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Geochronology of the Crystalline Basement of the Western Outer Carpathians' Source Areas – Constraints from K/Ar Dating of Mica and Th-U-Pb Chemical Dating of Monazite from the Crystalline 'Exotic' Pebbles

Paweł POPRAWA[1], Tomasz MALATA[2], Zoltán PÉCSKAY[3], Monika A. KUSIAK[4], Michał BANAŚ[5] and Mariusz PASZKOWSKI[5]

[1] Polish Geological Institute, ul. Rakowiecka 4, 00-975 Warszawa, Poland
[2] Polish Geological Institute, Carpathians Branch, ul. Skrzatów 1, 31-560 Kraków, Poland
[3] Institute of Nuclear Research, Hungarian Academy of Sciences, 4026 Debrecen, Bem tér 18/c, Hungary
[4] Nagoya University, Center for Chronological Research, 464-8602 Nagoya, Japan
[5] Polish Academy of Sciences, Institute of Geological Sciences, ul. Senacka 1, 31-002 Kraków, Poland

The Western Outer Carpathians (WOC) are composed of several major tectonic units, partly characterised by individual facies development. The units are composed of sedimentary fill of individual basins/subbasins. The basin-fill was detached from the original basement, deformed and thrusted over the European plate. The WOC sedimentary basins were supplied with detritus from several source areas, both external with relation to the WOC, like its northern rim, and internal, like e.g. Silesian ridge and Southern Magura ridge (e.g. Książkiewicz 1965). Judging from composition of pebbles deposited in the WOC flysch basins, often referred to as 'exotics', the source areas were build of broad variety of sedimentary and crystalline rocks (e.g. Książkiewicz 1965, Wieser 1985). Contribution of the later one to understanding of the WOC evolution is still rather limited, mainly due to lack of geochronological constraints.

Only during the last years geochronology of crystalline 'exotic' pebbles become a subject for systematic studies. First single K/Ar datings of mica from crystalline rocks derived to the WOC from the northern source area were reported by Lis (1980) and Ślączka (1999). More extended analysis, presented by Poprawa et al. (2004) and Malata et al. (2005), allowed to differentiate characteristics of the northern rim of the WOC, the Silesian ridge, the Southern Magura ridge and Marmarosh ridge respectively. CHIME analysis of monazite were conducted so far by Hanžl et al. (2000) for granite pebbles eroded from the western Silesian ridge, Michalik et al. (2004) for gneisses supplied form the central part of the Silesian ridge, Kusiak et al. (2004) for detrital monazites from the Dukla unit, as well as by Poprawa et al. (2005) for mostly metamorphic rocks derived from the northern rim of the WOC, the Silesian ridge, and the Southern Magura ridge.

The recent contribution is based on results of K/Ar dating of mica for 32 samples of metamorphic 'exotic' pebbles and for another 8 samples of igneous 'exotic' pebbles, representing every of the main source areas for the WOC basins. The results of K/Ar dating of different metamorphic rocks typically correspond to time of post-metamorphic cooling. In a case of biotite obtained age could reflect last tectono-thermal event. For the igneous rock the obtained ages most probably represents time of magmatic/volcanic activity. In a case of 3 sandstone samples detrital muscovite could be both of metamorphic and plutonic origin (Wieser 1985), with the first option more probable. Moreover for 6 'exotic' pebbles of metamorphic rock and one of granite, a single spot ages of monazite were analysed with chemical Th-U-total Pb isochron method (comp. Suzuki and Adachi 1991). In most cases for each individual monazite grain the CHIME age was determined for a few single spots. The main objective of the research is to obtain new constrains on geological setting of the source areas as well as on tectonic evolution and palaeogeography of the WOC.

Pebbles/blocks deposited to the WOC basins from the external, northern source record mainly the Neoproterozoic to Cambrian cooling after metamorphism (Poprawa et al. 2004). This, together with characteristic assemblage of crystalline and sedimentary 'exotics', suggest that the source of sediments was related to the Brunovistulicum and/or Małopolska massifs/terrains. The only exception is a sample of the upper Variscan granulite, eroded from the Variscan orogen, transported to the east and deposited in the Variscan foredeep, and afterwards recycled during the late Early Cretaceous from the Brunovistulicum to the Silesian subbasin. CHIME dating of monazite from metamorphic pebbles, representing the northern source, give the late Neoproterozoic to Caledonian single spot ages. For the northern source presence of the late Neoproterozoic-Cambrian granitoids was also revealed, both by K/Ar dating of mica and chemical Th-U-total Pb dating of monazite (Poprawa et al. 2005). K/Ar dating shown also, that the northern source supplied the WOC basins with detritus of the late-most Carboniferous to Permian andesites and porphyrites, typical for the NE part of the Brunovistulicum. Particularly interesting was a sample of granite pebble from the Skole unit, which revealed the late-most Cambrian to early-most Permian K/Ar age of mica. Directly to the north of Carpathians such granites are known only from the contact zone of the Brunovistulicum and Małopolska massifs/terrains.

The upper Cretaceous to Paleocene detritus of crystalline and sedimentary rocks from the Obidowa-Słupnice unit have characteristics resembling the northern source (Poprawa et al. 2004, 2005). K/Ar ages of biotite and CHIME single spots ages of monazite for gneiss pebble reveals the late Neoproterozoic to Caledonian metamorphism. It coincides with detritus of Carboniferous coal specific for Brunovistulicum. This together indicates that the Obidowa-Słupnice unit could be associated with Skole one and both represent common sedimentary basin, as proposed by Żytko and Malata (2001).

The Silesian ridge and the southern Magura ridge supplied the WOC basins with pebbles/blocks recording predominantly the Late Carboniferous to Permian metamorphism (Poprawa et al. 2004, 2005). This is documented by both K/Ar dating of mica and CHIME dating of monazite. Comparison of this data with the CHIME ages presented by Hanžl et al. (2000), shows that the late Variscan metamorphism was roughly coeval with granite emplacement in the western part of the Silesian ridge. Metamorphism and magmatic activity were related to Variscan orogeny (e.g. Nejbert et al. 2005).

The late Silurian to middle Devonian CHIME single spot ages obtained for the gneiss sample from Blizne (eastern part of Silesian subbasin, supplied by Silesian ridge) could be tentatively interpreted as related to the gneiss protolith. The Mesozoic CHIME ages might reflect tectonically induced thermal and diagenetic events, in particular the late Jurassic rifting in the WOC system (Poprawa et al. 2002, 2005). Other gneiss 'exotics' from Gródek at Rożnów Lake (central par of the WOC), derived also from the Silesian ridge, were studied also by Michalik et al. (2004). In that case in a spectrum of obtained ages the Variscan and older ones were rather rare and incoherent, while majority of spot gave ages falling into a time span of the Permian to Jurassic, concentrating within the Triassic. For a gneiss pebble collected from the same conglomerate level directly to the east of Gródek (location: Siekierczyna) Poprawa et al. (2004) obtained the early Permian K/Ar mica cooling age, which corresponds to the upper limit of the main cluster of CHIME ages from Michalik et al. (2004). However development of majority of monazites from Gródek gneisses postdates the main cooling phase after metamorphism, and could be related to tectono-thermal events, e.g. rifting (op. cit.). CHIME analysis for one sample of gneiss, eroded from the Southern Magura ridge shows that the main cluster of single spot ages on monazite document the Variscan metamorphism (Poprawa et al. 2005). This is coherent with K/Ar cooling age on muscovite for the same sample. Characteristic for this sample are clusters of CHIME ages being an equivalent of the Permian to Middle Triassic, and the Jurassic. Taking into account a palaeogeographic position of the source area south of the Magura basin, it is possible to speculate that the Triassic ages might reflect tectono-thermal event related to the Triassic rifting in the Pieniny basin, which was reconstructed by Birkenmajer (1988). For the other pebble from the location a biotite was dated with K/Ar method, giving the late-most Jurassic to early-most Cretaceous age, which might be in some relation with the Jurassic cluster of CHIME ages in the discussed sample. The late Jurassic K/Ar and CHIME age are tentatively related here with the rifting phase, causing development of the WOC flysch basins (Poprawa et al., 2002, 2005).

For a pebble of gneiss, which was supplied to the Dukla basin during the late Senonian-Paleocene from the north by unconstrained source area, the results of K/Ar dating document the late Variscan cooling after metamorphism. According to analysis of

Bąk and Wolska (2004) the protolith of the gneiss was a granite. A rather limited number of monazite CHIME single spot ages indicate, that the granite originated during the late-most Neoproterozoic to middle Cambrian time (Poprawa et al. 2005). It is however difficult to exclude an alternative interpretation, in which the cluster of older CHIME ages in this sample would be related to a protolith for the granite.

During the late Oligocene poorly rounded blocks of anchimetamorphic rocks (chlorite-rich fyllite and the chlorite-muscovite schist) were deposited in the eastern part of the Krosno Beds basin. Two analysed samples reveal the Albian to Cenomanian? cooling after metamorphism (Poprawa et al. 2004 Malata et al. 2005). This blocks were derived from a very proximate source, referred to as Marmarosh "cordillera". This clearly contrasts with facies of the Albian-Cenomanian sediments in the section of this part of the basin, which are represented by fine-grained, deep marine flysch and shale, characterized by a limited thickness. Such sediments can hardy develop in direct proximity of metamorphic domain. This stands for a significant Late Cretaceous-Paleogene convergence between Silesian basin and Marmarosh Massif, driven by collisional tectonics.

Comparison of characteristics of detritus derived from the individual source areas allows to conclude, that the WOC developed on the basement, being the southern prolongation of the Trans-European Suture Zone, composed of the Variscan and 'Cadomian' terrains. The contact zone of the Silesian basin and Silesian ridge coincided with palaeoboundary between basement of Variscan and 'Cadomian' orogenic consolidation to the south and north respectively. Development of Silesian ridge on the suture of Variscan and 'Cadomian' terrains could explain also a specific composition of detritus documented in one outcrop near Skrzydlna in central part of the WOC. In this location olistostrome in Menilite beds contains blocks of the late Variscan gneiss together with other type of Cadomian gneiss and unmetamorphosed Palaeozoic sedimentary cover. The suture of terrains, and therefore also location of Silesian ridge, represents a significant rheological contrast between two types of crust, strongly influencing development of the WOC. As it comes from above, conventional subdivision of the Western Carpathians into the Inner and Outer ones, documented by differences in orogenic phases and the Mesozoic facies development, does not corresponds to the basement domains.

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