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Using computer programs to model fractional differentiation in magma chambers. Estimation of layered intrusions parental magma

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This work presents the modeling results of fractional crystallization in magma chambers predicted by COMAGMAT 3.5 (Ariskin et al., 1993) and MELTS (Ghiorso et al., 1994) computer programs. The COMAGMAT program was designed to model igneous processes in magma chambers for systems that either open or closed with respect to oxygen. The program can simulate the effects of pressure (up to 12 kbar) for crystallization of mafic magmas. A set of thermodynamic constraints is the theoretical basis for the COMAGMAT. The constraints are calibrated to a general experimental database. Comparison of the calculated and experimental temperatures indicates an accuracy of +/- 10 oC (1G). A similar comparison of mineral compositions indicates that Fo, An, En and Wo contents can be predicted within 1-3 mol.% (Ariskin et al., 1993). The MELTS program uses the principles of energy potential optimization to calculate the minerals and melts phase equilibria. This program is based on calibration thermodynamical experimental database including liquid compositions from komatiitic to rhyolitic to nephelinitic. As examples we used modeling results Central (Borodina, 2003 a), Majalic (Borodina et al., 2004) and Muskox (Francis, 1994, Borodina, 2003 b) layered intrusions. Parental magma composition of the intrusions was estimated by COMAGMAT model. The main criterion of the modeling results accuracy is the correspondence the calculated minerals and cumulates compositions to observed rocks and minerals compositions (Ariskin et al., 1995). In accordance with the principle the calculated fractionation trend of the intrusions parental magma should be similar to the compositions trend of the layered cumulates at supposed physical parameters of crystallization. The petrochemical features of the intrusions rocks are consistent with fractional crystallization of picrite parental magma with 20 wt.% MgO, 7 wt.% FeO, Mg# =83,6 for Central intrusion, 26 wt.% MgO, 7 wt.% FeO, Mg# =86,9 for Majalic

intrusion and 30 wt.% MgO, 8,5 wt.% FeO, Mg# =86,3 for Muskox intrusion. The supposed physical parameters of fractional crystallization are: oxygen buffer QFM, 0,5 wt.% H2O, total pressure of 1 kbar for Central and Majalic intrusions, 2 kbar for Muskox intrusion. A conformity of composition trend of the layered cumulates with those of calculated cumulates suggests that the supposed parental magma compositions and the model physical parameters of fractional crystallization is similar to those of the intrusions. There is an excellent agreement between modeling results predicted by the COMAGMAT and the MELTS program up to fractional crystallization degree of 40-50% (Borodina, 2003 a). Differentiation was dominated by cotectic crystallization of olivine, clinopyroxene, orthopyroxene, and plagioclase. Thermodynamic modeling using the COMAGMAT program produced a crystallization sequences that are similar to those observed in the intrusions. The crystallization sequences are Ol+Sp; Pl; Cpx; Opx; Amf in Central intrusion and Ol+Sp; Cpx; Pl; Opx; Amf in Majalic intrusion. The order of crystallization of the Muskox intrusion parental magma changed from Ol;Cpx;Pl;Opx during the early stages of solidification to Ol;Opx;Cpx;Pl during later stages. The intermediate order Ol;Cpx;Opx;Pl is locally indicated (Irvine, 1970). According to modeling results the change in the main sequence of crystallization in the intrusion probably reflects contamination by surrounding metasedimentary rocks. This suggests that the layered rocks were formed by periodic injections of pulses of magma into an extant magma body. The order of crystallization change could represent compositionally distinct (due to rock contamination) magma pulses. Thus, the Muskox intrusion was evidently open to several additions of magma during its crystallization. The petrochemical features and modeling data of the Mackenzie dyke rocks and Coppermine River basalts suggest that these rocks appear to be similar to the residual melts as results of fractional crystallization of the Muskox parental magma. The work is supported by RFBR 07-05-00825-a, Scientific School grant 4933-2006.5, grant ONZ RAS 7.10.2.

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