Amphibolites in the Vicinity of the Nové Město na Moravě (NE Part of the Moldanubian Zone, Bohemian Massif) – the Evidence of Older Granulite Facies Metamorphism

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The north-eastern part of the Strážek Moldanubicum, close to its border with Svratka Crystalline Unit, is characteristic by occurrence of the variously migmatized biotite ± silimanite paragneisses, leucocratic biotite ± muscovite migmatites, including smaller, usually elongated bodies of the metamorphic mafic rocks, representing garnet-free or garnet ± clinopyroxene amphibolites to granulites, both locally banded, and rocks having (showing) features corresponding rather to garnet-rich restite. Except mentioned rocks, smaller bodies of ultramafic rocks such as serpentinites and pyroxenites also occur.

The mineral paragenesis typical for studied samples of amphibolites includes assemblage of the greenish to green-brownish pargasitic amphibole and plagioclase with $An_{29–85}$, which is sometimes complemented by preserved assemblage of garnet and clinopyroxene, corresponding to higher metamorphic grade, represented by transition between at least upper amphibolite and granulite facies. Garnets are predominantly of an almandine-grossular composition ($Alm_{40–60}$, $Gro_{24–35}$, $Pyr_{12–31}$, $Spe_{1–5}$) and often show inclusions of small grains of bluish clinopyroxene (up to ca 20% of Jd component), rutile, ilmenite and apatite. Other, not so common accesoric minerals are zircon, sphene, minerals of epidote group and quartz. Anhedral chlorite and biotite are rare retrograde phases in garnet-free amphibolites, while symplectites of green amphibole and plagioclase forming diablastic textures around garnet are typical for garnet amphibolites. Comparing basicity of plagioclases, inside symplectites is higher than outside (less than An_{50}) and is increasing towards the garnet, as a result of reactions producing An-rich plagioclase e.g.: $3\,Prp + 11\,Di + 7\,Qtz + 4\,H_2O = 4\,Tr + 3\,An$. The replacement of clinopyroxene by green to green-brownish amphibole on the rims is also documented in several samples of garnet amphibolites. No orthopyroxene or its relics was not found.

Binary diagrams based on the major oxides vs. SiO_2 chemistry suggest the existence of at least two suites of studied rocks. Amphibolites have characteristics corresponding to tholeiite series, only one sample is displayed in the calc-alkaline field of the AFM diagram. The REE values normalized by chondrite (Boynton, 1984) are characterised by Eu/Eu* (0.87–1.35), Ce_N/Yb_N (0.97–12.81), Ce_N/Sm_N (0.52–3.38) and Eu_N/Yb_N (1.14–2.40).

Hornblende-plagioclase geothermobarometry applied to pairs of horblende and plagioclase from symplectites surrounding garnets (Holland and Blundy, 1994), combined with amphibole geobarometry (Johnson and Rutherford, 1989; Schmidt, 1992) gave the interval 780.5 °C, 6.7 kbar and 797.7 °C, 8.5 kbar for the sample from the locality near the Rokytno village and 833.6 °C, 8 kbar and 861 °C, 9.9 kbar for the sample from the locality Pohledec. Although temperature values seem to be slightly overestimated, due to hornblende high persistence (up to 1000 °C, 10 kbar) the plagioclase-garnet-clinopyroxene ± hornblende assemblage is typical for both upper amphibolite and high-P granulite facies. Thus, it is no reason to be in doubt that some samples of garnet-clinopyroxene amphibolites represent rocks corresponding to amphibolite/granulite facies transition or that their peak metamorphism could be under granulite facies conditions.

References

BOYNTON W. V., 1984. Cosmochemistry of the rare earth elements: meteoritic studies. In: P. HENDERSON, (Editor), Rare Earth Elements Geochemistry. Elsevier. pp. 63–114.

HOLLAND T. and BLUNDY J., 1994. Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry. *Contributions to Mineralogy and Petrology*, 116: 433-447.

JOHNSON M. C. and RUTHERFORD M. J., 1989. Experimental calibration of an aluminium-in-hornblende geobarometer applicable to calc-alkaline rocks. *Geology*, 17: 837-841.

SCHMIDT W. M., 1992. Amphibole composition in tonalites as a function of pressure: an experimental calibration of the Al-in-hornblende barometer. *Contributions to Mineralogy and Petrology*, 110: 304-310.

Denudation Surfaces, Development of Pannonian Formations and Facies Distribution Indicate Late Miocene to Quaternary Deformation of the Transdanubian

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The Transdanubian Range (TR) suffered a moderate extension during the rifting of the Pannonian basin between ~18 and ~11 Ma. Post-rift phase was connected to the deposition of different "Pannonian" (e.g., Late Miocene) formations both on top of the TR and in fastly subsiding basins around it. Because of postulated thermal character of this subsidence, continuation of syn-rift faulting was generally not considered during late Miocene (Horváth, 1993). The paucity of direct structural data (see Balla and Dudko 1996) is mainly due to pure outcrop conditions. On the other hand, the distribution of the Late Miocene formations and their paleogeography have considerable implications for tectonic evolution. In our poster we present evidences of latest Mid-Miocene to Quaternary (?) faulting in the TR based on complex approach of late Miocene denudation and sedimentation. Part of these deformations occurred during the late Miocene post-rift stage, but significant deformation appeared during the “inversion” phase of the Pannonian basin (Horváth, 1995), after the Miocene and have neotectonic significances.

Late Miocene sequences of the TR can be divided onto three main cycles. The traditional “lower” and “upper” Pannonian cycles are consisted of lake or shore lake sediments with prograding delta lobes with maximal ~400m thickness (Jámbor, 1980, Magyar et al., 1999). They were partly eroded and covered by the third fluvial to terrestrial suite of maximal 150 m thickness. It is consisted of breccia and sand in the internal part of the TR but from sand, clay, paleosols, caliche in the foreground. This latest Miocene to Pliocene formation mainly occurs in the Vértes Hills (Csillag et al. 2002).

Some places Pannonian formations were deposited onto syn-rift Mid-Miocene sediments. However, they frequently occur directly on Mesozoic or Paleogene formations. In that scenario, Pannonian rocks occur on denudation surface, which may have complex origin but was re-exhumed and slightly evolved before late Miocene sedimentation. These surfaces were subhorizontal at time of formation and represent paleo-reference planes. We demonstrated the deformation of these denudation surfaces by tilting and/or faulting. Example of tilting is the Tapolca graben in the southern TR (Budai et al., 1999), where 1,5–2° tilting seems to occur during Pannonian sedimentation. Tilting was also demonstrated in the neighbouring Káli embayment using digital elevation model, borehole data and GIS softwares (Jordán et al., 2003). However, in the western Keszthely Hills ~1,5° tilting seems to be post-Miocene as indicated by the gradually lowering position of coeval shoreface sediments from 300 to 180 m southward.

The pre-Pannonian denudation surface was severely deformed in the Vértes Hills, resulting in formation of tilted halfgrabens and small pull-apart basins (Csillag et al., 2002, Fodor et al., in press). Pannonian to early Pliocene sediments overlying the denudation surfaces were involved in deformation of late Pliocene to Quaternary age. However, some newly formed late Quaternary denudation surface (e.g., pediments) truncate and post-date older faulting.

During the end of the second cycle (at the final stage of the Lake Pannon), the water expanded far onto the TR and invaded some smaller pre-existing negative morphological elements, like valleys, depressions. On the other hand, highest elevations remained above lake level. Fine-grained sediments (sometimes with lignite seems) and freshwater limestones may point to quiet depositional environment. On the other hand, the dissected topography of the TR was formed just before this final sedimentation stage. The strongly preformed topography was controlled by late Miocene (or latest Mid-Miocene) tectonics. Rarely found syn-sedimentary dykes demonstrate the syn-Pannonian of faulting along these scarps.

Dissected, tectonically controlled topography is also confirmed by the presence of abrasional gravel/conglomerate along a number of morphological cliffs. Their occurrence has frequently the same elevation as the youngest and highest preserved lake sediments in the surroundigs. Thus it is suggested that the abrasional sediments may indicate the highest water level in the lake. It is supported by the fact that at some places the rounded gravels gradually path upward to angular clasts, which do not show the effect of wave action but were probably formed as terrestrial talus sediments. On the other hand, the varying topographic position of abrasional sediments itself may point to post-sedimentary (e.g., post-Lake-Pannon) deformation.

Mesoscale faults and tilting of the Pannonian strata demonstrate latest Miocene or younger deformation (Balla and Dudko, 1996, Budai et al., 1999). The eastern boundary fault of the Vértes Hills displaces Pannonian and early Pliocene terrestrial sediments arguing for late Pliocene to Quaternary faulting. Tilting of the freshwater limestone of the Buda Hills is connected to latest Miocene or younger differential uplift.

Kinematics of faults can rarely be estimated. However, scattered arguments suggest normal faulting in E-W extension, strike-slip faulting in N-S compression – E-W extension. Sinistral(?) faulting due to local transpression can be attributed to final neotectonic deformation.

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References

BALLA Z. and DUDKO A., 1996. Faults in Pannonian sequences in Hungary. *Földtani Közlöny*, 126: 209-262.

BUDAI T., CSÁSZÁR G., CSILLAG G., DUDKO A., KOLOSZÁR L. and MAJOROS Gy., 1999. Geology of the Balaton Highland. Explanation to the Geological Map of the Balaton Highland, 1:50,000. Hungarian Geological Institute, Budapest pp. 257.

CSILLAG G., FODOR L., PEREGI Zs., ROTH L., and SELMECZI I., 2002. Pliocene-Quaternary landscape evolution and deformation in the eastern Vértes Hills, (Hungary): the heritage and reactivation of Miocene fault pattern. *Geologica Carpathica*, 53: 206-208.

FODOR L., CSILLAG G. and PEREGI Zs., in press. Reconstruction of the late Neogene-Quaternary(?) Kápolnapuszta pull-apart basin using denudation surfaces of complex origin. *Ann. Report of Geol. Inst. Hungary from 2002*.

HORVÁTH F., 1993. Towards a mechanical model for the formation of the Pannonian basin. *Tectonophysics*, 225: 333-358.

JÁMBOR Á., 1980. Pannonian in the Transdanubian Central Mountains. Annales Geol. Inst. Hung., 62, pp. 259.

JORDÁN Gy., CSILLAG G., SZŰCS A. and QVARFORT U., 2003. Application of digital terrain modelling and GIS methods for the morphotectonic investigation of Kali Basin, Hungary, *Zeitschrift für Geomorphologie*, 47: 145-169.

MAGYAR I., GEARY D. and MÜLLER P., 1999. Paleogeographic evolution of the Late Miocene Lake Pannon in Central Europe. *Paleogeogr. Paleoclimat. Paleoecol.*, 147: 151-167.