perature, n and m are stress exponents and A is an empirical constant. Then, flow stress can be expressed as a function of grain size and temperature

$$\Delta\sigma = (A_{(GSS)}/A_{(GSI)})^{1/n-m}.d^{-p/n-m}.\exp[(H_{(GSI)}-H_{(GSS)})/RT(n-m)] \quad (3)$$

Flow stress calculated for given temperatures is plotted into log grain size / log differential stress diagram expressing changes in strength of quartzites and marbles with changing temperature and grain size.

Equation (1) eliminates the influence of strain rate on flow strength. However, assumption that GSS and GSI creep exhibit equal contributions to bulk strain rate is not always valid because of changes in grain size and temperature throughout geological history. (Hickey and Bell 1996) suggested that changing $\dot{\varepsilon}$/T ratio during dynamic recrystallisation of monomineral polycrystalline aggregate causes changes in average grain size. Therefore, strain rate has to be taken into account, so that the equation (1) could be rewritten as

$$\dot{\varepsilon}_{(GSI)} = 10^{k}\cdot\dot{\varepsilon}_{(GSS)} \quad (4)$$

where k is a dimensionless strain rate parameter. If dynamic recrystallisation is associated with positive k values, then grain-boundary sliding will dominate and flow stress calculated from paleopiezometric equation will decrease. If dynamic recrystallisation is associated with negative k value, dislocation creep will dominate and flow stress can increase. Variable contribution of individual creeps can be thus controlled by intensity of texture as it was described in the experiment (Casey et al. 1998) and model (Casey and McGrew 1999).

This approach can be used to construct comparative rheological maps to assess strength of contemporaneously flowing two rock-forming minerals with large database of experimental flow parameters, e.g. marbles and quartzites. We can demonstrate that, e.g., marbles at high temperatures exhibit higher stress values than quartz and are therefore more competent.

References

CASEY M., KUNZE K. and OLGAARD D.L., 1998. Texture of Solenhofen limestone deformed to high strains in torsion. *Journal of Structural Geology*, 20(2/3): 255-267.

CASEY M. and MCGREW A.J., 1999. One-dimensional kinematic model of preferred orientation development. *Tectonophysics*, 303: 131-140.

DEBRESSER J.H.P., PEACH C.J., REIJS J.P.J. and SPIERS C.J., 1998. On dynamic recrystallization during solid-state flow: Effect of stress and temperature. *Geophysical Research Letters* 25 (18): 3457-3460.

DERBY B. and ASHBY M.F., 1987. On dynamic recrystallization. *Scripta Met.*, 21: 879-884.

HICKEY K.A. and BELL T.H., 1996. Syn-deformational grain growth: matrix coarsening during foliation development and regional metamorphism rather than by static annealing. *Eur. J. Mineral.*, 8: 1351-1373.

SHIMIZU I., 1998. Stress and temperature dependence of recrystallized grain size: A subgrain misorientation model. *Geophysical Research Letters*, 25 (22): 4237-4240.

Mafic Metavolcanic Rocks of the Sedlčany–Krásná Hora Islet (The Islet Zone of the Central Bohemian Pluton): Interpretation of Geochemistry and Petrology

Petra VÍTKOVÁ[1] and Václav KACHLÍK[2]

[1] *Institute of Geology, Academy of Sciences of the Czech Republic, Rozvojová 135, 165 00 Praha 6, Czech Republic*

[2] *Department of Geology and Palaeontology, Faculty of Science, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic*

The Sedlčany–Krásná Hora Islet is an isolated remnant of the metamorphic mantle of the Variscan Central Bohemian pluton shaped into an uneven rectangle ca. 20 by 10 km in size, elongated in the SE–NW direction, and composed of Late Proterozoic(?) to Early Palaeozoic rocks (Chlupáč 1989; Svoboda 1933). The Palaeozoic sequence is documented by fossil assemblages found in three stratigraphic levels (Ordovician ichnofossils, Silurian graptolites, Devonian crinoids) (Chlupáč 1989).

The bimodal metavolcanic rocks are present mostly within the metasedimentary sequence of the Late Proterozoic and/or Cambrian (?) Svrchnice Fm. (Chlupáč 1989). The mafic metavolcanics (lavas or subvolcanic bodies) are of Late Proterozoic and/or Early Palaeozoic age, and are distributed in the NW part of the Sedlčany–Krásná Hora Islet. In the metavolcanic suite, mafic metavolcanics (primarily basalts and basaltic andesites) prevail over felsic rocks (metamorphosed rhyolites). The mafic rocks are distinguished into two texturally defined types. Metabasites of the first type are very fine-grained to almost massive rocks, which exhibit somewhat more advanced degree of recrystallization compared to the representatives of the second type. The second type of metabasites is rich in relics of clinopyroxene phenocrysts.

The magmatic mineral assemblage of the mafic metavolcanic rocks is obliterated due to regional and contact metamorphisms. The existing mineral association of mafic rocks usually consists of pyroxene, amphibole and plagioclase. Some of the less altered samples contain relics of diopsidic pyroxene. Pyroxene phenocrysts are partially or completely replaced by uralitic amphibole. Amphiboles are calcic types represented by actinolite, actinolitic hornblende and magnesio-hornblende (Leake 1978). Plagioclases show wide variety of compositions from andesine to bytownite (Deer et al. 1966). Chlorite, epidote and biotite are accessory minerals.

In the TAS classification diagram (Le Maitre 1989) the mafic metavolcanics plot into the fields of basalts and basaltic andesites, with SiO_2 concentrations ranging from 48 to 52 wt.%. They include rather primitive basalts with MgO contents of 8-15 wt.%.

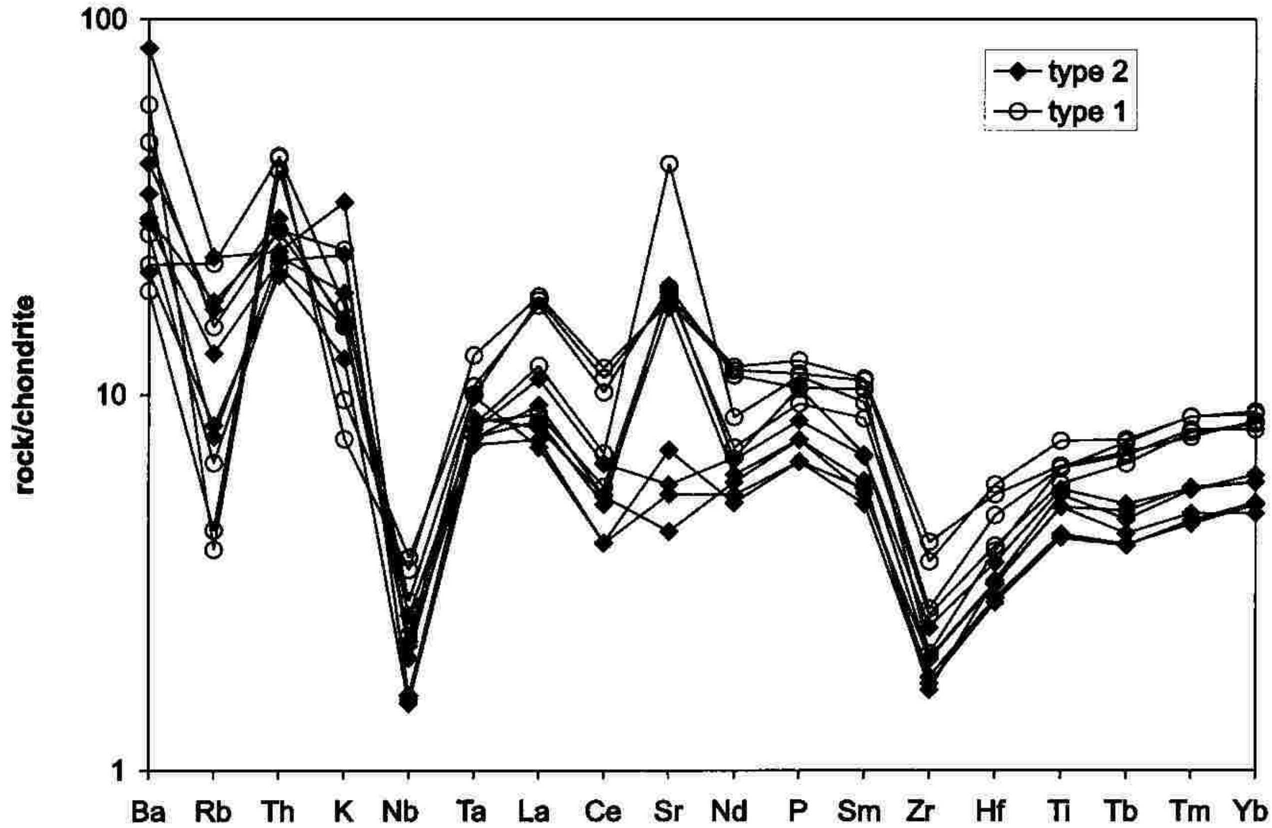

Fig. 1. Chondrite-normalized contents of trace elements in the metabasites of the Sedlčany–Krásná Hora Islet. Normalization after Thompson et al. (1984).

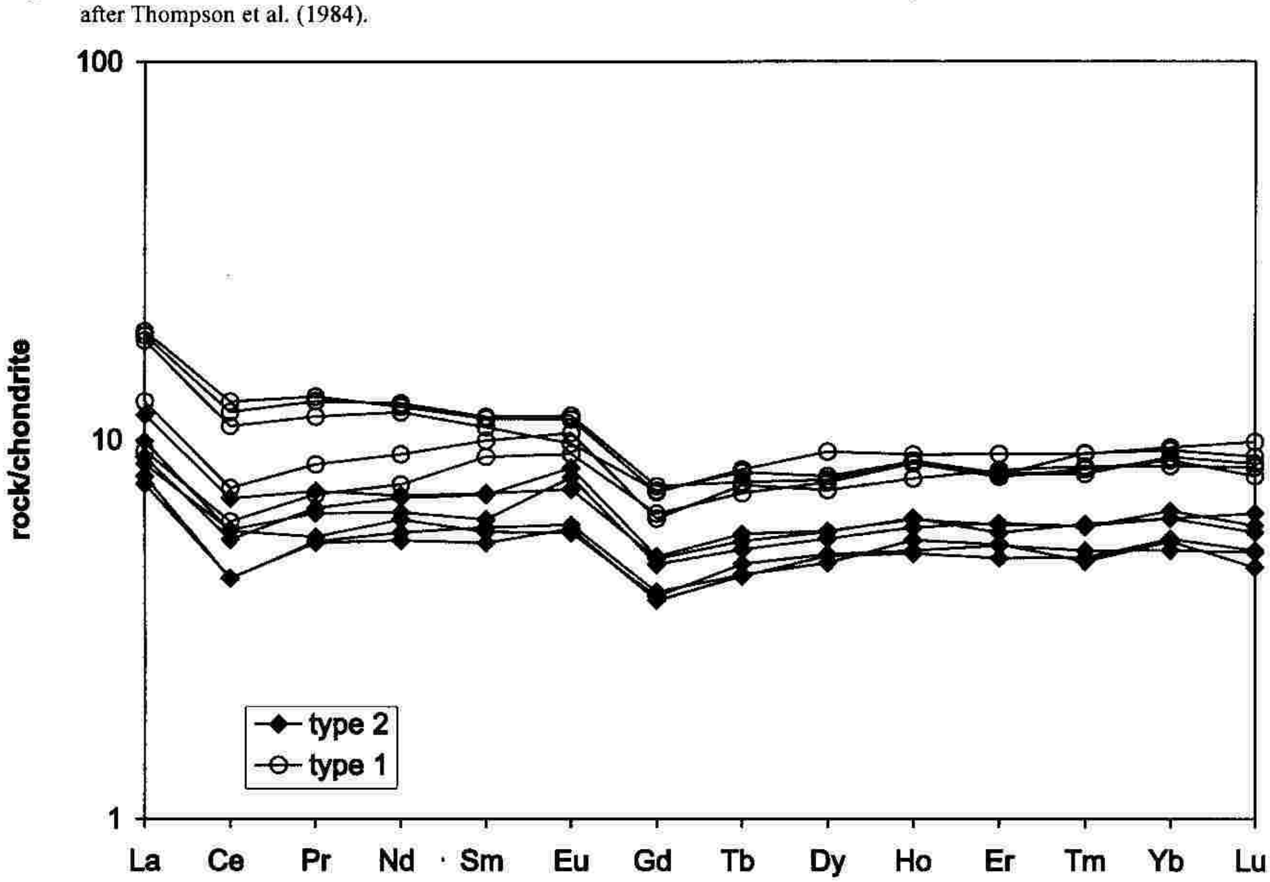

Fig.2. Chondrite-normalized REE patterns in the metabasites of the Sedlčany–Krásná Hora Islet. Normalization after Anders and Grevesse (1989).

The studied metabasites show high contents of transitional elements (Cr, Ni and Co) and low concentrations of LILE (such Rb and Sr), HFSE (Ti, Zr etc.) and REE. Many samples of mafic metavolcanic rocks are also depleted in Nb and Ta.

The Sedlčany–Krásná Hora Islet metabasites generally display typical tholeiitic patterns of chondrite-normalized trace element distributions (Fig. 1). The REE contents in metabasites are very low and the REE chondrite-normalized patterns are relatively flat – the $(Ce/Yb)_N$ ratios are 3.1–6.7 (Fig. 2). The rocks correspond to tholeiitic low-Ti basalts and basaltic andesites. The major and trace element composition of the rocks was locally modified by mobile element concentration changes during the Variscan tectonism.

Two samples of the metabasites – distinguished by the presence of pyroxene phenocrysts of up to 1 cm in diameter – correspond to geochemically primitive Mg-rich boninitic to picritic rocks of the depleted mantle derivation. They show characteristic features of the high-Ca boninitic lavas identical to those of the Upper Pillow Lavas of the Troodos Ophiolite Complex in Cyprus (Crawford et al. 1989; Rogers et al. 1989). These features are: SiO_2 content generally above 49 wt.%, high Mg# (Mg/[Mg+Fe_{TOT}]) values (0.65–0.75), TiO_2 content below 2 wt.%, values of CaO/Al_2O_3 above 0.75 and sum of alkalis below 2 %.

References

ANDERS E. and GREVESSE N., 1989. Abundances of the elements: Meteoritic and solar. *Geochimica and Cosmochimica Acta*, 53: 197-214.

CRAWFORD A.J., FALLOON T. J. and GREEN D. H., 1989. Classification, petrogenesis and tectonic setting of boninites. In: A.J. CRAWFORD (Editor), Boninites. Unwin Hyman, London, pp. 1-49.

DEER W.A., HOWIE R.A. and ZUSSMAN J., 1966. Porodoobrazuyushchiye mineraly (tom 4). Izdatelstvo Mir, Moskva.

CHLUPÁČ I., 1989. Stratigraphy of the Sedlčany–Krásná Hora metamorphic „islet“ in Bohemia (Proterozoic? to Devonian). *Časopis pro mineralogii a geologii*, 34: 1-16.

LEAKE B.E., 1978. Nomenclature of amphiboles. *American Mineralogist*, 63: 1023-1052.

LeMAITRE R.W. (Editor), 1989. A classification of igneous rocks and glossary of terms. Blackwell Scientific Publications, Oxford etc.

ROGERS N.W., MACLEOD C.J. and MURTON B.J., 1989. Petrogenesis of boninitic lavas from the Limassol Forest Complex, Cyprus. In: A.J. CRAWFORD (Editor), Boninites. Unwin Hyman, London, pp. 288-313.

SVOBODA J., 1933. Metamorfovaný ostrov sedlčansko-krásnohorský. *Archiv pro přírodovědecký výzkum čech*, 18: 1-66.

THOMPSON R.N., MORRISON M.A, HENDRY G.L. and PARRY S.J., 1984. An assessment of the relative roles of a crust and mantle in magma genesis: an elemental approach. *Phil. Trans. R. Soc. Lond.* A310: 549-590.

Tourmalines of Povondraite – "Oxy-dravite" Series from Alto Chapare, Cochabamba, Bolivia

Vladimír ŽÁČEK[1], Alfred PETROV[2], Jaroslav HYRŠL[3] and Petr ONDRUŠ[1]

[1] *Czech Geological Survey, P.O. Box 85, Klárov 3, 118 21, Praha 1, Czech Republic*

[2] *P.O. BOX 1728, Cochabamba, Bolivia*

[3] *Heverova 222, 28 000, Kolín 4, Czech Republic*

Tourmalines including povondraite occur with many additional minerals in a highly unusual rock called the Locotal Breccia, which represents brecciated metamorphosed Precambrian evaporite cap rock (Žáček et al. 1998). Locotal Breccia outcrops sporadically within a roughly 50 km² area of rain-forest topography in the Alto Chapare region, Cochabamba Department, Bolivia, in the steep eastern foothills of the Andes.

Povondraite as a new member of tourmaline group has an interesting history. The first specimen was studied by Walenta and Dunn (1977) and they described it as a new tourmaline ferridravite. Crystallographical study of Grice et al. (1993) showed that it is a Fe^{3+} analogon of buergerite in fact, with the composition Na $Fe_3^{3+}Fe_6^{3+}$ Si_6O_{18} $(BO_3)_3$ $(O,OH)_4$. Therefore a new name povondraite was proposed after Czech mineralogist and well-known tourmaline specialist Dr. P. Povondra. New study of Hawthorne and Henry (1999), in accordance with survey of additional ferrian tourmalines, shows that the ideal endmember formula of povondraite is:

Na $Fe_3^{3+}Mg_2Fe_4^{3+}$ Si_6O_{18} $(BO_3)_3$ $(OH)_3$ O and that there is solid solution between povondraite and "oxy-dravite":

$NaMgAl_2$ $MgAl_5Si_6O_{18}$ $(BO_3)_3$ $(OH)_3$ O.

New compositional data of Chapare tourmalines are in accordance with povondraite and "oxy-dravite" formulae, proposed by Hawthorne and Henry (1999). The present study proved for the first time the existence of nearly complete compositional range between povondraite and "oxy-dravite" (Fig.

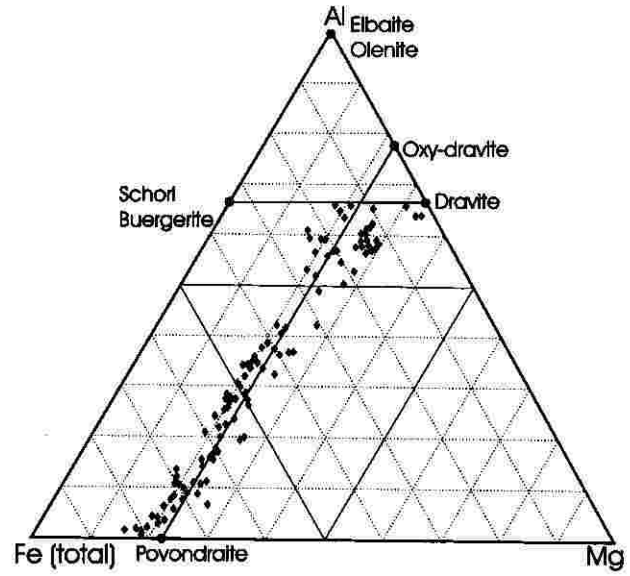

Fig. 1. Al – Fe^{tot} – Mg diagram for Chapare tourmalines.