IJASRM

International Journal of Advanced Scientific Research and Management, Vol. 2 Issue 7, July 2017.

www.ijasrm.com

ISSN 2455-6378

Source Rock of the Volcanic Fragments in Wadi Al-batin, Iraq: Geomorphological, Petrographical and Geochemical Evidences

Ahmad Y. Al-Gurairy[1,3]*, Abdelhalim S. Mahmoud[1,2] and Hussein Athab Aljibory[3]

[1] Department of General Geology and Geological Mapping, Russian state geological prospecting University, 117485, St. Miklokha-Maklaia, Building No.23, Moscow, Russia.

[2] Department of Geology, Faculty of Sciences, Fayoum University, Fayoum, Egypt.

[3] Department of Geography, Al-Qadisiyah University, Iraq.

Abstract

Geomorphologically, Wadi Al-Batin is a natural extension of Wadi Al-Rummah, which begins at the west and north-west highlands of Saudi Arabia. At the end of Wadi Al-Batin, a massive sedimentary delta "Alluvial Fan" covers large parts of Kuwait and south eastern Iraq. Wadi Al-Batin is the main responsible for the transfer of many types of igneous rock fragments and sediments to Iraq and Kuwait. The rock fragments dispersed in Wadi Al-Batin and its fan, SE Iraq include two volcanic rock verities associated with clastic sediments and nodular chert: (1) red colored fragments are mainly rhyolite and dacite of calc-alkaline peraluminous nature and display geochemical characteristics of anorogenic within-plate environments, and (2) dark colored fragments are basalt and banded rhyolite. Basalt suffered from notable geochemical and mineralogical effects of alteration leading to misleading classifications although; it is tholeiitic peraluminous and reflects the geochemical characteristics of orogenic arc-type. Petrographic and geochemical evidences indicate that the black dacite and trachyte rocks are actually basalt or andesite. Previous geomorphological, hydrogeological and environmental studies indicate that, the annual flood flows through the tributaries of the Al-Rummah Basin then connect to Wadi Al-Batin since Pleistocene till now carrying a heavy load of rock fragments and sediments from the high lands of W and NW Saudi Arabia; specifically from Ha'il and Al-Qassim then deposit them in areas of low altitude in Iraq and Kuwait in Wadi Al-Batin and his alluvial fan. There are several petrographic and geochemical similarities between Wadi Al-Batin rhyolites and some rhyolites in NW Saudi Arabia, especially from the areas around Ha'il, (namely Hadn formation type locality, Jabal Aja and Sarrah alkali rhyolite) and Al-Qassim, (namely Jabal Aban al Asmar “Samra rhyolite”). These results suggest that the volcanic rock fragments at Wadi Al-Batin derived from spatially two different suites of W and NW Saudi Arabia, especially from these areas in Ha'il and Al-Qassim which represent the upstream of Wadi Al-Batin watershed.

Keywords: Wadi Al-Batin, Al-Rummah Basin, alluvial fans, rhyolite, volcanic fragments.

1. Introduction

Wadi Al-Batin "Al-Batin Valley" starts at the north-eastern part of the Kingdom of Saudi Arabia, particularly at Al-Thamami area, where the village of Umm Oshair. It consists in its beginning of several stream valleys of seasonal runoff along the administrative boundaries between "Al-Sharqia" and Al-Riyadh in eastern Saudi Arabia that ranges in elevation from 500 to 650 m above sea level **(Fig.1)**. Then, Wadi Al-Batin continues along the administrative boundaries between Kuwait and Iraq to its end in the marshes of Al-Zubair in Iraq, which currently known as Al-Hammar Marshes **(Fig.2a)**. Ha'il and Al-Qassim regions represent the upstream and main source of Wadi Al-Batin sediments, where many valleys extending “SW-NE” descend from high altitude areas lied up about 1500 m above sea level, provide water supply for the main stream of Wadi Al-Rummah.

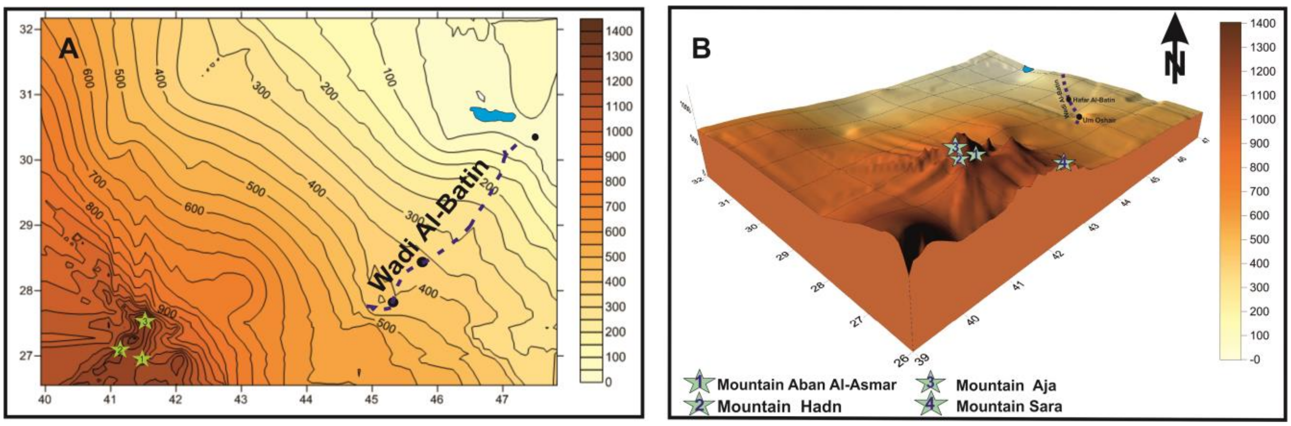

Figure 1. Simplified contour map (A) and 3D model (B) for parts from Saudi Arabia, Iraq and Kuwait, drawn with the program **Surfer 10,** with using coordinates from the website of U.S. Geological Survey. Stars illustrate the source areas for Wadi Al-Batin rhyolitic fragments.

It is worth to mention that, during Pleistocene the stream of Wadi Al-Batin was a natural extension from Wadi Al-Rummah, which was flowing from the east of the city “Al-Madina” in Saudi Arabia to the river of “Shatt Al-Arab” in Iraq **Al-Misnid (2008)**. The length of this river "Al-Rummah" was about 1200 km, but the global climate changes from the glacial period to the warm period at the end of the Pleistocene and early Holocene, have led to the drying up of this great river and the creeping sand dunes cut its stream into three parts (Wadi Al-Rummah with a length of about 600 Km, Wadi Al-Ajrady about 75 Km and Wadi Al-Batin about 450 Km). Before the sand dunes close the stream of Wadi Al-Rummah in many places, it had built a flood plain in Al-Dibdibah region northeast Saudi Arabia **Al-Misnid (2008)**. Geomorphologically, it is also responsible for the formation of the alluvial fan of Wadi Al-Batin in Iraq and Kuwait, and has a major role in the transfer clastics of different sizes and

ISSN 2455-6378

types from high regions of Ha'il, Al-Qassim and Al-Harrat (e.g. Harrat Khyber and Harrat Al-Thinin) to this region in Saudi Arabia, Iraq and Kuwait. **Sultan (2011)** argued that Wadi Al-Rummah drainage system from up-stream in Hijaz Mountain to the west of Shat Al-Arab River and Al Basrah city in the northeast was the longest dry river in our planet.

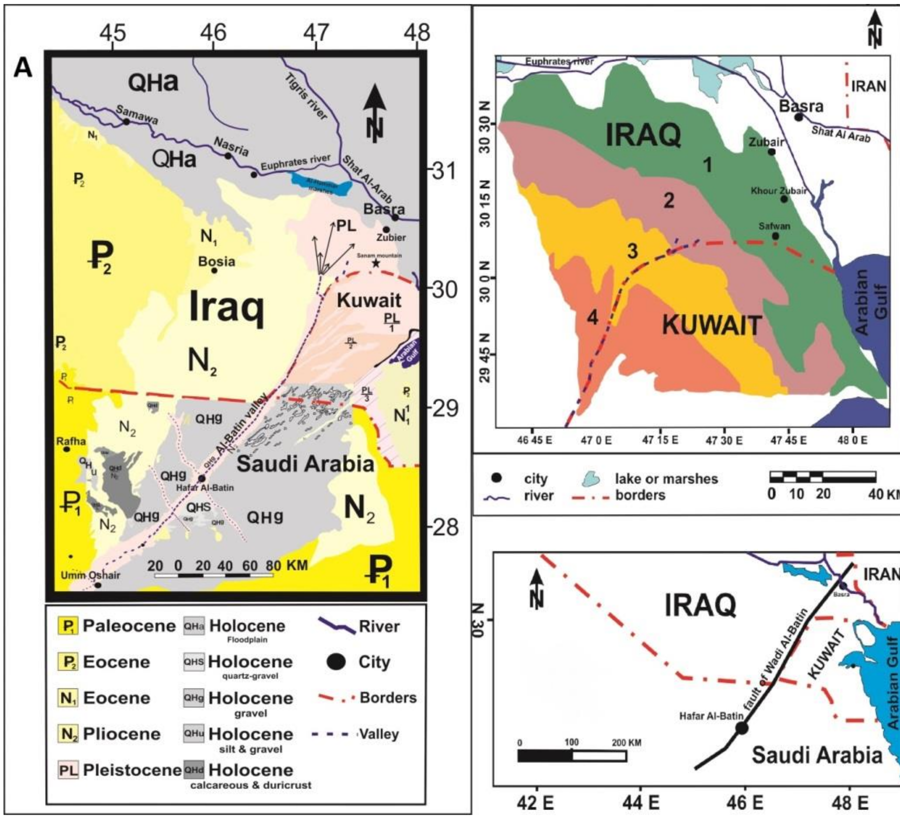

Figure 2. (**A**) Simplified Geological Map of the area around Wadi Al-Batin in Saudi Arabia, Iraq and Kuwait, after **Bramkamp and Ramirez (1960); Sissakian (2000); AlShuaibi and Khalaf (2011); HGG (1981)**; (**B**) Four stages of Wadi Al-Batin fan, after **Sissakian et al. (2014)**; (**C**) Fault of Wadi Al-Batin in Saudi Arabia, Iraq and Iran, after **Jassim and Buday (2006); Ma'ala (2009)**.

Sultan (2011) divided Wadi Al-Rummah into four integrated areas according to the physical geography and watershed system: (A) Upstream (Arabian shield), (B) Midstream (Al-Qassim), (C) Al-Nafud desert, and (D) Downstream **(Fig. 3b).**

2. Geological setting

Wadi Al-Batin crosses through the lands of three Arabic countries (Saudi Arabia, Iraq and Kuwait), so we will explain their geological setting in the three countries, as following:

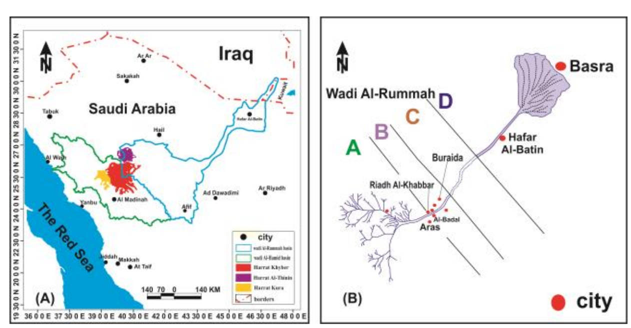

Figure 3. (A) the Basin of Wadi Al-Rummah -Wadi Al Batin in Saudi Arabia, Iraq and Kuwait , Modified after **Alwagdani**

and Basamed (2014); (B) Wadi Al-Rummah watershed areas “A, B, C, D”, after **Sultan (2011).**

2.1. Dibdibba Formation in Saudi Arabia

Dibdibba Formation occurs as an alluvial fan flanking the far northern part of Wadi Al Rimmah-Wadi Al-Batin system **(Fig.2b)**. It has a triangular shape with its apex near Al Qaysumah at northeast Saudi Arabia, and spreads northeastwards to cover the northern desert of Kuwait and the southern part of western Iraq **AlShuaibi and Khalaf, (2011); Al-Sulaimi and Pitty (1995).** The majority of the exposed geological formations on the surface here belong to Tertiary and Quaternary. Firstly, Umm Radhuma formation "Eocene - Paleocene" formed from cream, tan and gray limestone, dolomitic limestone, dolomite **(Fig. 2a)**. The Hofuf, Dam and Hadrukh formations “Miocene – Pliocene” formed from red, brown and gray marly sandstone, sandy marl and sandy limestone, but at the southern exposed Hadrukh formation of Miocene, include gray, tan, cream and pink calcareous silty sandstone, and locally cherty, at places confines non-marine fossils. The Quaternary deposits formed from calcareous hard crust of red, brown, gray, tan and yellow hard sandy limestone. Also, contain of limestone gravel and quartz gravel **Bramkamp and Ramirez (1960).**

2.2. Dibdibba Formation in Iraq

Dibdibah formation (Pliocene – Pleistocene), is exposed on the left side of Wadi Al-Batin between Busaiya in Iraq and Saudi – Kuwaiti borders. It is composed of poorly sorted sand, sandstone and gravels of igneous rock. The Dibdibah gravels consist mainly of acidic and intermediate igneous rocks (granite, granodiorite, rhyolite, and andesite), quartz, metamorphic rocks and chert **Jassim and Al-Jiburi (2009)**. The good roundness of even pebbles indicates that they transferred for long distance **(photo. 1)**. The size of gravel-pebble-boulder material reaches 2-20 cm.

Photo 1. The degree of roundness and major types of the pebbles from the deposits of the Wadi Al Batin:
A - quartz; B - rhyolite; C - basalt.

Quaternary sediments are composed from gypcrete “Pleistocene”; which formed cap rock over the Dibdibba Formation and alluvial fan sediments. These sediments are mainly derived from Pliocene and Pleistocene strata that occur in the northern part of Saudi Arabia. Whereas gypcrete is developed in north of Busaiya, south and southwest of Busaiya and Zubair areas form a cap rock over the Dibdibah Formation. The thickness of that gypcrete ranges from (0.5–1.0 m), indicates deposition in an arid climate. Depression Fill Sediments (Holocene) which are known as "Playa or Faidhah" are consisting mainly of clay and silt rich in SO_4, their thickness is (0.5–1.5 m). Wind Blown Sands (Holocene) forming sand dunes or longitudinal pattern of sand sheets; consist of fine to medium grained quartz **Jassim and Al-Jiburi (2009)**.

2.3. Dibdibba Formation in Kuwait

The land of Kuwait consists of flat-lying Tertiary rocks overlying the gently folded Cretaceous and Jurassic Formations **Milton (1967)**. Rocks types exposed in outcrops include Dammam Formation “Eocene”, the Ghar Formation “Oligocene”, Multa - Jal-Az-

Zor formation "Miocene-Pliocene", and Dibdibba formation "Pliocene-Pleistocene".
The Dammam Formation is a white, fine-grained cherty limestone **Owen and Nasr (1958).** Ghar, Multa and Jal-Az-Zor Formations are primarily composed of calcareous sandstones, sandy limestones and sand **Al-Sarawi et al. (2006).** Al-Dibdibba alluvial fan deposits in Kuwait can be divided into proximal alluvial (PL/1), deflation plain (PL/2), and distal flood plain (PL/3) sediments, **(Fig. 2a)**. The cross stratification and imbrications of the gravels indicate transportation from SW and W. At present, the Dibdibba area here consisting of ungraded conglomerates interbedded with pebbly granule sand, sandy mud and mostly covered by thin veneer of aeolian sands **AlShuaibi and Khalaf (2011)**.

3. Tectonic setting and Geomorphology

Through using Landsat images, many authors **Hancock et al. (1981); Al-Sarawi (1980); Ma'ala (2009)** revealed a 65 km of lineament linking the concealed fault zone beneath Wadi Al-Batin, this fault was active during the late Cretaceous - late Eocene, movements ceasing when the Red Sea began to open and the Arabian subplate was established, **(Fig. 2c)**. Al-Batin Fault Zone runs from the SW to the NE along the Wadi Al-Batin that forms the border between Kuwait and Iraq and originates from the eastern extremity of the Arabian Shield. The sense of movement on the fault has varied but the fault has an overall downthrown towards the NW **Jassim and Buday (2006)**.
A flat surface of Wadi Al-Batin is generally punctuated by some individual hills, which has a height of about 20-30 m. This region called Al-Dibdibba, which distinguished from other places in the presence of large quantities of gravels of different sizes and types, in addition to the clastic rocks from igneous, metamorphic and carbonate rocks. The surface of alluvial fan of the Wadi Al-Batin have a simple gradient towards the NE. Where the fan is formed there on the surface height of up to about 250 meters above sea level, and continues the surface downward direction towards the Arabian Gulf coast at gently sloping plain with a gradient averaging about 1.2 m/km **AlShuaibi and Khalaf (2011)**. Whereas **Sissakian et al. (2014)** subdivided this fan to four stages based on the difference in heights **(Fig. 2b)**.

4. Petrographic and Textural Descriptions

Based on microscopic examination, whole-rock composition, and trace element characteristics, the collected samples from the fan of W. Al-Batin are rhyolite, banded rhyolite, altered basalt (geochemically interpreted as trachyte and dacite), dacite, chert and quartz pebbles are described as follow:

4.1. Rhyolite

Rhyolites exhibit a wide variation in mineralogy, geochemistry and physical properties. They are mainly dark reddish brown color with one sample is black. Generally they are texturally porphyritic **(Fig.4a, b, d)** with exception; one sample shows myrmekitic intergrowth of quartz in k-feldspar **(Fig.4c).** Most of the collected rhyolite samples show predominance of quartz. Rhyolite shows strongly different modal percent of carlsbad twinned and simple twinned K-feldspar with minor plagioclase that may occur as individual grains or in clusters **(Fig.4b)**. The amount of phenocrysts compared to ground mass in most samples is high **(Fig. 4a)**. Mafics are generally replaced into opaques, chlorite or epidote with few standing pleochroic green microfibrous actinolite and biotite appear in some thin sections. Most of the samples are highly altered by the action of invading solutions show signs of hemitization, sericitiztion and kaolinitization by late metasomatic processes and aerial

ISSN 2455-6378

alteration affecting the phenocrysts and in the ground mass.

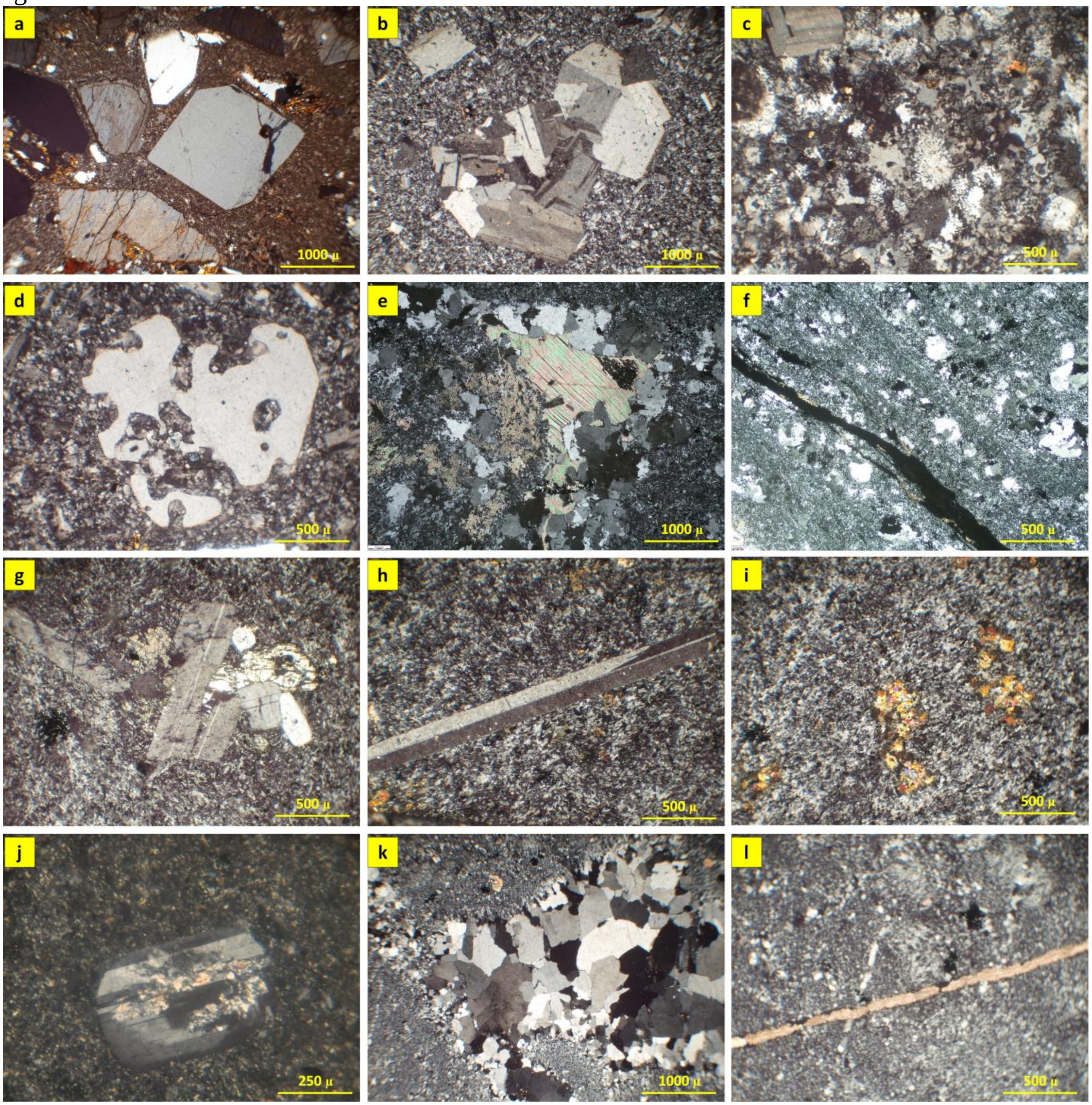

Figure 4. Photomicrographs of samples studied showing mineral compositions, textures and microstructures of the W. Al-Batin volcanic fragments: a- Rhyolite shows euhedral clear quartz and sanidine crystals in fine ground mass. b- Clot of plagioclase crystals enclosed by ground mass in porphyritic rhyolite. c- Myrmekitic texture in rhyolite where intergrowths of quartz and alkali feldspar form the groundmass of the granophyric block. d- Quartz grain in rhyolite with irregular outline with deep embayments filled with ground mass. e- Calcite replacement in the banded rhyolite. f- Banded rhyolite with veinlite of opaque iron solution fills cracks determining the foliation plane. g- Glomeroporphyritic texture in dacite with phenocrysts of plagioclase and pyroxene in kaolinitized ground mass. h- Long prismatic plagioclase crystal in dacite with fine ground mass. i- Clusters of epidote crystals in dacite showing variegated interference color. j- Zoning and lamellar twinning in plagioclase with altered lamellas to sericite in basalt. k- Cavity-

filling chalcedony and quartz in chert where quartz in the core of the amygdules have grown from the chalcedony substrate in the rim. l- Calcite vein filling the cracks and cut very fine veinlet of quartz in chert with fine ground mass of quartz and kaolinite.

4.2. Banded rhyolite

Banded rhyolite is composed of groundmass of quartz, devitrified glass, and kaolinite. Some quartz phenocrysts are converted to calcite by secondary metasomatic process. This rock appears as fine-grained grey colored foliated rock show typical rhyolite flow structure, including tiny elongate white vesicles filled with calcite and lined with quartz **(Fig.4e)** that are arranged parallel to the foliation. Calcite is a common constituent of some of the more altered rocks. It is present in the interstices and sometimes forms the core of irregular patches. It is assumed that it was formed by replacement of rock forming minerals and volcanic glass. In some parts all mafic minerals converted into opaques forming parallel lamellas define the foliation **(Fig. 4f)**.

4.3. Dacite

This rock is mostly fine-grained to cryptocrystalline, black colored with porphyritic, glomeroporphrytic **(Fig.4g)**, aphanitic and intersertal textures. This sample consists of plagioclase, quartz, augite, epidote and chlorite set in a microcrystalline matrix consisting of a dense mat of quartz and needle-like feldspars with glassy patches **(Fig. 4h)**. Apatite and magnetite are the most common accessory minerals. Mafic and opaque minerals usually tend to occur in clusters **(Fig. 4i)** giving the overall dark aspect to the rock.

4.4. Trachyte

The trachyte forms only a small part of the volcanic fragments in the study area. The hand specimen shows dark black color with fine grained texture. Under the microscope it appears micro-porphyritic with a few plagioclase **(Fig. 4g)** in a highly altered groundmass. The rock consists of k-feldspar, plagioclase phenocrysts in a fine-grained groundmass in which epidote is highly attributed. Plagioclase is ubiquitous as short tabular to prismatic phenocrysts **(Fig. 4g)**. Most of plagioclase in this altered rock both in ground mass and in phenocrysts has lost its polysynthetic twinning and is heavily sericitized. Opaques are always widely scattered throughout the groundmass and as a few micro phenocrysts. The common accessories are pyrite, magnetite and apatite. A set of micro veins of quartz and feldspar cut in the ground mass.

4.5. Chert

Chert is fine-grained texture with rare phenocrysts and large cavity-filling of chalcedony and quartz in vugs, fissures and minute openings **(Fig.4k)**. The quartz is the essential mineral in the samples. It is somewhat microcrystalline to cryptocrystalline or as fibrous chalcedony. The microcrystalline quartz commonly is clouded by opaque impurities and alteration minerals as kaolinite. In some spcimens, replacement veins of calcite have developed **(Fig.4l)**.

5. Geochemical Characteristics

5.1. Geochemistry of major oxides and trace elements

Selected samples of rock fragments from different parts of the fan of Wadi Al-Batin, have been analyzed for major and trace elements. Based on the geochemical data given in **(Table 1)**, a number of discrimination and correlation diagrams used to identify the chemical classification, nature and tectonic setting of the source rock for the studied volcanic fragments.

For appropriate classification, we used 2 diagrams depending on both major and trace element data. The total alkalis vs. silica (TAS) diagram **Le Bas et al. (1986)** diagram; **(Fig. 5a)**

International Journal of Advanced Scientific Research and Management, Vol. 2 Issue 7, July 2017.

IJASRM

www.ijasrm.com

ISSN 2455-6378

shows that Wadi Al-Batin volcanic fragments define a compositional spectrum from intermediate to felsic.

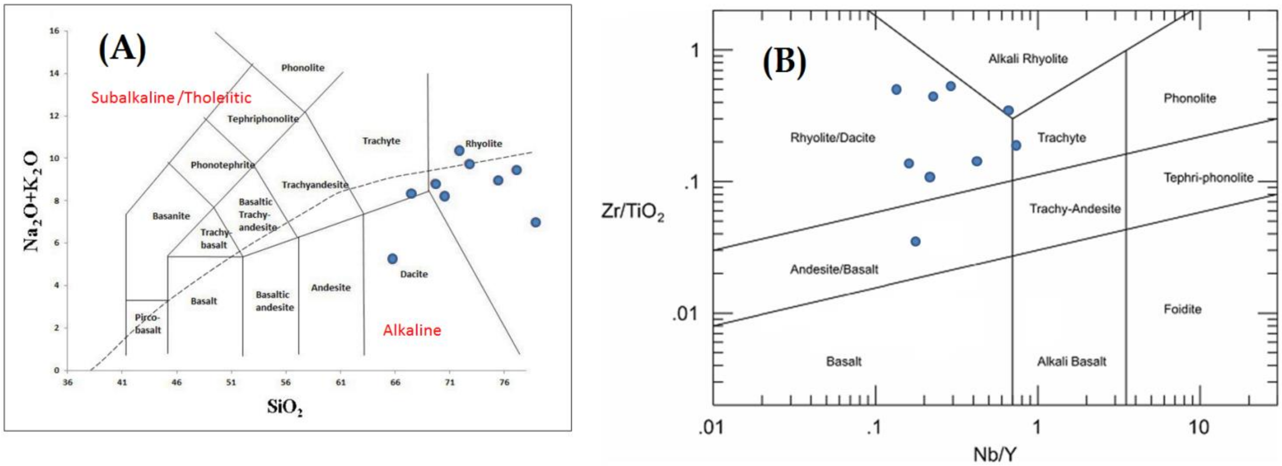

Figure 5. Geochemical classification of volcanic fragments of Wadi El-Batin based on major and trace element data: (a) SiO_2 vs. $Na_2O + K_2O$, after **Le Bas et al. (1986)**, and (b) Nb/Y vs. Zr/TiO_2 diagram, after **Pearce (1996)**.

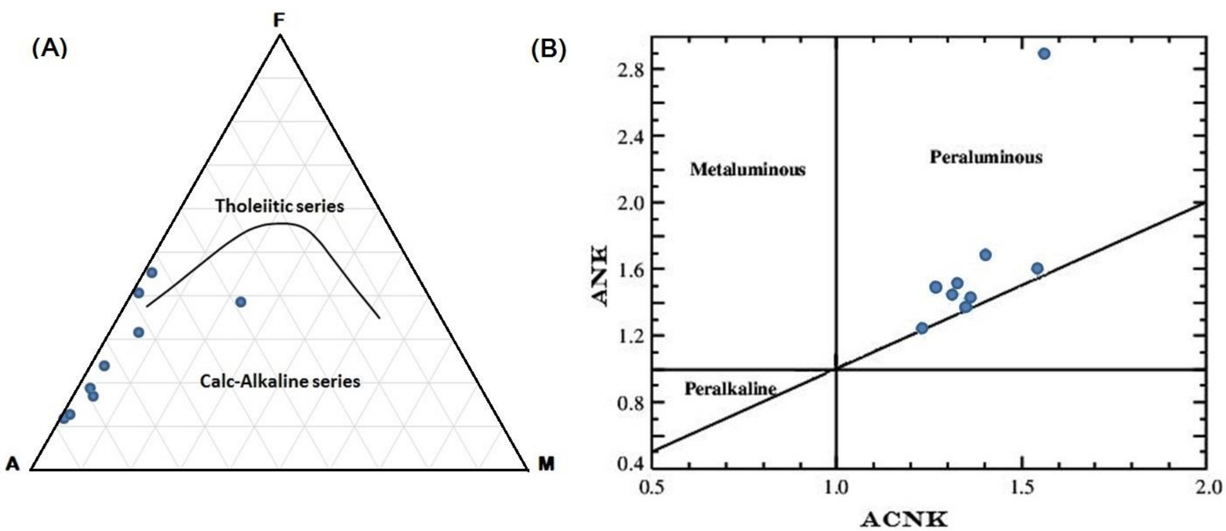

Figure 6. Geochemical nature for the studied volcanic fragments of Wadi El-Batin: a) AFM plot, after **Irvine and Baragar (1971)**, b) Shand's index Plot, after **Maniar and Piccoli (1989).**

They are rhyolite, dacite, dacite and trachyte in composition, where rhyolite is the dominant rock type. Also, classification of the rocks using Nb/Y versus Zr/TiO_2 diagram **(Fig. 5b)** of **Pearce (1996)** shows that most of the samples are rhyolites and alkali rhyolite with two samples plotted in the field of andesite/basalt and trachyte which were interpreted as dacite and rhyolite respectively using major element data.

From classification diagrams and microscopic examinations, it is inferred that the collected volcanic fragments are dominantly rhyolite with few basaltic samples suffered from chemical alteration changed their composition to dacite and trachyte as appeared in TAS diagram.

IJASRM
International Journal of Advanced Scientific Research and Management, Vol. 2 Issue 7, July 2017.
www.ijasrm.com
ISSN 2455-6378

Table (1): Whole-rock major and trace element analyses of the volcanic fragments from Wadi El-Batin, Iraq.

Sample no.	B-2	B-4	B-5	B-9	B-10	B-12	B-1	B-6	B-11
Rock type	Rhyolite					Banded rhyolite	Dacite	Trachyte	Nodular Chert
Major elements (wt. %)									
SiO_2	69.62	72.77	71.82	77.08	70.51	75.42	65.77	67.53	78.36
Al_2O_3	13.04	13.81	14.15	11.74	12.47	13.00	15.21	14.10	10.73
TiO_2	0.52	0.24	0.19	0.11	0.37	0.14	0.85	0.55	0.14
K_2O	3.50	4.97	5.85	5.88	2.73	4.09	2.30	3.21	4.97
Fe_2O_3*	4.41	2.08	2.51	1.31	5.70	1.30	6.34	6.82	2.19
MgO	0.90	0.39	0.31	0.11	0.12	0.08	1.58	0.33	0.25
Na_2O	5.31	4.78	4.49	3.58	5.47	4.85	2.93	5.14	1.78
CaO	1.41	0.46	0.20	0.05	1.26	0.90	4.50	1.79	0.28
MnO	0.10	0.05	0.03	0.01	0.16	0.05	0.13	0.21	0.05
P_2O_5	0.11	0.06	0.05	0.01	0.04	0.02	0.21	0.15	0.01
$Na_2O + K_2O$	8.81	9.75	10.34	9.46	8.2	8.94	5.23	8.35	6.75
Na_2O / K_2O	1.52	0.96	0.77	0.61	2.00	1.19	1.27	1.60	0.36
Trace elements (ppm)									
Cr (ppm)	23	<10	11	<10	<10	<10	19	<10	<10
V (ppm)	61	23	51	18	<10	<10	128	10	<10
Ni (ppm)	<10	<10	<5	<10	<10	<10	<5	<10	<10
Cu (ppm)	<10	<10	<5	<10	<10	<10	<10	36	<10
Zn (ppm)	109	47	96	68	158	29	97	131	105
Rb (ppm)	97	101	92	153	68	95	58	73	129
Sr (ppm)	173	94	436	65	161	118	414	253	38
Zr (ppm)	356	221	599	230	1102	162	173	482	362
Ba (ppm)	911	705	1426	140	950	787	653	774	523
U (ppm)	<5	<5	<5	<5	<5	<5	<5	<5	8
Th (ppm)	15	7	<5	22	7	9	<5	8	8
Y (ppm)	50	28	55	50	91	13	40	75	42
Nb (ppm)	11	12	17	34	13	10	7	12	10
Pb (ppm)	14	<10	19	16	10	16	<5	12	17
As (ppm)	<10	<10	56	26	<10	12	<5	21	<10

Total Fe reported as Fe_2O_3*

In the AFM plot **Irvine and Baragar (1971)**, all rhyolite rocks are plotted in the calc-alkaline field **(Fig. 6a)**, while dacite and trachyte are plotted in the tholeiitic field. The Shand's diagram **Maniar and Piccoli (1989)** shows the peraluminous tendency for all the volcanic rock samples under investigation **(Fig. 6b).**

According to Zr versus SiO_2 and Zn versus SiO_2 diagram **Collins et al. (1982)**, the majority of the rhyolite samples except one sample plotted in the A-type area, while dacite and banded rhyolite are plotted in I-type field.

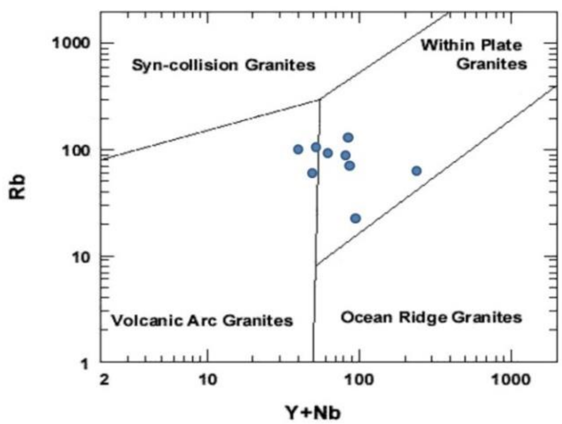

Figure 7. Rb vs (Nb+Y) tectonic discrimination diagram, after **Pearce et al. (1984).**

Majority of the study rhyolites except one sample are plot in the field of within plate granites in Rb versus Nb+Y tectonic discrimination diagram of **Pearce et al. (1984)**, while banded rhyolite, dacite and one rhyolite sample are plotted in the field of volcanic arc granites **(Fig. 7)**.

5.2. Chemical effects of alteration

During the interpretation of the chemical data, some care must be taken for alteration that is very visibly affected all the samples and their effects are observed in hand specimen, under microscope and in geochemical analyses, as noted above. From chemical analyses (Tab. 1-1), it is easily observed the enrichment of SiO_2 (average: 72 wt. %) and Al_2O_3 (average: 13.1 wt. %) and the depletion of MgO (average: 0.45 wt. %) and Cao (average: 1.2 wt. %), which reflect the role of alteration in changing chemical composition. We use the term alteration as defined by **McPhie et al. (1993)**; that is, the change in mineralogy and texture of a deposit, facilitated by the action of hot or cold aqueous solutions or gases. In many volcanic terranes the processes of diagenetic and hydrothermal alteration are inseparable and involve dissolution, replacement and precipitation of minerals along fluid pathways **Noh and Boles (1989)**. Rhyolite is more resistant to weathering during aerial transportation than basalt which explain the nearly absence of basaltic rocks in the area. The decay rate of the basalt to clay minerals is larger than those of rhyolite, i.e. the relative stability of silicic volcanics is higher than mafic volcanics, and this is due to that K-feldspar is more stable than Ca-plagioclase and in the other hand quartz is more stable than olivine, pyroxene and amphibole. As is common, in subaerial weathering environments (e.g. **Beane et al. (1986); Price et al. (1991)**, alteration appears to have variably affected K, Na, Rb, and Ba contents in the basaltic samples. **Thomson et al. (2014)** studied the weathering of a basaltic rocks and observed that weathering is sufficient to induce the loss of more than 50% of some cations (including >50% of MgO and MnO as well as ~38% of Fe_2O_3 and 34% of CaO), also he observed that it result in weakening of samples by as much as 50% of their original strength.

From our observations, it is suggested that the black colored samples which are geochemically interpreted as dacite and trachyte, have suffered from depletion of Mg, Fe, Ca and Mn contents and enrichment of Si and Al contents which significantly affect geochemical classification and nomenclature. These dark black dacite and trachyte samples have tholeiitic nature which suggests that they were actually basalts. Nb/Y versus Zr/TiO_2 diagram of **Pearce (1996)** enhances the suggestion that the dacite black sample is actually basalt or andesite.

6. Source rock of the volcanic fragments

From geological survey, rhyolites are widely distributed in W and NW Saudi Arabia. We compared a lot of them with Wadi Al-Batin rhyolites to find the faces of similarities to each other's. After that, with the help of simplified contour map, 3-D model **(Fig. 1a, b)** and the given map of the Al-Rummah Basin **(Fig. 3a)** by geological survey authority of Saudi Arabia and Wadi Al-Rummah watershed **Sultan (2011) (Fig. 3b)**, it is available to define the flow direction of flood from Pleistocene to todays, which carries loads of sediments and rock fragments from this high altitude then deposited them in areas of low altitude in Iraq and Kuwait throw Wadi Al-Batin. This study suggest that the volcanic rock fragments at Wadi Al-Batin came from the highlands of W and NW Saudi Arabia, especially from the areas around Ha'il 28° - 28 30' N , 41°30' – 42° E (namely Hadn formation type locality 26° 55' – 27° 12' N , 41° 00'- 41° 20' E, Jabal Aja 27°15' – 27° 45' N , 41°15' – 41°40' E and Sarrah alkali rhyolite 26°03' – 26° 10' N , 42°37' – 42°47' E) and Al-Qassim (namely Jabal Aban al Asmar 27° - 27° 05' N and 41° 30' – 41° 34' E). These terrains are located in the flood way where water collected from a complex network of many tributaries then connected to Wadi Ar Rummah, the largest and widest valley in the Arabian Peninsula, then a part of these fragments enter to Wadi Al-Batin and move till his fan **Almisnid (2008)**.

We introduce the geological faces of similarities between Wadi Al-Batin volcanics and these rhyolites as following:

6.1. Ha'il region

6.1.1. Hadn formation

To the south of the Ha'il quadrangle, layered rhyolitic and minor dacitic volcanics and associated sediments of the Hadn formation **Quick (1983); Kellogg (1983); Stoeser and Elliott (1985).** Hadn rhyolites are very similar to Wadi Al-Batin rhyolites in the geochemical nature where they are calc-alkaline and formed in anorogenic environment reflect continental crustal source **Stoeser and Elliott (1985)**.

6.1.2. Jabal Aja

The Jabal Aja intrusive complex consists of a 35 by 85 km complex of coarse-grained hypersolvus peralkaline granite to micrographic porphyritic granophyre and rhyolite. The porphyritic rhyolite (ajr) represents widespread sills within the core of the Jabal Aja granite. The rhyolitic dikes at Jabal Aja and Sarrah are alkaline appear to be equivalent to each other and contain alkali amphiboles (katophorite or arfvedsonite) in very fine grained, graphic to myrmekitic groundmass **Stoeser and Elliott (1985)** as some samples from Wadi Al-Batin rhyolites**.**

6.1.3. Sarrah alkali rhyolite

The Sarrah alkali rhyolite occurs as a large arcuate dike that forms a prominent ridge in the Qufar **Kellogg (1983)**, Ghazzalah **Quick (1984)**, and southeastern al-Qasr quadrangles. The dike at its maximum width is over 500 m and is over 30 km long. Texturally, the rock is very similar to the comendite porphyry of the Jabal Aja intrusive complex in the Ha'il quadrangle **Kellogg and Stoeser (1985)** as some samples from Wadi Al-Batin rhyolites.

6.2. Al-Qassim region

6.2.1. Jabal Aban al Asmar (Samra rhyolite)

The Asmar complex is exposed south of Wadi Al-Rummah and consists of nested, arcuate intrusions surrounding the central block of Samra coeval rhyolitic volcanic cover

Stuckless et al. (1982a); Cole (1985b); Cole and Bohannon (1985a, b). This recrystallized rhyolitic volcanic rocks are exposed in the central, highest parts of the Aban al Asmar mountains are defined as the Samra rhyolite. The rhyolites of Aban al-Asmar area (Samra rhyolite) are chemically and mineralogically similar to Wadi Al-Batin rhyolite. They are dominantly peraluminous and silica rich (73-77 percent silica) with dark brown varnish **Stuckless et al. (1982a); Cole (1984c); Cole and Bohannon (1985b),** as some samples from Wadi Al-Batin rhyolite.

7. Conclusions

Red and dark colored volcanic rock fragments widely dispersed in Wadi Al-Batin and his fan. The red colored fragments are mainly rhyolite, and banded rhyolite while the dark colored fragments are chert and altered basalt (although they fill in the fields of trachyte and dacite of TAS diagram). Rhyolites are typical calc-alkaline peraluminous volcanic rocks and display geochemical characteristics of anorogenic within-plate environments. On the other hand, basalt (classified as trachyte and dacite) are tholeiitic peraluminous reflect the geochemical characteristics of orogenic arc-type. Thus, it is suggested that they are derived from two different areas. This study deduce that the volcanic rock fragments at Wadi Al-Batin came from the highlands of W and NW Saudi Arabia, especially from the areas around Ha'il, namely Hadn formation type locality, Jabal Aja and Sarrah alkali rhyolite) and Al-Qassim, namely Jabal Aban al Asmar (Samra rhyolite). These rhyolites exhibit many are faces of similarities to Wadi Al-Batin rhyolites.

This requires similar studies in the part of Kuwait from the Wadi Al Batin fan, as well as the source areas of these volcanic fragments in Saudi Arabia, so that this study will be completed with scientific results, and thus we will have a comparative study within three Arabic countries.

Acknowledgments

Field work is carried out with the help of **Dr. Raheem Al-Abdan**, **Harth El Abdali** and **Colonel Wajdi Khaza'al**, we are greatly acknowledged for them. The authors thank the Russian state geological prospecting university for providing laboratories of petrography and geochemical analyses. Special thanks to **Prof. Korsakov A. K, Prof. Vershoba A.A.**, **Prof. Utenkov V. A**. and **Prof. Naravas A.K.,** who helped us in microscopic photography of our thin section. Thanks are also extends to **Dr. Sokolov S. A.** for the kind assistance with the computer programs. Also, we indebted to **Dr. A. Petrovich** (Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Russian Academy of Sciences) for help in analyzing major and trace elements.

References

[1] Al-Misnid A., alriyadh.com – Wadi Al-Rummah Flooding, 14 November 2008, number 14753, [2008].

[2] Al-Sarawi, M. A., Tertiary faulting beneath Wadi Al-Batin (Kuwait). Geol. Sot. Am. Bull., 9(I), p. 610-618, [1980].

[3] Al-Sarawi, M.A., El-Baz, F., and Koch, M., Geomorphologic controls on surface deposits of Kuwait as depicted in satellite images, Kuwait J.Sci.Eng.33(2), p.123-145, [2006].

[4] AlShuaibi, A. A. and Khalaf, F.I., Development and Lithologenesis of the Plaustrine and Calcrete deposits of the Dibdibba Alluvial Fan, Kuwait, Jornal of Asian Earth Science 42, p.423-439, [2011].

[5] Al-Sulaimi, J. S. and Pitty, A. F., Origin and Depositional Model of Wadi Al-Batin and its Associated Alluvial Fan, Saudi Arabia and Kuwait, Sedimentary Geology, 97(3-4): p. 203-229, [1995].

[6] Alwagdani, E. O., and Basamed, A., The Exploration and Evaluation of Water in Harrat Khybar, Saudi Arabia, WSTA 11th Gulf Water Conference, Muscat, Sultanate of Oman, 20-22 October 2014, 42 p, [2014].

[7] Bramkamp, R. A., and Ramirez, L. F., Geologic map of the Wadi al Batin quadrangle, Kingdom of Saudi Arabia, U.S. Geol. Survey Misc. Geol. Inv. Map I-203 A, scale 1:500,000, [1960].

[8] Beane, J. E., Turner, C. A, Hooper P. R, Subbarao, K. V., Walsh J. N., Stratigraphy, composition and form of the Deccan Basalts, Western Ghats, India. Bull Volcanol. 48, p. 61–83, [1986].

[9] Cole, J. C., Base data for the Al Abanat quadrangle, sheet 25/42 B, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Data-File USGS-DF-04-34, [1984c].

[10] Cole, J. C., Reconnaissance geology of the Al Abanat quadrangle, sheet 25/42B, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-05-14, 66 p., scale 1:100,000. USGS Open-File, p. 85-721, [1985b].

[11] Cole, J. C., and Bohannon, R. G., Reconnaissance geology of the An Nabhaniyah quadrangle, sheet 25/43 A, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-05-19, 32 p., scale 1:100,000. Also, 1985, U.S. Geological Survey Open-File Report, p. 85-723, [1985a].

[12] Cole, J. C., and Bohannon, R. G., Base data for the An Nabhaniyah quadrangle, sheet 25/43 A: Saudi Arabian Deputy Ministry for Mineral Resources Data-File USGS-DF-04-35, [1985b].

[13] Collins, W. J., Beams S. D., White A. J. R, Chappel B.W., Nature and origin of A-type granites with particular reference to southeastern Australia, Contributions to Mineralogy and petrology, 80, 180-200, [1982].

[14] Hancock, P. L., Al-Khatieb S. O. and Al-Kadhi, A., Structural and photogeological evidence for the boundaries to an East Arabian block, Geological Magazine, vol. 118 issue 5, p.533-538, [1981].

[15] Hunting Geology and Geophysics (HGG), Photographical survey of the state of Kuwait, submitted to the Kuwait oil company, Kuwait, [1981].

[16] Jassim, R. Z., and Al-Jiburi, B. M., Geology of Iraqi Southern Desert, Iraqi Bull. Geol. Min. Special Issue, p. 53−76, [2009].

[17] Jassim, S. Z., and Buday, T., Tectonic framework from Geology of Iraq “Edited by Saad Z. Jassim and Jeremy C. Goff” Published by Dolin, Prague and Moravian Museum, Brno, Czech Republic,pp.35-52, [2006].

[18] Irvine T. N., Baragar W. R. A., A guide to the chemical classification of the common volcanic rocks, Canadian Journal of Earth Sciences. 8, p. 523–548, [1971].

[19] Kellogg, K. A., Reconnaissance geology of the Qufar quadrangle, sheet 27/42 D, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-91, 35 p. Also, 1983, U.S. Geological Survey Open-File Report, p. 84-159, [1983].

[20] Kellogg, K. S., and Stoeser, D. B., Reconnaissance geology of the Ha'il quadrangle, sheet 27/416, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-05-1, 34 p., scale, 1:100,000. Also, 1985, U.S. Geological Survey Open-File Report, p. 85-418, [1985].

[21] Le Bas MJ, Le Maitre RW, Streckeisen A, Zanettin B. A chemical classification of volcanic rocks based on the total alkali–silica diagram. Journal of Petrology. 27, p. 745–750, [1986].

[22] Ma'ala, K.A., Geomorphology, Iraqi Bull. Geol. Min. Special Issue: Geology of Iraqi Southern Desert, p. 7− 33, [2009].

[23] Maniar PA, Piccoli PM. Tectonic discrimination of granitoids. Ball. Geol. Soc. Am. 101, p. 635-643, [1989].

[24] McPhie, J., Doyle, M., Allen, R., Volcanic Textures: a Guide to the Interpretation of Textures in Volcanic Rocks. University of Tasmania Centre for Ore Deposit and Exploration Studies, Hobart. 198 pp, [1993].

[25] Milton, D., Geology of the Arabian Peninsula, Kuwait. United States Geological Survey professional paper 560-F: P: 7, [1967].

[26] Noh, J.H., and Boles, J.R., Diagenetic alteration of perlite in the Guryongpo area, Republic of Korea. Clays and Clay Minerals, 37, p. 47-58, [1989].

[27] Owen, R. and Nasr, S, Stratigraghy of Kuwait-Basra. In:weeks.L.G. (Ed.).Habitat of Oil: a symposium. American Association of Petroleum Geologists, Tulsa, Ok, USA, P. 1252-1278, [1958].

[28] Pearce, J.A., A user's guide to basalt discrimination diagrams. In Trace Element Geochemistry of Volcanic Rocks (D.A. Wyman, ed.). Geol. Assoc. Can., Short Course Notes 12, p. 79-114, [1996].

[29] Pearce J.A., Harris N.B.W, Tindle A.G., Trace-element discrimination diagrams for the tectonic interpretation of granitic-rocks. J Petrol 25:956–983, [1984].

[30] Price R.C., Gray C.M., Wilson R.E., Frey F.A., and Taylor S.R., The effects of weathering on rare-earth element, Y and Ba abundances in tertiary basalts from southeastern Australia [J], Chemical Geology, 93, p. 245-265, [1991].

[31] Quick, J. E., Reconnaissance geology of the Ghazzalah quadrangle, sheet 26/41 A, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-91, 44 p. Also, 1983, U.S. Geological Survey Open-File Report, p. 83-331, [1983].

[32] Quick, J. E., Reconnaissance geology of the Zarghat quadrangle, sheet 26/40 B, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-04-28, 37 p. Also, 1984, U.S. Geological Survey Open-File Report, p. 84-794, [1984].

[33] Sissakian, V.K., Shihab, A.T., Al-Ansari, N. and Knutsson, S., Al-Batin Alluvial Fan, Southern Iraq. Engineering, 6, p. 699-711, [2014].

[34] Sissakian, V.K., Geological Map of Iraq, scale 1:1000 000, 3rd edit. GEOSURV, Baghdad, Iraq, [2000].

[35] Stoeser, D. B., and Elliott, J. E., Reconnaissance geology of the Al Qasr quadrangle, sheet 27/41 C, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-05-2, 51 p. Also, U.S. Geological Survey Open File Report, p. 85-255, [1985].

[36] Stuckless, J. S., VanTrump, G., Jr., Bunker, C. M., and Bush, C. A., Preliminary report on the geochemistry and uranium favorability of the postorogenic granites of the northeastern Arabian Shield, Kingdom of Saudi Arabia: proceedings, Pan-African Crustal Evolution in Arabia and northeast Africa, IGCP Project 164, [1982a].

[37] Sultan Al-Sultan, The wadi Ar Rumah watershed analysis using NOAA/AVHRR visible and thermal data, XIV World Water Congress, [Sep. 2011].

[38] Thomson, B. J., Hurowitz, J. A., Baker, L. L., Bridges, N. T., Lennon, A. M., Paulsen, G., Zacny, K., The effects of weathering on the strength and chemistry of Columbia River Basalts and their implications for Mars Exploration Rover Rock Abrasion Tool (RAT) results. Earth Planet. Sci. Lett. 400, p. 130–144, [2014].