Iranian Journal of Science & Technology, Transaction A, Vol. 33, No. A1
Printed in the Islamic Republic of Iran, 2009

GEOCHEMICAL INVESTIGATION OF NODULAR CHROMITES IN THE FORUMAD OPHIOLITE, NE OF IRAN*

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Abstract – The Forumad ophiolite in the northwestern part of the Sabzevar region has embraced the large depleted harzburgites and dunitic bodies associated with podiform chromitites. In some deposits, chromite grains have segregated as nodules. The stretched shape along with high Cr_2O_3 and TiO_2 contents are the characteristics of the nodules. Compared to the other Tethyan nodular chromites, the Forumad nodular chromites show high Cr content. The nodules formation seems to be the result of turbulent picritic magma flows accompanied by the water rich fluids.

Keywords – Nodular chromites, Geochemistry, Picritic melt, Forumad ophiolite, Iran

1. INTRODUCTION

Due to economic interest in the last decades, chromites have acquired the attention of geologists to describe the geochemistry and the genesis of these deposits. Thayer [1-2] first demonstrated the occurrence of podiform deposits in ophiolitic massifs. This type of chromite deposit generally occurs in depleted peridotites left after the extraction of basaltic magmas [3-4]. Podiform chromites vary in composition from high Al types (Al_2O_3>25 wt%) and Cr rich (Cr_2O_3= 45-60) varieties [5-6]. Nodular chromites are the dense concentrations of ellipsoidal masses of chromite crystals, and their accumulation in ophiolitic massif has been described by some authors (e.g., [7-9]). In the Forumad ophiolite, a part of the Sabzevar ophiolitic massif, one of the best occurrences of nodular chromites exists in the thick dunitic sequence of the transition zone. In this study, we will focus on the geochemistry and occurrence mode of the nodular chromites in the Forumad ophiolite.

2. FIELD DESCRIPTIONS

Ophiolitic sequence of the Forumad ophiolite shows an east-west trend following the main trend of the Sabzevar ophiolitic massif. Harzburgites, dunites, serpentinites, gabbroic-basaltic rocks, diabasic dikes, pyroclasites associated with limestones and cherts are the main rock units of the Forumad ophiolite (Fig. 1). The contacts between all of the rock units in this ophiolite are faulted and tectonized. Harzburgites can be divided into both orthopyroxene-rich harzburgites and depleted harzburgites. Depleted harzburgites gradually convert into thick dunitic bodies. The two later rocks contain chromites as euhedral disseminated grains. Some lenses of podiform chromitites are dispersed in dunitic bodies. These chromitites are either massive or as nodular types. Due to the plastic deformation, massive and nodular

*Received by the editor April 9, 2006 and in final revised form April 4, 2010
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chromitites have been occasionally stretched and appear as layer or as spindle respectively (Fig. 2). The length/width ratio of these spindles sometimes exceeds 5. Serpentinized olivines associated with disseminated chromites replete the spaces between the nodules.

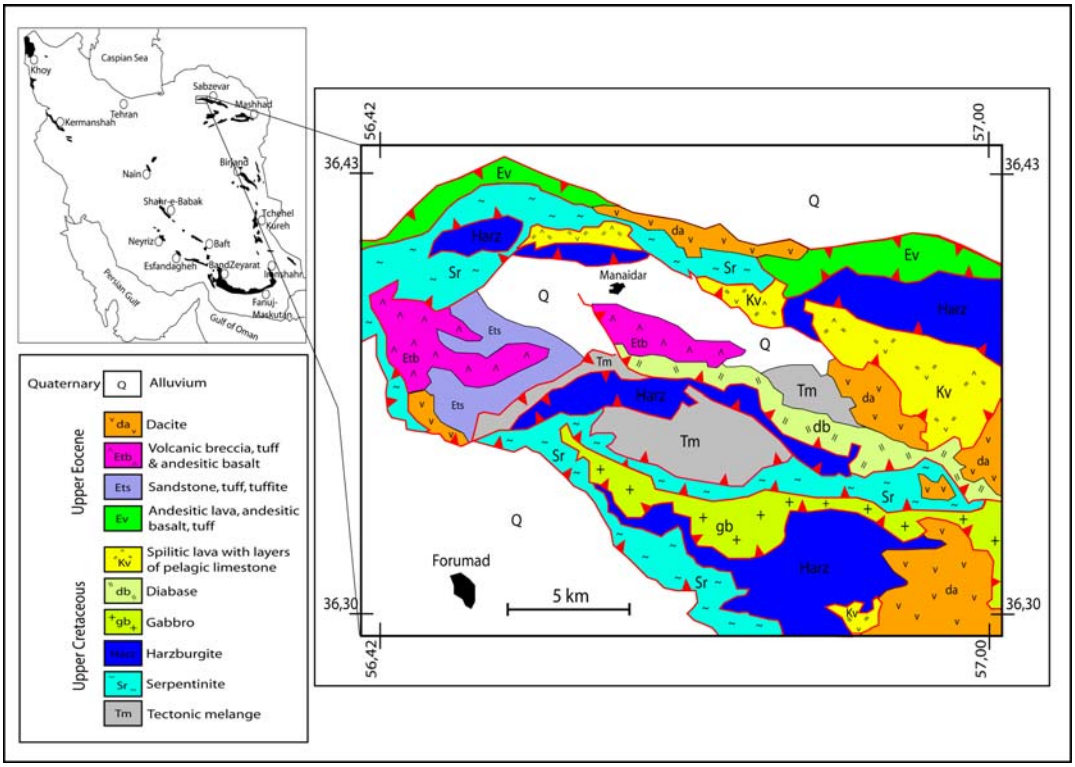

Fig. 1. Geological map of the Forumad ophiolite (modified after 1/100,000 map of Forumad)

Fig. 2. Elongated chromite nodules hosted in serpentinized dunites of the Forumad ophiolite. These nodules have been stretched, showing spindle-like form.

In addition to the occurrence of the Forumad chromite deposits (essentially in transition zone), in central parts of the Sabzevar ophiolites i.e., in the Kuh-Siah area, there are some small chromite pods, formed in the less depleted harzburgites of the mantle sequence with thin dunitic wall-rock (beneath the transition zone). The study of these small pods [9] confirms that there is a relatively weak geochemical correlation between the Kuh-Siah and the Forumad podiform deposits.

3. CHEMISTRY OF CHROMITES

Nodular chromites in the Forumad ophiolite are essentially composed of densely packed chromite crystals and show a high concentration of Cr_2O_3. The Cr_2O_3 content of these chromites varies between 58 and 60wt%, while Al_2O_3 content is about 11wt% (Table 1). This variation in Cr_2O_3 content is comparable to the chromites in the Kuh-Siah massif. The TiO_2 content of nodular chromites varies between 0.13 and 0.25 wt%. In the *Cr*-number (100Cr/Cr+Al+Fe^{+3}) versus *Mg*-number (100Mg/Mg+Fe^{+2}) diagram, the nodular chromites show a highly constant *Cr*-number (about 76%). The *Mg*-number varies between 65 and 67% (Fig. 3), as observed in the *Cr*-number vs. *Mg*-number diagram of Dick and Bullen [10]. Chromites in the Forumad ophiolite are comparatively higher in Cr and TiO_2 contents than those in the Kuh-Siah massif (Fig. 3). The TiO_2 content exhibits a positive correlation with the Fe^{+3}-number. Olivine grains as an interstitial phase between the nodules has been completely altered. In chromitites of the Kuh-Siah massif, in spite of pervasive serpentinization, the relics of olivines show Fo content of about 95% [9].

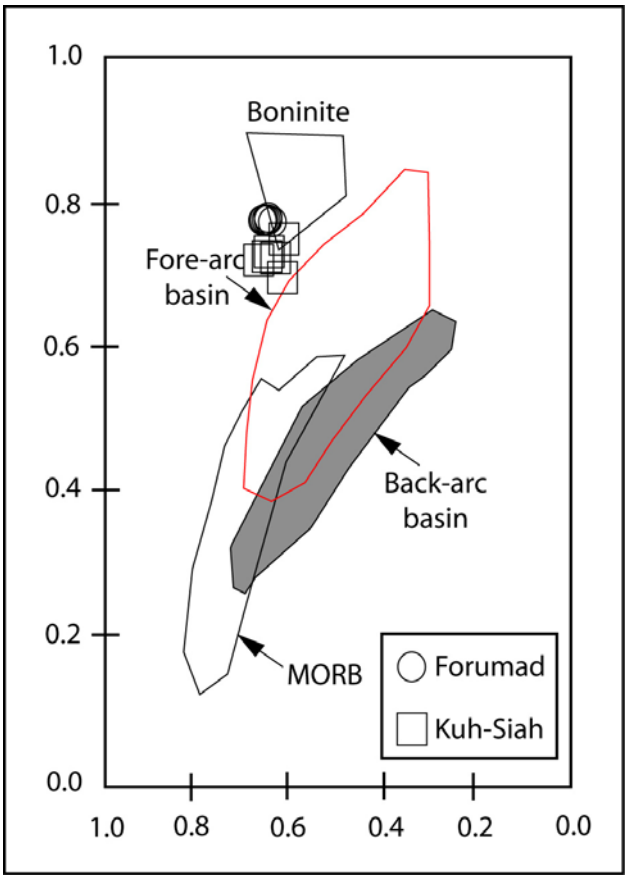

Fig. 3. The composition of the Forumad and the Kuh-Siah nodular deposits in *Cr*-number vs. *Mg*-number diagram of Dick and Bullen [10]. Individual data fields are the composition of chromites from back-arc and fore-arc basin peridotites.

Comparison of the Forumad nodular chromites with other nodular chromites occurring in Tethyan ophiolites such as the Turkey and Oman massifs, reflects that nodular chromites in the Forumad ophiolite show a higher concentration of Cr than other Tethyan ones (Fig. 4). Otherwise, the nodular chromites of the Forumad ophiolite, along with the other Tethyan chromitites, show a closer correspondence to the ophiolitic chromitites of Barnes and Roeder [11], except for the nodular chromites of the Wadi-Tayin massif (Oman) with low *Cr*-number (Fig. 4).

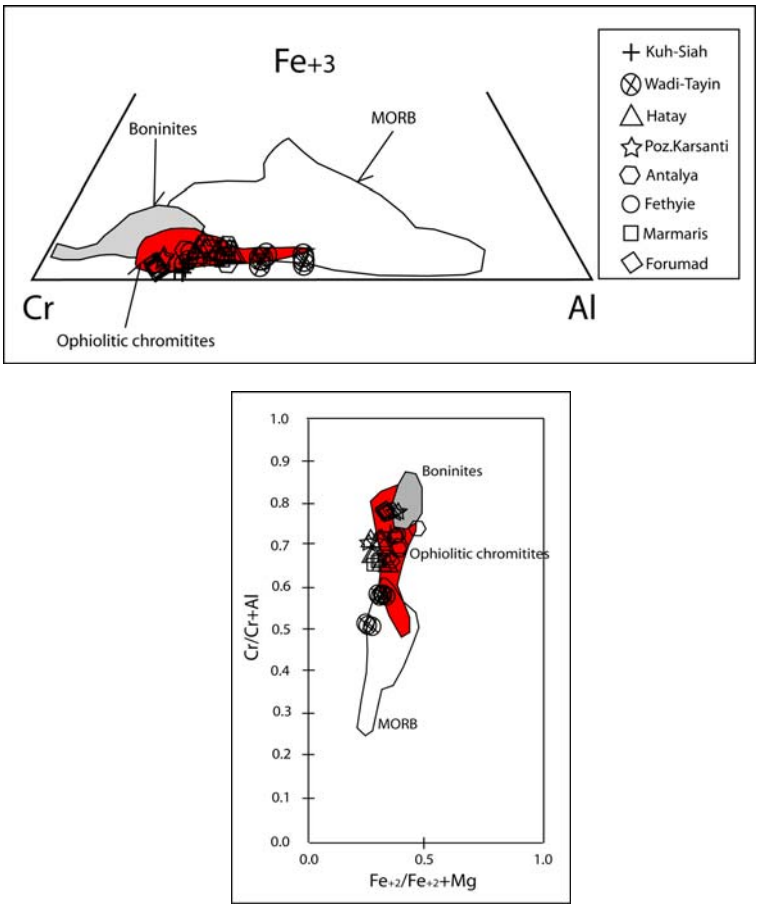

Fig. 4. Comparison of data points of the Forumad nodular chromites with the fields defined for the ophiolitic chromites, MORB and boninites by Barnes and Roeder [11]. In these diagrams, the composition of nodular chromites of the Forumad ophiolite is also compared with other Tethyan nodular chromites from the Marmaris-Fethyie, Hatay, Antalya, Pozanti-Karsanti (Turkey) and Wadi-Tayin (Oman) ophiolites, (all data from [7]). These nodular chromites show a closer correspondence to the ophiolitic chromitites of Barnes and Roeder [11], except the nodular chromites of the Wadi-Tayin massif (Oman) with low *Cr*-number.

4. CONCLUSIONS

Many authors have discussed the formation of podiform chromitites (e.g. [3, 7, 12-15]). Generally it is confirmed that these deposits are essentially formed in the SSZ (supra-subduction zone) environment due to the melt/rock (mantle) interaction [16-20]. In addition, some reasons have emerged to describe the formation of nodular chromites such as: the dissemination of chromifer globules in an immiscible silicate liquid [21-22], the spontaneous agglomeration of chromite grains in a turbulent magmatic zone [23-24], the agglomeration of chromites in the cavities of ascending magmatic conduits in the upper parts of the convective flows [3-25], the skeletal overgrowth of chromite mono-crystals [8] and finally, the segregation and down-spouting of the nodules in a basaltic system over-saturated in water [26].

Due to the high Cr content of the nodular chromites (associated with the Kuh-Siah chromitites), a picritic fluid could be responsible for the formation of these deposits. In 100Cr/(Cr+Al) vs. 100Mg/(Mg+Fe) and TiO_2 diagrams (Fig. 5), the Forumad chromites plot in the boninitic field is defined by Roeder and Reynolds [27], Dick and Bullen [10] and Kepezhinskas et al [28]. This type of magma generates in an initially developed island arc environment, although a back-arc model has been proposed by Noghreyan [29] for the formation of the Sabzevar ophiolites. Therefore, after generation of these picritic melts, podiform chromites can have formed as a result of the density difference between chromite

crystals and the surrounding melt. Moreover, the formation of the nodules indicates the existence of turbulent magmatic flows and partnership of water [26], a common phase in the arc environment. Due to the presence of the conjugate silicate melt-water system, the crystal faces of oxides are better wetted by water-rich fluids than by silicate melts [30], a feature which is supposed to help and to accelerate the formation of the nodules.

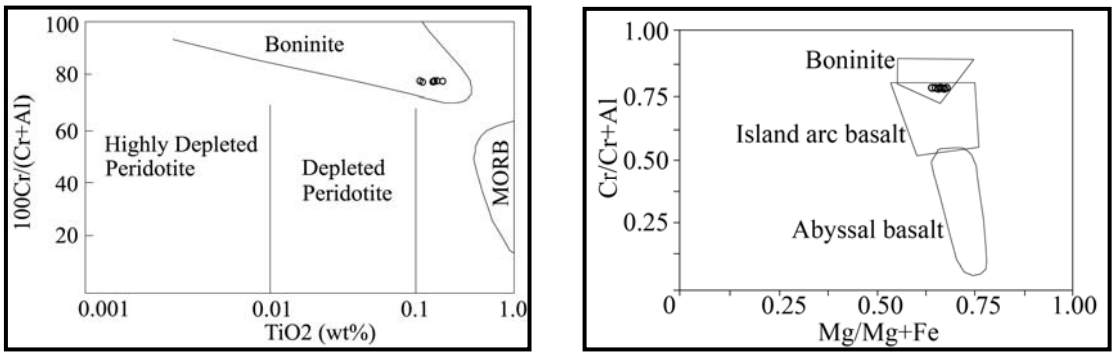

Fig. 5. *Cr*-number against TiO_2 content and *Mg*-number plots (after [10, 28]) for the nodular chromites of the Forumad area. All data in this diagram show tendency to plot in boninite field.

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