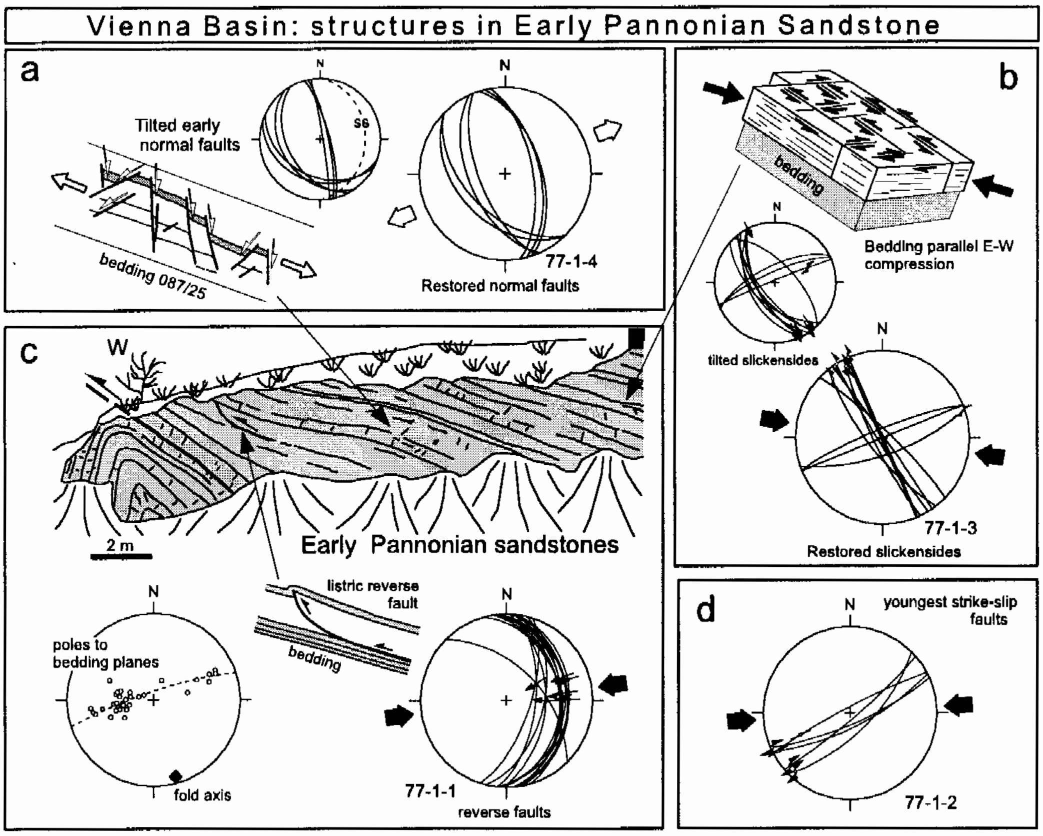

Fig. 5. Structural inversion due to E-W compression in the Vienna Basin - Early Pannonian sandstones near Eisenstadt. (a) Tilted normal faults indicate ENE-WSW directed bedding-parallel extension after restoration. (b) Tilted conjugate strike-slip faults indicate bedding-parallel E-W directed compression. (c) Older structures are tilted and cut during folding and west-directed thrusting. (d) Dextral faults crosscut the folded strata.

The deformed Pannonian strata at Steinbrunn are an excellent time constraint for E-W compression and mark the end of regional extension and subsidence in the Vienna Basin. Consequently, the change from horizontal extension to E-W compression took place after the late Early Pannonian (<9 Ma) and conformed with the end of pull-apart sedimentation. Quantitative subsidence analysis of the Vienna Basin by Lankreijer et al. (in prep.) shows termination of subsidence at about 7-5 Ma (Late Pannonian). Subsequent uplift and erosion brought the top of Neogene sediments to an recent elevation of up to 400m above sea-level (Decker, this vol.).

The Styrian Basin

The Styrian Basin is the westernmost part of the Pannonian Basin and rests on top of the trailing edge of an eastward extruded wedge. Middle to Late Miocene normal faults constrain NE- to SE-directed extension in the Styrian Basin (Jung, 1995). Near Hartberg, extensional faults in Middle Pannonian sediments show that extension continued up to the Late Miocene (Fig. 6a). Evidence for subsequent compression in Middle Pannonian strata comes from inverted SE-directed normal faults which turned into reverse faults with E-dipping lineations (Fig. 6c). Beside conjugate normal faults which indicate NE-directed extension (Jung, 1995); site 136-2 near Hartberg exhibits small scale conjugate compressional reverse faults which show reverse offsets up to 10 cm (Fig. 6b). The east- and west-dipping faults constrain an E-W directed compression of post-Middle Pannonian age. We interpret that after Early to Late Miocene basin subsidence and extension, the Styrian Basin was affected by horizontal compression.

Extension and subsidence in the Styrian Basin occurred during the Early to Late Miocene (Early Pannonian; Sachsenhofer et al., in press; Sachsenhofer, this vol.). Contrasting from basin subsidence modeling which predicts a continued subsidence for the Late Miocene to Quarternary (Sachsenhofer, this vol.), subsidence stopped and uplift and erosion began in the Late Miocene and continued through the Pliocene up to recent. This sudden change is interpreted as the result of the major change in the stress field from extension to E-W directed compression (Peresson and Decker, 1996c). The age of the compressional event conforms with the onset of tectonic uplift at about 7 Ma shown by the subsidence curves computed by Sachsenhofer (this vol.).

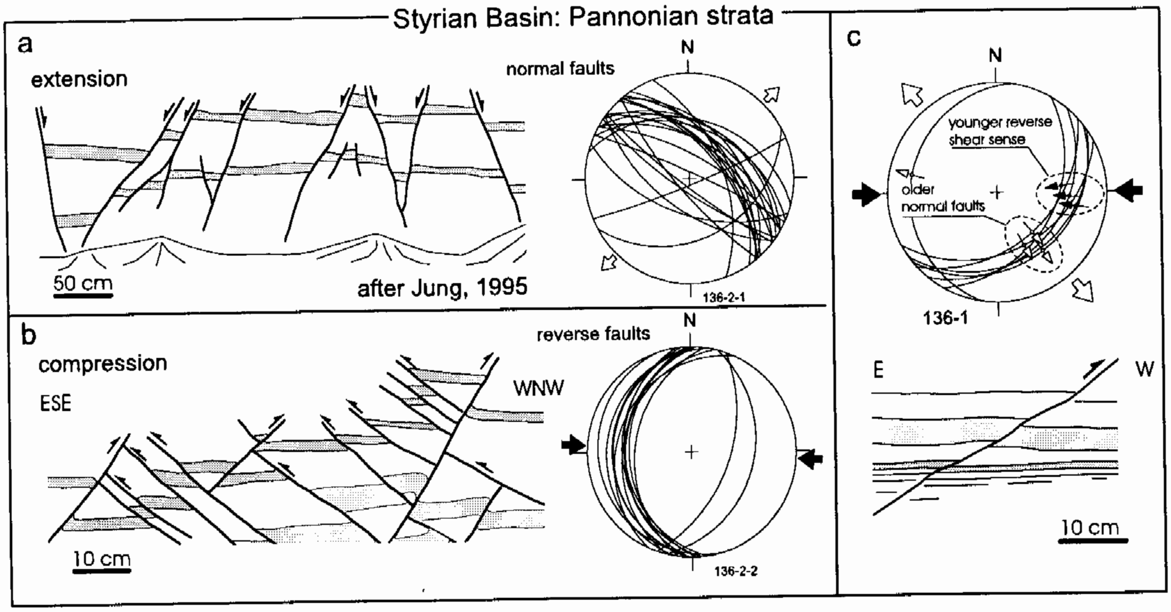

Fig. 6. Faults in Pannonian age strata of the Styrian Basin near Hartberg. (a) Normal faults due to NE-SW extension (Jung, 1995). (b) Small scale, east- and west dipping reverse faults in the same site indicate E-W compression. (c) Normal faults (NW-SE extension) which have been reactivated with reverse slip due to approximately E-W directed compression.

The Pannonian Basin

The Early to Middle Miocene tectonic evolution of the Pannonian Basin was characterized by the eastward motion of crustal wedges escaping from the Eastern Alps (Fig. 1; Royden, 1983; Bergerat, 1989; Ratschbacher et al., 1991; Horváth, 1993). Extension was attributed to back-arc extension behind a retreating subduction boundary in the Outer Carpathians by Royden (1993). Early to Middle Miocene paleostresses show a N-S compressional and E-W tensional strike-slip regime and a subsequent stage of dominant E-W directed tension (Bergerat, 1989; Csontos et al., 1991). Localized subsidence and Early to Middle Miocene synrift deposition (Rumpler and Horváth, 1988) was replaced by regional subsidence of a broad sag basin accumulating up to 4 km post-rift sediments during the Late Miocene (Horváth and Rumpler, 1984; Horváth and Pogácsás, 1988; Rumpler and Horváth, 1988; Tari et al., 1992; Horváth, 1993). Despite subsidence in central parts of the Pannonian Basin continued until Quarternary (Horváth et al., 1994), there is evidence that extension and normal faulting stopped during the Pannonian stage. Reverse slip reactivation of earlier normal faults was described by Horváth et al. (1994). Seismic sections exhibit reverse faulting of basement blocks onto Early to Middle Miocene synrift strata and inversion of rifted troughs. The compressional event was dated 10 to 8 Ma.

Field evidence for Pannonian age compression in the Bakony mountains within the Pannonian Basin is presented in Figure 7. Late Cretaceous marly limestones are separated by a NE-trending dextral fault from Pannonian sandstones which overly Oligocene to Lower Miocene conglomerates (Fig 7f). Conjugate NE-trending dextral and NW-trending sinistral faults in the Pannonian sediments point to E-W directed shortening (Fig. 7e) and correlate to reactivated Early Miocene faults in the older formations (Fig. 7a, b, c, d). Calcite fibers on WNW-striking dextral faults in the Late Cretaceous limestone were affected by stylolitic solution during sinistral reactivation of the planes (Fig. 7c, d). This sinistral reactivation can be dated by the occurrence of similar oriented sinistral faults in the Pannonian sandstone (Fig. 7e).

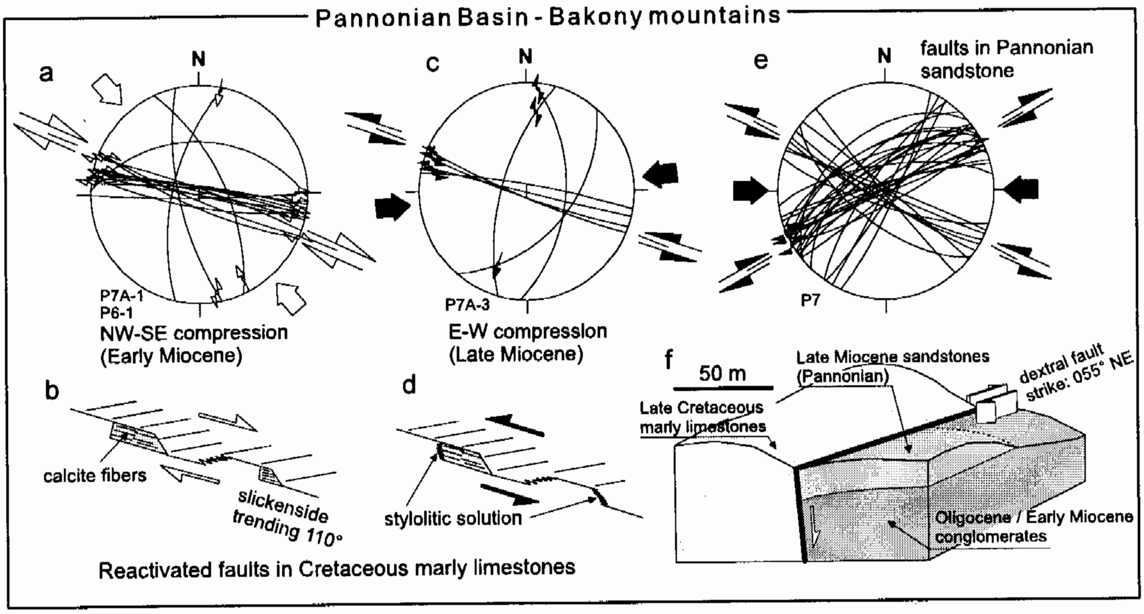

Fig. 7. Miocene structures in the Bakony Mountains (Bakonyjako, Hungary). (a) WNW-striking dextral faults in Late Cretaceous marly limestones and Oligocene conglomerates. (b) Calcite fibers and stylolites proof older dextral slip at WNW-striking slickensides in the limestone. (c, d) Stylolitic solution of calcite fibers indicate reversal of the shear sense at the WNW-striking slickensides which turn to sinistral. (e) Conjugate shear fractures in overlying Pannonian sandstone indicate E-W compression. (f) Schematic sketch of the outcrop. A NE-striking dextral fault of Pannonian age separates Oligocene conglomerates and overlying Pannonian sandstones from Late Cretaceous limestones, in which reactivated faults were identified.

Discussion and Conclusion

Timing of E-W compression and correlation to thrusting in the Eastern Carpathians

Timing of the E-W compressive event in the Alpine-West Carpathian and Pannonian region is constrained by overprinted Early to Middle Miocene faults and deformed Early and Middle Pannonian sediments (9 - 6 Ma) of the Vienna Basin, the Styrian Basin and of the Bakony mountains (Fig. 5, 6, 7). This ages correlate to thrust ages in the Eastern Carpathians, where E-directed thrusting onto the European plate was still in progress. In contrast, thrusting in the Eastern Alps, Western and Central Carpathians terminated significantly earlier between 17 and 11 Ma. In the Eastern Carpathians, the youngest sediments which were affected by significant east-directed thrusting and E-W compression are of Khersonian to Maeotian age (map by Dumitrescu et al., 1968; Maeotian: 10 - 7.1 Ma, Rögl this vol.). These stages correlate to the Late Pannonian of the Central Paratethys.

Pliocene N-S directed compression post-dated E-W compression in the Pannonian Basin (inset in Fig. 8; Csontos et al., 1991) indicating the transient character of the E-W compressive event. In the Eastern Carpathians, E-W compressive structures were overprinted during Pliocene-Pleistocene N-S directed compression of the "Wallachian" phase (Hippolyte, 1995; Ratschbacher et al., 1993). These data set the lower time limit for E-W compression to 9 Ma and the upper limit to 5.6 Ma (lower Pliocene stage boundary) giving a maximum duration of about 3.5 Ma for the E-W compressive event in the Alpine-Carpathian-Pannonian region.

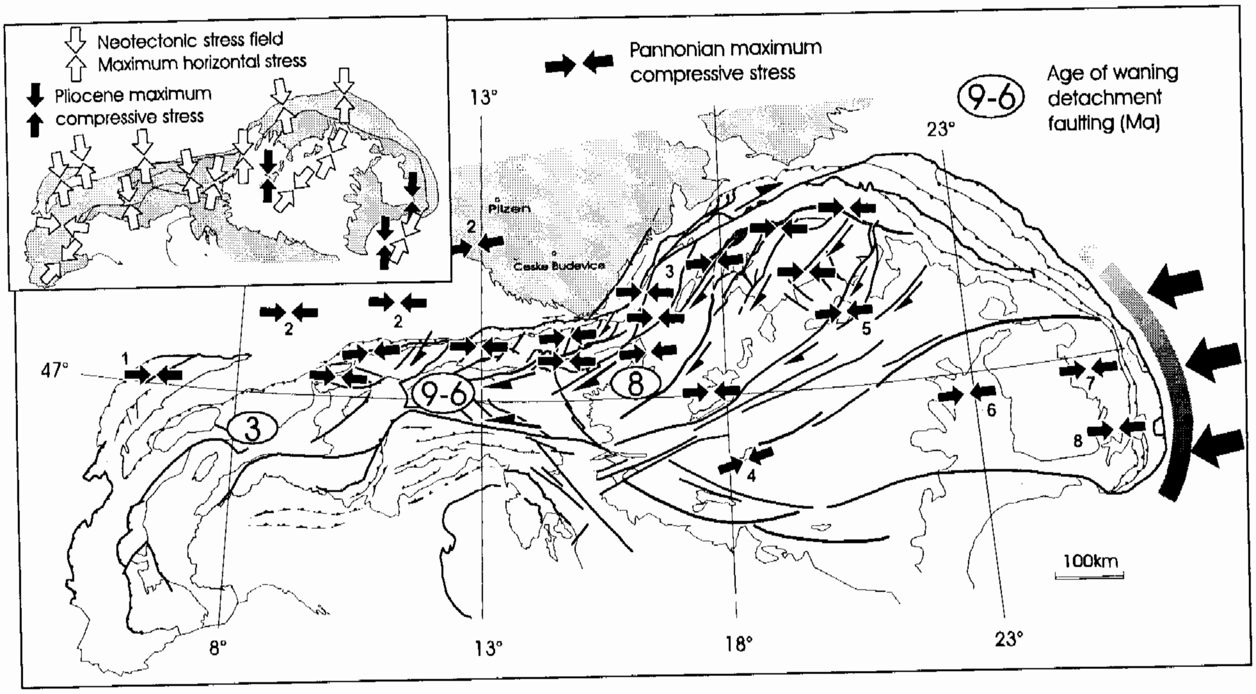

Fig. 8. Late Miocene dynamics in the Alpine-Carpathian-Pannonian region. Regional E-W directed compression, reactivation of faults which formed during eastward extrusion and the termination of east-directed collapse in the Eastern Alps occurred contemporaneously with late-stage subduction and thrusting in the Eastern Carpathians. Labeled supplementary paleostress data from (1) Plessmann, 1972; (2) Bergerat, 1987; (3) Fodor et al., 1990; (4,5) Csontos et al., 1991; (6) Györfi and Csontos, 1994; (7) Linzer, 1995; (8) Hippolyte, 1995. Inset: Pliocene and recent NE-SW to NW-SE compressive stress fields indicate the transient character of E-W compression (Data from Csontos et al., 1991; Müller et al., 1992; Becker, 1993; Ratschbacher et al., 1993; Bergerat et al., 1995; Hippolyte, 1995).

The Late Miocene change from E-W extension to E-W compression

Kinematic and paleostress data from the Alpine-Carpathian-Pannonian area demonstrate that the directions of shortening and the orientations of the maximum horizontal compressive stresses were consistently directed E-W during the Late Miocene (Fig. 8, Peresson and Decker, 1996a). This orientation was markedly different from the Middle Miocene situation, where N-S compression and E-W directed tension prevailed.

Middle Miocene lateral extrusion and upper plate extension in the Pannonian area was explained by the existence of a eastward retreating subduction zone in the outer Central and Eastern Carpathians (Fig. 9a; Royden and Burchfiel, 1989; Royden, 1993). Subduction roll back was related to slab pull forces provided either by negatively buoyant oceanic lithosphere which may have formed the basement of the outer Carpathian flysch nappes, or by thinned continental crust of the subducted European passive margin. Compressive stress coupling of upper and lower plate at the retreating plate margin was low and compression was restricted to the outer Eastern Carpathian thrust belt (Fig. 9a). Compression was not transmitted into the interior of the upper plate, or the magnitudes of N-S and vertically directed stresses superceded E-W compressional stresses. Both dynamic conditions can explain the net extension of the Pannonian lithosphere.

The change from Middle Miocene extension to Late Miocene E-W directed compression expressed a complete reorganization of the kinematics in the Alpine-Carpathian-Pannonian area. Kinematic consequences included dextral slip reversal along earlier sinistral strike-slip faults which bounded the extruded wedges of the central Eastern Alps (e.g. Salzach-Ennstal fault; Vienna Basin fault system). Eastward lateral extrusion therefore ended in the Late Miocene due to fundamental dynamic changes in the Eastern Carpathian subduction zone. There, increasing compressive stress coupling occurred after all oceanic or thin continental crust was consumed and up to 60 km thick continental crust of the Tornquist-Teisseyre zone entered the subduction zone (compare crustal thickness map by Horváth, 1993). Subduction retreat which formerly enabled eastward extrusion and upper plate extension was replaced by "soft collisional" convergence (Fig. 9b). This caused a pulse of increased E-W directed compressive stresses. Paleostress data show that Late Miocene plate margin compression was transmitted across the Eastern Carpathian thrust belt through the previously thinned Pannonian upper plate far into the Eastern Alps and governed the stress field up to a distance of 1400 km behind the plate boundary (Fig. 8, 9b). In the Eastern Alps magnitudes of E-W directed stresses superceded N-S compressive stresses which resulted from the continued northward drift of the Adriatic plate. Lithospheric strength modeling showed that after Early to Middle Miocene collision and extension in the Eastern Alps and in the Pannonian area almost all remaining strength of the lithosphere was carried by the brittle upper crust (Cloetingh, personal comm.; Banda and Cloetingh, 1992; Genser et al., 1996; Sachsenhofer, this vol.). Late Miocene long-distance stress transmission occurred in this shallow, rheologically strong layer and stress was concentrated in the brittle upper crust. Differential stresses were high enough to cause fault reactivation and fracturing in the brittle upper crust of the Eastern Alps.

In the Pannonian Basin system, the shift from synrift to the postrift subsidence conformed with the Late Miocene stress change. This change from tension to compression of the subsiding basin system may have contributed to the pronounced post-rift subsidence of the Pannonian area by stress-induced downward flexure of the loaded Pannonian lithosphere (Cloetingh and Kooi, 1992; Horváth et al., 1995). Downward flexure during E-W compression and subsequent Pliocene to recent roughly N(E)-S(W) compression (Csontos et al., 1991; Becker, 1993; Gerner et al., 1995) may have substantially modified subsidence in the Pannonian area (Horváth et al., 1994; 1995).

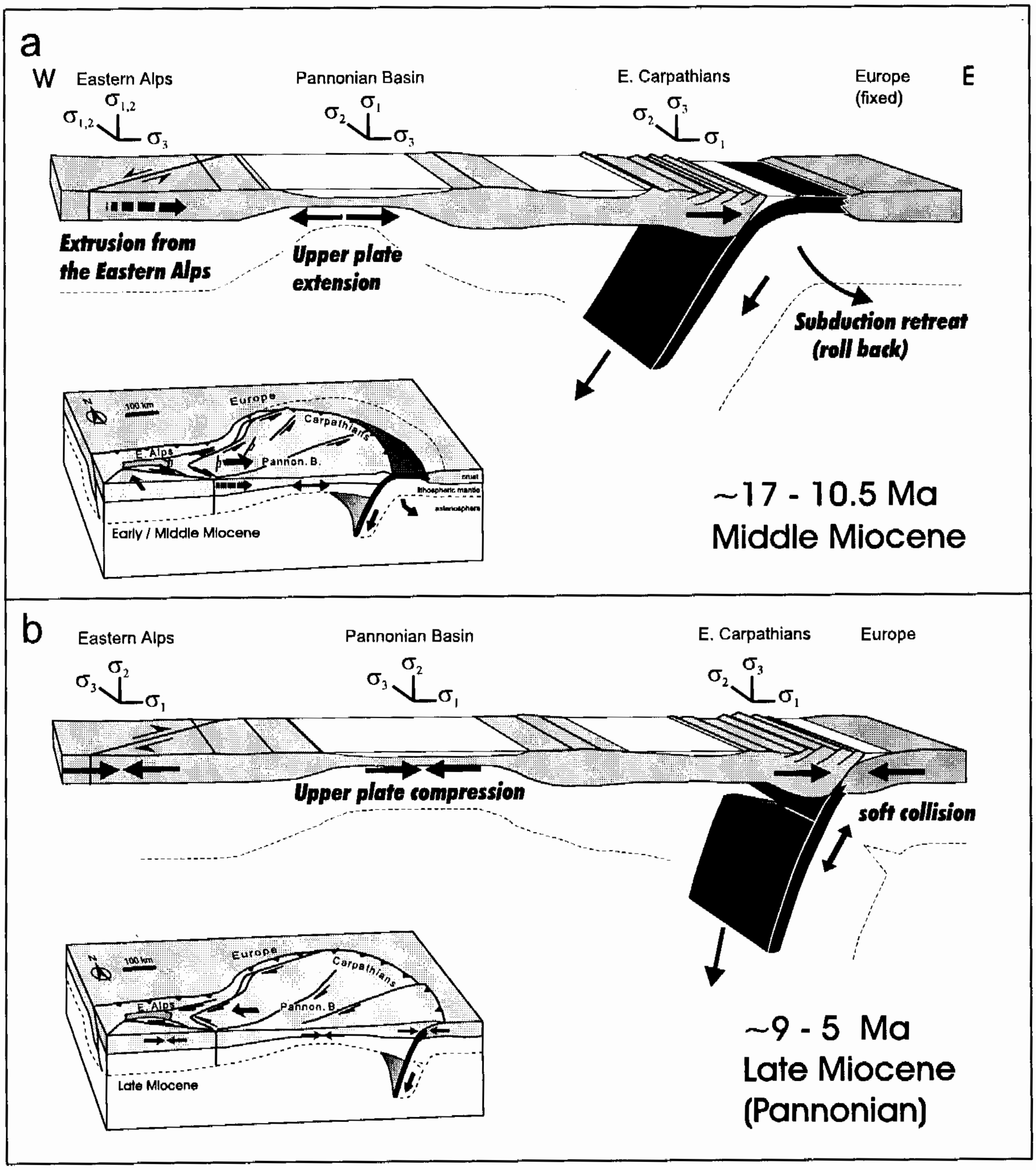

Figure 9. Schematic E-W directed lithospheric cross sections through the Alpine-Carpathian-Pannonian region and Miocene plate tectonic models.

(a) Early to Middle Miocene stresses in the Eastern Alps resulted from continued N-S shortening (σ_1 N-S, σ_3 E-W) and east directed extension (σ_1 vertical, σ_3 E-W). Rifting of the Pannonian Basin system occurred in a stress regime with generally E-W directed σ_3. The thrust regime in the Eastern Carpathians was characterized by horizontal compression (σ_1 E-W, σ_3 vertical). Block model shows Miocene east-directed collapse and lateral extrusion in the Eastern Alps (Ratschbacher et al., 1991). Lateral motion was linked to thrusting in the Outer Central and Eastern Carpathians. Extrusion and upper plate extension in the Pannonian region were enabled by the retreat of the subduction boundary in the Outer Carpathians (Royden, 1993).

(b) Subduction retreat in the Eastern Carpathians was locked after the entrance of thick buoyant continental crust into the subduction zone which terminated both, upper plate extension of the Pannonian area and lateral extrusion in the Eastern Alps. The increased mechanical coupling of upper and lower plate resulted in the transmission of compressive stresses (σ_1 E-W) into the upper plate and in the reversal of Early to Middle Miocene structures (e.g. Salzach-Ennstal fault zone).

E-W compression dominated for a maximum time interval of 3.5 Ma between the Late Pannonian and the Pliocene. After the cessation of E-W compression in the Pliocene a roughly N-S compressive stress field was re-established which persists to the present (inset Fig. 8). Neotectonics of the Mur-Mürz fault, the Vienna-Basin fault and the Lavant fault deduced from recent seismicity are similar to the Middle Miocene escape tectonics (Gutdeutsch and Aric, 1987; Gangl, this vol.). There is, however, no evidence for neotectonic strain similar to the Middle Miocene deformation.

Acknowledgments

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