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GEOLOGY AND GEOCHEMISTRY OF THE TERTIARY VOLCANIC ROCKS AND THEIR ALLIED INTRUSION AT NW AD DHALA PROVINCE, REPUBLIC OF YEMEN

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DEDICATION

To My

PARENTS

To my Daughter

Rhagad

To my Son

Ahmad

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Abstract

The study area is located in the NW Ad Dhala province to the north of Aden, Republic of Yemen. It straddles the northwestern part of the Gulf of Aden margin. It also occupies the south-easternmost outcrops of the Yemen Trap Series (YTS) (late Oligocene- early Miocene). The Yemen Trap Series (YTS) and the Yemen Volcanic Series (YVS) (late Miocene-recent) form the Yemen Volcanic Group (YVG). The Latter comprises all Cenozoic volcanic rocks of Yemen, in which it represents part of the youngest known continental flood volcanism province that is associated with the emplacement of Afar plume, continental break up, rifting and formation of the Red Sea and the Gulf of Aden.

The rock units exposed in the study area are classified into two folders: (1) the Tertiary volcanic rocks and (2) their allied Tertiary intrusion.

The Tertiary volcanic rocks are divided into two main groups; (1) the older main volcanic pile; and (2) younger dykes, sills, plugs and flows. The main volcanic pile covers the entire of the study area and consists of mafic flows (flood basalts), intermediate flows (of very limited area extent) and inclusions, felsic flows and the pyroclastic rocks (ignimbrite and tuff). The younger dykes, sills, plugs and flows include the youngest rock units in the study area and comprise mafic, intermediate and felsic rocks.

Tertiary intrusion invaded successfully the rocks of the main volcanic pile and comprises gabbroic, syenitic and monzonitic rocks. It has a semicircular shape and located at the center of the study area and divided into two parts by NW-SE trending fault running parallel to Wadi Ad Dhumar. Syenite composes > 85% of the total volume of this intrusion, gabbro constitutes about 10% whereas monzonite forms the rest of per cent (app. 5%).

This study gives detail description and explanation of all rock units that exposed in the study area including field observations, petrography, opaque mineralogy and geochemistry as well as the hydrothermal alteration that affected this volcanic district.

Field study embraces the distribution, description, field relations of the different rock units cropping out in the study area whereas petrography gives detail description of the mineral constituents, textures and alteration of these rocks. Opaque mineralogy studies the distribution and the description of opaque minerals of these rocks and highlights on their intergrowths and their applications in the petrogenesis of these rocks.

Geochemical study indicates that the volcanic rocks display a good bimodal geochemical distribution represented by mafic (basalt) - felsic (trachyte-rhyolite) suite and all rocks have

within plate tectonic setting and alkaline affinity, except the felsic rocks which straddle between alkaline and sub-alkaline suites.

The basaltic rocks were derived from spinel-garnet lherzolite mantle source through the partial melting (8-25%) at intermediate depth (75-90 km) and intermediate pressure (3 GPa) with no or very small crustal contributions. Thus, the compositional range of basaltic rocks can be interpreted as the result of variable degrees of partial melting of mantle source and fractional crystallization. The mantle-derived magma implies mixing between large fraction of lithospheric mantle melt and small plume melt where the contribution of Afar plume into the genesis of these rocks increases with time from older flood basalts to younger dykes and sills.

The felsic volcanic rocks were derived from A-type magmas and two mechanisms can be considered for their petrogenesis; (1) differentiation products from enriched mantle-derived magma through the extensive fractional crystallization after the formation of basaltic and intermediate rocks in this area; (2) the AFC process through the interactions between the mantle-derived magmas and continental crust (extensive fractional crystallization and slight assimilation).

The intermediate rocks were derived from enriched mantle-derived basaltic magma through fractional crystallization process and represent an intermediate stage between mafic (basaltic) and felsic rocks. The scarcity of these rocks can be ascribed to the scarcity of intermediate melts generated during fractional crystallization and zoned magma chambers.

Pyroclastic rocks (ignimbrites and tuffs) show wide range of chemical composition extending from mafic through intermediate to felsic rocks.

All plutonic rocks of the Tertiary intrusion and hypabyssal syenitic dykes have alkaline affinity and within plate tectonic setting. The systematic changes in chemical and mineralogical composition from gabbro through monzonite to syenite indicate that the Tertiary intrusion was formed from the same enriched mantle-derived basaltic magma and its evolution from gabbro to monzonite and syenite is controlled by the fractional crystallization process without any significant crustal contributions.

Gabbroic rocks were derived from enriched mantled-derived basaltic magma subjected to localized chemical effects which produce modal metasomatism in the mineralogy of these rocks. Then, syenitic rocks were crystallized from A-type magma (A_1 group) through the extensive fractional crystallization without significant contribution of the AFC process. However, monzonitic rocks represent an intermediate stage between syenitic and gabbroic rocks and their small size can be ascribed to the small portion of intermediate melt generated during the magma differentiation and to the zoned structure of magma chamber.

The study area was subjected to the same tectono-magmatic history and structural patterns that affected of the Gulf of Aden and the Red Sea margins. The faults are normal and have NW-SE and NNE-SSW directions similar to that found in the western Yemen and Ethiopia. The dykes have NW-SE (dominate), N-S and NE-SW directions similar to the dyke swarms that found in the adjacent areas (Radfan, Al' Anad and Al Musaymir), western Yemen and southern Saudi Arabia. The NW-SE and N-S trending faults and dykes are approximately parallel to the main Red Sea trend and reflect NE extensional regime caused by the movement of the Arabian plate away from Africa. However, NE-SW trending dykes are related to the Gulf of Aden and can be compared with counterpart dykes from Radfan and Al Musaymir areas.

Petrography, opaque mineralogy and geochemical data testify that the studied rocks were subjected to various degrees of hydrothermal alteration represented by the replacement of the primary minerals or the precipitation of secondary minerals in the vesicles, fractures and veinlets.

Six mineralogical alteration types (facies) have been identified in the study area include argillic, advanced argillic, phyllic, phyllic-propylitic, propylitic, and potassic.

All rocks were affected by hydrothermal alteration to various degrees where the basaltic rocks display more pronounced effects. All analyzed samples used for geochemical study don't show large-scale chemical changes during the hydrothermal alteration where the HFSEs and REE are not significantly affected, however LILEs show variable degrees of mobility. Hence, the variations of HFSE and REE of the analyzed samples ascribed to magmatic processes and are utilized for identifying the geochemical features and petrogenesis of the studied rocks.

Field investigations, petrographic study and geochemical data give indications on the presence of both magmatic and hydrothermal mineralizations through the presence of anomalous values for Cr and Ni and the presence of optimized conditions for the formation of epithermal gold and other precious metals and further detailed works regarding the mineralizations in the study area are strongly recommend.

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