

Occurrence of manganese ores in different tectonic settings in the NW Himalayas, Pakistan

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In Pakistan, the occurrences of manganese ores have been reported in the Hazara area of North West Frontier Province, Kuram, Bajaur and North Waziristan agencies and the Lasbela-Khuzdar regions of Baluchistan. This study is mainly focused on the comparison of mineralogy and geochemistry of the manganese ores of Hazara and North Waziristan areas of Pakistan. The former occurs in the continental while the latter occurs in the ophiolitic sequences. In Hazara area, the ferromanganese ores are present in three localities (i.e., Kakul, Galdanian and Chura Gali) near Abbottabad within the Hazira Formation of the Kalachitta-Margala thrust belt of the NW Himalayas of the Indo-Pakistan plate. The Hazira formation of Cambrian age is a relatively thin unit (up to 150 m thick) of reddish-brown ferruginous siltstone, with variable amounts of clay, shale, ferromanganese ores, phosphorite and barite. It has a conformable lower contact with the Abbottabad Formation (Cambrian) and an unconformable upper contact with the Samana Suk limestone (Jurassic). In Waziristan area, the manganese ores occur in two localities (i.e., Saidgi and Barazai) within the Waziristan ophiolite complex, which is located along the western margin of the Indian plate in the north-western part of Pakistan. These ores, both banded and massive in nature, are hosted by metachert and generally overlying the meta-volcanics.

Mineralogically, the ferromanganese ores of Hazara area are divided into Kakul-Galdanian and Chura Gali ores. The Kakul-Galdanian ores contain relatively more hematite and less Mn-Fe phases such as bixbyite, partridgeite, hollandite, pyrolusite and

bruinite than those of Chura Gali. Bixbyite and partridgeite are the dominant Mn-bearing phases in these ores. Among the gangue minerals iron-rich clay, alumino-phosphate minerals, apatite, barite and glauconite are present in variable amount in both the ore types. The textural behavior of the ore phases suggests recrystallization and remobilization during greenschist facies metamorphism. The Waziristan ores are dominantly composed of braunite with lesser amount of bixbyite and pyrolusite. Hematite occurs as additional minor phase in the ores of Shuidar area. Cryptocrystalline quartz is the only silicate phase occurring in these ores.

Chemically, composition of the Hazara ores differs from those of the Waziristan. In Hazara ores, Mn/Fe ratio is highly variable and ranges from 0.46 to 5.25. These ores exhibit a line of descent from LREE to HREE with a small positive Ce anomaly. Their Σ REE is higher than the hydrothermal Mn deposits and lower than the hydrogenous crust. The Waziristan ores are having Mn/Fe ratio in the range of 3 to 755. Their Major and trace elements data as well as the REE pattern, showing deep negative Ce anomaly, is typical of the submarine hydrothermal manganese ores. The petrochemical characteristics suggest that the ferromanganese ores of Hazara area have originated by a mixed hydrothermal-hydrogenetic source in shallow water or continental shelf environment due to the upwelling of anoxic deep seated water while the Waziristan manganese ores were formed along the sea-floor spreading centers within the Neo-Tethys Ocean and were later obducted as part of the ophiolite complex.