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MINERAL OCCURRENCES IN THE BADIA REGION/NE JORDAN

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ABSTRACT

The Cenozoic continental basaltic rocks exposed in northeast Jordan are the northern extension of the North Arabian Province, which covers a total of more than 46,000 km2, of which 12000 km2 are only in Jordan. The mineral resources of the Badia region in northeast Jordan are very important to the national economy of Jordan, due to the fact that unlimited reserves of industrial commodities are widely distributed in the region. Therefore, one of this research aims of this map is to indicate the occurrences and distribution of the mineral resources in the northern Badia Region. To facilitate study, evaluate and exploit these resources for the investors in this sector. The idea was to shed light the location of the previously indicated mineral resources and to indicate the location and distribution of the newly discovered localities during this mapping project. The paper summarizes the available data published on the mineral commodity and the results of the analysis, which were carried out as part of this work.

1. Introduction

The mineral resources of the Badia region are very important to the national economy of Jordan, due to the fact that unlimited reserves of industrial commodities are widely distributed in the region. Therefore, one of the main aims of this paper is to indicate the occurrences and distribution of the mineral resources in the northern Badia Region. To facilitate study, evaluate and exploit these resources for the investors in this sector. The idea was to show on the map the location of the previously indicated mineral resources and to indicate the location and distribution of the newly discovered localities during this mapping project. Therefore, each mineral resource was given a different symbol shown on the map. The paper summarizes the available data published on the mineral commodity and the results of the analysis, which were carried out as part of this work.

2. Basalt

(a) Occurrences. it is the most widespread mineral resources in the mapped area, covering more than 70%. Two quarries were indicated in the map, one is less than 3km to the north of Tell Hassan and the second is about 22km to the east of Safawi. Several potential areas are present in the area, mainly the extensive exposed Abed Olivine Phyric Basalt Formation, which can be considered as suitable occurrences for future exploitation programs.

(b) Reserves and Production. The area holds unlimited reserves of basalt and because of its wide availability, it was formerly used for construction purposes. During the Nabatian, Roman Byzantine and early Arabic periods, basalt was extensively used in Northeast Jordan. It is evidenced from the ancient castles (Qasr) in the area such as Qasr Al Azraq, Qasr Usaykhim, Qasr Uaynid, Qasr al Huwaynit Deir el Kahf and Umm el Jimal, which are built completely from the basalt. The old buildings of Al Azraq town and the BRDP center at Safawi (an abandoned oil pumping station, H5) were also built of basalt. In the present time, basalt is not used anymore as a building stone in the area with few exceptions.

(c) Physical and Technical Properties. The physical characteristics of basalt as resistance to weathering and corrosive chemicals, durability and strength with a low porosity and permeability makes it a potential source as a decorative stone (Table 1).

Table 1. Physical properties of the basalt of NE Jordan, (from Nawasreh, 1993)

Density (g/cm^3)		2.50-2.77
Unconfined compressive strength (kg/cm^2)		225.5-5437
Specific gravity (g/cm^3)	bulk	2.66-2.80
	saturated surface	2.70-2.85
	apparent	2.82-2.92
Water absorptipn(%)		1.47-2.28
Abrasion (%)		23.4-28.4
Crushing strength (atm)		1700-2200
Cohesive strength (atm)		320-440
Thermal conductivity for melt at STP* (cal/cm^2)		1-30
Thermal conductivity for rock at STP(cal/cm^2)		4-6
Heat capacity at constant pressure (cal/c/g)		0.2-0.3

*STP *is standard temperature and pressure*

3. Rock Wool and Cast Basalt

(a) Definition. Rock wool (an artificial product) is composed of extremely thin silicate fibers, where basalt forms more than 70% of the raw material with siliceous or argillaceous rock, make up the rest.

(b) Occurrences. As was indicated earlier, basalt is the most widespread mineral resource in the area, however, those areas suitable for rock wool and cast basalt are not indicated in the map, because detailed studies to verify there physical and chemical properties was not carried out. The evaluation of the NE Jordan basalt for cast industry is highly recommended.

(c) Uses. Rock wool is used in insulation and energy conservation. These can be used as loose "wool", but can also be bonded together with resin binders to form rolled mats, rigid panels and pipe sections. Rock wool has the following properties:

- Low coefficient of heat transfer;
- High acoustical insulation;
- Weather, water, & damp proof;
- Light in weight;
- Noncombustible;
- Non corrosive.

(d) Physical and Technical properties. Rock Wool: Basalt suitable for this wool industry needs to have low $Ti0_2$, MgO, FeO contents and high alkali contents. Homogeneity of the raw material, fine-grained texture and low melting point are also important. The basalt exposed in NE Jordan are almost similar to those quarried by the Jordan Rock Wool Company and are of good potential rock wool industry. The standards requirements for rock wool are as follows:

$$Ma\ of\ acidity=(Si0_2+Al_20_3)/(MgO+CaO) =2.5\text{-}3.0$$

Cast basalt (petrurgy): It requires a raw material similar in composition to that used by rock wool industry. Basalt must be alkaline, undersaturated with respect to silica, homogeneous with a constant composition, fine-grained and not weathered. A raw material with a low melting point is necessary i.e. melting is executed on an industrial scale using 10-30 cm pieces at 1300° C. Table 3 shows the chemical and mineral composition of basalt needed for cast basalt. *Table 3 Chemical and mineralogies! composition for cast basalt, after Ibrahim (1997).*

Table 2. Chemical and mineralogical composition for cast basalt, after Ibrahim (1997)

SiO_2 (%)	43.5-47.0	CaO (%)	10.0-12.0
Al_2O_3 (%)	11.0-13.0	MgO (%)	8.0-11.0
TiO_2 (%)	2.0-3.5	Na_2O (%)	2.0-3.50
Fe_2O_3(%)	4.0-7.0	K_20(%)	1.0-2.0
FeO (%)	5.0-8.0	P_20_5 (%)	0.5-1.0
MnO (%)	0.2-0.3		
magnetite		4-8	
pyroxene		45-60	
olivine		10-15	
plagioclase		15-25	
nepheline		0-10	

The standards requirements for cast basalt are as follows:

- Ma = (SiO+Al203)/(MgO+CaO) = 1.1-3.0;
- Mb = (Ab'+2.3Di' + 1.8Hy') CIPW normative = 123-136.

4. Scoria (Pozzolana)

(a) Occurrences. Scoria (Pozzolana) is widely distributed in the map area, such as Tell Rimah, Tell Hassan, Jibal Zumal al Hashshad (two cones), Jabal Mafarid al Asfar (three cones), Jibal al Aritayn (two cones), Jibal al Manasif al Gharbya (three cones), Jibal al Manasif ash Sharqiyya (six cones), Jabal al Fahem., south and southeast of Jabal al Asfar (six cones), Tulul Ashaqif (six cones), Jabal ed Dhirwa, Tulul el Bassus (three cones) and Tulul el Ghussaun (three cones).

(b) Uses. The scoria deposits from all the above-mentioned cones are of great potential for use in cement industry, in agricultural applications and as lightweight aggregates. In the cement industry, pozzolana is added to the cement for two purposes:

- A corrective material for Fe content in the cement mixture in proportions up to 10% by weight before the reaction in order to produce Portland cement;
- An additive material, to standard Portland cement in proportions from 10-30% by weight at low temperature and then ground finely to produce Portland pozzolanic cement.

(c) Reserves and Production. Exploitation of scoria is a relatively simple, surface mining operation. Expected reserves of pozzolana in the map area are huge, estimates from some of the important volcanic cones are illustrated Table 4.

Pozzolana is currently quarried from Tell Rimah and Tell Hassan for use in cement industry and in agricultural applications, by the Jordan Cement Company and Al-Qawasmeh Company. The total production of pozzolana from the map area in the last four years exceeds 600,000 ton, as shown in Table 5.

Table 4. The estimated reserves of pozzolana in the Badia region. Data from Jordan Cement Company (1985) except * from Al-Malabeh(1993).

Locality	Reserve (x 10^6 ton)
J. Fahem*	10.46
J Aritayn (N)	67
J. Aritayn (S)	102
J. Ufayhimat (N)	25
J. Ufayhimat (S)	21
J. Jilad	68
J. al Manasif al Gharbya	91
J. al Manasif ash Sharqiyya	6
J. Ushayhib	4
Total	394.46

Table 5. Annual production of pozzolana from the map area in thousand ton. * data from Abed and Omari (1994)

Year	1992*	1996	1997	1998	1999
Tell Rimah		91.862	222.621	100.757	199.892
Tell Hassan		3.400	4.509	10.396	11.900
Total	410	95.262	227.130	111.153	211.792

(d) Physical and Technical Properties. Some of the important physical parameters of the pozzolana in the Badia region are given in Tables 6 and 7.

Table 6. Physical parameters of Tell Hassan and Jabal Fahem pozzolana (from Al-Malabeh, 1993). Hco is cone height and Wco is cone basal width

Parameters	Tell Hassan	Jabal Fahem
Water absorption	10.8 %	9.2 %
Main colors	gray, gray to brown	brown, gray, reddish-brown
Abrasive value	35 %	52 %
Unit weight	1010 kg/m^3	980 kg/m^3
Specific gravity	1.801 g/cm^3	1.79g/cm^3
Aspect ratio		Hco = 0.026 Wco

Table 7 Selected physical properties of the pozzolana in the area. Data from Jordan Cement Company (1985).

Locality	Hydraulic Factor	Strength (Nt/cm^2)	Specific Gravity (g/cm^3)	Loss on Ignition (%)
J. Fahem	41	1212	1.4	5.6
J. Aritay n (N)	52.5	1190	*1.57*	6.5
J Aritayn (S)	31	810	1.85	6.6
J. Ufayhimat (N)	39	1112	1.78	5.8
J. Ufayhimat (S)	37.5	729	1.64	9.7
J. Jilad	22	-	1.7	5.8
J. Al Manasif al Gharbya	41	1005	1.59	2.7
J. Al Manasif ash Sharqiyya	19	280	1.58	4.7
J. Ushayhib	28	210	1.64	2.6

For cement industry, the hydraulic factor is an important parameter, the higher is this factor the more suitable is the material. The hydraulic factor of the pozzolana varies from 19 to 52.5. It was reported by the Jordan Cement Company (1985) that the presence of zeolites enhances significantly the hydraulic factor of the pozzolana.

During this mapping project, selected samples from the pozzolanic material of Jabal ed Dhirwa were evaluated. The study revealed that pozzolana is characterized by bad cementing, good sorting and with specific gravity of 1.6 g/cm3. Size classification of Jabal ed Dhirwa pozzolana.

Table 8. Chemical composition of Jabal ed Dhirwa pozzolana

Major Oxide	Wt%	Major Oxide	Wt%
SiO2 (%)	40.24-46.63	MgO (%)	5.00-5.07
CaO (%)	11.88-16.00	TiO2 (%)	1.33-1.45
Fe2O3 (%)	7.66-8.43	K2O (%)	1.03-1.22
Al2O3(%)	12.50-13.86	Na2O(%)	2.68-5.12

5. Zeolites

(a) Definition. Zeolites are a group of hydrated alkali alumino-tektosilicates, which are characterized by their open crystalline structure.

(b) Occurrences. In the mapped area, zeolites were indicated in several areas including Jabal Aritayn (N) and Jabal Aritayn (S), Tell Rimah, Tell Hassan, Tulul Al Ashaqif and Jabal Hannoun. Phillipsite tuff was discovered by Dwairi (1987) in Jabal Aritayn (S), whereas, the economic zeolite deposits in the other localities in the Badia region were discovered by Ibrahim, (1996b) occurring in the Aritayn Volcaniclastic Formation and are restricted to a diagenetic zone with variable thickness from few meters up to 20 m.

(c) Uses. Based on their unique structure zeolites can be used in the following applications:

- Slow release fertilizers and soil amendments;
- Industrial and municipal wastewater treatments;
- Gas and oil purification;
- Animal nutrient, fish and poultry farming;
- Reduce strong odor intensity and ammonia gas concentration from farms.

(d) Reserves and Production. Quantitative determination of zeolites indicate that the mineral content range between 20% to 65% by weight (Ibrahim, 1996b; Ibrahim and Inglethorpe, 1996). Preliminary studies indicate the presence of a huge reserve. Small quantities of the zeolitic tuff is extracted from Jabal Aritayn (N) every year (Table 9) by an American-Jordanian Company (Green Technology) and exported to Israel. The zeolitic tuff product is activated by synthetic fertilizers for agricultural and gardening uses. Unfortunately, zeolite deposits from Tell Rimah area are over exploited as being mined along with pozzolana for the Jordan Cement Company.

Table 9. Annual production of the zeolitic tuff from Jabal Aritayn (N)

Year	1997	1998	1999
Production (Ton)	3193	543	408

(e) Physical and Technical Properties. Using simple mineral processing techniques, zeolite grade could be concentrated to the range between 85% and 96% (Ibrahim, 1996b; Ibrahim and Ingelthorpe, 1996). The identified zeolite minerals are phillipsite, faujasite and chabazite. From the Badia region 8 zeolite concentrates were produced, and were given the symbols: Zeordan 1 - Zeordan 8 (Ibrahim, 1996b). Experimental investigations on the zeolitic tuff emphasized the importance of the Jordanian zeolites for use in wastewater treatment plants and as a soil conditioner and as slow-release fertilizer.

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