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THE AUSTROALPINE CRYSTALLINE UNITS IN THE EASTERN ALPS

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The Austroalpine unit experienced a complex Phanerozoic history, documented by its (meta)sedimentary sequences and a large number of magmatic rocks. Due to imprints during the Variscan, Permotriassic, eo-Alpine and Alpine tectonometamorphic events large parts of the Austroalpine unit consist of crystalline rocks. These rocks show different metamorphic histories, different relations to Permomesozoic cover series and they occur in different tectonic positions. Based on their distribution within the Alpine orogene the Austroalpine unit can be subdivided in a Lower and an Upper Austroalpine unit, both consisting of several nappe systems. In this article a simplified introduction in the history of the Austroalpine unit and a short description concentrating on the lithological content of the nappe systems is given. After that some aspects on the relationsships of these nappe systems are discussed in the frame of recent publications. The latter include reviews on the teconic style of the Alps (SCHMID et al., 2004), the post-Variscan metamorphic history (HOINKES et al., 1999; SCHUSTER et al. 2004) and the geochronological data of the area (THÖNI, 1999).

Phanerozoic history of the Austroalpine unit

In early Paleozoic times the Austroalpine unit formed a part of the northern margin of the Gondwana continent. It consisted of a Cadomian crust and Lower Paleozoic sedimentary sequences (VON RAUMER et al., 2002). During the formation of the Pangea supercontinent the Austroalpine unit experienced the Variscan tectonometamorphic event in the late Devonian and Carboniferous. After that, in Permian times it was affected by lithospheric extension and a related high temperature-low pressure metamorphism. In the Triassic the Meliata-Hallstatt ocean, a part of the westernmost Tethys oceanic realm opened in the southeast of the Austroalpine unit. Since that time the Austroalpine unit formed a shelf area with a southeast facing passive margin towards the Meliata-Hallstatt ocean and huge carbonate platforms were deposited on top. The opening of the Jurassic Piemont-Ligurian ocean, which is related to spreading in the Atlantik ocean, separated the Apulian microplate and the Austroalpine unit as a part of it from the European continent. This tectonic rearrangement caused the formation of a passive continental margin to the northern of the Austroalpine unit and sinistral strike-slip tectonic in its southern part. The strike slip tectonic destroyed the passive continental margin towards the Meliata-Hallstatt ocean (FRANK & SCHLAGER, in prep.). The ocean was moved towards the east and replaced by transferred Austroalpine elements and the Southalpine unit, which were located further in the west during the Triassic. Early Cretaceous convergence of Africa, Apulia and Europe caused the closure of the Meliata-Hallstatt oceanic realm. This plate tectonic event is referred as the eo-Alpine tectonometamorphic event. The Austroalpine unit experienced major eo-Alpine reworking as the transferred Austroalpine elements were thrusted towards west to northwest onto the former southeastern continental margin. In this sense the transferred Austroalpine elements formed the tectonic upper plate whereas those of the passive margin formed the lower plate in a continental subduction setting (see discussion). After the metamorphic peak in the Middle Cretaceous, the eo-Alpine metamorphic rocks of the lower plate were exhumed, partly in a pro- and retro wedge geometry. Also in the Middle Cretaceous ongoing convergence caused the transformation of the Austroalpine northern passive margin (WAGREICH, 2001) towards the Piemont-Ligurian ocean in an active margin, and slices from this margin were subducted southeastwards under the eo-Alpine nappe pile. This process caused a metamorphic imprint within the subducted units. As the deformation related to the closure of the Piemont-Ligurian and Valais ocean is defined as Alpine, the eo-

Alpine and the Alpine deformation were active in the Austroalpine unit simultaneously since that time. After the closure of the Piemont-Ligurian and Valais ocean the Austroalpine and Southalpine unit together formed the tectonic upper plate when they were thusted northwestwards onto the European plate. In Oligocene times the southern part of the Austroalpine and the adjoining Southalpine unit were affected by the Periadriatic magmatism.

Subdivision of the Austroalpine unit:
The proposed subdivision of the Austroalpine unit by nappe systems shall reflect the Jurassic platetectonic arrangement and the eo-Alpine and Alpine tectonometamorphic events. The definitions given for the nappe systems allow subdividing nearly the whole Austroalpine unit. However there are some problematic elements which do not fit to one of the nappe-systems unequivocally, based on the present day data set (e.g. the Innbruck quartzphyllite nappe).

The ***LOWER AUSTROALPINE UNIT*** is defined as that part of the Austroalpine unit which formed its northern margin towards the Piemont-Ligurian ocean in Jurassic to early Tertiary times. For this reason it was affected by the opening and closure of this oceanic realm. During the opening in the Jurassic the Lower Austroalpine unit suffered extension, expressed by the formation of klippen, halfgrabens and the deposition of breccias (HÄUSLER, 1987; FROITZHEIM, N. & MANATSCHAL, G., 1996). When the Piemont-Ligurian and Valais oceans were closed during the Alpine orogenic event in Upper Cretaceous to Tertiary times, the Lower Austroalpine nappes were involved in the subduction process and experienced a structural reworking and also an anchizonal to greenschist facies metamorphism (SCHUSTER et al. 2004). They were squeezed between the Upper Austroalpine nappes and the Penninic nappes.
Most parts of the Lower Austroalpine units contain a Variscan metamorphic basement, remnants of Paleozoic metasediments and Mesozoic cover series. The latter are starting with lowermost Triassic metaconglomerates and quartzites. Characteristic for the Carnian strata of the eastern part is a “Keuper” facies with gypsum and shales. The sequences reach up to Jurassic sediments represented by syntectonic breccias. In the eastern part of the Eastern Alps the sequences are tectonically truncated at different stratigraphic levels (TOLLMANN, 1977).
The Lower Austroalpine unit is widespread in Eastern Switzerland, particularly along the south-western margin of the Austroalpine nappe system. It comprises the Err-Bernina nappe system, the Ela nappe (FROITZHEIM et al. 1994) and slivers of Lower Austroalpine nappes along the north-eastern margin of the Austroalpine nappes. Material from the Lower Austroalpine unit is present in several tectonic zones of the Engadine Window (MEDWENITSCH, 1962). In the southern part of the Tauern Window the Matrei Zone is a mélange containing olistoliths derived from the Lower Austroalpine realm (FRISCH et al, 1989), but it also contains material from the Piemont-Ligurian ocean. The same is true for the Nordrahmenzone in the northeastern part of the Tauern Window. In the hanging wall of the Matrei Zone the Melenkopf and Sadnig Series are interpreted as Lower Austroalpine crystalline basement and late Paleozoic metasediments (FUCHS & LINNER, 1995). Along the eastern frame of the Tauern Window the Radstatt nappe system and the Katschberg Zone hold a Lower Austroalpine position, whereas in the northwest it is represented by the Hippold nappe. At the eastern margin of the Alps the Wechsel nappe and the Semmering nappe (exclusively Grobgneiss nappe) will be part of the Lower Austroalpine unit, as they are the lowermost Austroalpine nappes in that area.

The ***UPPER AUSTROALPINE UNIT*** comprises the remaining major part of the Austroalpine unit. It represents a complex nappe stack which formed by the eo-Alpine tectonometamorphic event. During the Alpine event, it stayed in an upper plate position and Tertiary deformation is restricted to brittle faulting.

With respect to the late Jurassic paleogeographic arrangement the Northern Calcareous Alps are built up by the ***Bajuvaric*** and the ***Tirolic nappe system*** (FRISCH & GAWLICK, 2003). Both nappe systems are composed of Permomesozoic sedimentary sequences (TOLLMANN, 1985; MANDL, 2000) which experienced a diagenetic, anchizonal or lowermost greenschist facies metamorphic imprint during the eo-Alpine tectonometamorphic event.

The nappe system of the ***Greywacky zone*** is underlying the Tirolic Nappe system. It includes the Noric, Veitsch, Vöstenhof-Kaintaleck and Silbersberg nappe (NEUBAUER et al., 1994). Except the Vöstenhof-Kaintaleck nappe, which consists of Variscan metamorphic paragneisses, micaschists and amphibolites, all these nappes are built up by Paleozoic sequences. All of them are in contact with transgressive Permian (meta)sediments. Additionally the lowermost Silbersberg nappe contains alkaline volcanic rocks. The whole nappe pile got an anchizonal to greenschist facies metamorphic imprint during the eo-Alpine event. However the nappes of the Greywacky Zone are not genetically linked, because the uppermost Noric Nappe is in stratigraphic contact with the Tirolic Nappe system of the Northern Calcareous Alps, whereas the other nappes are not.

The remaining part of the Upper Austroalpine can be subdivided in four nappe systems:

The ***Silvretta-Seckau nappe system*** is the tectonically lowermost of these nappe systems, overlying the Lower Austroalpine unit. It is built up by biotite-plagioclase gneisses and subordinate micaschists. Typical are hornblende gneisses, layered amphibolites, augengneisses and a wide spectrum of different orthogneisses, whereas only in some nappes ultramafic complexes, migmatites and Variscan eclogites occur. According to NEUBAUER (2002) the magmatic rocks reflect collisional, subduction and rifting processes active from the Precambrian to the Ordovician. Additionally orthogneisses of the Variscan tectonometamorphic cycle occur. In the tectonic lowermost parts in the west (Languard and Campo-Sesvenna-Silvretta nappe) also Permian pegmatites and gabbros (BENCIOLINI, 1994), related to Permotriassic extension are present (SCHUSTER et al., 2001). The units of the Silvretta-Seckau nappe system experienced a Variscan metamorphic imprint up to high amphibolite facies conditions and local anatexis. For those parts which contain Permian pegmatites also a Permotriassic thermal imprint up to amphibolite facies conditions can be expected. The eo-Alpine metamorphic imprint reached uppermost anchizonal to amphibolite facies conditions. Most of the units show remnants of transgressive Permomesozoic cover sequences. The Silvretta nappe is locally covered by Carboniferous strata and shows a transgressive contact to the Bajuvaric nappe system (ROCKENSCHAUB et al. 1983).

The Silvretta-Seckau nappe system consists of the following elements: In the west large areas are covered by the Languard and Campo-Sesvenna-Silvretta nappes, whereas to the south of the Tauern Window the Lasörling Complex shows the typical features. To the east of the Tauern Window the Schladming, Seckau-Troiseck, Speik, Waldbach and Kulm Complex belong to the Silvretta-Seckau nappe system.

The *Koralpe-Wölz nappe system* comprises a series of basement nappes which lack Permomesozoic cover series. Within the nappe system several groups of units with special lithological composition and a distinct metamorphic grade can be traced over long distances.

The tectonically lowermost part consists of lower greenschist facies units (e.g. Ennstal Quartzphyllite unit). Above the Wölz Complex is characterised by garnet micaschists with a dominating eo-Alpine metamorphic imprint of upper greenschist to amphibolite facies grade. Locally a Permotriassic greenschist facies imprint is documented. The overlying Rappold Complex experienced a Variscan, Permotriassic and eo-Alpine amphibolite facies imprint. Characteristic are gneisses with kyanite pseudomorphs after andalusite ("Disthenflasergneisses") and Permian pegmatites. Permian granites occur in several places whereas pre-Permian orthogneisses are not known until now. Also the eclogite-bearing units are characterised by "Disthenflasergneisses" and Permian pegmatites. Most eclogites derived from amphibolites but some of them developed from Permian MORB-type gabbros (MILLER

& THÖNI 1997). In the eclogite-bearing units some pre-Permian orthogneisses are known especially from the western part of the Koralpe-Wölz nappe system. The present day mineral assemblages can be explained by a Permotriassic amphibolite facies imprint and an eo-Alpine eclogite- and a following amphibolite facies overprint. The Plankogel Complex rests on top of the eclogite-bearing units in the Saualpe-Koralpe area. It is characterised by garnet-bearing micaschists which also show kyanite pseudomorps after andalusite. Further intercalations of Mn-quartzites, serpentinites amphibolites, marbles and Permian pegmatites occur. The Plankogel Complex is characterised by a Permotriassic imprint which reached up to amphibolite facies conditions, which is overprinted by an amphibolite facies eo-Alpine event. The uppermost part of the Koralpe-Wölz nappe system consists of several units rich in garnet-bearing micaschists. Some of them are very similar to the Wölz Complex, but in all of them an eo-Alpine upper greenschist to amphibolite facies metamorphic imprint is the predominant crystallisation phases.

The *Ötztal-Bundschuh nappe system* occupies a position on top of the Koralpe-Wölz nappe system. Its lithological composition and pre-Alpine metamorphic history is quiet similar to that of the Silvretta-Seckau nappe system. The predominant lithologies are biotite-plagioclase gneisses with micaschists, amphibolites and a wide range of orthogneises. Also Variscan eclogites and pre-Variscan migmatites are known (MILLER & THÖNI, 1995). Remnants of transgressive Permotriassic cover sequences are present on top of the pre-Alpine basement. A Variscan metamorphic imprint reaching amphibolite facies conditions has been documented in the pre-Alpine basement, whereas the eo-Alpine imprint is decreasing upwards from amphibolite to greenschist facies conditions. The Ötztal-Bundschuh nappe system consists of the Ötzal nappe with the Brenner Mesozoics and the Bundschuh nappe with the lower part of the Stangalm Mesozoics (Stangnock Scholle, TOLLMANN, 1977).

The structurally highest *Drauzug-Gurktal nappe system* comprises tectonic blocks bordered by steeply dipping Alpine faults, which are located directly to the north of the Periadriatic lineament, as well as nappes on top of the Koralpe-Wölz and/or Bundschuh-Gurktal nappe system. The tectonic blocks (e.g. Drau Range, Defferegger Alps; SCHUSTER, 2003) consist of a Variscan amphibolite facies metamorphic basement, Paleozoic metasediments and Permomesozoic sedimentary sequences. A Permotriassic imprint reached high-amphibolite facies conditions with local anatexis and pegmatites in the lowermost parts. It runs out towards the top of the pre-Permian rocks. An eo-Alpine overprint shows greenschist facies at the base and diagenetic conditions in the uppermost part of the units and therefore the pre-Alpine structures and metamorphic assemblages are well preserved.

The nappes comprise the Steinach nappe, Gurktal nappe (Murau, Stolzalpen and Ackerl nappe) and the nappes of the Graz Paleozoic. All of them consist of Paleozoic metasedimentary sequences. Only the Ackerl nappe is built up by a Variscan metamorphic basement. Permomesozoic cover series are only present on top of the Gurktal nappe. In all of these nappes upwards decresing eo-Alpine conditions from greenschist facies at the base to diagenesis at the top have been observed.

Discussion and Conclusions

The Alpine orogene is the result of two independent continental collisions (FROITZHEIM et al., 1996): The Alpine event is due to the collision of Europe and the Apulian plate after the subduction of the Piemont-Ligurian and Valais ocean, whereas the eo-Alpine event resulted from the disappearance of the Meliata-Hallstatt ocean. The Penninic nappes mark the Alpine suture zone. The latter is very prominent and can be traced along the entire Alps. On the other hand there is no oceanic Meliata-Hallstatt suture zone known in the Alps and occurrences of the Meliata zone are restricted to tiny tectonic slices within the easternmost part of the Northern Calcareous Alps. These slices do not show indications for a high-pressure metamorphic imprint. Due to this situation the question arises how the eo-Alpine event in the

Alps is linked to the subduction of the Meliata-Hallstatt ocean. For this discussion it is important to note that the Austroalpine unit is the only one in the Alps with an intense eo-Alpine structural and metamorphic imprint and therefore its internal structure is of interest.

As mentioned above the Koralpe-Wölz nappe system consists of basement nappes which show the most intense eo-Alpine structural and metamorphic imprints and this nappe system lacks transgressive Permomesozoic sediments. It contains the eo-Alpine eclogites it therefore it stayed in a lower plate position during the eo-Alpine event. To the east of the Tauern Window it is dipping towards the south. Within the nappe pile the eo-Alpine metamorphic grade is increasing from greenschist facies at the base to eclogite and following high amphiboite facies in the central part. Above the metamorphic conditions are decreasing again until greenschist facies at the top. This implies an inverted metamorphic field gradient in the lower part and an upright gradient in the upper part of the nappe pile. The latter formed during the post peak-metamorphic exhumation of the eo-Alpine high-pressure rocks by NW-N directed thrusting (KROHE, 1987) in the lower part and by SE-directed normal faulting in the upper part. According to THÖNI (1999) the metamorphic peak occurred at 100 ± 10 Ma. Due to this internal structure the Koralpe-Wölz nappe system represents a kind of extrusion wedge. On the other hand to the southwest of the Tauern Window (Texel and Schneeberg Complex) the eo-Alpine high-pressure rocks are dipping northwards and extrude southeastwards (SÖLVA et al., 2001). The situation in the southwest of the Tauern Window (Millstatt and Radenthein Complex) seems to show a similar style.

The Ötztal-Bundschuh and the Drauzug-Gurktal nappe system are tectonically overlying the Koralpe-Wölz nappe system. Their Mesozoic sediments show characteristic facies successions which fit to those of westerly located parts of the Southalpine and to the western part of the Northern Calcareous Alps (LEIN et al, 1997). When Miocene orogen-parallel stretching, that occurred in the context of the un-roofing of the Tauern window is retro-deformed (FRISCH et al. 1998), it becomes clear that the Ötztal and Bundschuh nappes as well as the Steinach and Gurktal nappe were originally connected. All these nappes took place by west to northwest-directed thrusting (RATSCHBACHER et al., 1986) prior to the metamorphic peak. As their metamorphic imprint reached amphibolite facies conditions in the southern parts of the Ötztal-Bundschuh nappe system they formed an at least 20 km thick thrust sheet. This thrust sheet formed the tectonic upper plate which buried the rocks of the Koralpe-Wölz nappe system. It was thinned and disintegrated later on by normal faultig and erosion, during eo-Alpine and Alpine extensional tectonics.

Also the Tirolic nappe system and the Noric nappe where affected by west to northwest-directed thrust tectonics prior to 100 Ma. They formed an internal nappe stack and overthrusted the southern part of the Bajuvaric nappe system. Based on paleogeographic reconstructions (HAAS et al., 1994) the Tirolic units (including the Juvavic units, FRISCH & GAWLICK 2003) formed the southeastern margin of the Austroalpine unit towards the Meliata-Hallstatt ocean in Triassic times. For several arguments the same position has been proposed for parts of the Koralpe-Wölz nappe system (FRANK, 1987, Abb. 8; THÖNI & JAGOUTZ, 1993). However, as there is no oceanic Meliata-Hallstatt suture in the Alps it is most likely that this margin was destroyed prior the eo-Alpine thrust tectonic started. This might have happened during Jurassic strike-slip tectonics. With respect to the present day arrangement the Ötztal-Bundschuh and the Drauzug-Gurktal nappe system may have bordered the former southeastern margin of the Austroalpine unit in the early Cretaceous. In this case the Tirolic nappe system and the Noric nappe will have been stripped of from the Wölz-Koralpe nappe system when the Ötztal-Bundschuh and the Drauzug-Gurktal nappe system took place.

The Silvretta-Seckau nappe system, the Bajuvaric nappe system the lower nappes of the Greywacky zone and the Lower Austroalpine unit represent elements from the northern part of the Austroalpine unit.

In Conclusion: There is no oceanic Meliata-Hallstatt suture zone in the Alps. However the

Austroalpine unit can be subdivided in an eo-Alpine tectonic upper and lower plate. The border of these elements is the thrust plane between the Koralpe-Wölz and the Ötztal-Bundschuh and Drauzug-Gurktal nappe system.

References

BENCIOLINI, L. (1994): Metamorphic evolution of the Silvretta gabbro and related rocks (Upper Austroalpine, Central Alps). Its bearing on the pre-Mesozoic history of the Alpine area basement. - Mem. Sci. Geol., 46: 353-371.

FRANK, W. (1987): Evolution of the Austroalpine Elements in the Createaeous. – In: Flügel, H. W. & Faupl, P. (Eds.): Geodynamics of the Estern Alps. - 379-406, Deuticke, Vienna.

FRISCH, W., GOMMERINGER, K, KELM, U. & POPP, F. (1989): The Upper Bündner Schiefer of the Tauern Window - A key to understanding Eoalpine orogenic processes in the Eastern Alps. - In: FLÜGEL, W. & FAUPL, P. (Eds.): Geodynamics of the Eastern Alps. - 55-69, Deuticke, Vienna.

FRISCH, W. & GAWLICK, H.-J. (2003): The nappe structure of the central Northern Calcareous Alps and ist disintegration during Miocene tectonic extrusion - a contribution to understanding the orogenic evolution of the Eastern Alps. - Int. J. Earth Sci. (Geol. Rundschau), 92: 712-727.

FRISCH, W., KUHLEMANN, J., DUNKL, I. & BRÜGEL, A. (1998): Palinspastic reconstruction and topographic evolution of the Eastern Alps during late Tertiary tectonic extrusion. - Tectonophysics 297: 1-15.

FROITZHEIM, N. & MANATSCHAL, G. (1996): Kinematics of Jurassic rifting, mantle exhumation, and passive-margin formation in the Austroalpine and Penninic nappes (eastern Switzerland). - Bull. Geol. Soc. Am., 108: 1120-1133.

FROITZHEIM, N., SCHMID, S.M. & CONTI, P. (1994): Repeated change from crustal shortening to orogen-parallel extension in the Austroalpine units of Graubünden. - Eclogae geol. Helv., 87: 559-612.

FUCHS, G. & LINNER, M. (1995): Das Ostalpine Kristallin der Sadnig-Gruppe in Beziehung zur Matreier Zone. - Jb. Geol. B.-A., 138/1: 55-65.

HAAS, J., KOVÀCS, S., KRYSTYN, L. & LEIN, R. (1994): Significance of Late Permian-Triassic facies zones in terrrane reconstructions in the Alpine-North Pannonian domain. - Tectonophysics, 242: 19-40.

HÄUSLER, H. (1987): The northern Austroalpine margin during the Jurassic: breccias from the Radstädter Tauern and the Tarntaler Berge. – In: Flügel, H.W. & Faupl, P. (Eds.): Geodynamics of the Estern Alps. - 103-111, Deuticke, Wien.

HOINKES, G., KOLLER, F., HÖCK, V., NEUBAUER, F., RANTITSCH, G. & SCHUSTER, R. (1999): Alpine metamorphism of the Eastern Alps. – Schweiz. Mineral. Petrogr. Mitt., 79: 155-181.

LEIN, R., GAWLICK, H.-J. & KRYSTYN, L. (1997): Paläogeographie und tektonische Herkunft des Drauzuges - Eine Diskussion auf der Basis von Fazies- und Conodont Colour Alteration Index (CAI)-Untersuchungen. - Zentralblatt Geol. Paläont. Tel I, 5/6: 471-483.

MANDL, G. (2000): The Alpine sector of the Tethyan shelf - Examples of Triassic to Jurassic sedimentation and deformation from the Northern Calcareous Alps. - Mitt. Österr. Geol. Ges., 92: 61-77.

MEDWENITSCH, W. (1962): Zur Geologie des Unterengadiner Fensters (österreichischer Anteil). - Eclogae Geol. Helv., 55: 460-468.

MILLER, CH. & THÖNI, M. (1995): Origin of eclogites from the Austroalpine Ötztal basement (Tirol, Austria): geochemistry and Sm-Nd vs. Rb-Sr isotope systematics. - Chem. Geol. (Isotope Geoscience Section), 122: 199-225.

MILLER, CH. & THÖNI, M. (1997): Eo-Alpine eclogitisation of Permian MORB-type gabbros in the Koralpe (Eastern Alps, Austria): new geochronological, geochemical and petrological data. – Chem. Geol., 137: 283-310.

NEUBAUER, F. (2002): Evolution of late Neoproterozoic to early Palaeozoic tectonic elements in Central and Southeast European Alpine mountain belts: review and synthesis. - Tectonophysics, 352: 87-103.

NEUBAUER, F., HANDLER, R., HERMANN, S. & PAULUS, G. (1994): Revised Lithostratigraphy and Structure of the Eastern Graywacke Zone (Eastern Alps). - Mitt. Österr. Geol. Ges., 86: 61-74.

RATSCHBACHER, L. (1986): Kinematics of Austro-Alpine cover nappes: changing translation path due to transpression. - Tectonophysics, 125: 335-356.

VON RAUMER, J., STAMPFLI, G.M., BOREL, G.D. & BUSSY, F., 2002. The organisation of pre-Variscan basement areas at the north-Gondwanan margin. – Intern. J. Earth Sciences, 91: 35-52.

ROCKENSCHAUB, M.J., THEINER, U. & FRANK, W. (1983): Die Struktur von Phyllit- und Phyllitglimmergneiszone bei Landeck. - Die frühalpine Geschichte der Ostalpen Jahresbericht, 4: 223-237.

SCHMID, S.M., FÜGENSCHUH, B., KISSLING, E. & SCHUSTER, R. (2004): Tectonic map and overall architecture of the Alpine orogen. - Eclogae Geol. Helv, 97/1: 93-117.

SCHUSTER, R., SCHARBERT, S., ABART, R. & FRANK, W. (2001): Permo-Triassic extension and related HT/LP metamorphism in the Austroalpine - Southalpine realm. - Mitt. Geol. Bergbau Stud. Österr., 44: 111-141.

SCHUSTER, R. (2003): Das eo-Alpidische Ereignis in den Ostalpen: Plattentektonische Situation und interne Struktur des Ostalpinen Kristallins. - Arbeitstagung Geol. B.-A. Blatt 148 Brenner, 2003: 141-159.

SCHUSTER,R., KOLLER, F., HOECK, V., HOINKES, G. & BOUSQUET, R. (2004): Explanatory notes to themap: Metamorphic structure of the Alps – Metamorphic evolution of the Eastern Alps. – Mitt. Österr. Miner. Ges., 149: 175-199.

SÖLVA, H., THÖNI, M., GRASEMANN, B. & LINNER, M. (2001): Emplacement of eo-Alpine high-pressure rocks in the Austroalpine Ötztal complex (Texel group, Italy/Austria). - Geochimica Acta, 14: 345-360.

THÖNI, M. (1999): A review of geochronological data from the Eastern Alps. – Schweiz. Mineral. Petrogr. Mitt., 79/1: 209-230.

THÖNI, M. & JAGOUTZ, E. (1993): Isotopic constraints for eo-Alpine high-P metamorphism in the Austroalpine nappes of the Eastern Alps: bearing on Alpine orogenesis. - Schweiz. Mineral. Petrogr. Mitt., 73: 177-189.

TOLLMANN, A. (1977): Geologie von Österreich. Band 1. Die Zentralalpen. – 766 pp, Deuticke, Wien.

TOLLMANN, A. (1985): Geologie von Österreich. Band 2. Außerzentralalpiner Anteil. – 710 pp, Deuticke, Wien.

WAGREICH, M. (2001): A 400-km-long piggyback basin (Upper Aptian-Lower Cenomanian) in the Eastern Alps. - Terra Nova, 13: 401-406.