References

DE BRESSER J.H.P. and SPIERS C.J., 1997. Strenght characteristics of the r, f and c slip systems in calcite. *Tectonophysics*, 272: 1-23.
JAMISON W.R. and SPANG J.H., 1976. Use of calcite twin lamellae to infer differential stress. *Bull. Geol. Soc. Am.*, 87: 868-872.
LACOMBE O. and LAURENT P., 1996. Determination of deviatoric stress tensors based on inversion of calcite twin data from experimentally deformed monophase samples: preliminary results. *Tectonophysics*, 255: 189-202.
MUEGGE O., 1883. Beiträge zur Kenntnis der Strukturflächen des Kalkspathes. *Neues Jb. Miner.*, 1: 32-54.
ROWE K.J. and RUTTER E.H., 1990. Paleostress estimation using calcite twinning: experimental calibration and application to nature. *J. Struct. Geol.*, 12: 1-17.
TURNER F.J., 1953. Nature and dynamic interpretation of deformation lamellae in calcite of three marbles. *Am. J. Sci.*, 251: 276-298.

The Alps-Dianrides-Carpathians Connection: a Compilation of Tectonic Units as a First Step for Retrodeforming the Pre-Miocene Configuration

Stefan SCHMID, Bernhard FÜGENSCHUH and Kamil USTASZEWSKI

Geologisch-Paläontologisches Institut, Bernoullistrasse 32, 4056 Basel, Switzerland

In an attempt to understand the evolution of the Alps-Dinarides-Carpathian connection in time and space we attempted to design a tectonic map of the entire system. This map was arrived at by compiling existing geological maps and by using subsurface information taken from the literature for those parts of the system that are covered by very thick Mio-Pliocene (in case of the Pannonian basin) or Mid-Cretaceous to Pliocene deposits (in case of the Transylvanian basin). This map will serve as a base map for a series of retrodeformations we plan to perform in the future. The first obvious step in such retro-deformations consists in establishing the pre-Mid-Miocene (pre 20 Ma) geometry of the various tectonic units of the system. The retro-deformation of Mio-Pliocene rotations and translations was sketched for the first time by the pioneering work of Balla (1987). Many attempts were made later on, including attempts to retrodeform the situation during Tertiary and/or Cretaceous orogeny (i.e. Csontos and Vörös 2004). There is also a large amount of very differing reconstructions regarding the opening of the various oceanic domains of Neo-Tethys, including the Alpine Tethys (e.g. Haas and Pero 2004, Stampfli and Borel 2004). However, all attempts to retrodeform configurations valid for Early Tertiary and/or Mesozoic configurations have to rely on a careful retrodeformation of the rather spectacular rotations and translations that led to the the invasion of various "blocks" into the Carpathian embayment during the Miocene to Pliocene, and such a retro-deformation is not available in sufficient detail yet. The reasons for this are manyfold, but one important reason is that we do not have a clear picture yet as to what the link was between the different orogens of the system (Alps, Carpathians, Dinarides). Establishing these links will serve as an important input for restoring Miocene extension, shortening, strike slip faulting and rotations, all of them unfortunately overlapping in space and time. Hence this complex partitioning of strains, translations and rotations is therefore extremely difficult to retro-deform without having a clear concept as to how exactly these orogens were linked in pre-Miocene times.

Our map individualised the following most important tectonic elements, grouped into the following series of first-order tectonic units:

1. Miocene thrust belt: This thrust belt is the only feature that is common to Alps and Carpathians and which can be followed from the Alps all the way around the East Carpathians into the bending zone NW of Bucharest. The South Carpathians were juxtaposed with the Moesian platform by strike-slip movements along curved faults rather than by thrusting (Schmid et al. 1998). This belt consists of, from external to internal, (a) the thrusted internal fore-deep, (b) the Tarcau-Skola nappe system, and (c) the Audia-Macla-Convolute flysch-Silesian-Ducla-Subsilesian nappe system.
2. Europe-derived allochthons: These comprise, from external to internal, (a) the Helvetic and Subpenninic unists of the Alps and the Danubain nappes of the South Carpathians, (b) the Briançonnais terrane of the Alps that terminates west of the Tauern window (Schmid et al. 2004a), (c) the Rhodope unit of still uncertain position, (d) the Bukovinian-Getic-Sredna Gora nappe system, and (d) the Serbo-Macedonian unit.
3. The Tisza "block" with mixed European and Apulian affinities: This block broke off Europe during the middle Jurassic, i.e. at the same time as the Piemont-Liguria ocean of the Alps opened. Hence it had European affinities before this opening, being positioned well north of Neotethys (Meliata). As a function of the opening of an ocean between Tisza and Europe, this block moved into a paleogeographic position that is comparable to that of the Austroalpine nappes, hence the post-rift sediments such as late Jurassic Maiolica and/or radiolarites exhibit "Apulian" affinities. We distinguished, from external to internal, (a) the Bihor-Mescek nappe system that is closest to the

eastern extension of the Piemont-Liguria ocean beyond Alps and West Carpathians, (b) the Codru nappe system, and (c) the Biharia nappe system that is closest to the passive margin adjacent to Neotethys (Meliata), an ocean that must have been located well south of the Piemont-Liguria ocean within the area of the future Tisza "block".

4. Apulia-derived allochthons: In the Alps these elements are often refered to as being derived from the Apulian plate, encompassing all the elements originally positioned south of the Piemont-Liguria ocean and being incorporated into the Alpine nappe stack (so-called Austroalpine nappes). This terminology, however becomes more and more problematic further to the east, where one has to distinguish between those parts of "Apulia" which were originally postioned south of the Meliata or Neotethys embayment. Hence, in the Eastern Alps and the Western Carpathians (including the Transdanubian ranges, i.e. within what is often refered to as ALPCAPA) we have to distinguish between these two parts of „Apulia". Hence we distinguished, from external to internal (a) Lower Austroalpine nappes, Semmering nappe system and Tatricum, (b) Upper Austroalpine nappes originally psotitioned north of Meliata (as is the case for the Lower Austroalpine) which include the Northern Calcareous Alps, basement nappes such as the Silvretta and Seckau units, as well as the Veporicum and Gemericum of the West Carpathians, (c) an eoalpine high-pressure belt that marks an eclogitic suture which represents the westernmost tip of the Neotethys embayment but which mostly consists of eclogitized continental crust (Koralpe-Wölz units of the Alps, to be traced southeastwards into the Pohorje of Slovenia and around the overlying Graz Paleozoic into units that are preserved SW and NE of the Rechnitz window and which possibly can be traced in the subsurface of the Pannonian basin across the danube SE of Bratislava, where they are finally cut off by the Hurbanovo-Diosjenö line that links them to the Darno ophiolites), and (d) the Upper Austroalpine nappes that mark the southern margin of Meliata and that occupy a paleogeographic position that is close to that of the easternnmost Southern Alps that extend into Slovenia and Southwestern Hungary (Drauzug, Gurktal nappes, Graz Paleozoic, Transdanubian ranges). Thereby we abondened the concept of a "Middle Austroalpine" nappe system in favour of this new subdivision, first proposed by Schmid et al. (2004a).
5. Apulia-derived thrust sheets (Southern Alps and Dinarides): These consist of (a) the external Dinarides which are seperated from the Southern Alps by the eastward continuation of a south-vergent dextrally transpressive Mio-Pliocene thrust front in northeatern Italy (Friuli) and Slovenia, that we trace into Hungary as far east as south of lake Balaton. (b) the Southern Alps that extend into Slowenia and westernmost Hungary (Julian South-Karawanken unit of Haas et al. 2000), (c) the internal Dinarides, including the Bükk Mountains of Northern Hungary, and (d) the Jadar, Ivanjica, Korab and Pelogonian "massifs" or "blocks" that represent units positioned below the obducted Vardar and which hence are considered to be part of the distal Apulian margin, adjacent to the Meliata-Vardar-oceanic domain.
6. Ophiolites, suture zones and accretionary prisms with oceanic components: These comprise a series of elements, which may be traced a long way along strike, but whose interrelationships remain rather unclear in many cases, due to our still poor state of knowledge regarding the retro-deformation of Miocene deformations and translations and our still poorer knowledge concerning the Tertiary (Paleocene-Eocene) and Creatceous orogenic cycles. They are, from external to internal in respect to the Alps-Dinarides-Carpathian system (a) The Ceahlau-Severin ocean that is considered a lateral extension of the Piemont-Liguria ocean by some authors, but which we regard as being positioned in a more external position, i.e. closer to stable Europe (b) the Valais-Rhenodanubian or North Penninic ocean, a northern branch of the Alpine Tethys that opened relatively late (Jurassic-Cretaceous boundary) along a scar that extends from the Pyrenees to the Alps and the West Carpathians (Magura flysch), positioned north of the Iberia-Briançonnais block, (c) the Pieniny klippen belt that, amongst elements derived from continental ribbons of uncertain origin (Apulian?), contains elements of the Piemont-Liguria ocean, (d) the Piemont-Liguria-Kriscevo-Solnok-Sava ocean whose scar we trace from the Alps eastwards all along the eastern tip of ALCAPA in northern Romania, where they cross the Carpathian mountains in order to join the Midhungarian fault system that links them with that part of the Vardar ocean that stayed open until the Cretaceous-Teriary boundary (Sava belt), giving rise to back-arc magmatism further north (banatites of the Tisza block and the eaternmost Europe-derived allochthons). (e) the Meliata--Darno-Szavarskö-western Vardar-Dinaridic-Mirdita ophiolites and Jurassic accretionary prisms, consisting of remanants of Triassic ocean floor (Meliata) and parts of the Jurassic "Vardar" ocean (all the other elements) that simply represent the Jurassic parts of Neotethys which were obducted onto the Meliata accretionalry prism and the distal passive margin represented by the internal Dinarides during the Latest Jurassic , and (f) the Transylvanian-South Apuseni- eastern Vardar which also represents obducted parts of the Vardar ocean, whereby the original direction of Late Jurassic obduction remains enigmatic due to reworking during Mid-Cretaceous orogeny that produced an oceanic scar between Tisza and the the Europe-derived allochthons (Getic-Bukovinian nappe system) sealed by Creatceous-age post-orogenic sediments.

This map will serve as a basis for evaluating Miocene disruption of a belt of Cretaceous and Tertiary age orogen characterized by extreme achanges along strike, including changes in subduction polarity (Alps-Carpathians polarity vs. Dinaridic polarity, see Schmid et al. 2004b). This map is too large to be reproduced in this abstract, but which may be obtained any time as a color version by simply writing to Stefan.Schmid@unibas.ch.

References

BALLA Z., 1987. Tertiary paleomagnetic data for the Carpatho-Pannonian region in the light of Miocene rotation kinematics. *Tectonophysics*, 139: 67-98.

CSONTOS L. and VÖRÖS A., 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. Paleogeography, Paleoclimatology, *Paleoecology*, 210: 1-56

HAAS J. and PERO S., 2004. Mesozoic evolution of the Tisza Mega-unit. *Int J. Earth Sci.*, 93: 297-313.

HAAS J., MIOC P., PAMIC J., TOMLJENOVIC B., ARKAI P., BERCZI-MAKK A., KOROKNAI B., KOVACS S. and FELGENHAUER E.R., (2000). Complex structural pattern of the Alpine-Dinaridic-Pannonian triple junction. *Int. J. Earth Sci.*, 89: 377-389.
SCHMID S.M., BERZA T., DIACONESCU V., FROITZHEIM N. and FÜGENSCHUH B., 1998. Orogen-parallel extension in the Southern Carpathians. *Tectonophysics*, 297: 209-228.
SCHMID S.M., FÜGENSCHUH B., KISSLING E. and SCHUSTER R., 2004. Tectonic map and overtall architecture of the Alpine orogen. *Eclogae geologicae Helvetiae*, 97: 93-117.
SCHMID S.M., FÜGENSCHUH B., KISSLING E. and SCHUSTER R., 2004. TRANSMED Transects IV, V and VI: Three lithospheric transects across the Alps and their forelands. In: W. CAVAZZA, F.M. ROURE, W. SPAKMAN, G.M. STAMPFLI and P.A. ZIEGLER (Editors), The TRANSMED Atlas: The Mediterranean Region from Crust to Mantle. Springer, Berlin and Heidelberg, attached CD (version of the explanatory text available from the first author as a pdf-file upon request).
STAMPFLI G.M. and BOREL G., 2004. The TRANSMED transects in space and time: constraints on tzhe paleotectonic evolution of the Mediterranean domain. In: W. CAVAZZA, F.M. ROURE, W. SPAKMAN, G.M. STAMPFLI and P.A. ZIEGLER (Editors), The TRANSMED Atlas: The Mediterranean Region from Crust to Mantle. Springer, Berlin and Heidelberg, pp. 53-80.

Geochronological Constraints of Mesozoic and Tertiary Reworking of Paleozoic Basement Units in SW Carpathians

Karel SCHULMANN[1], Raymond MONTIGNY[1], Ondrej LEXA[1], Shah Wali FARYAD[2] and Petr JEŘÁBEK[2]

[1] 1UMR 7615,16 Ecole et Observatoire des Sciences de la Terre, Universite Louis Pasteur Strasbourg, F-67084 Strasbourg, France
[2] Institute of Petrology and Structural Geology, Charles University, 128 43 Prague, Czech Republic

We present a set of twenty new K-Ar cooling ages from metamorphic rocks of Vepor and Gemer units. The rocks have been collected in agreement with recently defined structural succession of deformations in southern part of West Carpathians (Lexa and Schulmann 2003). These authors interpreted the earliest Cretaceous deformation fabric – the prominent Gemer Cleavage Fan (CGF) to result from an indentation of southern block of unknown origin with the Gemer Paleozoic basement. The second structural fabric in this domain is the flat amphibolite to greenschist flat foliation reworking the Variscan metamorphic and igneous structures of the Vepor basement in the north (Janák et al. 2001). The first structure which is common to Vepor and Gemer tectonic units is so called Trans-Gemer Shear Zone (TGSZ), which constitutes the southern contact between both units and transects the central part of the Gemer unit including the GCF. This sinistral transpressive shear zone is duplicated in the Vepor basement further to the north, where two large scale shear zones rework the flat Cretaceous foliation. In addition, Faryad and Henjes Kunst (1997) and Arkai and Faryad (2003) described Jurassic high pressure event that affected Permian and Triassic rocks of Meliata accretionary wedge as well as southeastern part of Gemer unit. Faryad et al. (2004), based on purely structural observations, proposed that westward Jurassic thrusting of Meliata accretionary wedge affected also western part of the Gemer unit perpendicular to main Cretaceous northward shortening direction.

The first group of samples has been collected from southernmost Lower Paleozoic and Permian Gemer sequences affected by east dipping cleavages indicating top to the west thrusting. Muscovites growing in this intense slaty cleavage yielded three ages ranging between 198 and 165 Ma. The second group of ages was determined from muscovites growing in cleavage of central and western part of GCF and yielded four ages ranging between 141 Ma and 114 Ma. Two muscovite cooling ages of 83 and 87 Ma were produced from flat metamorphic fabric reworking Late Carboniferous and Permian cover of the eastern part of the Vepor basement. Eight new K-Ar ages ranging between 115 and 80 Ma were produced from Late Carboniferous slates and to different degree reworked Variscan basement of the Vepor complex along the southern contact with the Gemer Lower Paleozoic rocks. Finally, fresh biotite from contact aureole of small pegmatitic granite intrusion penetrating the Permian cover of the Vepor complex yielded cooling age 49.7 Ma.

These data shed a new light on a Mesozoic and Tertiary metamorphic and tectonic history of south Carpathians. We confirm a hypothesis that the Lower to Middle Jurassic shortening (198–165 Ma) of Paleozoic basement of Carpathians is a large scale crustal event, which is responsible for significant reworking of the Gemer unit. The switch in plate movements from E-W to N-S occurred already during Lower Cretaceous times (between 140–110Ma) and is responsible for large scale and heterogeneous reworking of the whole Gemer unit resulting in formation of GCF. The Late Cretaceous age of flat metamorphic fabric in the Vepor basement (87–83 Ma) very shortly preceded the welding of Gemer and Vepor units, which is manifested by formation of TGSZ and development of internal Vepor sinistral transpressive shear zones also during Late Cretaceous times (85–75 Ma). Finally, the Eocene age of magmatism affecting the Vepor and Gemer boundary indicates that this major Carpathian tectonic contact zone was thermally and possibly also mechanically rejuvenated during Tertiary period.

References

ARKAI P., FARYAD S.W., VIDAL O. and BALOGH K., 2003. Very low-grade metamorphism of sedimentary rocks of the