

Oligocene (NP zones 17–21) deposits of Unit 2 consist of three subunits: Subunit 2-1 is composed of thick conglomerates commonly filling erosional scars cut into Unit 1 and the basement (deep-water canyon); Subunit 2-2 consists of dark shales containing up to 5 m thick bodies of conglomerates and thick sandstone beds (slope deposits); and Subunit 2-3 is composed of dark shales with minor thin sandstone and conglomerate beds (interchannel deposits of deep turbiditic system). Unit 2 gradually passes into Unit 3, mostly showing the Early Rupelian age based on nannoplankton. The alternating sandstone and shale deposits may be divided into two subunits based on sandstone:shale ratio and sandstone bed thickness. Spatial distribution of both subunits varies both vertically and laterally. The deposits are interpreted as proximal and distal overbank deposits of a turbidite system.

The lowermost deposits of Unit 1 were deposited during marine transgression and represent a transgressive systems tract. Coarse-grained deposits of Subunit 2-1 and shales with conglomerates and sandstones of Subunit 2-2 are thought to be deposited during relative sea-level fall, representing a lowstand

systems tract. The shales of Subunit 2-3 reflect deposition in a quiet, low-energy environment during rising sea level (transgressive systems tract). The gradual transition into Unit 3, interpreted as turbidite system deposits, suggest lowering of relative sea level. The nannoplankton from these deposits was mostly assigned to nannoplankton zones NP 20–21 suggesting building of this turbidite system on the boundary between the Eocene and Oligocene.

Comparison of the relative sea-level curve constructed from sedimentary record in the study area and the eustatic sea-level curve shows a little fit, suggesting that the eustatic sea-level variation was not the main trigger responsible for the sedimentation in the investigated part of the CCP Basin. Similarly, the climate during the Late Eocene and Early Oligocene was stable and probably did not influence the sedimentation. It seems that the most important factor influencing sedimentation was the tectonic activity. It controlled basin size and shape, canyon-floor gradient, shelf width and local relative sea level determining the type of sedimentation and the resulting sedimentary succession.

R – an Alternative to Spreadsheets and Special Software for Geochemical Calculations and Plotting

Vojtěch JANOUŠEK

Czech Geological Survey, Klárov 3, 118 21 Praha 1, Czech Republic

The interpretation of whole-rock geochemical data from igneous and metamorphic rocks often requires complex and time-consuming calculations. Nowadays, these are commonly performed on a personal computer using dedicated software (e.g., MinCalc – Melin and Kunst 1992, NewPet – Clarke 1993, and MinPet – Richard 1995). However, unless either detailed documentation is provided, or the user is skilled in the particular programming language, it is complicated to figure out exactly which algorithm has been employed by the author. Moreover, any modifications to the original program are usually difficult or even impossible as it is not a common practice to make the source code available to the public.

To eliminate these major drawbacks, a freeware QuickBasic 4.5 package for recalculation of major-element analyses, named NORMAN, has been developed (Janoušek 2000). It is capable of computing parameters according to the most common normative calculation schemes and consists of several core modules designed for importing and editing of the input data, selecting an appropriate calculation scheme, display, printing and saving the output data. The calculation algorithms are stored in nearly independent modules with a simple structure. The advantage of the chosen approach is the simplicity, availability and open architecture that enables an average user not only to follow, but also, if need be, to modify the algorithms applied to his data.

However, NORMAN is essentially limited to DOS/WIN 95/98 and QuickBasic is difficult and time-consuming to program, especially for graphic outputs – hence NORMAN lacks these. Writing a system based on a spreadsheet such as MS Excel would not eliminate these setbacks either, as for more complicated calculations the spreadsheet tends to become too complex and prone

to errors; moreover, Excel's plotting capabilities are limited and far from being of a publication quality.

A viable alternative seems to be R, a system for statistical computation and graphics (Ihaka and Gentleman 1996) that is based on statistical programming language termed S (Becker et al. 1988). R is a very high-level language, which means that the generated code is short and – compared with other languages – relatively easily understandable. It is also completely platform-independent, as R implementations are available for the most common operating systems (Unix, WIN 95/98/NT). Additionally, R produces high-quality graphic output (e.g., PostScript, HPGL, WMF) and has tools for interaction with the plots that, for instance, make possible identification of the plotted points or their interactive selection. Apart from built-in basic arithmetic, matrix, database and statistical functions, there are numerous add-on packages available (see Hornik 2000 for a complete up-to-date list and further details on R). Last but not least, R is free 😊.

To date, a great majority of the NORMAN modules have been ported into the new environment. In addition, most of the common geochemical plots used for interpretation of igneous rocks (e.g., Harker diagrams, AFM, spider diagrams, REE plots) as well as numerous classification diagrams (e.g., TAS, R_1 – R_2 , geotectonic diagrams for granitoids and basaltoids) are now ready to use. Functions for forward and reverse modelling of main igneous petrogenetic processes (fractional crystallization, binary mixing, AFC) utilising major- and trace-element data and/or radiogenic (Sr–Nd) isotope compositions were also written as were basic modules to interpret these (calculating initial Sr and Nd compositions, Nd model ages etc.). The aim is to build – partly on the basis of analogous S-based software written for Sun compatible computers by Farrow (1991) – a single,

coherent and platform-independent system for interpretation of whole-rock geochemical data that would have high-level plotting capabilities. It should be straightforward to use by ordinary geochemists but, at the same time, easily expandable by the more demanding ones.

This work was supported by the Czech Grant Agency Grant 205/97/P113; the author is indebted to C.M. Farrow (Computing Service, University of Glasgow) for intoxicating with the idea using S / R in geochemical calculations and for invaluable discussions.

References

- BECKER R.A., CHAMBERS J.M. and WILKS A.R., 1988. *The New S Language*. Chapman & Hall, London.
- CLARKE D., 1993. NewPet for DOS. Accessed November 15, 1999, at URL <ftp://www.esd.mun.ca/pub/geoprog/np940107.exe>.
- FARROW C.M., 1991. GCDX (Geochemical Data System) v. 2.0 – Reference manual. Dept. of Geology & Applied Geology, University of Glasgow.
- HORNIK K., 2000. The R FAQ. Accessed January 28, 2000, at URL <http://www.r-project.org/doc/FAQ/R-FAQ.html>.
- IHAKAR. and GENTLEMAN R., 1996. R: A language for data analysis and graphics. *Journal of Computational and Graphical Statistics*, 5: 299–344.
- JANOŠEK V., 2000. NORMAN, a QuickBasic programme for petrochemical re-calculation of whole-rock major-element analyses on IBM PC. *J. Czech Geol. Soc.*, in print.
- MELÍN M. and KUNST M., 1992. MinCalc development kit 2.1. Geol. ústav Akademie věd, Praha.
- RICHARD L.R., 1995. MinPet: Mineralogical and petrological data processing system, version 2.02. MinPet Geological Software, Québec, Canada.

Evolution of Ślęza and Nowa Ruda Ophiolites: Oceanic and Continental Stages Recorded in Stable Isotope Composition of Silicate Minerals

Mariusz O. JĘDRYSEK, Anita WEBER-WELLER and Anna SZYNKIEWICZ

Laboratory of Isotope Geology and Biogeochemistry, University of Wrocław, Cybulskiego 30, 50-205 Wrocław, Poland

Hydrogen and oxygen isotope ratios in mafic and ultramafic rocks of Ślęza (SI) and Nowa Ruda (NR) ophiolite complexes (N margin of Bohemian Massif, Sudetes Mts., SW Poland) were analysed. This was done to assess the role of ocean-floor metamorphism and continental processes in the evolution of these two ophiolites.

Geological position of the NR and SI has been briefly described in another abstract by the same authors (this volume). Structural evolution of rocks is not necessarily accompanied by formation of new minerals; however, it may apparently result in the redistribution of isotope ratios in the deformed primary minerals. Thus, isotope analyses may be a good tool to reconstruct geological conditions of structural evolution of rocks. Mesosstructural observations in SI revealed the presence of primary magmatic lamination S_0 and metamorphic and/or tectonic foliations S_1 , S_2 , S_3 and S_4 . Moreover, 6 systems of slickensides were observed. In the case of the sheeted dykes member (amphibolites), the S_0 may be considered as a sequence of rhythmic variations of the structure, parallel to the margins of the dykes. In lower members of the ophiolite complex, the S_0 is dark and light lamination. In the metagabbro, the leucocratic laminae are composed predominantly of feldspars and products of their hydrothermal decomposition. The melanocratic laminae are composed mostly of diagenetic and uraltic hornblende. In the ultramafic cumulates the light laminae consist mostly of chlorites, tremolite and primary calcite, and the dark ones are relics of pyroxenes and amphiboles. In the tectonites (serpentinities), the S_0 exists in the presence of flat sectors composed predominantly of pyroxene relics, and the overlying spaces are filled mostly with olivine and products of its decomposition.

The S_1 , in general, is parallel to S_0 , but sometimes one can observe centimetre-scale intrafoliation folds F_1 , formed during

the D_1 deformation. Despite that in the outcrop scale, no F_2 folds were registered, the S_2 foliation is very clear, especially in ultramafic rocks. It is developed as typical schistosity possibly formed during deformation D_2 . Generally, the S_2 is perpendicular to S_0 and S_1 . The D_3 deformation of S_2 yielded meter-scale open folds F_3 . The S_3 surfaces are not penetrative and occur only in ultramafic rocks as the axial cleavage in F_3 folds. The F_4 folds were registered in schistose serpentinites and amphibolites as small knick folds with cataclasis developed along axial planes (S_4). The S_4 surfaces in ultramafic cumulates occur only in a few zone of cataclasis.

In non-mineralised (ore minerals are accessory or not observed) rocks, the $d^{18}O$ whole-rock (wr) value varies from 3.97 ‰ (Ślupiec tectonised gabbro) to 8.35 ‰ (G-J serpentinites). These values are typical for ophiolitic sequences. It has been suggested earlier that ocean water was an important factor controlling hydrogen isotope ratios in chlorite from rodingites in GJ and sulphur isotope ratios from amphibolites in SM. Therefore, it can be expected that advances in ocean-floor metamorphism (higher w/r ratio and lower temperature) would leave hydrogen and oxygen isotope offprint in whole rocks, too. Therefore, vertical profiles in SI ($\delta^{18}O$) and NR (δD and $\delta^{18}O$) ophiolites were constructed, and isotope values versus the distance from petrologic Moho were plotted (Figs 1-3). In general, overall vertical distributions of δD and $\delta^{18}O$ values do not show a regular pattern. Nonetheless, the upper horizons of gabbro (dominantly fine-grained) close to the contact with subvolcanic rocks (amphibolites), show clear upward decrease in δD value in NR (Fig. 1), increase in $\delta^{18}O$ value in NR (Fig. 2) and decrease in $\delta^{18}O$ value in SI (Fig. 3).

Temperature and mineralogical composition are the dominant factors governing D and O isotope fractionation in the