Sulfur Transfer into Mafic Magma from Sediment—Reaction of Sedimentary Sulfides with and into Mafic Magmas

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There is ample evidence (e.g., δS^{34} and S/Se) that much of the S in that magmatic nickel deposits is derived from sedimentary rocks. However, exactly how the S is transferred from the sediments to the magma is not clearly understood. In part, this is because the site of S addition to the magma is generally not the site of the formation of an ore deposit and, thus, these locations are not well studied. In order to understand the process of S transfer to the magma, one needs to look at the site of contamination rather than the ore deposits. A suitable example of this is the basal unit of the Duluth Complex (Minnesota).

The basal unit contains numerous Ni-Cu occurrences and, importantly, xenoliths of partly melted black shale. The nature and texture of the sulfide minerals changes from tiny Po + Cp intergrowths in the contact aureole to droplets in the partial melt in the xenoliths, to Po + Cp + Pn ± Cb patches in the mafic rocks. The whole-rock δS^{34} and S/Se and the tenor of As, Bi, and Sb decrease and Ni, Cu, and PGE tenor increase with distance from the xenolith. In addition, the Ni, Cu, and PGE tenors are higher in the xenoliths than in the contact aureole. In situ laser ablation analysis of the Cp from the three different settings shows that the Cp from the black shale in the aureole has the highest As, Bi, and Sb concentrations, the xenolith Cp has intermediate values, and the Cp from the mafic rocks has the lowest values.

Combining all of these observations, we suggest that S was incorporated into the mafic magma when xenoliths underwent partial melting to form a granitoid melt with sulfide droplets. The higher Ni, Cu, and PGE content of these sulfides compared to the aureole sulfides content could be due to diffusion of these elements from the mafic magma through the granitoid melt into the xenolith sulfide melt. As the degree of melting increased, some granitoid melt escaped into the mafic magma, carrying the sulfide droplets with it. The degree of melting of some xenoliths was sufficient for large portions of the silicate part of the xenolith to dissolve into the mafic magma, leaving a residual of refractory material rimmed by semimassive to massive sulfides which are rich in As, Bi, and Sb but very poor in Ni and PGE because they have only interacted with a little mafic magma. Correspondingly, for the disseminated sulfides the δS^{34}, S/Se, As, Bi, and Sb decrease and the Ni and PGE increase away from the xenolith because the sulfides interacted with more mafic magma as they were transported into the magma chamber.