Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 48 (1) 165-170 (2016)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Petrography and Geochemistry of the Ghar-e-Hira, Makkah, Saudi Arabia

I. SIDDIQUI[++], M. H. AGHEEM, M. K. SAMOON

Centre for Pure and Applied Geology, University of Sindh, Jamshoro, Sindh, Pakistan

Received 6th January 2015 and Revised 18th February 2016

Abstract: Petrographic study, SEM images, mineral chemistry and whole-rock geochemistry were performed on a rock sample from Ghar-e-Hira. It is medium-grained, subequigranular, and comprises plagioclase (sodic andesine), quartz, K-feldspar, biotite, opaque oxide, muscovite and sphene. Some biotite is altered to chlorite. The small quantity of K-feldspar suggests that the rock is tonalite. The high amounts of SiO_2 and Al_2O_3 with substantial CaO and Na_2O, and high Na_2O/K_2O support the petrography in classifying the rock as tonalite. The peraluminous nature of the rock suggests a sedimentary protolith.

Keywords: Ghar-e-Hira, Petrography, Geochemistry, Tonalite, Makkah

1. INTRODUCTION

The term Ghar is an Arabic word for cave. Caves may be formed by artificial or natural processes. Geologically, natural caves are formed by the action of/dissolution by water, melting of ice under/inside glaciers, tectonic displacement, or as gas chambers and flow tubes in volcanic areas. Some caves are spacious and provide protection and shelter. There are innumerable caves in the world, and many of these became important, even sacred, during the history of mankind through mythological, social, and/or religious attachments. For example, a number of them have been considered to be haunted by evil spirit. Some have been used as sites for social gatherings, such as the Sar-kali Khamatsa in Hangu (northern Pakistan) where the local nobility would celebrate the first hair-cut of their male children. The Greek god Zeus was thought to be born in a cave on Mount Ida or mount Dikte on the island of Crete (Buxton, 1994). Various scared Hindu and Buddhists caves are known in India (Palmer, 1991). Caves and tunnels have also been produced artificially for protection, escape, or connectivity, e.g., various caves were made in pyramids in Egypt (Baldwin, 1938), and in Ireland and Christian Romanesque churches in northern Europe (Devereux, 1992). Beijing city has underground caves constructed for protection. In Saudi Arabia, hundreds of caves of limestone and volcanic origin are found (Pint, 2009, Kumar, 2013), particularly in deserts where caves named Dahls and Survival, Dharb Al Najem, etc. are located (Pint, 2003; Khan, 2003; Hussain *et al.,* 2006; Pint, 2009).

For centuries many caves have been used as places of worship by disciples of different religions. The most important and holy cave for the Muslims is the Ghar-e-Hira. This cave has a special religious sacredness, because the prophet of Islam, Muhammad (صلیاللهُ علیه وآلهِ وسلم/ Peace Be Upon Him), visited it for mediation and consolation. According to the Islamic faith, it was here, in 610 AD, that he ultimately received first revelations of God from Jibriel (علیه السلام), i.e., angel Gabriel. It is the holy cave where Jibriel (علیه السلام), according to Al-Qur'an (96:1-3), the holy script of Islam, commanded the prophet to read, اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (Read! In the name of Allah, who created, man from a clot); خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ, اقْرَأْ وَرَبُّكَ الْأَكْرَمُ الَّذِي عَلَّمَ بِالْقَلَمِ (Read! and your God is the most magnanimous, (he who taught) the use of pen, taught man which he knew not). These were the first Quranic verses that prophet Muhammadصلیاللهُ علیه وآلهِ وسلم received in the holy cave of Ghar-e-Hira.

Location

The Ghar-e-Hira is located on the way to the Mina, about 3.5 kilometers from Makkah Mukarramah) on the Al-Sail road (21°27'25'' N and 39°51'31" E), at an altitude of 550-600 m above mean sea level (Fig. 1). The area is in the southwestern part of Hejaz region of the Saudi Arabian shield. The cave Hira is located on the Jabal Noor with steep slope of granitic rock of medium to coarse-grained texture. The cave is about 3.7 m long and 1.60 m wide. Although a few details exist for this particular cave, but majority of these have been carried out from religious point of view. During the performance of Hajj 1434 AH (i.e., 2012 AD) and Umra in 2013 AD, the first author visited this cave and under religious zeal collected a sample of the granitic rock of the cave for detailed petrography and geochemistry.

[++]Corresponding author: I. SIDDIQUI siddiqui57@gmail.com 0092-3332622429

Geological Setting

Many workers have carried out studies on the geology of the Kingdom of Saudi Arabia. Among the earlier ones were Brown and Jackson (1960). Several other contributors include USGS-ARAMCO (1963), Schmidt *et al.* (1973), Johnson (2005), and Johnson and Kattan (2005).

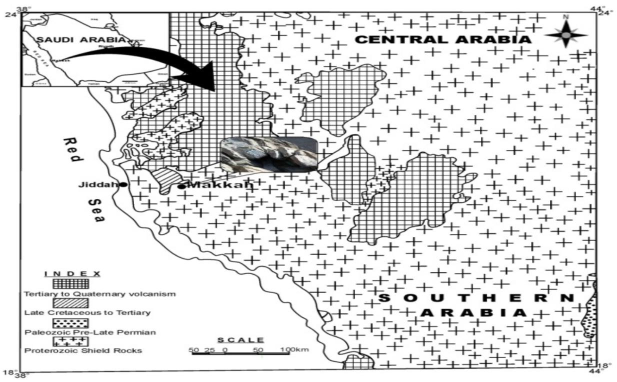

Fig. 1 Map showing the location and geology of Ghar-e- Hira and surrounding area (Redrawn from Vaslet, 1990).

Geologically, Saudi Arabia is divided into four extensive terrains. These are: 1) Pre-Cambrian to Proterozoic Arabian shield, 2) Phanerozoic Arabian Platform, having clastic, calcareous and evaporitic successions, 3) Tertiary "harrats" (extensive basalt plateaus), and 4) Narrow Red Sea coastal plain **(**Greenwood, 1997**)**. The western half of Saudi Arabia belongs to the shield, where diverse igneous and metamorphic rocks are exposed and at places are overlain by lava flows. The Saudi terrain is generally in the form of deserts, but the western part comprises low relief mountains rising from the flat desert. In addition, these hills are penetrated by batholiths of acidic to intermediate composition and, being resistant to weathering and erosion, occupy the highest point (Gettings *et al.,* 1983, 1986).

The hills surrounding the Holy Ka'aba and Makkah are also made of igneous rocks in the form of a batholith of Jabal Al-Noor. These rocks are generally granodioritic in composition and rise vertically throughout the central part of Jabal Al-Noor. The Jabal Al-Noor is a part of the Arabian Shield, which is dominated by various types of igneous, metamorphic and sedimentary rocks of Precambrian and Lower Palaeozoic age (Greenwood *et al.* 1976). There are also subsidiary sedimentary rocks and basaltic lava flows belonging to Tertiary and Quaternary period (Solami, 2006). It is generally thought that the Arabian Shield had split away from the African shield along the rifts of the Red Sea and the Gulf of Aden during more than two episodes of sea floor spreading (Bender, 1975). One of these is pre-early Miocene and the second belongs to post-Miocene rifts time (Johnson and Kattan, 2008). On the basis of fold-fault pattern of the shield along with some stratigraphic relationships, Johnson and Kattan (2008) proposed that the shield has undergone two orogenic cycles.

Jabal Al-Noor is geologically related to the Ju'ranah complex. It is composed of tonalite and subordinate granodiorite. It has sharp steep intrusive rocks that are composed mainly of medium- to coarse-grained hornblende tonalite (Moore and Al-Rehaili, 1989). Other geologic units in Al-Noor Mountain and surroundings include gabbro, diorite, quartz diorite, granite, microgranite, zibarah group, alluvial fan deposits, and alluvial, elluvial, eolian sand deposits (Jackson *et al.,* 1984).

Around Jabal Al-Noor, i.e. Makkah quadrangle, two main trends of structures are present. The first trend is related to Precambrian phase of deformation showing faults dipping north-north east to northwest. The northeasterly trending faults displace the northwesterly faults. The second trend of structures shows faulting, fracturing, and shearing developed due to Red Sea rifting. The northwesterly faults show normal sense of displacement dipping steeply to the southwest.

Ghar-e-Hira is located on the southwestern edge of the batholith or the young plutons that are elongated, foliated, sheared and faulted (Youssef *et al.,* 2015). Not a cave in strict geological sense, it is a perfect arrangement of steeply dipping large rectangular blocks. A tapering cavity has developed between these settings of joint pattern to give it a shape of small triangular cave-like opening (Siddiqui, 1999).

2. MATERIALS AND METHODS

Polarizing microscope was used for petrography. Pressed pellets were analyzed by WD-X-Ray Fluorescence (XRF) spectrometer for the routine major elements. In support of the petrogrpahic data of polarizing microscope, Scanning Electron Microscope was used for the study of surface and textural features of the constituent minerals. Energy Dispersive Spectrometer was utilized for elemental analysis of four grains. A half inch polished chip was examined through SEM for textural features. After thorough examination, a portion of this chip was selected to determine the chemistry of four mineral grains. All of the analytical work was performed in Advanced Research Laboratories, Centre for Pure and Applied Geology, University of Sindh, Jamshoro-Pakistan.

3. RESULTS AND DISCUSSION

Petrography

A 11x6 cm fresh rock sample was collected from the proper Ghar-e-Hira. Megascopic examination of the sample shows that it is gray in color, roughly equigranular, and medium to coarse-grained. Dark coloured mineral grains are conspicuously dispersed in quartz and white feldspar (plagioclase) grains that make the bulk of the rock **(Fig. 2).**

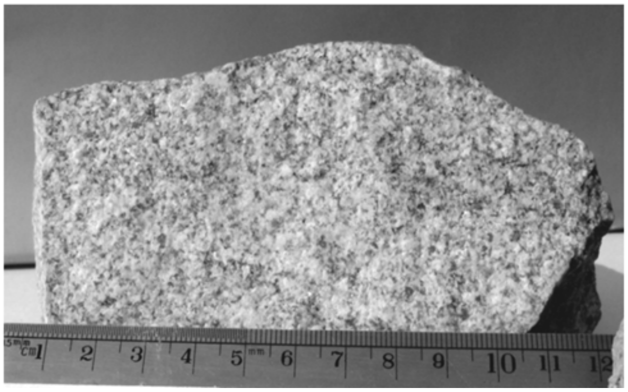

Fig. 2 Rock specimen collected from Ghar-e-Hira, Saudi Arabia.

Thin section study reveals that the rock is medium-grained and subequigranular. It is essentially made up of plagioclase (70 vol%) and quartz (21%) **(Fig.3A, B, C).** Potash feldspar (3%), biotite (2.5%), muscovite, opaque oxide, chlorite (about 1% each), apatite, sphene and prehnite (all three in trace amounts) are present as varietal and accessory constituents **(Fig. 3A, B, C, D, E, F).** The plagioclase is fresh and sodic andesine. It commonly displays excellent albite twins, but at places some pericline and Carlsbad twins are also seen. Biotite is the most abundant of the mafic minerals and some of it is altered to chlorite. The prehnite also appears to be an alteration product. The higher percentage of plagioclase and lower of K-feldspar, along with more than 20% quartz suggest that the sample is tonalite (Plutonic). But it is of noteworthy that there are hundreds of caves within Saudi Arabia, the majority of which occur in volcanic rocks of Tertiary "harrats" (Pint, 2009) and in limestone.

Mineral Chemistry

During imaging it was found that the quartz and plagioclase are very fresh-looking and constitute the major portion of the chip (Fig. 4). The texture is generally equigranular and medium to coarse grained. Four spot analyses in fresh-looking grains are presented in **(Table 1)**. The biotite analysis (GH-1) has been recalculated on (22O) basis while the three plagioclase analyses (GH-2, 3, and 4) have been recalculated on 32(O) basis. The recalculated analyses do not conform strictly to ideal compositions of the phases (compare Deer *et al.,* 2013), which raises the possibility of analytical uncertainty or alteration.

The biotite analysis contains higher SiO_2, CaO, Na_2O, and distinctly lower K_2O than standard biotite. These peculiarities are clearly reflected in the recalculated formula which contains lower sums of cations (Fe+Mn+Mg = 5.12) in X site than those of trioctahedral mica (ideal value = 6), and (Ca+Na+K = 1.81) in X site instead of ideal value (2 cations). These departures may suggest that despite the fresh look, the analyzed grain was altered. The presence of chlorite, prehnite, and (secondary?) muscovite, together with high SiO_2, CaO and Na_2O leads to think that alteration was complex and not straight forward chloritization. Jan and Howie (1982) have discussed the possible causes of chemical changes in biotitic micas from Kohistan, northern Pakistan. Grew *et al.* (1982) attributed the lowering of K_2O in biotitic micas in eastern Otago schists, New Zealand, to hydrothermal alteration and leaching.

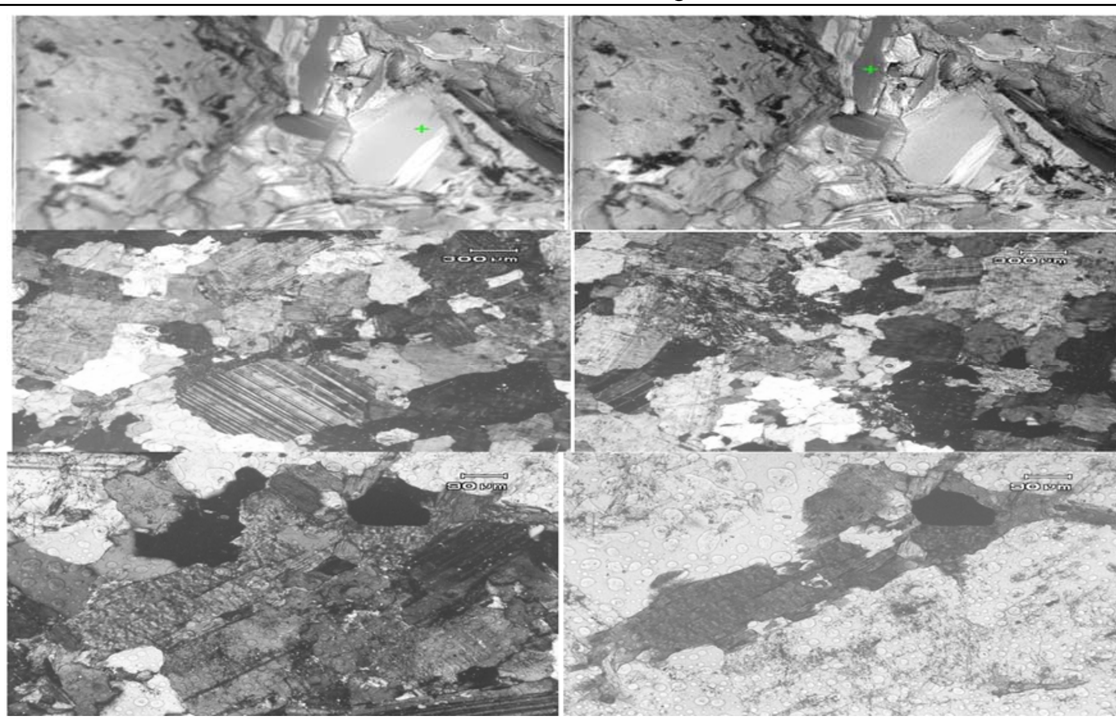

Fig. 3 Photomicrographs, where major portion is of plagioclase and quartz. The plagioclase (andesine) is with albite twinning. After quartz, the dominant phase is biotite altered in chlorite. Some ores are also visible.

F* = total iron expressed as Fe^{2+} in 1 and Fe^{3+} in 2-4.
GH-01: Biotite; GH-02 to 04: Andesine

Ti	0.324	--	--	--
Fe*	1.827	0.153	0.153	0.139
Mn	0.029	--	--	--
Mg	1.865	0.113	0.246	0.135
Ca	0.176	1.245	1.331	1.367
Na	0.670	3.088	3.207	2.442
K	0.966	0.176	0.264	0.261
Z	8.00	15.83	15.71	15.94
X	1.81	4.62	5.08	4.21
Y	5.12	--	--	--
100Ca/ (Ca+Na)		28.7	29.3	35.9

F* = total iron expressed as Fe^{2+} in 1 and Fe^{3+} in 2-4.
GH-01: Biotite; GH-02 to 04: Andesine

All three of the plagioclase analyses have lower total amount of cations (Mn+Mg+Ca+Na+K) in Z site (ideal value = 16), and higher amounts of cations (Si+Al+Ti+Fe^{3+}) in X site than the ideal value of 4. Analysis GH-4 is, however, close to ideal composition. All the three analyses also contain higher FeO* and MgO than those normally reported in EPMA analyses and point to analytical error. The 100Ca/(Ca+Na) of the analyses are 28.7, 29.3 and 35.9. The higher value of the analysis GH-4, matches with the optically determined composition as well as the normative anorthite.

Major Element Geochemistry

The whole rock major element geochemistry of the studied sample is given in **(Table 1)**, together with CIPW norms. The normative An value [(Ca/(Ca+Na) = 37.2)] of the rock matches perfectly with that of the plagioclase composition (sodic andesine) determined optically. High amounts of SiO_2 (69.8 wt%) and Al_2O_3 (17.10 wt %), substantial CaO and Na_2O (4.8 and 4.2 wt %), low total iron (Fe_2O_3 2.3 wt %), and high Na_2O/K_2O suggest that the rock is indeed tonalite. The high quantity of andesine plagioclase and quartz, and low orthoclase and mafic components in the norms **(Table.2)** support the petrographic study and classification of the rock as tonalite.

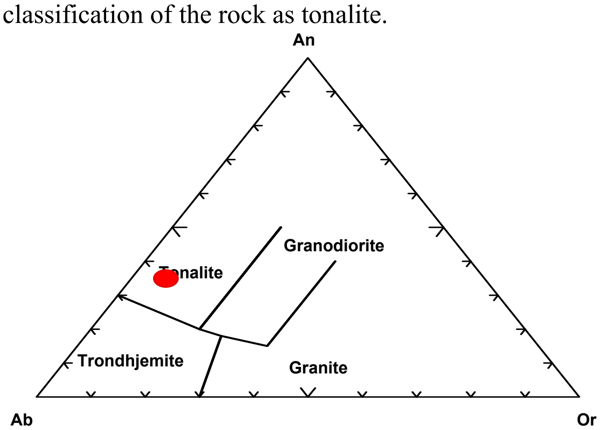

Fig. 5 Ternary diagram showing that the analyzed sample is tonalite (fields are after Barkar, 1979).

Table 1 Mineral Chemistry through EDS.

Sample	GH-1	GH-2	GH-3	GH-4
SiO_2	41.01	56.37	56.48	57.71
TiO_2	2.92	0	0	0
Al_2O_3	17.36	23.56	24.87	25.12
Fe_2O_3	16.45	1.09	1.12	1.02
CaO	1.11	6.24	6.85	7.05
MgO	8.48	0.48	0.91	0.5
MnO	0.23	0	?	0
Na_2O	2.34	8.55	9.12	6.96
K_2O	5.13	0.74	1.14	1.13
P_2O_5	?	0	0	0
Total	95.03	97.03	100.49	99.49

Structural formulas calculated on the basis of 22 oxygen for biotite and 32 oxygen for andesine

On the basis of normative Ab, Or and An values, the sample classifies as sodic according to Irvine and Baragar (1971), and in the diagram of Barkar (1979) for the classification of granitic rocks the analysis plots in the tonalite field **(Fig. 5).** The sample, according to the scheme of de la Roche *et al.* (1980) is of sub-alkaline nature **(Fig. 6).** In the Shand's molar Al/((Na+K) vs. Al/(Ca+K=Na+K) discrimination diagram of Maniar and Piccoli (1989), which is used to determine magma source lithologies, it plots in the field of peraluminous rocks **(Fig. 7),** suggesting a sedimentary protolith as source rock.

Table 2 Major element analysis along with CIPW norms of Ghar-e-Hira sample, Saudi Arabia.

Oxides	(Wt. %)	Norms	(Wt. %)
SiO_2	69.8	%AN	37.25
TiO_2	0.16	Q	28.94
Al_2O_3	17.1	Or	4.14
Fe_2O_3	2.32	Ab	37.82
CaO	4.76	An	22.46
MnO	0.07	C	1.3
MgO	1.15	Hy	3.18
Na_2O	4.21	Mt	1.21
K_2O	0.7	Il	0.22
P_2O_5	0.18	Hem	0.35
SO_3	0.05	Ti	0
Total	100.51	Ap	0.38

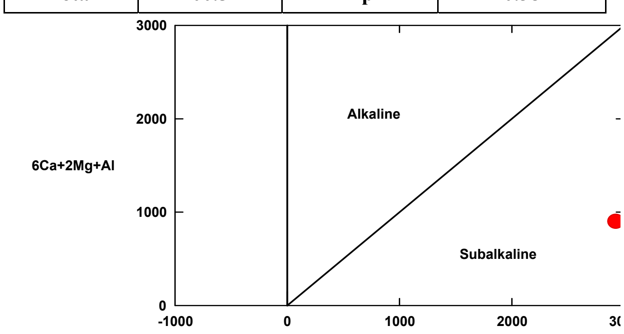

Fig. 6 The diagram of De La Roche *et al.* (1980) indicates the studied sample is of sub-alkaline nature.

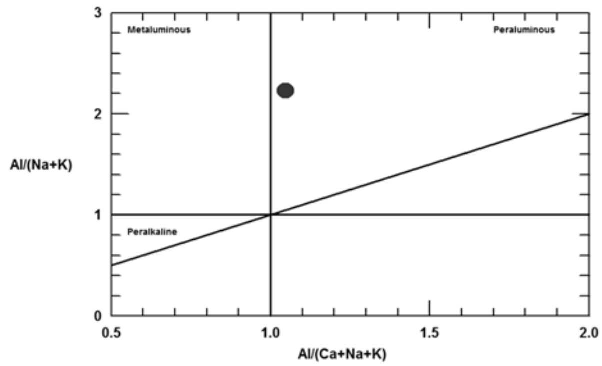

Fig. 7 Diagram showing that the Ghar-e-Hira sample belongs to peraluminous type of magma (after Maniar and Piccoli, 1989).

4. CONCLUSIONS

It is concluded that the Ghar-e-Hira is entirely different from the caves present in Saudi Arabia or elsewhere in the world in terms of petrography and geochemistry. The petrography, mineral chemistry and whole-rock geochemistry indicates that the rock, made up of plagioclase, quartz, K-feldspar, biotite, opaque oxide, muscovite and sphene, is tonalite in composition. The geochemical data also points out that the sample is of sub-alkaline nature, and of peraluminous type, suggesting a sedimentary protolith.

ACKNOWLEDGEMENT

The authors pay especial thanks to Dr. M. Q. Jan, Professor Emeritus of NCE in Geology, University of Peshawar, Pakistan for thin section study and valuable suggestions for the improvement of manuscript.

REFERENCES:

Al Quran, Chapter: Al-A-'Alaq, verses: 1-3. and E. S., Baldwin, (1938), Egyptian architecture as cultural expression. Appleton century, New York.

Barker, F., (1979), Trondjemite: definition, environment and hypotheses of origin, In: Barker, F., ed., Trondjemites, dacites, and related rocks: New York, Elsevier, 1-12.

Bender, F., (1975), Geology of the Arabian Peninssula: Jordan: U. S. Geological Survey Professional Paper 560-1, 36.

Buxton, R., (1994), Imaginary Greece: The contexts of mythology, Cambridge University Press: 1994.

Brown, G. F., R. and O. Jackson, (1960). The Arabian Shield. Int'l Geological Congress 2, 21 session,9, 69-77.

Craw, D., D. S. Coombs, and Y. Kawachi, (1982), Interlayered biotite-kaolinite and other altered biotites and their relevance to biotite isograd in eastern Otago, New Zealand. Mineralogical Magazine 45, 79-85.

Deer, W. A., R. A. Howie, and J. Zussman, (2013), An Introduction to the Rock-forming Minerals, 3rd ed. London: Mineralogical Society.
ISBN 9780903056274, 498.

Dela R., H., J. Leterrier, P. G. Claude, and M. Marchal, (1980), A classification of volcanic and plutonic rocks using R1-R2 diagrams and major element analyses - its relationships with current nomenclature. Journal of Chemical Geology, 29, 183-210.

Devereux, P., (1992), Secrets of ancient and scared places: The world's Mysterious heritage, London: Blandford, 192.

Gettings, M. E., H. R. Blank, W. D. Money, and J. H. Healy, (1983), Crustal structure of southwestern Saudi Arabia., U. S. Geological Survey, California. Open File Report 83-638.

Gettings, M. E., H. R. Blank, W. D. Money, and J. H. Healy, (1986), Crustal structure of southwestern Saudi Arabia. Journal of Geophysical Research, 91 (B 6), 6491-6512.

Greenwood, W. R., R. J. Fleck, and R. J. Roberts, (1997), Precambrian geological history and plate tectonic evaluation of the Arabian shield. Saudi Directorate General of Mineral resources, Bulletin 24, 350Pp.

Hussain, M., F. Al-Khaifah, and N. I. Khandaker, (2006), The Jabal al-Qarah caves of Hofuf area, northern Saudi Arabia: A geological Investigation. Journal of Cave and Karst Studies, 68 (1), 12-21.

Irvine, T. N. and W. R. A. Baragar, (1971), A guide to the chemical classification of the common volcanic rocks. Canadian Journal of Earth Science, 8, 523-548.

Jackson, N. J., N. J. Walsh, and E. Pegram, (1984), Geology and geochemistry and Petrogenesis of late Precambrian granitoids in central Hijaz region of Arabian shield. Contrib. Mineralogy and Petrology 87, Springer Verlag, 205-219.

Jan, M. Q. and R. A. Howie, (1987), Some garnets, epidotes, biotitic micas, and feldspars from the southern part of Kohistan, NW Pakistan. Acta Mineralogica Pakistanica 3, 5-25.

Johnson, P. R., (2005), Explanatory Notes on the Map of Proterozoic Geology of western Saudi Arabia. Saudi Arabian Geological Survey Technical Report SGS-TR-2006-4, 62Pp.

Johnson, P. R. and F. H. Kattan, (2008), Lithostratigraphic Revision in the Arabia Shield: The impacts of Geochronology and Tectonic analysis. The Arabian Journal for Science and Engineering, 33 (1C), 3-16.

Khan, M., (2003), Rock art of Saudi Arabia. Journal of Arts 2, 447-475.

Kumar, A., (2013), Geological and Environmental observations on Ali Baba (A Qurah) caves and Al Hasa Oasis of Al Hofuf in eastern province of Saudi Arabia: an overview of quaternary history of the Arabian Peninsula. Earth Science India 5 (I), 1-19.

Maniar, P. D., and P. M. Piccoli, (1989), Tectonic discrimination of granitoids. Journal of Geological Society of America, Bulletin, 101, 635-643.

Moore, T. A., and M. H. Rehaili, (1989), Geologic map of the Makkah Quadrangle, sheet 21D, Kingdom of Saudi Arabia. Saudi Arabian Directorate General of Mineral Resources, Geoscience Map GM-107C, Scale 1: 250,000, 62.

Pint, J., (2003), Desert caves of Saudi Arabia: Stacey Internal London, 120Pp.

Pint, J., (2009), The lava caves of Khyber, Saudi Arabia. Proc. 15th International Congress of Speleogy, Texas. 1873-1878.

Palmer, A. N., (1991), Origin and morphology of limestone caves, Geological Society of America Bulletin, 103, 1-21

Schmidt, D. L., W. R. Hadley, L. Greenwood, R. G. Conzalez, and G. F. Brown, (1973), Stratigraphy and Tectonism in southern part of the Precambrian Shield of Saudi Arabia, Saudi Arabian Directorate General Bulletin of Mineral Resources, 8, 13Pp.

Siddiqui, N. K., (1999), A geologist's visit to Ghar-e- Hira, daily Dawn, (27th June, 1999). Herald Publisher Karachi.

Solami, A. A., G. A. Barakati, S. A. S. Sayed, S. A. Bahloul, and B. A. Tunsi, (2006), Engineering geological mapping of the Holy city of Makkah al Mukarramah, Saudi Arabia, AEG2006, Paper Number 552, Geological Society of London.

USGS-ARAMCO., (1963), Geological map of Arabian Peninsula, U. S. Geological Survey Misc. Geological Investigations Map, 270Pp.

Vaslet, D. (1990), Upper Ordovician glacial deposits in Saudi Arabia. Episodes, 13(3), 147-161.

Youssef, A. M., B. Pradhan, M. Al-Kathery, G. D. Bathrellos, and D. Skilodimou., (2015), Assessment of rock fall hazard at Al Noor Mountain, Makkah city (Saudi Arabia) using spatio-temporal remote sensing data and field investigation. Journal of African Earth Science 101, 309-321.