THE EFFECT OF NI ON SULPHIDE SOLUBILITY IN MAFIC MAGMAS: 2. USE OF A NEW VERSION OF COMAGMAT TO MODEL SULPHIDES IN GABBRO-NORITIC MELTS AND OL CUMULUS PILES

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In an accompanying paper we presented a new version of the COMAGMAT magma crystallization model [1-3] allowing one to model various sulfide-silicate assemblages [2] and the effect of NiO content in the melt on SCSS, silicate minerals and sulphide compositions [3]. The model can quantify a combined effect of the temperature decrease, FeO-enrichment and NiO depletion in the melt on the sulfide proportion during crystallization of multiply saturated cotectics, such as Ol+Pl, Ol+Pl+Aug, or Pig+Pl+Aug. Another important feature of the COMAGMAT-5.1 model is its ability to define onset of sulphide saturation during solidification of cumulus piles, including exchange with major and minor components between cumulus crystals and trapped liquid. An example of such calculations for primitive rocks from the Dovyren intrusion (Nothern Baikal area, Russia) is given below.

The Dovyren pluton is a lens-shaped body (~26´3 km) of Late Proterozoic age which is sub-conformable with its host rocks being nearly vertical due to post-intrusive folding. The modal layering of the massif was thoroughly examined in its central part (~3 km thick), in which the base is made up of a unit of plagioclase lherzolites (100-150 m) followed by four zones corresponding to a succession of cumulus minerals in the Layered Series: dunite (Ol+Chr, 800-900 m) → troctolite (Ol+Pl+Chr, ~700 m) → Ol gabbro (Pl+Ol+Cpx) → Gabbronorites (Pl+Ol+Cpx±Opx±Pig) [4]. The most primitive rocks of this intrusion were found to make up ~3 m thick chilled zone composed of picro-dolerites which are replaced upward by Ol-rich peridotites. These rocks are still characterized by a chilled doleritic groundmass containing an increased amount of olivine. As a result, very fast increase in the bulk MgO content is observed with a complementary 2-fold depletion of rocks in Ti, Al, Ca, K, and P. Another specific feature of these peridotites is their relatively low iron and higher Ni contents, as compared to other Pl-lherzolites which are predominant in the bottom zone. This suggests the chilled samples to represent more primitive material which is likely to characterize the parental magma of the Dovyren intrusion. The FeO-MgO trend displayed by these rocks suggests that they originally contained olivine ~Fo87-88 at ~1270-1300oC [1, 4].

We applied COMAGMAT-5.1 to six contact Ol-rich peridotites in attempt to simulate changes of their equilibrium melting-crystallization relationships with decreasing temperature. These calculations were carried out at 1 atm pressure, with crystal increment of 0.5% and QFM conditions. Assuming the NiO and S contents of the chilled rocks to correspond to their original values, all of the calculated crystallization trajectories suggest S-undersaturated conditions for the assumed parental melts at temperatures > 1270oC. This is considered as an evidence for a later appearance of sulphides in more crystallized olivine cumulus at lower temperatures. In support of this conclusion we performed two additional calculations. The first one included equilibrium crystallization for one of the high-magnesia picrodolerites in the temperature range from 1320oC (11 wt% MgO in the melt, equilibrium with Fo88) to ~1100oC. This modelling was assumed to approximate the trapped melt evolution during solidification of Ol-enriched cumulus pile. Similar modelling was carried out for the same initial melt (1320oC, 11 wt% MgO) assumed to be free of Ol crystals. Principal difference between these two calculations is concerned with the onset of sulphide saturation. In case of the “Ol cumulus pile” first sulphide were calculated to appear at 1209oC (~62 percent crystallized, Table), slightly earlier than plagioclase and pyroxenes appeared on the liquidus.

In case of the Ol-free magma the first sulphides were observed at lower temperatures (£1173oC) in the stability field of Ol-Pl-Opx-Cpx assemblage. These differences in modelling results for the same primitive melt composition is explained by the effect of different bulk NiO contents in the modelled systems. The proposed parental melt contained only of 500 ppm NiO as compared to 2300 ppm NiO in the cumulus picrodolerite (Table). It means that the presence of a large amount of Ni-enriched Ol crystals should be considered as a “Ni-buffer” which does not allow for NiO content in the melt to decrease significantly during crystallization and solidification of cumulus piles. Such a buffering is considered to decrease SCSS in the residual trapped liquid, as it follows from the pronounced effect of Ni on sulphide solubility [3].

We believe that this issue is of a significant importance. Following from the results of our modelling with COMAGMAT-5.1, one can conclude that due to the enrichment in NiO, olivine cumulates possess a greater potential for early precipitation and separation of sulphides compared to genetically related gabbronoritic melts which may be separated from the original cumulus piles to crystallize independently.

Table. Modelled differences in onset of sulphide saturation in partly crystallized Ol cumulus and crystallizing independently high-Mg melt

Initial Ol-cumulus (1320°C): 2315 ppm NiO, 0.030 wt%S	**Initial melt (1320°C): 517 ppm NiO, 0.067 wt%S**
Before onset of Opx	After onset of Opx
T = 1209°C	T = 1173°C
% cryst = 61.8 wt%	% cryst = 32.5 wt%
Fo in Ol = 86.3	Fo in Ol = 80.1
NiO in melt = 254 ppm	NiO in melt = 150 ppm
SCSS = 0.078 wt%	SCSS = 0.099 wt%
Ni in sulphide = 17.7 wt%	Ni in sulphide = 12.2 wt%

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Biography

Alexey Ariskin Graduated from the Moscow State University, Geochemistry Department, in 1978. He has abtained his Phd in Geochemistry from the Vernadsky Institute in 1985, and a degree of Doctor of Sciences in the field of Geochemistry in 1999. Alexey's research interests include: computer simulation of the crystallization of basalt magmas at low to high pressures; causes and mechanisms of sulphide saturation and precipitation during magmatic evolution; and the dynamics of heat-mass transport in magma chambers.