

Hydrothermal alteration of Ni-rich sulfides in peridotites of Abu Dahr, Eastern Desert, Egypt: Relationships among minerals in the Fe-Ni-Co-O-S system, f_{O_2} and f_{S_2}

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ABSTRACT

The Neoproterozoic peridotites of Abu Dahr, Eastern Desert of Egypt, consist mainly of highly depleted harzburgites that have experienced multiple stages of serpentinization (lizarditization and antigoritization) and carbonation/listvenitization in a forearc environment. The Abu Dahr forearc harzburgites are more oxidized than oceanic mantle, with the oxygen fugacity (f_{O_2}) values ranging from FMQ+0.41 to FMQ+1.20 (average = +0.60 FMQ), and were equilibrated at temperatures of 910–1217 °C and pressures of 4.1–7.8 kbar. This study has documented for the first time the presence of various Ni-rich Ni-Fe (-Co) sulfide and metal phases along with Fe-oxides/oxyhydroxides in serpentinized-carbonated peridotites of the Abu Dahr forearc. Here I concentrate on the relationship between redox state and Fe-Ni-Co-O-S minerals with emphasis on the role of hydrothermal processes in upgrading magmatic sulfide tenors, desulfurization (sulfur-loss) of magmatic pentlandite and hydrothermal upgrading of the sulfide phases in Abu Dahr forearc environment. The minerals involved are high-Ni pentlandite ($Fe_4Ni_5S_8$), cobaltian pentlandite ($Fe_{3.47}Ni_{4.78}Co_{0.75}S_8$), heazlewoodite ($Fe_{0.07}Ni_{2.93}S_2$), godlevskite ($Fe_{0.26}Ni_{8.73}Co_{0.01}S_8$), millerite ($Fe_{0.01}Ni_{0.98}Cu_{0.01}S$), awaruite ($Ni_{75}Fe_{21}$) and native Ni ($Ni_{93}Fe_3$), and nickeliferous magnetite and goethite. Chalcopyrite is a rare mineral; other Cu-phases, Fe-sulfides and Ni-arsenides/phosphides are not present. Texturally, Ni-sulfide and alloy minerals occur as interstitial disseminated blebs of either solitary phases or composite intergrowths with characteristic replacement textures, documenting strong variations in oxygen and sulfur fugacities (f_{O_2} - f_{S_2}). Sulfide assemblages are divided into three main facies: (1) pentlandite-rich; (2) godlevskite-rich; and (3) millerite-rich. Textural relationships imply the following sequence: (a) primary pentlandite → cobaltian pentlandite, with partial replacement of the latter by awaruite and/or heazlewoodite along with magnetite; (b) heazlewoodite is replaced by godlevskite, which in turns is replaced by millerite; (c) Ni-rich awaruite breaks down to millerite; and finally, (d) magnetite is completely replaced by goethite. The sulfide mineralogy reflects the magmatic and post-magmatic evolution of the complex. The primary magmatic processes gave rise to pentlandite, whereas the secondary Ni-sulfides together with the metallic alloys formed in response to changing f_{O_2} and f_{S_2} conditions associated with post-magmatic serpentinization and carbonation. Serpentinization-related Ni-Fe-Co remobilization from magmatic olivines resulted in; (1) upgrading the Ni-Co tenors of pre-existing primary pentlandite, and desulfidation to form low-sulfur sulfides (mainly heazlewoodite) and awaruite under extremely low f_{O_2} and f_{S_2} conditions; (2) in situ precipitation of secondary Ni-sulfides in the presence of extra sulfur as aqueous H_2S derived from the desulfurization of magmatic pentlandite or native Ni when f_{S_2} approaches 0; (3) transformation from low-sulfur pentlandite- and godlevskite-rich assemblages to the high-sulfur millerite-rich assemblages related to later carbonation with increasing f_{O_2} ; and (4) partial dehydration of antigorite serpentinites under high-pressure conditions (>1 GPa) generated Ni-rich awaruite in equilibrium with the prograde assemblage antigorite-metamorphic olivine at higher f_{O_2} and f_{S_2} within subduction channel. The mineralogical, chemical, and thermal similarities with other serpentinite-related Ni-sulfides worldwide suggest that Ni minerals in the Fe-Ni-Co-O-S system record changing f_{O_2} and f_{S_2} during progressive serpentinization and carbonation.

Keywords: Abu Dahr forearc, Ni-rich sulfides, oxygen and sulfur fugacities, replacement textures, serpentinization and carbonation, desulfurization, subduction channel.