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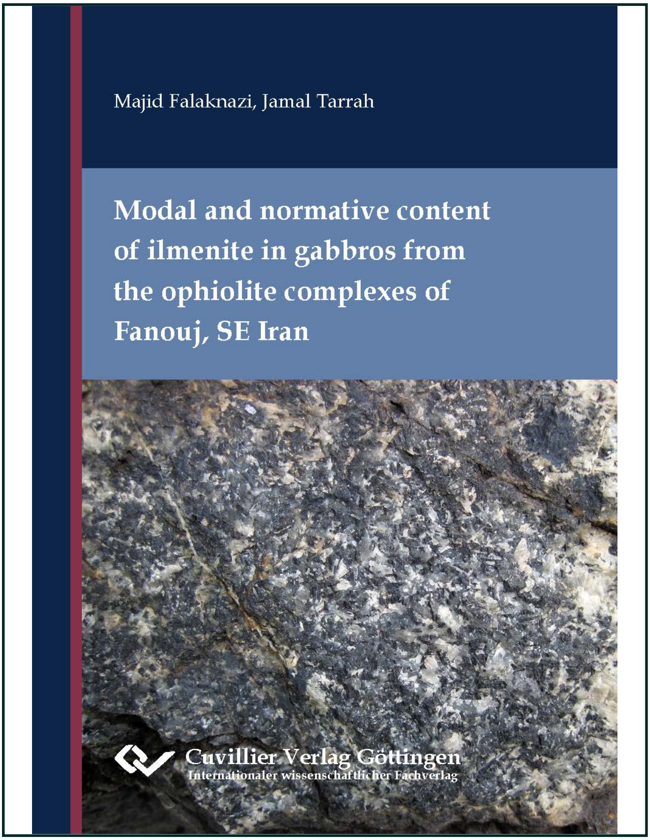
Modal and normative content of ilmenite in gabbros from the ophiolite complexes of Fanouj, SE Iran



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Modal and normative content of ilmenite in gabbros from the ophiolite complexes of Fanouj, SE Iran

Abstract

Ophiolites of west Fanouj (southeast Iran) are mainly composed of three mafic units including gabbros and diabasic rocks. The ophiolite complexes of this area lead, in addition to common rock-forming minerals, to titanium-containing mineral phases such as ilmenite. Seven titan-bearing gabbros from the west Fanouj ophiolite complex and a coarse-grained placer sample were analyzed by XRD and XRF on their mineralogical and chemical composition, respectively. The amount of ilmenite was calculated from the chemical analysis using TiO_2 content. The normatively determined values (n) were compared with the modal values (m) measured from the peak intensity ratios of the XRD patterns. The difference between the normative (n) mineral contents and the modal (m) data [(n-m) x m^{-1} x 100] is 13±27% (mean value ± standard deviation) and are within the range of the error of mineralogical methods such as optical and X-ray techniques. Since Fe was not included in the normative method, a test was performed by comparing the content of Fe measured by XRF with the amount of Fe, which result from the modal determination of all iron-bearing minerals present in the samples. This approach confirmed data deriving from the normative approach on ilmenite quantification.

Key words: Fanouj, mineralogical composition, ilmenite, normative method, modal

1. Introduction

Titanium plays a major role in industrialized countries. This metal is very important due to the various and strategic applications in many branches of industry, such as, to mention only a few applications here, as static metal in the engine and in the interior construction of aircraft, in the chemical and alloy industry (Banerjee & Williams 2013; Falaknazi & Karimi 2019). Titanium is the ninth most common element in the Earth's crust, averaging 0.9% Ti (Turekian 1977). The mineral ilmenite is the most common phase containing titanium. Other occurrences such as in zircon and in micas are from minor importance. Mostly the mafic anorthosite is the main rock containing ilmenite.

Studies on parts of the ophiolites in southern (Rajabzadeh et al. 2011) and southeastern Iran indicate that rocks occurring there are rich in titanium. With the difference that ilmenite is observed in Iranian ophiolites in gabbros and not on anothosite. Mafic and ultramafic rocks could be important in terms of Fe and Ti mineralization (Mücke 2003; Morisset et al. 2013; Devaraju et al. 2014). The largest Iranian ilmenite reserve has been observed in the ophiolites of western Fanouj, Sistan and Baluchestan province (Falaknazi and Karimi 2014). In all microscopic studies performed it was observed that ilmenite is located next in direct vicinity to magnetite, which indicates that the titanium reserve in the west of Fanouj is from orthomagmatic origin. The west part of Fanouj gabbros in terms of breadth and depth are much richer in ilmenite than other ilmenite-containing gabbros in Iran. It has a lithological unit in terms of diabasic and three gabbro units that have previously been studied mineralogically and geochemically (Falaknazi and Karimi 2016).

In this paper, one of the Gabbro units (gb1) which is superior to other gabbros in terms of mineralization of ilmenite, is investigated. The most important gabbros in the Fanouj region are large relatively coarse-grained gabbros. These coarse grained gabbro in the western area of the Fanouj ophiolite complex are defined as the origin of alluvial placers (Falaknazi and Karimi 2016). Placers are important sources of jewelry, precious metals, minerals containing rare elements, zircon and titanium minerals (Harben and Kuzvart 1997; Rattigan and Stitt 1990; Williams1990; MacDonald 1983; Morley 1982). As result of erosion combined with decomposition of high density minerals, such placer deposits formed contain a concentrate of ilmenite and magnetite (Robb 2005). For comparison of the mineralogical composition, one of these placer samples occurring in Fanouj regions was considered in the analyses too.

The mineralogical composition of igneous rocks can be examined either directly or modally (using mineralogical methods such XRD) or through the normative calculation based on the chemical analysis results of the bulk rock. The use of mineralogical methods has a wide range of limitations (Dultz and Graf von Reichenbach 1995a; Dultz 1997; Fichter et al. 1998; Tarrah et al. 2000). If direct mineralogical methods are not available for quantitative analysis, use of the normative method can be an option (Tarrah 2016). However, this assumes that the occurring minerals and their specific chemical composition are known. The purpose of this study was to analyze the mineral content of ilmenite by XRD in seven gabbros together with one placer sample and to compare the results with the normative ilmenite content using TiO_2 content from chemical analysis. For verification results from normative calculation of ilmenite, modal data deriving from XRD and in addition the sum of ∑Fe in the different mineral phases occurring, which is not included in the normative calculation based on TiO_2 content, is used.

2. Material and methods

2.1. Gabbros of Fanouj and previous analyses

The studied mafic masses in the west of Fanouj have an area of 60 km^2 and are located 200 km in the south west of Iranshahr (Province Sistan-Baluchistan). In terms of geological position the mafic masses are almost situated in the ophiolite complex at the top of Makran Zone in the South subduction of Jazmurian. Mafic masses in the west part of Fanouj are located above the coastal Makran fault and below Fanouj Fault. The ophoilite masses in the west of Fanouj consist of gabbro massif, diabasic dikes and less amount of micro durite. These massifs are surrounded by alluvial deposits of the Quaternary period which in some low areas covers the gabbro (Fig. 1). Gabbro units of ophiolite of the west of Fanouj are divided into three parts: lower, middle and upper. Upper gabbro (gb) form the north central part of the area. The gabbro is of a low height and is partly covered with alluvial deposits. Middle gabbro (gb2) covers different outcrops of the eastern part and the lower gabbro (gb1) is located in the western part almost as a highlands. In this article sampling and analyses were conducted on gabbro unit gb1.

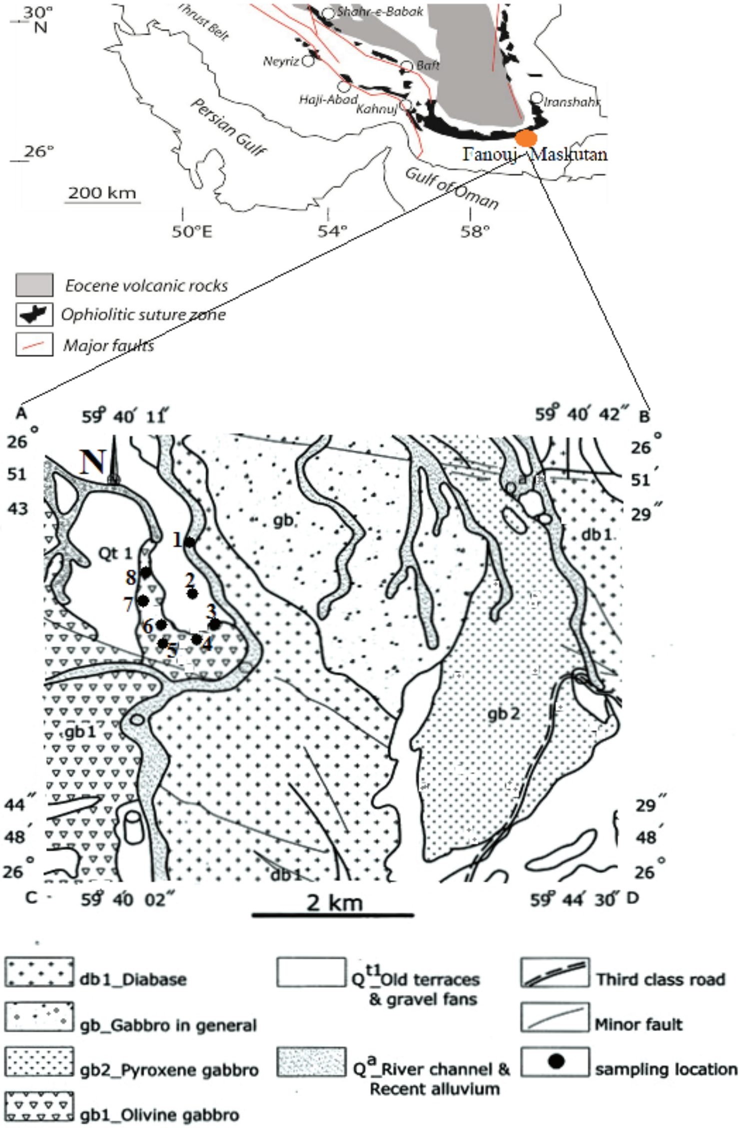

Fig. 1. Geological map of west Fanouj ophiolite complex (adapted from Arshadi and Mahdavi, 1987

It seems that the lower gabbro has reached to the highest point due to tectonic processes or greater thickness compared to other gabbro and has formed the highest gabbro massif. In contrast, middle and upper gabbro massif have been buried so that a large part of this gabbro is placed under alluvial deposits or are visible on the surface as outcrop (Fig. 2).

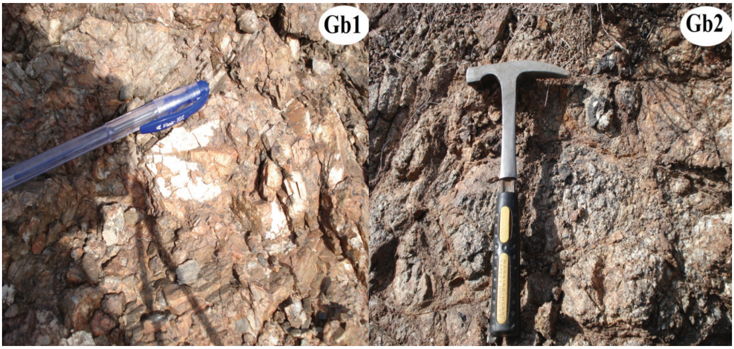

Fig. 2. Observation of Gabbro outcrops containing ilmenite (appearing black) in a matrix of large anorthite feldspars (reddish-grey) in the study area of the west Fanouj ophiolite complex(Gb1: Lower Gabbros, Gb2: Middle Gabbros).

The normative calculation of ilmenite content using TiO_2 and its modal determination from XRD data was applied to relatively coarse grained high grade gabbros from the west of the studied area from Fanouj ophiolite complex for the samples Fn2, Fn7, Fn8, Fn11, Fn14, Fn15, Fn16 and Fn 17 (Fig. 1). Fn14 is considered as a placer sample. These samples were analyzed chemically and mineralogically by Falaknazi & Karimi 2014 and Falaknazi & Karimi 2016. For the present study selected chemical (Fe (tot) / TiO_2) and mineralogical data were taken from the previous studies mentioned above. Total content of Fe (tot) and TiO_2 was determined using X-ray fluorescence analysis using the LiBO technique. Minerals were identified by X-ray diffractometry with unoriented (texture free) preparations of milled samples on glass slides.