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Biogeochemical study of chromite bearing zones in Forumad area, Sabzevar ophiolite, Northeastern Iran

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ABSTRACT

Chromite ores in Forumad area from Sabzevar ophiolite belt, northeastern Iran are surrounded by magmatic dunite that is rich in nickel as compared with other ultramafics. Chromium is intensively bonded within chromite and is not an essential element for plant's life cycle, whereas Ni is more bioavailable and is an essential constituent of plant enzymes. Determined bio-concentration factor (BCF) for Ni in *Salsola orientalis* S.G. Gmel., the predominant plant species on the soils developed on dunite zones from 20 locations (average 0.81) indicated that Ni can be successfully used as a pathfinder for tracing the chromite ore bodies hosting dunites in the studied area. In soils developed on serpentinized ultramafics, maximum total concentrations of 719, 1150, 181, 617, 4481, 2314, and 20,790 μg g^{-1} were determined for Ni, Cr, Co, Mn, Fe, Mg, and Ca, respectively by using Atomic Absorption Spectroscopy (AAS). Dry climate, low rainfall and high temperature of the area lead to grow a specific flora including annual and perennial herbaceous plants. The chemical data showed excellent correlation coefficient between Cr and Ni (0.91) in soils developed on dunite zones. Investigation on 107 species from 30 families, growing on the studied soils indicated that *S. orientalis* could consider as promising plant for prospecting of chromite ores in Sabzevar ophiolite belt in reconnaissance survey.

1. Introduction

Biogeochemical techniques used in mineral prospecting are based on soil and plant relationships (Al-Farraj and Al-Wabel, 2007; Ebong et al., 2007; Ghaderian and Baker, 2007; Ololade et al., 2007; Pratas et al., 2005; Reeves et al., 2007). Soil forms the upper layer of the regolith and supports plant life. Knowledge of soil chemistry is an essential prerequisite for the proper understanding of biogeochemical patterns. Close relationship between the soil and its vegetation is to the extent that it can be considered as an integral part of the biogeochemical technique (Palmer, 1995).

Plant growing on soil is dramatically affected by the host soil composition which leads to the selection of a specific flora. Plants respond to elemental composition of host soil in three ways: exclusion, indication or accumulation. Biogeochemists use soil-indicator plants to prospect ore deposits of valuable metals (Altinözlü et al., 2012; Brooks, 1998; Ghaderian and Baker, 2007; Pratas et al., 2005; Reid and Hill, 2012). The biogeochemical techniques focus on chemical analyses of plants and provide a cost-effective means to assess the composition of near-surface materials in order to detect the presence of ore deposits beneath the earth surface. There is also an increasing interest in the study of plant–soil relationship for phytoremediation, phytoextraction and phytomining (Al-Farraj and Al-Wabel, 2007; Ebong et al., 2007; Ololade et al., 2007; Reid and Hill, 2010).

Since serpentine plants have been well studied and ultramafic rocks are abundant on the earth's crust, plants growing on serpentinized rocks are successfully used in biogeochemical prospecting (Freitas et al., 2004; Sequeira and Pinto da Silva, 1991). The serpentinized ultramafics are rich in Fe and Mg with high concentration of Ni and Cr, thus soils formed on these geological materials contain high levels of magnesium and iron and also have much more nickel and chromium compared to many other soils. For example, high contents of Ni were reported from some serpentine derived soils (up to 2%) (Altinözlü et al., 2012). Serpentine soils tend to be shallow and dry (Proctor and Nagy, 1992), thus plant species growing on these soils and their physiognomy are different from those of non-serpentine areas. The soils are also characterized by low concentrations of some essential nutrients such as N, P, K, and high Mg/Ca ratio. Manganese content of the soils is slightly higher than many other soil types (Ghaderian et al., 2007; Proctor, 1999).

Ultramafic rocks are widely exposed in Iran and most of them belong to Neo-Tethyan ophiolite belt (Rajabzadeh et al., 2013), hence soils derived from serpentinized ultramafics cover substantial areas in many locations of this country (Fig. 1). The metallic deposits have been described by some authors from Iranian section of Neo-Tethyan ophiolite (Rajabzadeh and Moosavinasab, 2013; Rajabzadeh et al., 2013). Although these ophiolites contain important chromite ores

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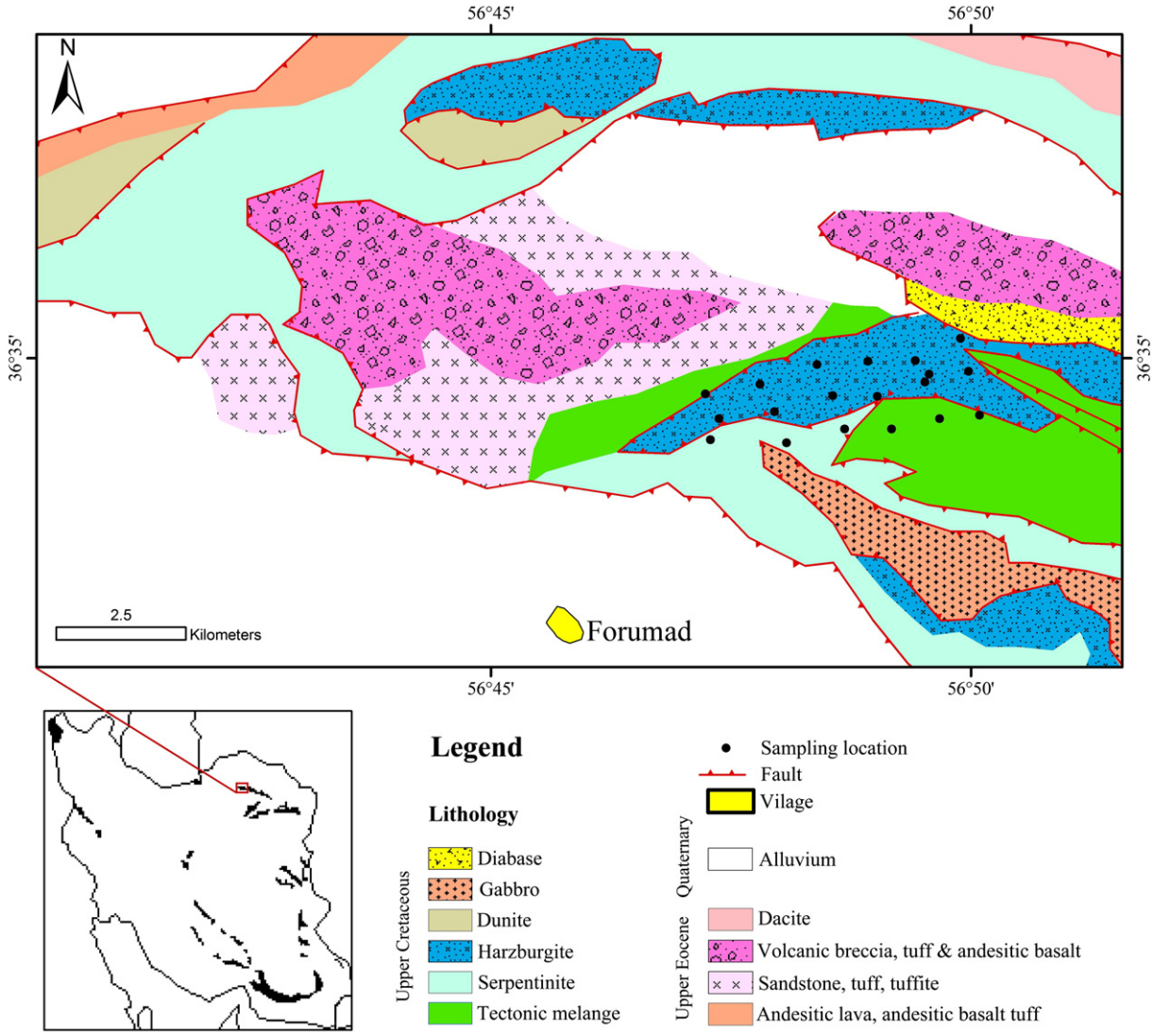

Fig. 1. Geological map of Sabzevar ophiolite in Forumad area (modified after 1/100000 map of Forumad, Geological Survey of Iran).

exploited in many areas, there is little information on the flora and biogeochemistry of them.

Sabzevar ophiolite massif in northeastern Iran at Forumad area is regarded as one of the important mining areas for chromite ore deposits. In this ophiolite, the podiform chromite deposits intensely surrounded by serpentinized dunite envelopes, generally formed at the basal part of the ophiolite lithological column. As far as we know, despite high potential for mining activities in this area, no study has been conducted with a biogeochemical point of view. The main goal of the current research is to develop the application of biogeochemical methods in Sabzevar ophiolite belt at Forumad area for chromite prospecting. Due to the high resistance of chromite (major Cr-bearing mineral) against weathering and high concentrations of Ni in olivine structure (principal mineral of dunite which is the host rock of chromite) (Naldrett, 2004), in this study, soil and plant relationship was examined in order to present indicator plant species, accumulating Ni with the aim of their utility in biogeochemical exploration as additionally or integrated with other traditionally methods of the chromite ore deposits.

2. Field description

The Sabzevar ophiolite is part of the northern branch of Neo-Tethyan ophiolite belt in the Middle East that links the Mediterranean ophiolites (e.g. Turkish, Troodos and Greek) to more easterly Asian ophiolites (e.g. Tibetan). The age of ophiolite emplacement into continental margin is estimated to be Late Cretaceous and it may be related to the Lesser Caucasus development (Shojaat et al., 2003). The ophiolite belt in northeastern Iran appears in a region of 150 km long and 10–30 km wide, trending east–west and composed of harzburgite (main rock), dunite, serpentinite, gabbro and microgabbro, diabasic dikes, and pyroclastic rocks (Fig. 1). In some areas, the ophiolite is intensively tectonized, results in the formation of litho-structural unit called ophiolite mélange which includes mafic and ultramafic rocks, chert, limestone, and exotic rock blocks. In Forumad area, the harzburgites are divided into orthopyroxene-rich harzburgite and depleted harzburgite. The latter rock gradually converts to thick dunite bodies which may contain podiform chromites as tabular and lens shape deposits. The dispersed deposits are found in massive or nodular types (Shafaii Moghadam et al., 2009).

Forumad area is located in semi-arid to arid region with cold winters and hot summers. The average annual rainfall is 235 mm and hence physicochemical weathering progresses moderately. Topographically, higher parts of the area are constituted by mafic–ultramafic rocks in association with limestone, mostly found northward. Vast plains in south of the study area are covered by a very thick alluvium, reaching 100 m in thickness. Due to regional dry climate and nearly high relief, soils overlaying ultramafics of the Sabzevar ophiolite in Forumad are