

## **Petrology and geochemistry of nickeliferous peridotites in the charbast area (NW of Fariman)**

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### **Abstract**

*The Fariman ophiolite complex is a nickeliferous peridotite and our recent investigations revealed more than 5000 ppm of Ni in Chahrbast area. The nickel deposit associated with ultramafic complexes in the area. This type of deposit is the major source of Ni.*

*The Fariman ophiolite complex in northeastern Iran consists of a well-deformed amphibolite, peridotites (dunite, lherzolite, harzburgite), serpentized peridotites, gabbros, sheeted dikes, pillow and massive lava and pelagic sedimentary rocks as well as radiolarian chert. The high-grade metamorphic rocks are immediately adjacent to the peridotites and the gabbros. Result suggests that Fariman ophiolite is equivalent to the Sabzevar ophiolite and was formed as a result of closure of the northeastern branch of central Iranian microcontinent.*

*The ultramafic samples were determined by XRF and XRD to be mixtures of chromite, and Ni-Ti-Cr-Fe oxide/hydroxide compounds. There is still ambiguity about the origin of Ni-Ti-Cr-Fe oxides, but they can be related with Progressive differentiation of liquids residual from basic magma leads to late enrichment in Ni. Typically olivine crystallization results in concentration of Ni. The later alteration will help to more concentration of Ni in the rocks.*

*Primary lithochemical haloes in the area quite complex, including both enrichment and depletion zones. These appear to be spatially linked to each other and maybe viewed as a single geochemical system. The forms and sizes of geochemical ore deposit systems vary, ranging from a few hundred square meters to thousands of square meters.*

**KEYWORDS:** *Fariman, Ti oxides, Ni group minerals*

### **Introduction**

The Fariman – Asadabad ophiolite is situated in the eastern part of Iran (Khorasan Province), about 85 Km south of Mashhad (Fig. 1). The Fariman ophiolite is a highly altered ophiolite complex located along the northeastern boundary of the Iranian microcontinent (CIM). The complex consists of a well-deformed igneous rocks consist of peridotites (lherzolite, harzburgite and dunite), serpentized peridotites, pyroxenite, gabbros, sheeted dikes, massive and pillow lava sequences that exhibits a wide range of compositions from basalt to andesite and minor plagiogranite as well as pyroclastic rocks (e.g. tuff). The sedimentary rocks include a variety of pelagic fossiliferous carbonates to Lower deep- and shallow-marine rocks. The high-grade metamorphic rocks are immediately adjacent to the peridotites and the gabbros.

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The deposit modeling of the Fariman-type ores has proven to be a difficult task. Their lithological association, intense deformation and strong re-mobilization cause ambiguity on the primary setting of the ore deposition. In this paper an attempt is made to understand the origin of *nickeliferous peridotites in the Fariman complex* from the geochemistry and petrologic relationships.

### Geological setting

A combination of petrographic observations and analyses of incompatible trace elements and rare earth elements indicates the presence of at least two different types of extrusive rocks in the Fariman ophiolite. According to Lensch, (1980), there are six ophiolite massifs exposed in the (Fariman-Torbat-Hydareih-Kashmar-Sabzevar) area and each one exhibits unique characteristics in the distribution of various ophiolitic units. For example, the Fariman and Torbat complexes have the largest ultramafic and serpentinites unit,

The geology of the area is illustrated in Fig. 2. In the area, metamorphic rocks are the oldest formations and comprise amphibolites overlain unconformably by Upper Cretaceous ultramafic and mafic as well as pyroclastic, limestone and radiolarian cherts.

### Results

The Fariman ophiolite complex is a *nickeliferous peridotite* and our recent investigations revealed more than 5000 ppm of Ni in Chahrbast area. The nickel deposit associated with ultramafic complexes in the area.

Two main Ni anomaly zones were identified in the area. The SE part of the deposit and the central part (the main set). The ultramafic rocks are host to the Ni in both zones. Three main trends of faults and joints (W-E, N-S and NW-SE sets) are identified in the area (Fig. 2). The W-E set is the oldest one and the main mineralization in the area is associated with this set.

Primary litho-geochemical haloes in the area quite complex, including both enrichment and depletion zones (Table 1). These appear to be spatially linked to each other and maybe viewed as a single geochemical system. The form and size of geochemical ore deposit systems varies, ranging from a few hundred square meters to thousands of square meters.

Textures, mineralogy and chemistry of the phases are indicative of a high temperature magmatic origin. A secondary assemblage of fine-grained iron oxides and sulfides developed in altered ultramafic rocks. Magnetite and hematite are among the minerals formed during serpentinization.

Our petrologic analysis and mineralogical data reveal important differences in texture, mineral chemistry, and fabric orientation in the Fariman-Asadabad ophiolitic complex; these data allow us to subdivide the complex into three blocks. In the west, the Abdarou Block is composed of porphyroclastic textured, gabbro and peridotites, which are linked with tectonic events. In the east, the Diglan Block is composed of highly altered peridotites and the central part (the Asad-Abad Block) is composed of highly altered peridotites plus sheeted dykes.

All studied *nickeliferous* rocks are associated with dominantly ultramafic, peridotite bodies. They range from small (a few meters) lenses, to massifs up to several hundreds meter in length and several tens of meters thick. These fault-bound bodies frequently include small proportions of basaltic rocks, mostly dykes and some gabbro stocks.

The chemical analyses for rocks of the mafic–ultramafic complexes are listed in Table 1. They are low in silica, with SiO<sub>2</sub> ranging from 41% to 52%. The rocks from west area show larger variations relative to those from east area, which suggests more intensive fractional crystallization in the northwest area.

The chemical compositions of the peridotite bodies imply that they consist of residual mantle peridotites (Lherzolite, harzburgites and dunites). In the area peridotite massifs generally contain only 0.28 to 0.45 wt.% Al<sub>2</sub>O<sub>3</sub>. their compositions thus corresponding to highly residual harzburgites and dunites.

The ultramafic samples were determined by XRF and XRD to be mixtures of chromite, and Ni-Ti-Cr-Fe oxide/hydroxide compounds. Trace amounts of nickeliferous copper; occur in hematite veinlets and at the center of hematized former sulfide grains. Supergene alteration has affected most of the sulfides. There is still ambiguity about the origin of Ni-Ti-Cr-Fe oxides, but they can be related with Progressive differentiation of liquids residual from basic magma leads to late enrichment in Ni. Typically olivine crystallization results in concentration of Ni. The later alteration will help to more concentration of Ni in the rocks.

High nickel content (generally 750 to more than 5000 ppm) is the most distinctive geochemical characteristic of Fariman complex. Nickel abundances above the level of 100 ppm in VMS deposits are already considered high and indicative of a mafic–ultramafic component in the metal source. Low Ni concentrations, mostly between 20 and 250 ppm, seem to characterise also ultramafic floored massive sulphides at modern mid-oceanic ridges attesting to the relative immobility of Ni in the seafloor hydrothermal processes.

Fractionation of olivine is the main factor controlling the abundance of Ni in the magma. Cr is controlled by fractionation and accumulation of chromite. But Co is controlled mainly by fractionation and accumulation of olivine, these elements correlate with Al<sub>2</sub>O<sub>3</sub> and show trends typical of fractional crystallization in ultramafic and mafic magmas. Ni correlates negatively with SiO<sub>2</sub>, decreasing systematically from 3400 ppm in ultramafic rocks to 511 ppm in some of the mafic

rocks. Cr exhibits a positive correlation with Ni in the mafic and ultramafic rocks (Figs. 6 to 7). In an AFM (Na<sub>2</sub>O+K<sub>2</sub>O–FeO–MgO) diagram, the rocks follow a tholeiitic trend (Fig. 8). The rocks show similar chemical trends suggesting that they crystallized from common parent magma.

The geochemical data suggests that the mineralization at the complex occurred under early crystallization; olivine and spinel accompanied the commencement of each main mineralization stage and were followed by sulfide minerals, chalcopyrite and pyrite. These evidences suggest segregation followed by oxygen and sulfur fugacity changes were the main important processes in Ni precipitation within the system. At the area, as in most ophiolitic complex, alteration along fault planes at the commencement of mineralization permitted the introduction of a deep, multistage, circulating fluid into the ore forming system.

## **Conclusion**

The present study leads to the following conclusions:

- 1) The major mineralized rock type in the area is peridotite, which contains variable amounts of olivine. The geochemical data indicate that these mafic–ultramafic complexes are represented mainly by cumulates.

2) The data allow us to subdivide the complex into three blocks. In the west, the block is linked with tectonic events. In the east, the block is composed of highly altered peridotites and the central part is composed of highly altered peridotites plus sheeted dykes.

3) The complex ranges from depleted harzburgite to Ni-bearing serpentinized lherzolite. The lherzolites record oxidizing conditions. In contrast, lherzolites record more reducing redox conditions, possibly as a result of late-stage interactions with fluids associated with serpentinization. The presence of lherzolite plus podiform chromitite, implies channeled magmatic flow, with limited interaction with harzburgites. A mixed cumulate reactional origin for the peridotites and chromitites explains the presence of podiform chromitite, Ti-rich spinels and Ni-bearing serpentinites.

4) The availability of Mn, Ti and Co in solution (the Eh, pH conditions) may be the major controlling factors of the incorporation of Mn, Ti or Co in the lattice of chromite.

5) The mafic-ultramafic intrusions host significant magmatic Ni-Cu mineralization, which appears to have formed at early and intermediate stages in the crystallization histories of the intrusions. But the origin of the Nickeliferous peridotite of Fariman- is complex, and is best explained by an evolutionary model.

## References

- Farrow, C.F.G., Watkinson, D.H., (1992). Alteration and the role of fluids in Ni, Cu, and platinum-group element deposition, Sudbury Igneous Complex Contact, Onaping-Levack area, Ontario. *Mineralogy and Petrology* 46, 67– 83.
- Lensch, G. (1980) Major element geochemistry of the ophiolites in north-eastern Iran. In: A. Panayiotou, Editor, *Proceedings to International Ophiolite Symposium*, Geological Survey Department, Republic of Cyprus, pp. 398–401
- Naldrett, A. J., (1999). World-class Ni -Cu-PGE deposits: key factors in their genesis. *Mineral Deposita* 34, 227–240

**Table 1- Representative chemical analyses of nickeliferous peridotite from the northwestern Fariman**

	peridotite	Gabbro	Chromite	
SiO <sub>2</sub>	38.55	49.77	4.79	
TiO <sub>2</sub>	0.01	1.64	0.15	
Al <sub>2</sub> O <sub>3</sub>	0.27	12.97	4.44	
Fe <sub>2</sub> O <sub>3</sub>	8.20	11.88	17.37	
MgO	38.35	7.66	18.66	
MnO	0.09	0.19	0.20	
CaO	0.31	9.92	0.20	
Na <sub>2</sub> O	0.27	2.55	0.15	
K <sub>2</sub> O	-	0.48	-	
NiO	0.39	-	0.20	147 ppm of Ni in gabbro
Cr <sub>2</sub> O <sub>3</sub>	0.34	-	53.30	511 ppm of Cr in gabbro
V <sub>2</sub> O <sub>5</sub>	-	-	0.08	422 ppm of V in gabbro
LOI	13.20	2.37	0.33	
Total	99.98	99.43	99.67	

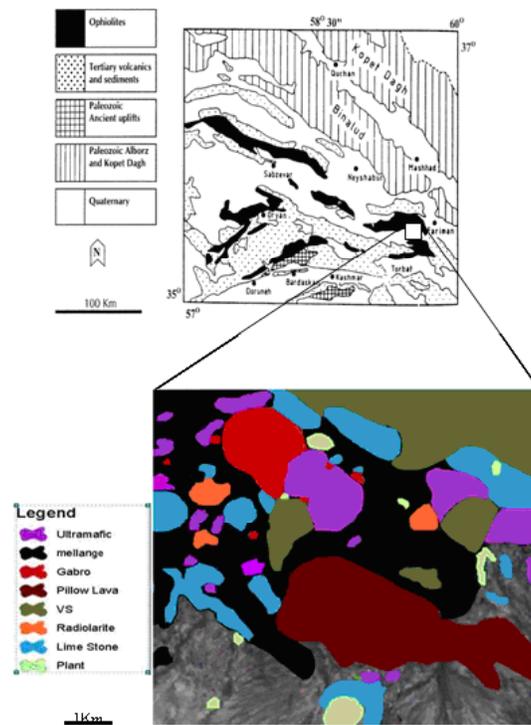


Fig.1. A geological map of the Fariman complex showing distribution of the main lithological units and the location of the studied *nickeliferous peridotite*

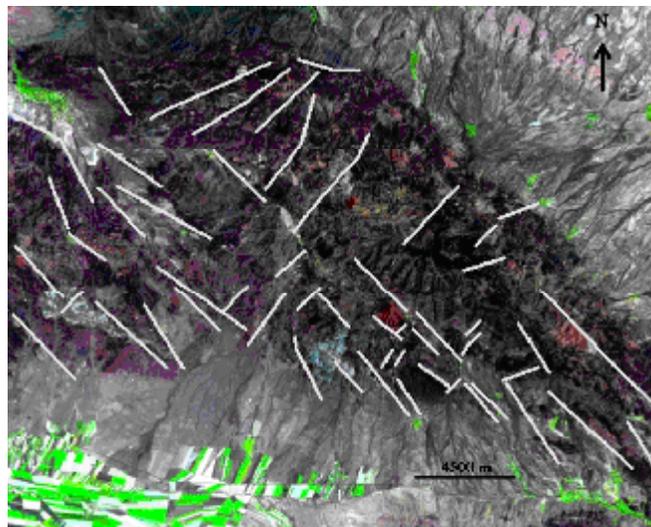


Fig.2- A map showing the main trends of faults and geotectonic zones of ophiolitic complex of northwestern Fariman.

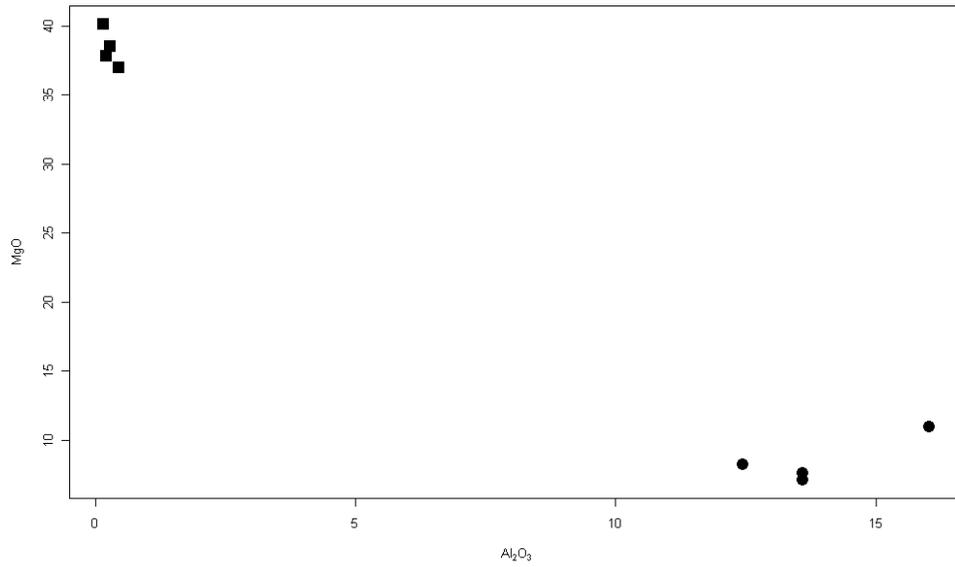


Fig. 3- A plot of the MgO versus Al<sub>2</sub>O<sub>3</sub> contents in *ophiolitic complex* of northwestern Fariman.

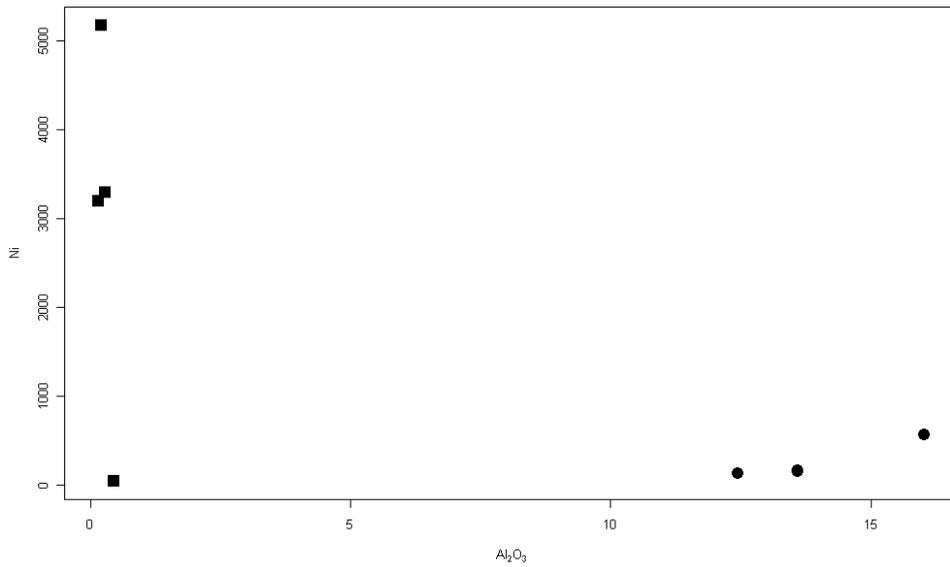


Fig. 4- A plot of the Ni versus Al<sub>2</sub>O<sub>3</sub> contents in *ophiolitic complex* of northwestern Fariman.

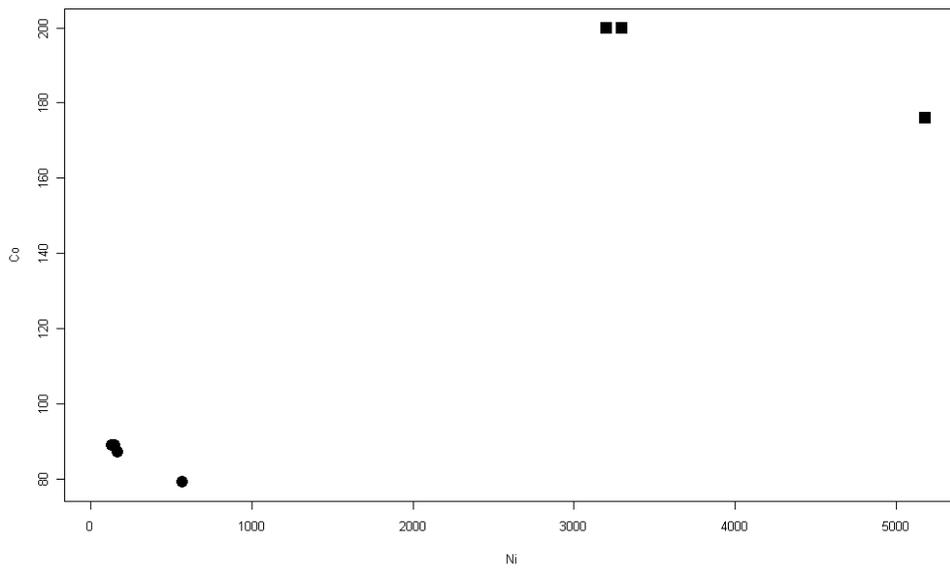


Fig. 5- A plot of the Ni versus Co contents in *ophiolitic complex* of northwestern Fariman.

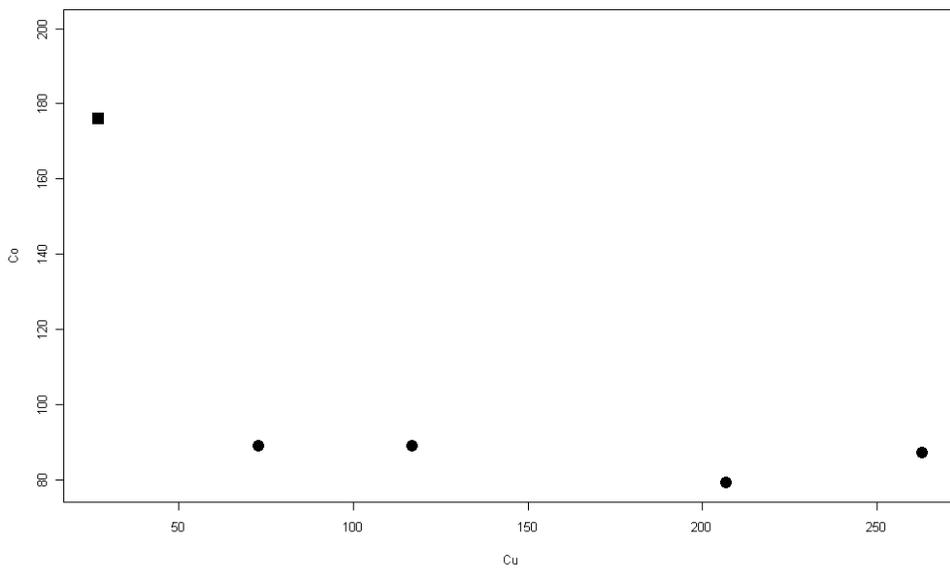


Fig. 6- A plot of the Cu versus Co contents in *ophiolitic complex* of northwestern Fariman.

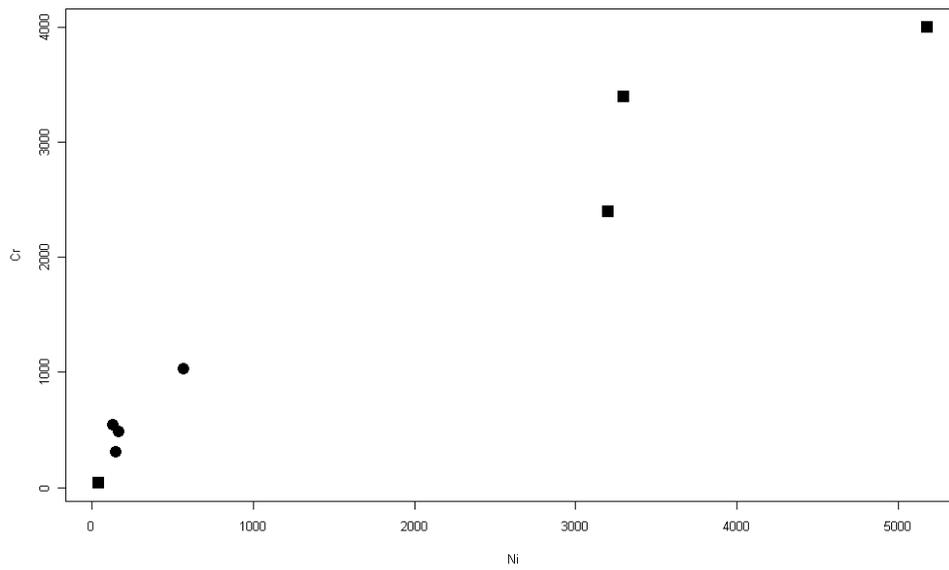


Fig. 7- A plot of the Cr versus Ni contents in ophiolitic complex of northwestern Fariman.

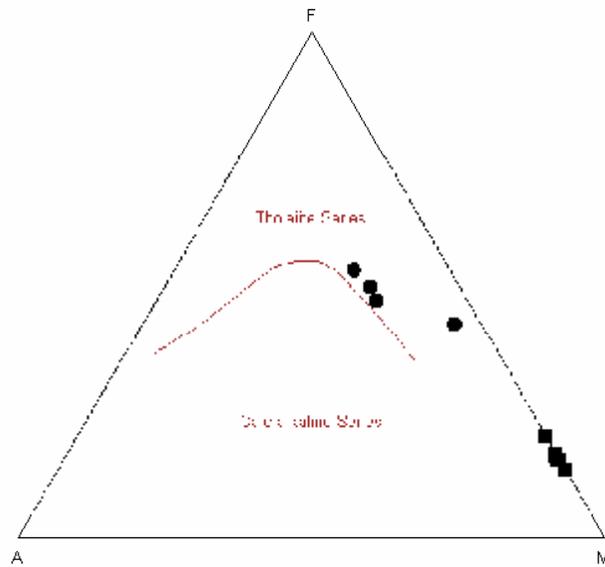


Fig.8- AFM diagram (A=Na<sub>2</sub>O+K<sub>2</sub>O, F = FeO, M= MgO) for rocks from the Fariman complex