Effect of Elemental Composition of Fe-Ti Oxides on their Thermomagnetic Curves

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Chemical composition of Fe-Ti oxide minerals, an important component of both intrusive and extrusive magmatic rocks, reflects the evolution of magma. The relationship between the composition and geological processes is shown in the ternary diagram of O'Reilly (1984), indicating how various geological processes such as low-temperature oxidation ("maghemitization"), high-temperature or deuteric oxidation, hydration, or kinetically controlled inversion of structure from metastable to stable forms, are associated with magnetic mineralogy. In the present investigations, the effect of elemental composition of Fe-Ti oxides on their thermomagnetic curves was studied on volcanic rocks of the České středohoří Mts.

The elemental composition of the studied Fe-Ti oxide phases was measured in polished thin sections employing Link ISIS 300 energy-dispersive system equipped with CamScan IV electron microscope. The system was operated at an accelerating voltage of 15 kV and a sample current of 2.5 nA. Temperature variation of magnetic susceptibility of the studied volcanic rocks was measured on CS-3 Furnace Apparatus (from 20 °C to 700 °C), CS-L Cryostat Apparatus (from −196 °C to 20 °C), and KLY-3S Kappabridge.

The chemical composition of the most abundant spinel-group minerals is more variable than that of ilmenite-group minerals. The ratio $Mg/(Mg+Fe^{2+})$ of titanomagnetites is highly variable (0.1 to 0.7) in basanites and nephelinites, and usually <0.2 in tephrites and trachybasalts. Separate groups are the titanomagnetites from essexites and camponites, both with $Mg/(Mg+Fe^{2+})$ <0.05, where $Fe^{3+}/(Fe^{3+}+2Ti)$ is between 0.8 and 1.0 for essexite and between 0.4 and 0.5 for camptonite. The Cr/(Cr+Al) ratio is used to identify rock types enriched in Al. Of the rock types measured in this study, the Cr/(Cr+Al) ratio is <0.3 in tephrites, trachybasalts and some basanites and nephelinites, and between 0.4 and 0.7 in other basanites and nephelinites.

Thermomagnetic curves of the rocks under investigation can be divided into several types as follows: simple heating curves with low Curie points (T_c) (between 150 °C and 300 °C), simple heating curves with high T_c (between 450 °C and 580 °C), heating curves with two or more maxima ("humps") and with simple cooling curves, and heating curves with two or more maxima and with complicated cooling curves.

Characteristic T_c of pure titanomagnetite $Fe_{2.4}Ti_{0.6}O_4$ and magnetite Fe_3O_4 are ≈150 °C and 580 °C, respectively (Dunlop and Özdemir, 1997). Different oxidation states and contents of Al and Mg impurities in the titanomagnetites result in various shapes of thermomagnetic curves and various Curie points. Al and Mg impurities lower the T_c, while oxidation raises the T_c.

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P-T Pseudosections, Zoned Garnets and Structural Records from two Structurally Different Mica Schists of the Stronie Formation in the Orlica-Śnieżnik Dome

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Tectono-metamorphic records in mica schists of the volcano-sedimentary Stronie Formation from two localities – Złoty Stok-Trzebieszowice Shear Zone (ZSTSZ) and Krowiarki Mts. – within the Lądek-Śnieżnik Metamorphic Unit (LSMU) were compared using techniques of structural and phase-equilibrium analysis. Both the areas are characterized by the occurrence of very similar rock types, which distinctly contrast in their structural characteristics. ZSTSZ is the NE–SW-trending shear zone with steep foliation, whereas the Krowiarki Mts. region is a strongly folded domain with predominant foliation dipping at relatively low angles. P-T pseudosections for the effective bulk compositions in the KFMASH model system were calculated for a precise determination of the metamorphic paths for rocks of both areas using THERMOCALC program. A combination

of structural analysis and P-T data allows the reference of the observed structural differentiation of the studied areas to the obtained metamorphic histories.

The most widely observed structural feature within rocks of the Stronie Formation is a gently dipping metamorphic foliation S2 connected with the development of tight to isoclinal folds F2 plunging at low angles to the NE and SW. Earlier foliation S1 was developed parallel to the axial planes of folds F1, intrafolial relicts of which can be observed only locally. The original orientation of the S1 foliation and F1 folds is unclear. Evidence concerning this matter varies in the area of the LSMU: at some places, data support the hypothesis about its steep orientation while in other parts of the region the observed features indicate that the orientation of the S1 foliation was close to the orientation of the S2 planes into which it was later transposed. Folding connected with the D2 stage was accompanied with shearing generally along the E–W direction, leading to development of a weak stretching lineation interpreted as the effect of a flexural slip along folded layers. Much stronger shearing episode (D3) took place in the later stage and is particularly well recorded in the rocks of the ZSTSZ where the S2 foliation was reactivated and transposed into steep (locally almost vertical) shear planes.

Thermobarometric calculations, with special regard to the information from the PT pseudosections, were carried out for the mineral assemblages assigned to each deformation stage. Shapes of the obtained P-T paths are very similar in both cases. This suggests that structurally different parts of the volcanosedimentary sequence of the Stronie Formation were metamorphosed in the same geotectonic regime. The conditions of metamorphism, obtained by standard thermobarometry calculations and by modelling of changes in the composition and modal proportion of garnets during growth reveal that the samples from the ZSTSZ and the Krowiarki Mts. underwent metamorphism under similar temperature conditions, but at slightly different depths. Maximal burial of those rocks corresponds to a pressure of ~8.5 kbar, whereas the sample from the Krowiarki Mts. reveals the peak pressure of about 7 kbar. The peak pressure for the sample from the ZSTSZ, characterized by the trivariant equilibrium grt+chl+st, is recorded in the intertectonic garnet cores, which show straight inclusion patterns defining the earliest identifiable foliation S1. In the ZSTSZ mica schists, subsequent increase in temperature accompanied with a decrease in pressure led to syntectonic development of garnet rims with curved inclusion patterns. This stage was contemporary with D2 folding and shearing observed throughout the Orlica-Śnieżnik Dome. Garnets from the sample coming from the Krowiarki Mts. contain curved inclusion trails (mainly of qtz, ru, ilm and bt) across the entire grain which implies their one-staged, syntectonic growth contemporary with the formation of garnet rims in the ZSTSZ rocks during the D2 stage. Later beginning of garnet formation in the studied rocks from the Krowiarki Mts. can be explained by the differences in the bulk composition and by shallower depth of burial prior to the D2 stage of deformation. Late stage of deformation and metamorphism in the ZSTSZ was connected with strong isobaric heating – up to about 600 ºC – under low-P conditions, connected with late Variscan granitic plutonism. This episode led to the late- to post-kinematic development of andalusite blasts, which are a prominent feature of rocks from the ZSTSZ as the unit developed under a sinistral transpression regime. Deformation connected with this stage can also be observed in the Krowiarki Mts. area, however, in this region it proceeded under lower temperature, leading to the development of stretching lineation trending NNE–SSW or NNW–SSE.

The structural and phase-equilibria lines of evidence show that the tectono-metamorphic evolution of the Stronie Formation in the area of the LSMU was that of early burial to a depth not exceeding the upper amphibolite-facies conditions and subsequent uplift connected with subvertical shortening and flattening strain (orientation and geometry of the F2 folds), during which the peak of regional metamorphism took place. This stage of deformation led to the reorientation of the S1 foliation, which originally was probably steep. Only minor differences observed in the P-T trajectories obtained for rocks from the two compared areas indicate similar tectonometamorphic conditions for the Stronie Formation of the LSMU. Contrasting structural and kinematic characteristics of the ZSTSZ are an effect of localized shearing.

Structure and Episodic Tectonic Evolution of the Lower Crustal Accretionary Wedge: in Moldanubian Zone, Austria

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Structural succession observed in the Moldanubian Zone in the northern Waldviertel in Austria is interpreted as an episodic evolution of deep crustal wedge.

The E-W oriented profile in the area of Karlstein and Raabs is traced from the Monotonous unit to the west, across the Gföhl unit in the centre to the Raabs unit to the east. N-S elongate body of the Gfohl orthogneiss is rimmed in the west by serpentinites and amphibolites and in the east by a belt of felsic and mafic granulites. The Raabs unit contains anatectic paragneisses, amphibolites and a large body of Kolmitz gneiss consisting of highly anatectic para- and ortho- gneisses.

The first recognized structure is moderately to steeply eastward dipping gneissosisty, which is well-preserved along at the western and eastern border of the Gfohl orthogneiss and