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Geological and Tectonic Setting of Andesitic Rock in Central Eastern Desert, Egypt

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Abstract

Objective. The current study aims to detect the geologic features, geochemical characteristics and tectonic setting of the investigated rock using field observations and geochemical analyses.

Research methods. This work contains both field work (Collection samples and drawing of a new geological map) and laboratory work (preparation of thin sections for petrographic studies by polarizing microscope), X-ray Fluorescence analysis (XRF) in Institute of Biology, Southern Federal University and Mass-Spectrometer with Inductively Coupled Plasma (ICPMS) at the central Laboratory of Russian Geological Institute.

Result. Investigated andesitic rock belongs to Dokhan volcanic that located in the Central Eastern Desert of Egypt a long Qena-Safaga Road. It is considered as one of the most important shear zones in Eastern Desert that includes distinctive rocks and economic mineral deposits. The investigated rock belongs to late to post tectonic magmatism of the East African Orogeny (EAO). Petrographically: Dokhan volcanic is represented by andesite according to petrographical studies. It consists of plagioclase, quartz, in addition to mafic minerals. Geochemically, the investigated andesite samples plotted in calc-alkaline nature.

Conclusion. Tectonically, andesite samples fall in arc lava and continental fields. They are enriched in Ba, Sr, Rb, K, Nb and Ce with marked depletion in the most HFSEs like those of island arc calc-alkaline series.

Keywords: Tectonic setting, Andesite, Eastern Desert, Egypt.

Introduction

The investigated rock is restricted in Qena-Safaga road in the Central Eastern Desert (CED) of Egypt as shown in (fig. 1). It occurs in the Arabian Nubian Shield (ANS) and is made up of arc-inter-arc rock associations, which are represented by dismembered ophiolitic slabs thrust over the deformed arc terrane. Generally, volcanic rocks belong to the (EAO) of Neoproterozoic rocks that related to the (ANS), are divided into three groups. First and second groups are considered as the oldest rocks that are classified into metavolcanics and younger metavolcanics, occasionally they represent in the central and southern Eastern Desert. They are characterized by mafic to intermediate with subordinate felsic rocks. Older metavolcanic rocks have low-K tholeiitic, while younger metavolcanics rocks contain low- to medium-K calc-alkaline accompanied with subduction-related processes (back-arc basins and island arcs) [1]. Otherwise, the third type includes

Dokhan volcanics and occur mainly in the northeastern desert and southern Sinai [2, 3] stated that the Hammamate sediments are younger than Dokhan volcanic, while other authors mentioned that the Hammamate sediments were associated with eruption of the Dokhan volcanic as reported by [4]. According to Rb-Sr ages; Dokhan volcanics have 610–560 Ma, 600–585 Ma for the Hammamate sediments, and younger granites have 610–550 Ma [5]. Dokhan volcanics recognize varicolored and thick sequence of lava flows with their pyroclastics and represented by basalt, basaltic andesite, andesite, rhyolite, rhyodacite and dacite related to their mineral composition (Basta et al., 1980; Stern, Gottfried 1986). Numerous workers have been studied area along Qena-Safaga road [6–12]. The examined rock units are represented by Island Arc/back-arc assemblage (Oceanic crust terrain), late to post orogenic (Continental crust terrain) [13].

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Figure 1. Image shows the location map of the study area
Рисунок 1. На рисунке показано местоположение изучаемой области

Materials and methods

Elements were determined using ICP-MS technique, after digestion of the fused beads with HF + HNO₃. Pure solution external standers were used for calibration. Elements were determined by ELAN-DRC-6100 ICP-MS at the central Laboratory of Russian Geological Institute. Also, the major oxides and some trace elements were measured by X-ray Fluorescence analysis (XRF) in (Institute of Biology, Southern Federal University). Thin sections were investigated under microscope and the modal analyses have been calculated at Faculty of Sciences, Al-Azhar University.

Geological setting

It represents about 6% of exposed rock units and restricted in the southeastern part of the mapped area (fig. 2), it is located along the asphaltic road of Qena-Safaga near of Safaga city. Andesite is recognized by imperial porphyry (fig. 3, a), medium to coarse-grained massive rock, reddish in color and highly jointed in NNE-SSW directions. It has high peaks, jointed with predominant trending NNE-SSW, casing the columnar like huge plugs. It is intruded directly by granitic porphyry at the asphaltic road found in (fig. 3, b).

Petrographical studies

According to QAP classification diagram of volcanic rocks of [14], it has been andesite in composition (fig. 4, a). It occurs as fine to medium grained rocks of gray to black color. Andesite is composed essentially of plagioclase, hornblende and biotite, with few amounts of quartz and alkali feldspar. Iron oxides are the accessory

minerals. Sometimes it is characterized by porphyritic texture (fig. 4, b). Plagioclase: It occurs as andesine composition (An₃₀–A₄₀), covering an area up to 59% of main rock constituents. It is represented by euhedral to subhedral crystals, up to 1.6 mm in length and 0.8 mm in width, often showing albite-Carlsbad twins (figs. 4, b, c) and zonation. Sometimes, it is partly altered to sericite. Quartz: It covers an area up to 11% of rock constituents, occurs as fine-grained anhedral subordinate crystals and distributed among other mineral constituents. Hornblende: It is represented by subhedral to anhedral crystals, covers an area ranging from 11% to 16% of mineral compositions of rock. It is green in color pleochroic from green (=X) to pale brown (=Y) and brown (=Z) (fig. 4, c), it is partly or completely altered to chlorite. Biotite: It occurs as flaky crystals, up to 0.4 mm in length and 0.2 mm in width. Biotite covers an area ranging from 10% to 14% of rock compositions (fig. 4, b), sometimes, it is altered to chlorite. Alkali feldspar: It occurs as fine to medium grained, up to 0.04 mm in length and 0.02 mm in width. It covers an area up to 3% of rock compositions (fig. 4, b), sometimes; it is represented by microcline and orthoclase crystals associated with other minerals of rock. Iron oxides: They are represented by deep black grains scattering over the rock mineral constituents and disseminated within the different minerals (fig. 4, b). They cover an area up to 3.6 % of the rock composition.

Geochemistry of the investigated andesitic rock

The results of the complete analyses of the major oxides, trace and rare earth elements of andesite samples are given in (table. 1).

Figure 2. Geological map of Um Taghir area formed from integrated remotely sensed data processing and field observation

Рисунок 2. Геологическая карта района Ум Тагир, сформирована на основе интегрированной обработки данных дистанционного зондирования и полевых наблюдений

Figure 3. Field photographs: a – showing andesite rock (D. V) directly is intruded by granitic porphyry (Gr. d) at asphaltic road; b – imperial porphyry of Andesite

Рисунок 3. Полевые фотографии: а — андезитовая порода (D. V), непосредственно прорванная гранитным порфиром (гр. d) у асфальтированной дороги; б — "императорский порфир" андезит

Figure 4. Photomicrographs showing: a – modal composition of the investigated andesitic rocks on QAP diagram of Streckeisen classification (1976); b – euhedral phenocryst of plagioclase surrounded by fine grains of alkali feldspar (Ak), quartz (Qz) and iron oxide (In) showing porphyritic texture; c – Plagioclase phenocryst (P) associated with hornblende (Hb)

Рисунок 4. Микрофотографии, показывающие: а – модальный состав исследованных андезитовых пород на диаграмме QAP по классификации Штрекейзен (1976); б – идиоморфный вкрапленник плагиоклаза, окруженный мелкими зернами щелочного полевого шпата (Ak), кварца (Qz) и оксида железа (In), показывающий порфировую структуру; в – вкрапленник плагиоклаза (P), в ассоциации с роговой обманкой (Hb)

Geochemical classification of the investigated andesitic rock

A lot of parameters are used here to classify and follow up the chemical affinity of the investigated rocks. According to the classification of $\text{Na}_2\text{O} + \text{K}_2\text{O}$ versus SiO_2 binary diagram of [15], the plots of analyzed andesite samples fall in andesite field (fig. 5, a). Therefore, to verify this classification binary plot of [16] using a portion of immobile elements SiO_2 versus Zr/TiO_2 have been used, all samples plotted in the field of andesite (fig. 5, b), as well as geochemical classification of andesitic rock is coinciding with petrographic classifications as shown in (fig. 4, a).

Magma type of the investigated rock unit

The magma type of the studied rock unit is discussed on the base of the following proposed diagrams. The discrimination binary diagrams of $\text{K}_2\text{O}-\text{SiO}_2$ according to [17, 18] (fig. 5, c) shows the investigated andesite samples plotted in calc-alkaline nature. The calc-alkaline nature has been confirmed by Zr versus Y binary diagram (fig. 5, d) proposed by [19].

Tectonic setting of the investigated rock unit

Immobile incompatible elements were plotting in tectonic discrimination diagrams to determine the tectonic setting of andesitic lava. According to Ti versus Zr binary diagram of [20], the studied andesite has been plotted in volcanic arc setting (fig. 5, e). On the $\text{TiO}_2-\text{K}_2\text{O}-\text{P}_2\text{O}_5$ ternary diagram (after [21] which can be used to distinguish between oceanic and continental basalts. All the analyzed andesite samples plot in continental field (fig. 5, f).

Trace and Rare earth elements of the studied rock

Andesite samples on the N-MORB normalized spider diagram [22] (fig. 5, g) show enrichment in Ba, Sr, Rb, K_2O and Zr in addition to depletion in the most HFSEs similar to the island arc calc-alkaline affinity. The distribution of the rare earth elements in andesite show slightly depletion of REE pattern (La to Lu), and significant little or no sign of Eu-anomaly as shown in chondrite-normalized REE diagrams of [23] (fig. 5, h).

Table 1. Major oxides, Trace and Rare Earth Elements (REE) of andesitic rock**Таблица 1. Основные оксиды, редкие и редкоземельные элементы (РЗЭ) андезитовой породы**

Major oxides	Andesite					
	Sample number					
	57a	61a	63a	57b	63b	63c
SiO ₂	62	61.6	61.4	61	61.2	63
Al ₂ O ₃	15.2	14.7	14.78	16.1	16.0	15.5
Fe ₂ O ₃	8.5	6.03	7.59	9.0	8.0	7.7
FeO	1.2	1.6	1.4	1.0	1.3	1.6
CaO	3.26	4.97	4.51	3.4	3.6	2.9
MgO	2.57	2.77	2.43	2.6	2.4	2.3
P ₂ O ₅	0.23	0.33	0.35	0.2	0.3	0.4
TiO ₂	1.06	0.93	1.3	1.0	1.1	1.2
Na ₂ O	3.4	3.6	3.1	3.5	3.4	3.7
K ₂ O	1.88	1.54	1.41	1.7	1.8	1.4
L.O.I.	0.4	1.22	1.09	0.5	0.9	0.16
Av	99.7					
Trace Elements						
Cr	34	42	61	51	46	47
Ni	96.4	107	55.8	96.0	56	54
Cu	87	90.3	44	85	87	91
Zn	92	88.3	122.2	95	121	118
Zr	145	154	132	142	137	141
Rb	19.2	18	18.45	20	19	18.4
Y	14.5	13.6	13.8	15	14	15.6
Ba	285	278	281	291	286	287
Pb	28.7	28.3	36.8	29	38	39
Sr	753	921.8	601.7	762	612	618
Ga	14	15	10	13	12	11
V	109.8	105	138.4	110	128	132
Nb	16	22	17	15	16	18
Co	45.8	54.7	69.3	47	64	61
U	0.77	0.55	0.63	0.8	0.7	0.6
Th	2.75	2.33	1.86	2.6	2.0	2.1
Rare Earth Elements (REE)						
La	16.2	18	17.7	17	18	16
Ce	40	38.4	39.2	42	41	43
Pr	5	6	5.2	7	6	5
Nd	23	24.5	22.6	25	23	22
Sm	4.5	5	4.6	4.4	5.0	4.9
Eu	1.5	1.3	1.4	1.4	1.6	1.7
Gd	4.6	4.8	4.2	5.0	4.9	5.2
Tb	0.4	0.7	0.5	0.5	0.8	0.9
Dy	3	3.2	2.9	2.5	3.1	3.2
Ho	0.8	0.4	0.6	0.7	0.5	0.65
Er	1.5	1.7	1.4	1.5	1.6	1.8
Tm	0.3	0.4	0.2	0.3	0.4	0.35
Yb	1.6	1.8	1.4	1.5	1.7	1.54
Lu	0.1	0.4	0.2	0.3	0.2	0.18
ΣREE	102.5	106.6	101	109.1	108	106.4
Eu/Sm	0.33	0.26	0.3	0.31	0.32	0.34
Av(Eu/Sm)	0.31

Figure 5. Binary diagrams showing: *a* – Classification of the studied andesite using total alkalis vs silica (TAS) diagram [15]; *b* – Chemical classification of the andesitic rock of the study area based on SiO_2 – Zr/TiO_2 [16]; *c* – SiO_2 – K_2O diagram with fields after [17, 18] distinguishing the different melt series for andesite; *d* – Zr vs Y diagram proposed for the studied andesite after [19]; *e* – Plots the investigated andesite on Ti–Zr diagram of [20]; *f* – TiO_2 – K_2O – P_2O_5 ternary diagram for andesitic rock after [21]; *g* – MORB-normalizing diagram of investigated andesitic rock [22]; *h* – Chondrite-normalized REE diagram [23] of investigated andesitic rock

Рисунок 5. Бинарные диаграммы: *a* – классификация изученного андезита по диаграмме общего содержания щелочей и кремнезема (TAS) [15]; *b* – химическая классификация андезитовых пород района исследований на основе SiO_2 – Zr/TiO_2 [16]; *c* – SiO_2 – K_2O диаграмма с полями по [17, 18], выделяющими разные серии расплавов для андезита; *d* – Zr vs Y – диаграмма, предложенная для исследуемого андезита по [19]; *e* – положение исследуемого андезита на диаграмме Ti–Zr [20]; *f* – TiO_2 – K_2O – P_2O_5 тройная диаграмма для андезитовой породы по [21]; *g* – диаграмма MORB-нормализации исследуемой андезитовой породы [22]; *h* – хондрит-нормированная диаграмма REE [23] исследуемой андезитовой породы

Conclusion

Dokhan volcanics are restricted in the Central Eastern Desert of Egypt on the Qena-Safaga road. The Qena-Safaga shear zone one of the most important structural occurrences in Central Eastern Desert of Egypt. Andesitic rock belongs to Neoproterozoic rocks that related to the Arabian Nubian Shield (ANS). According to petrographical studies Dokhan volcanics are represented by andesite, it consists of plagioclase, quartz, alkali feldspar and hornblende in addition to iron oxides.

Geochemically, the investigated andesitic rock has calc-alkaline affinity, as well as andesite has been erupted in volcanic arc setting. On the N-MORB normalized spider diagram, they show enrichment in Ba, Sr, Rb, K, Nb and Ce in addition to depletion in most HFSEs similar to the island arc calc-alkaline series. The distribution of the rare earth elements in andesite show slightly depletion of REE pattern (La to Lu), and significant little or no sign of Eu-anomaly.

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Геологическое и тектоническое положение андезитов в Центрально-Восточной пустыне, Египет

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Аннотация

Цель. Настоящее исследование направлено на выявление геологических особенностей, геохимических характеристик и тектонических условий исследуемой породы с помощью полевых наблюдений и геохимического анализа.

Методы исследования включают в себя как полевые (сбор образцов и составление новой геологической карты), так и лабораторные работы (подготовка тонких разрезов для петрографических исследований с помощью поляризационного микроскопа), атомную абсорбцию, рентгеновский флуоресцентный анализ (XRF) Геологическое и тектоническое положение андезитов и масс-спектрометрия с индуктивно связанной плазмой (ICP-MS) в лаборатории Геологического института РАН.

Результат. Исследуемая андезитовая порода относится к вулкану Дохан, который расположен в Центрально-Восточной пустыне Египта, по дороге Кения–Сафага. Он считается одной из важнейших зон сдвига в Восточной пустыне, которая включает в себя отличительные породы и экономические месторождения полезных ископаемых. Исследуемая порода относится к позднему посттектоническому магматизму восточноафриканской орогении (ЕАО). Вулкан Дохан сложен андезитом по петрографическим исследованиям. Он состоит из плагиоклаза, кварца в дополнение к мафическим минералам. Геохимически исследованные образцы андезита имеют известково-щелочную природу.

Заклучение. Тектонически, андезит попадает в поля островодужных и континентальных базальтов. Они обогащены Ba, Sr, Rb, K₂O и Zr с заметным обеднением большинства HFSE, таких как известково-щелочные островодужные серии.

Ключевые слова: тектоническая обстановка, андезит, Восточная пустыня, Египет.

ЛИТЕРАТУРА

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