



## Geology and formation of titaniferous placer deposits in Upper Jogaz Valley area, Fanuj, Sistan and Baluchestan province, Iran

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Submitted: Nov. 16, 2013

Accepted: Oct. 27, 2014

**Keywords:** *Titaniferous placer, ilmenite, Upper Jogaz Valley, Fanuj*

### Introduction

The Fanuj titaniferous placer deposits are located 35 km northwest of the Fanuj, Sistan and Baluchestan province (1). The studied area comprises a (2) small part of the late Cretaceous Fanuj-Maskutan (Rameshk) ophiolite complex (Arshadi and Mahdavi, 1987). Reconnaissance and comprehensive exploration programs in the Fanuj district (East of the 1:100000 Fanuj quadrangle map, Yazdi, 2010) revealed that the Upper Jogaz Valley area has the highest concentration of titaniferous placer deposits. In this study, geology and formation of the titaniferous placer deposits in Upper Jogaz Valley area are discussed.

### Materials and Methods

(3) Forty samples were collected from surface and drainage sediments to evaluate the potential for titaniferous placers. Mineralogical studies indicated the high Ti (ilmenite bearing) areas, which led to detailed exploration by 29 shallow drill holes and 9 trenches. A total of 61 sub-surface samples were collected for heavy mineral studies and ore grade determination.

The exploration studies suggest that the the Upper Jogaz Valley area in the Fanuj district has a high potential for titaniferous placer deposits. Extensive exposures of black sands in the streambeds of this area suggested detailed sampling, so that 12 holes were drilled (2-3 m depth) from which 26 samples were collected, and five trenches were excavated to 2-4 m depth (4). The distribution of drill holes and trenches were plotted with "Logplot" software for further interpretation. Twenty-two samples from these drill holes were analyzed for TiO<sub>2</sub>.

### Results

The reconnaissance and comprehensive exploration in Fanuj district shows that the Upper Jogaz Valley area has the highest concentration of titaniferous placer deposits. The general geology of the region and petrology and mineralogy of collected samples suggest that the source rock of the Upper Jogaz Valley titaniferous placers is the hornblende- and olivine-gabbro unit of the Fanuj-Ramesh ophiolites.

The Ti-rich sediment distribution in drill holes and trenches indicates that the titaniferous placers are distributed in an area of about 0.8 km<sup>2</sup> and follow the Upper Jogaz river system. The titaniferous placers are concentrated mainly in three beds with thicknesses of 30 to 100 cm. The study of heavy minerals shows that ilmenite is the main ore mineral and titanomagnetite, rutile and sphene are present as trace minerals. The ilmenite concentration varies in the Upper Jogaz Valley fluvial sediments, in which the concentration of ilmenite generally increases away from source rock to reach a maximum concentration downstream.

The geological evidence indicates that the titaniferous placers were deposited as a fluvial placer and originated from weathering and erosion of ilmenite-rich gabbros. The presence of low-grade deposits and sparse heavy minerals in the Upper Jogaz river coarse sediments is probably related to hydraulic equilibrium (Robb, 2005). Entrainment sorting created thin layers of heavy minerals (i.e., ilmenite) on the Upper Jogaz streambed. The occurrence of Ti-rich layers in fine sand and silt beds is probably due to shear sorting.

(5) The ophiolite sequence is well exposed in the study area. This sequence is composed of

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cumulative peridotites, layered and massive gabbros, diabasic sheeted dikes, basaltic pillow lavas and pelagic sediments. The layered gabbros were the main source of the ilmenite Ti mineralization. The highest concentration of Ti was observed in the eastern and northern parts of Upper Jogaz Valley area, which are mainly covered by olivine- and hornblende-gabbros (6). The western part of the area is covered by an unaltered diabase unit. The study of several polished sections from the Upper Jogaz Valley gabbros shows ilmenite as the main Ti-bearing mineral with anhedral to subhedral crystals 5 to 400 microns in size.

The drill hole and trench data suggest that the deposits follow the morphology of the present-day Upper Jogaz river. The Ti placer beds accumulated over an area of 0.8 km<sup>2</sup> with 2.3 % and 5.06% ilmenite in Upper Jogaz Valley upstream and downstream consequently.

The study of heavy minerals shows that ilmenite is the main heavy mineral in the Upper Jogaz Valley sediments with 120 $\mu$  to 3 mm, semi-angular to rounded grains with weak sorting. Titanomagnetite, rutile and sphene are present as accessory minerals. Pentlandite, magnetite, chalcopyrite and millerite are also observed as intergrowths or inclusions in ilmenite.

### Conclusions

The investigation of ilmenite concentration in fluvial sediments of the Upper Jogaz deposit represents a gradual increase of ilmenite concentration away from the source rock. Titanomagnetite, sphene and rutile have similar enrichment patterns to ilmenite. This suggests that

all Ti-bearing minerals had a similar behavior in the Upper Jogaz Valley fluvial system.

The geological and petrographic evidence suggests that the origin of the Upper Jogaz Valley placer is the weathering of the Ti-rich gabbros. The higher concentration of ilmenite in the lower part of the valley is probably caused by the lower water energy and flow downstream. The mechanisms of hydraulic sorting (Slingerland and Smith, 1986), such as free settling of grains, entrainment of grains from a granular bed load by flowing water and shear sorting of grains in a moving fluidized bed were important in the enrichment of titaniferous placers in the downstream sediments.

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