POLSKIE TOWARZYSTWO MINERALOGICZNE – PRACE SPECJALNE
MINERALOGICAL SOCIETY OF POLAND – SPECIAL PAPERS
Zeszyt 24, 2004; Volume 24, 2004

Aleksandra GAWĘDA[1], Jolanta BURDA[1], Milan KOHUT[2]

THE ROLE AND TYPE OF HYBRIDISATION PROCESSES IN THE FORMATION OF QUARTZ DIORITES FROM THE TATRA MTS. (CENTRAL WESTERN CARPATHIANS)

Abstract: Dioritic rocks from the Tatra Mts. of the Western Carpathians have been studied in detail. Field relations together with new mineral and WR data suggest for rather mechanical mingling than chemical mixing at their origin. Mingling of lower crustal, mantle influenced melt together with common crustal magma was the predominant process. We suppose that crystallisation of dioritic rocks took place from above 800^{o}C to below 600^{o}C Sources of these intermediate magmatic rocks were most probably recycled oceanic crust and/or sub continental lithosphere. It is inferred that these dioritic rocks originated during early stages of main Meso-Variscan period as they display pre-plate collision character compared to surrounding collisional granites, although have partly concomitant age (350 – 340 Ma).

Keywords: Tatra Mountains, quartz diorite, crustal and mantle magma, hybridisation, mingling.

INTRODUCTION

Many granitoid plutons have been formed by the repeated magma pulses, of different source and geochemistry. In some cases the granitic plutons are associated by the more mafic dioritic bodies, usually volumetrically less significant, but important for understanding of the thermal history of granitoid magmatism. Their origin is interpreted in two ways:

1. As mafic precursors, usually the products of hybridisation of the gabbroic/basaltic magma by the granite host magma (Pitcher, 1997; Bea at al., 1999);
2. As syn-plutonic dykes and pipes, representing the case of intrusion/invasion of basic magma into the unconsolidated and relatively cooler granitic host (Pitcher, 1997);

Hybridisation between two magmas is a widespread process, which usually show many transitional stages: from homogeneous **mixing**, when the separate magmas and their components lost their identity and both magmas reveal the drastic compositional modification to form a new hybrid magma, to the **mingling**,

[1]*University of Silesia, Faculty of Earth Sciences, Będzińska st. 60 41-200 Sosnowiec, POLAND,*
[2]*Geological Survey of Slovak Republic, Mlynska Dolina 1, 81704 Bratislava, SLOVAKIA*

where the components of original magmas preserved their individual characteristics.

GEOLOGICAL SETTING

The Tatra Mountains are one of the several crystalline basements located in the Alpine belt of the Central Western Carpathians. The crystalline basement of the Tatra Mountains is composed of polygenetic Variscan granitoid intrusion – volumetrically predominant - and the metamorphic envelope, pre-Variscan in age. E-W elongated granitoid pluton is composed of different petrographical types of granitoids (Kohut, Janak 1994), differing also in age (Poller et al. 2001)

Quartz diorite – the most mafic variety (341 Ma), equigranular biotite granodiorite to tonalite (314 Ma), biotite and biotite-muscovite granodiorite to granite, sometimes porphyric (320-330 Ma), granites and granodiorites with abundant phenocrysts of K-feldspars and strongly developed oriented fabric (so called Goryczkowa type, no age determined). A sporadic appearance of dioritic rocks is documented nearly from all core mountains in the Carpathians Belt (Uher et al. 2001). There are several occurrences of quartz-diorites in the Tatra Mts. e.g. Ornak Ridge, Starorobociański Peak, Kościeliska Valley, Velická Valley, Krížne, Baranec. Quartz-diorites form small (up to 2 m thick) sills and pods in the metamorphic envelope rocks in the Western Tatra Mts. and occur as blocks, solidified probably before the granite intrusion, differing in size, inside both the common Tatra granite and High Tatra granite. They are homogenous, equigranular, usually coarse- to medium-grained. The petrogenetic meaning of quartz diorites for the evolution of granitoid magmatism in the Tatra Mts. was not discussed till now.

SAMPLING AND EXPERIMENTALS

Rock samples weighting about 4-5 kg each were taken from the western slopes of Ornak, northern and eastern slopes of Starorobociański Wierch, northern slopes of Kończysty Wierch, from Velicka Valley, Križne, Baranec. The microprobe analyses were carried out on Cambridge Microscan M9 microprobe in University of Wrocław. Standard "wet" chemical analyses of 9 samples were carried out in the Department of the Geochemistry, Mineralogy and Petrology, University of Silesia, Sosnowiec, Poland and 5 samples - in the Slovak Geological Survey, Bratislava, Slovakia. Trace elements were analysed in Activation Laboratories Ltd. (Canada) by ICP-MS method and in Memorial University of Newfundland in Canada by ICP-MS and ICP-ES methods. As the comparative material the published analyses of granitoides from the High Tatra Mts. were used. Zircon analyses were carried out using FET Philips XL 30 with EDS (EDAX), at the University of Silesia, faculty of Earth Sciences, Sosnowiec.

RESULTS

Geochemistry: In the investigated quartz-diorites the SiO_2 content ranges from about 53 wt % to about 61 wt. %. These values are a little higher than the average for the Western Carpathian diorites (54.15 ± 3.88 wt.%). Most of the samples are Q-normative, except one (JB4 sill from W slope of Ornak) which is Ol-normative. ASI values are within the range of 0.684 – 0.97. The TiO_2 content fall in the wide range of 0.68-2.24 wt %, while Zr content ranges from 80 to 370 ppm. Both elements show no correlation with SiO_2 and each other. The quartz diorites reveal high content of ΣREE = 256-394 ppm and show slight LREE-enrichement but in general flat REE patterns with missing or small Eu-anomaly (the calculated Eu/Eu* values in a narrow range of 0.937-1.065). The investigated quartz diorites can be classified to calc-alkaline series. On the multicationic R1 – R2 diagram (Batchelor & Bowden, 1985) the investigated rocks plot in the pre-plate collision magmas field, as the other Tatra granitoids, forming together a weak trend (Fig. 1). On the Pearce discrimination diagrams (Pearce et al. 1984) all quartz-diorite (and the rest of the Tatra granitoids) samples plot in the VAG field.
Mineralogy: Their main mineral components of the rocks under investigation are: plagioclases ($An_{24-29}Ab_{70-75}Or_{1-2}$), three group of amphiboles (Mg-hornblende, actinolitic hornblende and actinolite), biotite and quartz. Accessory phases are represented by: epidote group (epidote and allanite), titanite, K-feldspar (0-5,7 % vol.), magnetite, pyrite, chalcopyrite, hematite, zircon, monazite, xenotime and apatite. Euhedral zircon forms change from short, prismatic varieties (S_{12}) to elongated ones (S_7). Colour index M` falls in the range of 21-50,9 (adequate to quartz-diorites to quartz-meladiorites).

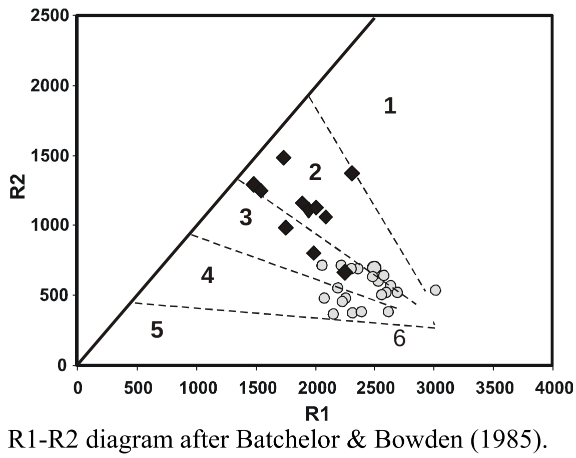

Fig. 1. Multicationic R1-R2 diagram after Batchelor & Bowden (1985).
Explanations: solid diamonds – quartz diorites; circles – Tatra granites. 1 – mantle fractionates, 2 – pre-plate collision suites, 3 – post-collisional suites, 4 – late orogenic magmas, 5 – anorogenic suites, 6 – syn-collisional suites (anatectic)
R1 = 4Si – 11(Na + K) – 2(Fe + Ti), R2 = 6Ca + 2Mg +Al.

Geothermobarometry: The application of a so-called zircon geothermometer (Watson, Harrison 1983) gave the temperatures dropping from 822°C [(KZ4) – 773 (ZT9) – 737 (VT15)] to 735°C (ZT100). The crystallisation of main minerals can be traced by hornblende – plagioclase geothermometer (Blundy, Holland 1990), coupled with the application of hornblende geobarometer (Schmidt 1992). According to these calculations the stabilisation of the amphibole – plagioclase paragenesis occurred in the range of 5 - 4.5 kbar (±0.6 kbar) dropping to about 2 kbar (±0.6 kbar), while the temperature of amphibole-plagioclase equilibration dropped from 718°C to 584°C (±75°C).

DISCUSSION

Geochemistry: Metaluminous/subaluminous character of the quartz diorites is documented by the A/CNK values of 0.694-0.970 and Rb/Sr ratios in the range of 0.0645 - 0.1078, what is typical of non-evolved lower crustal, mantle influenced magma. Nd/Th ratios are typical of the crustal magmas. However, elevated HREE content and La_N/Yb_N = 14.86 – 34.50 indicate the primitive none-fractionated character of the dioritic magma. On most of the binary/ternary diagrams Tatra diorites and Tatra granites form two populations, with no linear trend. The investigated quartz diorites are defined here as pre-plate collision magmas, with VAG affinity, but the statement if the generation of the magma took place in such conditions is of speculative character.

Mineralogy: The presence of monazite and xenotime, although sporadical, also suggest the crustal origin, while the presence of allanite in the same samples suggest rather opposite, mantle-influenced character of the dioritic parent magma. Zircon morphology suggest the crustal component predomination

Isotope data: Mantle influence is indicated by the isotopic characteristics: I_{Sr} = 0.70399 – 0.70414 with ε_{Sr}^{340} = 0.0 ~ -2.0 and ε_{Nd}^{340} = 0.7 ~ 1.9 (Poller et al. 2001), as well as low oxygen isotope value $\delta^{18}O_{SMOW}$ = 8.3-8.58‰ (Gawęda & Jędrysek as well as Kohut & Nabelek, unpublished data). The chronological position of the quartz diorites can be speculated from the R1-R2 diagram as the older than all Tatra granites, what is supported by zircon U-Pb dating showing the age of diorite emplacement as 341 ± 4 Ma while the intrusion of the High Tatra granites was dated as 314±4 Ma (Poller at al. 2001). Such age of quartz diorites seems to be in general consistent with the age of partial melting suggested by the Rb-Sr isochrone age as 345 ±9.5 Ma (Gawęda 1995), what suggests the possibility that mafic magma could cause the heating of the metamorphic complex and anatexis during shearing. In this scheme quartz diorites can represent the remnant of the appinitic type magma, predating the High Tatra granite intrusion, hybridised by the crustal components.

CONCLUSIONS

1. The quartz diorites crystallised from the hybrid magma. Mingling of lower crustal magma with a mantle component and crustal magma was the predominant process. The hybrid magma was emplaced during the Early-Variscan magmatic event about 340 Ma.
2. The quartz diorites represent pre-plate collision magma batch, they can be viewed as mafic precursors for the High Tatra granite.
3. The crystallisation of the magma took place in the temperature range > 800°C to < 600°C during decompression of the Tatra Massif. Presence of quenched amphibole and acicular apatite are indicative of quenching in their partly solidified host granitic rocks at mid-crustal level.

REFRENCES

BATCHELOR R.A., BOWDEN P. 1985: Petrogenetic interpretation of graniitoid rock series using multicationic parameters. Chem. Geol. 48: 43-55.

BEA F., MONTERO P., MOLINA F. 1999: Mafic precursors, peraluminous granitoids, and late lamprophyres in the Avila batholith: a model for the generation of Variscan batholiths in Iberia. The Journal of Geology, 107: 399-419.

BLUNDY J.D., HOLLAND T.J.B. 1990: Calcic amphibole equilibria and a new amphibole – plagioclase geothermometer. Contrib. Mineral. Petrol. 104: 208-224.

GAWĘDA A. 1995: Geochemistry and Rb/Sr isochron age of pegmatites from the Western Tatra Mts. (S-Poland). Geol. Carpathica, 46, 2: 95-99.

KOHUT M., JANAK M. 1994: Granitoids of the Tatra Mts., Western Carpathians: Field relations and petrogenetic implications. Geol. Carpathica, 45, 5: 301-311.

PEARCE J.A., HARRIS N.B.W., TINDLE A.G. 1984: Trace element discrimination for the tectonic interpretation of granitic rocks. J.Petrol., 25: 956-983.

PITCHER W.S. 1997: The mingling and mixing of granite with basalt: a third term in a multiple hypothesis. in: The Nature and Origin of Granite, Chapmann & Hall, 1997,Chapter 9: 144-167.

POLLER U. TODT W., KOHUT M., JANAK M. 2001: Nd, Sr, Pb isotope study of the Western Carpathians: implications for the Paleozoic evolution. Schweiz. Mineral. Petrogr. Mitt. 81: 159-174.

SCHMIDT M.W. 1992: Amphibole equilibria in tonalite as a function of pressure: an experimental calibration of the Al-in-hornblende barometer. Contrib. Miner. Petrol. 110: 304-310.

UHER P., PETRIK I., KOHUT M., AMBRUŻ J. 2001: Dioritic rocks of the Western Carpathians. In: Granitic plutonism of the Western Carpathians:characteristics & evolution. Bratislava.

WATSON E.B., HARRISON T.M. 1983: Zircon saturation revisited: temperature and composition effects in a variety of crustal magma types. Earth Planet. Sci Letters, 64: 295-304.