MINISTRY OF ENERGY AND MINERAL RESOURCES
Mineral Status and Future Opportunity

KAOLIN

Prepared By

Dr. Suha M. Yasin — **Geo. Ali Ghannam**

Edited By

Geo. Julia Sahawneh — **Geo. Marwan Madanat**

2014

CONTENTS

List of Figures

List of Tables

List of Appendices

Kaolin

1. Introduction

Kaolin is white, soft, plastic clay mainly composed of the fine grained platy mineral kaolinite; a white hydrous aluminum silicate, $Al_2Si_2O_5(OH)_4$, containing 23.5% alumina, 46.5% silica, and 14% water. It is soft, with a moderate refractive index of 1.56, and occurs as extremely small hexagonal-shaped crystals of micron and submicron size.

It is used in the manufacturing of white-ware ceramics, and the main use now is in the filling and coating of paper. It is also used as filler in paints, rubber, plastics and many other productions. Whiteness, fineness and controllable particle size are well known criteria of kaolin.

Kaolin deposits are classified as primary or secondary in origin. Primary (Residual) kaolin is formed by in situ alteration of granite or granitic gneiss, while secondary kaolin may have been formed by transportation and deposition of kaolinite that was formed somewhere else.

2. Kaolin Applications and Specifications

Table (1): Kaolin Specifications for industrial uses (Industrial Minerals Handy Book IV, 2002).

Industry	Specification
Paper grade: **1. Filler grade**	Kaolinite >90%, low Fe_2O_3 and TiO_2 (<1%), low abrasive quartz (1-2%), brightness of 80+%, particle size of 50-70% <2 μm and Brookfield viscosity <4000cpe.
2. Coating grade:	Kaolinite 90-100%, low Fe_2O_3 (0.5-1.8%) and TiO2 (0.4-1.6%), no abrasive quartz, brightness of 85+%.particle size of 80-100% <2 μm and Brookfield viscosity <7000cpe.
Paint and plastic: **Paint grade**	Average particle size 0.2 μm or hegman grind 6+, GE brightness 90-92, pH 6-8, oil absorption 41-46 (ASTM D281),and free moisture
Ceramic grade:	75-85% kaolinite, bone china and porcelain require a fired brightness of 83-91%, 1180ºC and <0.9%Fe2O3. Viscosity control and strength of clay bodies are important. Other critical tests include modulus of rupture, casting rate, PCE and shrinkage.
White ware	50% kaolin, 20% ball clay.
Stoneware	60% kaolin, 10% ball clay.
Porcelain (tableware, cookware)	20% kaolin, 30%ball clay.
Electrical porcelain (insulators in power generation and transmission)	25%kaolin, 25% ball clay.
Earth ware (colored pottery, base material for sanitary ware, tiles)	20-30% kaolin, 20-30% ball clay
Vitreous chinaware (sanitary ware, tableware)	25%kaolin.

Refractory grade:	Refractory clays are required to withstand temperature of 1500ºC (PCE19). Other tests include re-heat, hot load test, panel spalling test, apparent porosity, bulk density, and cold crushing strength. Refractory clays may be classified based on Al_2O_3 content low alkali and iron are preferred.
Fiberglass grade	Used as a source of Al_2O_3 and SiO_2. Typical content is 37% Al_2O_3 and 44% SiO_2 with max. 1% Fe2O3, 2% Na_2O, and 1%H_2O.
Rubber grade	Kaolin is classified by particle size as hard or soft, with hard clays having a slightly smaller particle size which yields a stiffer uncured compound resulting in a higher tensile strength and abrasion resistance when cured. The pH required is 4.5-5 since fillers with an excessively acidic pH acceterate the curing of rubber formulation resulting in premature curing in the mold.
Cosmetic grade:	(Light kaolin BP) maximum 2 ppm arsenic, 20ppm heavy metals, 350 ppm chlorides; 15 wt.% LOI; pH 7.5±0.5.

3. Locations and Geological Setting

The kaolin deposits are almost exhausted in Mahis and Ghour Kabid areas (Central Jordan). Other kaolin deposits are exposed in four main locations in south Jordan; Batn el-Ghoul (Jabal al Harad), Al-Mudawwara, Jabal Umm Sahm and Dubaydib (Figure 1, Figure 2 & Table 2). All areas have been exploited to a small extent. Mudawwara kaolin is still not exploited.

The three deposits are of Ordovician Age (Llanvirn-Llndovery). Locally, both Batn el-Ghoul and the Al-Mudawwara deposits belong to the Al-Batra Mudstone member. The thickness of this member ranges between 15 and 60 m at Batn el-Ghoul to more than 80 m at Al-Mudawwara area. It is exposed in a wide area near the surface and the overburden is thin.

On the other hand, Jabal Umm Sahm and Dubaydib deposit belongs to Al-Hiswa Sandstone Formation, with a thickness of about 35 m. This formation is exposed in the area with an overburden thickness ranging between 0 - 25 m. Attachment maps show the location and geology of kaolin deposits in Jordan.

3.1. Batn El-Ghoul Deposit

This area is located about 70 km southeast of Ma'an city about 280 km south of Amman city on both sides of Ma'an - Mudawwara road. The elevation of the upper surface of the deposit ranges between 690 -730 meter above sea level.

3.2. Al-Mudawwara Deposit

It is located about 120km SE of Ma'an city, about 10km east of Al-Mudawwara police station. The elevation of the upper surface of the deposit ranges between 720 and 750m above sea level.

3.3. Jabal Umm Sahm and Dubaydib Deposit

It is located about 45Km east of Al-Quweira town, south to Al-Hiswa railway station, and can be reached by Wadi Rum-Al Disi tourist road. The elevation of the upper surface of the deposit ranges between 850 - 950m above sea level.

The three area deposits are easily accessible by metalled roads and tracks. Metalled roads connect the three areas with the neighboring countries and Aqaba harbour. In addition to the electrical network, the communication system and the railway line that serve Phosphate Mine Company also pass close to the three deposits.

The area of deposits is characterized by an arid climate, from April to October the climate is hot, dry summer with an average temperature of 35° C; and from November to March is cold, dry with an average temperature of 15° C. The rainfalls occur rarely during the winter and the average rainfalls ranges from 50 to 100mm annually.

Figure (1): Jordanian kaolin deposits location.

Table (2): Natural Resources Authority studied areas.

Area		Area (Km^2)	Coordinates (Palestine Belt)		Name of sheet	Authors
			East	North		
Batn el-Ghoul	Eastern area	25	240000-245000	0886000-0891000	Jabal al Harad	Barkat & Hammory/ 1994
	Western area	10	236000-239000	0891000-0896000		
		37.5	240000-246550	0880500-0886000		Abu Salah & Ghannam/ 2001
	First area		239000-243000	0897000-0900000		Madanat, Ghannam & Al-Rousan/ 2005
	Second area		233000-238000	0898000-0902000		
Hiswa	Part A	3	214000-215000	0884000-0887000	Jabal Umm Sahm	The Jordanian Co. for Mining and Processing of Kaolin & Feldspar/ 1997
	Part B	20	216000-220000	0885000-0890000		
	Part C	27	215000-218000	0893000-0902000		
Al-Mudawwara		150	257000-267000	0850000-0865000	Al-Mudawwara	Kailani & Abu Salah/1997
Jabal Umm Sahm	First area	17.6	220000-225000	0874000-0862500	Jabal Umm Sahm & Bir As Saladih	Abu Salah & Ali Ghannam & Nidal Mehyar/ 2000
Dubaydib	Second area	14.9	222300-225000	0862500-0869000	Dubaydib & Jabal Ladghayn	Abu Salah & Ali Ghannam & Nidal Mehyar/ 2000

4. Estimated Reserves of the Jordanian Kaolin

4.1. Areas with Kaolin Potential

According to Natural Resources Authority, estimated kaolin reserves in various areas in Jordan are as follows in Table (3).

Table (3): Geological reserves of kaolin deposits.

Location		areas	Reserve (Mt)		Thickness (m)
Batn el-Ghoul	Barkat & Hammory/1994	Eastern area	894	**2200**	7.5-47
		Western area	406		
		Surface hills	9.5		
	Abu Salah & Ghannam /2001		884		
Al-Mudawwara				**9700**	22-102
Al-Hiswa				**54**	3-20
Jabal Umm Sahm & Dubaydib				**1090**	2-4

5. Kaolin Properties

5.1. Chemical Properties

Following table (4) shows the results of the chemical analysis for kaolin samples in different studied areas.

Table (4): Major oxides contents of the kaolin in studied areas.

Area	Al_2O_3 %		SiO_2 %		Fe_2O_3 %	
	max.	min.	max.	min.	max.	min.
Batn el-Ghoul	25.37	14.01	68.32	47.79	8.37	4.05
Al-Mudawwara	27.54	13.36	70.20	41.87	10.54	4.54
Al-Hiswa	29.27	12.94	78.88	49.04	9.09	1.15
Jabal Umm Sahm & Dubaydib	24.70	17.00	61.97	49.04	11.04	3.50

5.2. Mineralogical Properties

Kaolin deposits are mainly composed of kaolin and quartz minerals and other minerals as minor content (Table 5).

Table (5): Mineralogy of kaolin deposits.

Sample No.	Q	K	M	F	G	P	Al	H
Al-Mudawwara	**	***	*	-	*	-	-	-
Batn El Ghoul	***	***	*	*	*	*	--	-
Jabal Umm Sahm	***	***+	*	*	*	*	*	*
Dubaydib	***	***+	*	*	*	*	*	*

Q = Quartz. K = Kaolinite. M = Mica. F = Feldspar. G = Gypsum.
P = Pyrite. Al = Alunite. *** = Major. ** = Minor. * = Trace.
H=Hematite.

6. Processing of Jordanian Kaolin

In order to compete with the regional and worldwide markets, Jordanian kaolin should be upgraded. Following some research attempts performed on the Jordanian kaolin for upgrading purposes, the Jordanian kaolin could be upgraded and be used in some industries as in the following:

- Using the Jordanian clays as a raw material in Ceramics industry was proved successfully by the study of the clay deposits in Jabal Umm Sahm by Al-Momani (2000). Al-Momani used the clay (Light grey-A1, dark grey-A2 and varied coloured-A3) in tiles and sanitary ware manufacturing. The results showed that the physical, chemical, mineralogical, technical and industrial characteristics of Jabal

Umm Sahm clay deposit could compete with the standard specifications (Table 6). In addition, he demonstrated that Umm Sahm kaolin could be used as filler and extender in Paints industry.

Table (6): Comparison between the typical chemical composition and the technical properties of clay materials for ceramics tiles (Al-Momani, 2000).

Typical chemical composition and technological properties (%) of clay materials for ceramic tiles from different countries		**Chemical composition and technological properties (%) of Al-Hiswa clay deposits-Jordan (Kaolin A1, A2, A3)**		
Chemical Composition (wt. %)				
SiO_2	44.90-70	52.32-58.73		
Al_2O_3	19.61-32.0	19.25		
Fe_2O_3	0.5-8.6	1.80		
TiO_2	0-1.4	0.83		
CaO	0-1.0	0.06		
MgO	0.05-1.96	0.15		
K_2O	0.05-1.98	1.39		
Na_2O	0-1.0	0.08		
SO_3	0.12-0.80	0.31		
L.O.I	7.5-13.60	9.36		
Technological Properties (wt. %)				
		Kaolin A1	Kaolin A2	Kaolin A3
Plastic Limit (wt. %)	16-26	23.51	23.56	18.09
Liquid Limit (wt. %)	23-42	40.32	41.48	30.05
Plastic Index (wt. %)	9-26	16.81	17.92	11.96
Brightness	21.60- 84.43	19.02-74.46		
Water absorption □ 1050°C □ 1250°C	 17.87 4±3	 16.6-23.3 7.4-8.8		
Firing Shrinkage □ 1050°C □ 1250°C	 4.4 11.4	 0.8-2.18 8.3-14.4		

- Clay deposits in Batn el Ghoul studied by Bayook (1992). The studies concluded that the deposits are suitable for ceramics industry and as a source for Aluminum (Table 7).

Table (7): Chemical composition of Batn el Ghoul clay deposits (whole rock sample and less than 2μm

	SiO_2 %	Al_2O_3 %	TiO_2 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	L.O.I %
Batn el Ghoul clay	47.62	24.89	0.72	6.11	1.01	0.49	0.84	2.35	15.68
Size fraction <2μm	45.75	32.29	0.89	4.06	1.00	0.07	0.17	2.28	13.15
Ball clay	54.10	30.08	1.20	1.00	0.30	0.20	0.01	2.20	10.20
China clay	48.00	36.30	0.10	1.00	0.30	0.10	0.10	1.80	12.30

- Awawdeh (1991) evaluated Batn el Ghoul clay and concluded that it can be used as bricks, tiles, drainage pipes and as can filler in rubber and plastics. Many industrial experiments done on the clay such as color measurements, oil absorption, Plasticity, shrinkage, water absorption.

- In 1995 Tahat and Zawahreh from mineral processing and upgrading department in NRA done many upgrading experiments on Jabal Umm Sahm & Dubaydib kaolin. The results were encouraging to be used in different industries (Table 8).

- Batn el Goul clays were successfully tested and used in manufacturing stoneware pipes and tiles by Geoindustria (2000).

- Mudawwara clays were used in producing light building materials, which only mentioned briefly in the Czech report, Geoindustria (2000).

Table (8): Jabal Umm Sahm & Dubaydib kaolin upgrading results (Tahat & Zawahreh, 1995).

Trench No.	Elements%	Before Upgrading (%)	After Upgrading (%)
Ms1	Al_2O_3	24.0	31.8
	Fe_2O_3	5.0	1.91
	SiO_2	49.0	48.61
Ms2	Al_2O_3	26.0	31.9
	Fe_2O_3	6.0	1.61
	SiO_2	52.0	45.61

7. Investment Opportunities

7.1. Cement Industry

Cement industry is one of the most important players in the Jordanian mining sector. Thus, it depends solely on the domestic natural minerals as raw materials such as kaolin. There is a rapid growth in local cement market due to the recent booming in the building construction industry and one of the promising markets for Jordanian cement is rebuilding Iraq.

From exports and import quantities of different types of cement (Table 9), it can be seen that the country export quantities more than imports which is limited in white cement and nil for Portland cement in 2005. In year 2006 nearly the export nil and quantities were exported this is due to the high boom in building sector and some problems in the Jordan Cement Factory which exported the needed quantities from Egypt (Table 9).

Table (9): Exported and imported quantities (tons) of different types of cement (Statistic Department, 2006).

Commodity	Country	2005		2006	
		Export Quantity	Import Quantity	Export Quantity	Import Quantity
White Cement	Free Zone	205		236	
	Syria	39,177		21,914	
	Saudi Arabia	268			
	Egypt		10,471		8,392
Portland Cement, Other Than White Cement	Free Zone	347		23	
	Palestinian N.A.	29,653			
	Iraq	118,856			
	Syria	55,971			
	Saudi Arabia				32
	Egypt				19,546
Aluminous Cement	U.K.		4		6
Other Hydraulic Cements	Saudi Arabia		118		48
	Italy		6		

Two currently cement factory are in process the third and may be two more will start production in few years later. This will increase future demands on kaolin. Potential areas which have huge reserves of kaolin are Batn el-Ghoul and Jabal Umm Sahm and Dubaydib areas which exploitation still limited in it and Mudawwara area which not exploit yet.

7.2. Ceramics (Sanitary Ware and Tiles)

Jordan is one of the less well-known ceramics manufacturing bases in the Middle East. However, the kaolin producers have enhanced their position on the global stage due to a steadily expanding domestic market and a program of product improvement. Kaolin produced from two areas: Mahis area for ceramics applications and Batn el-Ghoul for floor tiles.

Jordan Ceramic Industries Co. (JCC) was the first ceramic company registered in 1966. It Ceramic Industries Co. (JCC) was the first ceramic company registered in 1966. It the following principal ceramics factories have also been set up: Arab Ceramic, Al Mass Company for Ceramic, International Ceramic Co. (stopped using local kaolin) and Al Moosely Shop. Still consumption of local kaolin from these companies still limited. Many other companies exist but all of its products are imported. It can be noticed from the tables the big difference between exported and imported quantities. Hundred thousands tons of imported tiles indicate that still there is a good opportunity to invest in this sector, to cover Jordan and neighbour countries market needs. So, more studies on the kaolin processing and developing this industry are recommended.

The renewal and the development of the ceramic industry have brought about a great demand for training the workforce employed in the sector. Technicians should continuously taking part in training programs which provide courses in ceramic tile production processing and machinery operation, so they can keep up with the constant changes and innovations taking place in the ceramic industry.

7.3. Artistic Ceramic Ware

It is worth mentioning that in Jordan today there are many shops producing artistic ware such as simple vases, statues, murals and oriental dishes, many of which are decorated with holy pictures. There is also a growing demand for these items by the increasing amount of tourists that are flocking to the country.

Virtually all of these artistic ware suppliers are small-scale concerns and as such depend heavily on the country's large factories to assist with the processing of their raw materials and supply of glazes and other decorative materials.

To date this system has been working well, but the increasing prevalence of cut-price ornamental ware from China is just starting to have an effect on the viability of some of these smallest craft shops.

7.4. Tableware and Kitchenware

This industry nearly does not exist. It is restricted to what manufactured with artistic ware. Table (24) shows that exported quantities are very limited and as other ceramics products most of it imported.

7.5. Stoneware (Pipes and Tiles)

The usability phase of Geoindustria technological work (2000) resulted in verification of the suitability of Batn el Ghoul deposit sequence as ceramic clay for production of the stoneware assortment, i.e. stoneware pipes, and stoneware floor tiles namely. Two qualitative clay types are present in Batn el Ghoul, with low Fe2O3 content (white

claystone) and high Fe2O3 content (mottled claystone). The white claystone can be easily separated by means of hand sorting of bulks and fragments of the mined claystone mottled layer. Because of the light colored and non-vitreous body after burning, white clays are classified as ceramic clay suitable for alumina white ware production. The red colored portion of the claystone mottled layer remains in quality of the raw material suitable for the stoneware production.

Bulk sample used composed of 75% of Batn el Goul clay and 25% of Czech fire-clay grog RAKO. The blends for production of stoneware pipes and floor tiles manufacturing were prepared. The tubes were pressed, dried and fired in the industrial units of Calfrig in Borovny; the tiles were pressed, dried and fired in KERMAST Co. factory in Prunerov.

The technological parameters of the processes and the qualitative parameters of the test products are summarized in tables (10 & 11).

Depending on the technological and geological data Geoindustria proposed to establish ceramic plant. The production of various stoneware pipe products was assessed as the most preferable assortment in Jordan. Considering the European relations the annual production capacity on 14,000 tonne is applied as minimal for the feasible plant establishment, and the most common pipe diameters (100-300mm) were chosen for the proposal of factory production line. Considering the presumed plant capacity the well explored geological reserves in volume of about 500,000 tonne will be sufficient to cover the capacity of 14,000 tonne/annal of pipe products for the period of 30 years.

Pilot plant test of clay from Batn el Ghoul clay		
Product	Elbow 60º, diameter 125 mm	
Material	Stoneware	
Composition	Batn el Ghoul clay sample, crushed below 1 mm	75%
	Czech fire-clay grog RAKO grain size 0-1.25 mm	25%
Procedure	- Pressing from plastic material, working moisture 14.7%. - Drying in tunnel drier wit max. temperature 85ºC for 96 hours, shrinkage after drying 3.7%. - Firing of non-glazed tube (elbow) in tunnel kiln with max. temperature 1230ºC for 53 hours, shrinkage after firing 5.6%.	
Surface finish	Non-glazed, raw surface, cream color	
Properties	Weight	9.5 kg
	Water absorption	3.7%
	Modulus of rupture	32 MPa
	Resistance against acids and bases 0.4-13.4 pH	
	Length of live	Min. 100 years
	Joint of tubes	Polyurethane or rubber
Applicability	Municipal sewage network, sewage collectors, drainage of airports and highways	
Ecological respect	Natural material, unobjectionable, environment-friendly both in production and prospective liquidation as well, 100% recyclable	

Table (10): Qualitative parameters of stoneware pipes (GIS Geoindustry, 2000).

Pilot plant test of clay from Batn el Ghoul clay		
Product	Elbow 60º, diameter 125 mm	
Material	Stoneware	
Composition	Batn el Ghoul clay sample, crushed below 1 mm	75%
	Czech fire-clay grog RAKO grain size 0-1.25 mm	25%

Procedure	- Pressing from plastic material, working moisture 14.7%. - Drying in tunnel drier wit max. temperature 85ºC for 96 hours, shrinkage after drying 3.7%. - Firing of non-glazed tube (elbow) in tunnel kiln with max. temperature 1230ºC for 53 hours, shrinkage after firing 5.6%.	
Surface finish	Non-glazed, raw surface, cream color	
Properties	Weight	9.5 kg
	Water absorption	3.7%
	Modulus of rupture	32 MPa
	Resistance against acids and bases 0.4-13.4 pH	
	Length of live	Min. 100 years
	Joint of tubes	Polyurethane or rubber
Applicability	Municipal sewage network, sewage collectors, drainage of airports and highways	
Ecological respect	Natural material, unobjectionable, environment-friendly both in production and prospective liquidation as well, 100% recyclable	

Table (11): Qualitative parameters of stoneware tiles (GIS Geoindustry, 2000).

Pilot plant test of clay from Batn el Ghoul clay		
Product	Tile 180x180x31 mm	
Material	Stoneware	
Composition	Batn el Ghoul clay sample, crushed below 1 mm	75%
	Czech fire-clay grog RAKO grain size 0-1.25 mm	25%
Procedure	- Pressing from granules, working moisture 6.5%. - Drying on free-air for 168 hours, shrinkage after drying 0.3%. - Firing of tiles in gas shuttle kiln with max. temperature 1180ºC for 16 hours, shrinkage after firing 1.2%.	
Surface finish	- unglazed raw surface, cream color - glazed on green tile	
Properties	Weight	1.6 kg
	Water absorption	38.9%
	Modulus of rupture	28 MPa
	Compression strength	35 Mpa
	Resistance against acids and bases 0.4-13.4 pH	
	Length of live	Min. 100 years
	Joint of tubes	Polyurethane or rubber
Applicability	Out-door and in-door pavements, corridors and galleries, terraces, swimming-pool kerbs etc.	
Ecological respect	Natural material, unobjectionable, environment-friendly both in production and prospective liquidation as well, 100% recyclable	

8. References

Abu Lihie, O. 1988. Geological Map of Dubaidib Area. NRA.

Abu Salah, A. and Ghanam A. 2001. Kaolin Deposits in Baten el-Ghoul (Jabal Al-Harad). NRA (Arabic Report).

Abu Salah, A., Ghanam A and Mehyar, N. 2000. Kaolin Deposits in Disi Area (Jabal Um Sahm/Dubaydib). NRA (Arabic Report).

Abu Snober, M. and Qararah M. 1998. Clay Evaluation in Halabat Area for White Cement. NRA (Arabic Report).

Ala'li, J. 2001. Evaluation and Beneficiation of Silica Sand and Kaolinitic Sandstone in South of Jordan. Ph.D. Thesis, Nottingham University, U.K.

Al-Dalou, A., Al-Sbaie, I. and Mahmod, S. 1999. Geochemical Prospecting for Jebel El-Qannasieh Sheet Area. NRA.

Al-Momani, T. 2000. Characterization, Industrial Utilization and Environmental Impact of the Hiswa Clay Deposits, South Jordan. Ph.D. Thesis, University of Jordan.

Alshaaer, M. 2000. Stabilization of Kaolinitic Soil from Jordan for Construction Purposes. M.Sc. Thesis, University Ghent, Belgium.

Awawdeh, M. 1991. Assessment of Batn El Ghoul Clay, Jordan. M.Sc. Thesis, Leicester University, U.K.

Barakat, H. and Hamouri M. 1994. Baten el-Ghoul Kaolin. NRA (Arabic Report).

Barjous, M. 1997. Pre-processing Investigation of the Kaolin minerals of the Disi Sandstone Formation from the Wadi Araba-Jordan. The Second Jordanian Mining Conference, Jordan.

Bayook, A. 1992. Batn El Ghoul Deposits as a Potential Source for Aluminum. M.Sc. Thesis, University of Jordan.

Boom, G. Van Den and Hussein, I.M. 1964. Note on the Clay Deposits of Mahis Ghor Kabid no. 28. German Geol. Mission, 5p, Amman.

Droubi, F. and Zawahreh M. 1996. Kaolin Processing in Baten el-Ghoul Kaolin Area. NRA (Arabic Report).

Droubi, F. and Zawahreh M. 1997. Kaolin Processing in Mudawwara Area. NRA (Arabic Report).

EGE SERAMIK sanitary ware 2000. Turkish Sanitary Ware. Asian Ceramics and Glass magazine, November.

GIS Geoindustria Report, 2000. Ceramic Clay in: Geological and Technological Evaluation of Selected Mineral Resources in Jordan.

Hadadin, M. 1989. Geology of Clay in Jordan. NRA (Arabic Report).

Hadadin, M. 1996. Clay Seminar. NRA (Arabic Report).

Hall, P.K. 1970. The Mahis Clay Deposit; Geological Aspect. NRA, 50p.

Hall, P.K. and Nimry, Y. 1970. The Mahis Clay Deposits. NRA.

Harben, P.W. 2002. Kaolin, In: The Industrial Minerals Handy Book. Black Wood, UK. 174-182p.

Hussein, I.M. 1965. Geology and Clay Possibilities in the Area between Mahis and Ghor Kabid No. 38. German. Geol. Mission Rep., 89p. Prepared for the NRA.

Ibrahim, H.M. 1965. Geology and Clay Possibilities in the Area between Mahis and Ghor Kabid No. 38. NRA, 56p.

Khalil B. 1994. The Geology of Al-Disa Area (Qannassiya) Map Sheet scale 1:50.000.

Khoury, H. and El Sakka, W. 1986. Mineralogical and Industrial Characteristics of Batun El Goul Clay Deposit Southern Jordan. Applied science 1:321-351.

Kilani, G. and Abu Salah, A 1997. Mudawwara Kaolin. NRA (Arabic Report).

Mahasneh, K. And Zurqiah, N. 2004. Mining Sector Performance During 2003, compared with the previous four years. Industrial Liaison Division. Natural Resources Authority.

NRA Annual Reports, 2005, 2004, 2003, 2002, 2001, 2000.

Odeh, A. 2000. Jordan Ceramics. Asian Ceramics and Glass magazine, August.

Sa'sa, A. and Abu Taha, I. 1983. Batn El Ghoul Clay and Its Future Utilization. NRA.

Stockwell, L.E., Hillier, J.A., Mills, A.J., White, R., and Chapman, G.R. 2002. World Mineral Statistics 1996-2000. British Geological Survey.

Swzzi, G. 2003. World Production and Consumption of Ceramic Tiles. Ceramic World Review n. 53.

Tahat, O. and Zawahreh M. 1995. Processing and Upgrading Jordanian Clays. NRA (Arabic Report).

The Jordanian Company for Mining and Processing of Kaolin and Feldspar, W.L.I. 1997. Hiswa Clay Exploration and Geology. Volume 1.

USGS 2001. Mineral year book 2001. Africa and the Middle East. US department of the interior.

Weber, L and Zsak, G. 2003. World Mining Data. In Cooperation with the Association of Mining and Steel (Vienna) and the National Committees for the Organization of the World Mining Congresses. Volume 18, Vienna, 230p.

Yasin, S. 1999. Kaolin Seminar. NRA (Arabic Report).

Yasin, S. 2001. Comments on GIS Geoindustry Report (Geological and Technological Evaluation of Selected Mineral Resources in Jordan-Kaolin Report). Directorate of Mineral Exploration, NRA.

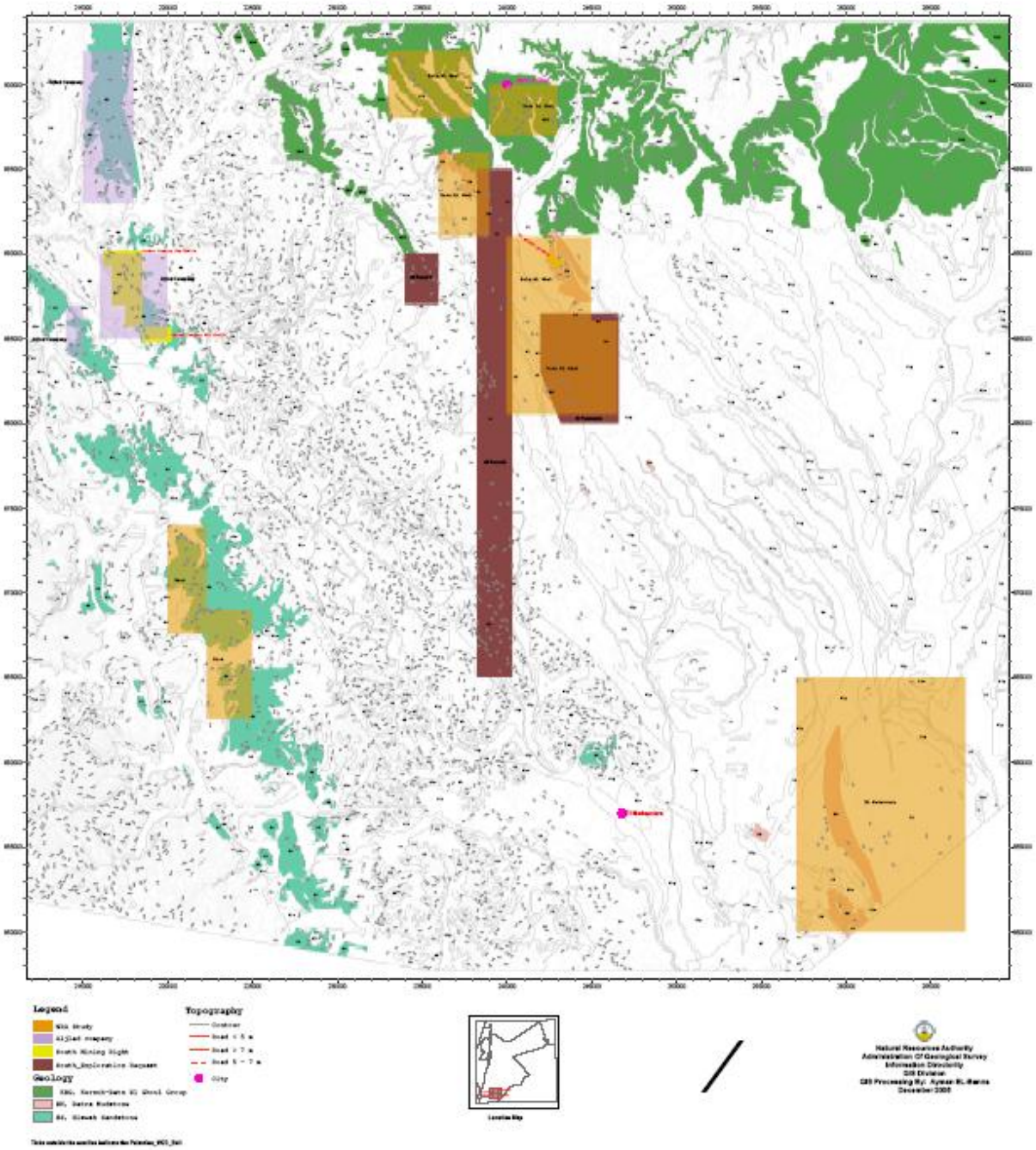
Zawahreh, M. 1997. Kaolin Uses. NRA (Arabic Report).

Zawahreh, M.1989. Clay Seminar. NRA (Arabic Report).

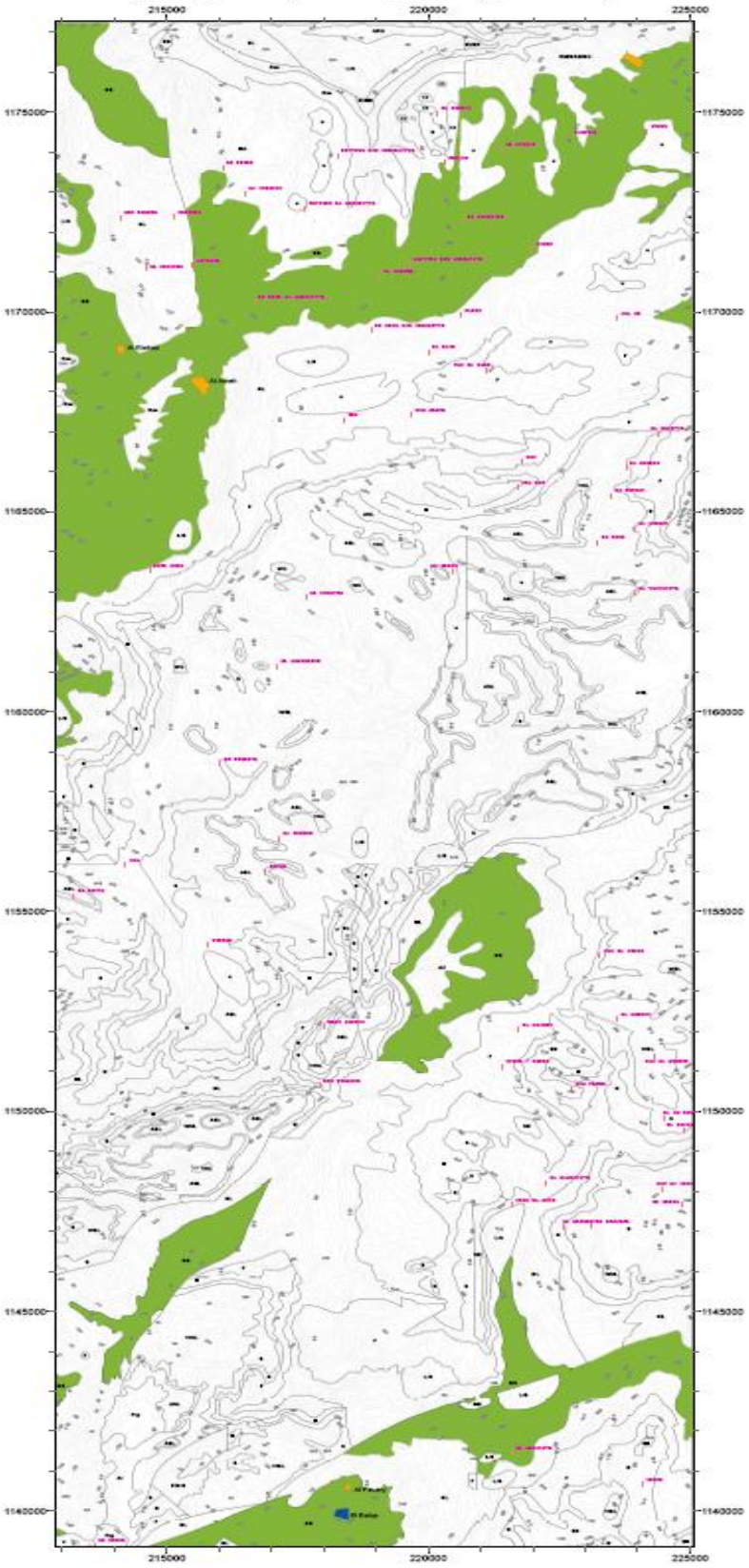
Appendices

Appendix (1): Kaolin deposits and mining rights map (South Jordan).
Appendix (2): Kaolin deposits and mining rights map (Al-Salt District).

Appendix (1): Kaolin Deposits & Mining Rights Map (South Jordan)

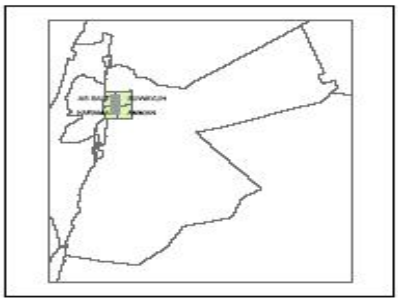


Appendix (2): Kaolin Deposits & Mining Rights Map (Al Salt District)



Natural Resources Authority
Administration Of Geological Survey
Information Directority
GIS Division
GIS Processing By: Ayman EL-Banna
December 2006

Scale Map 1:50000



Location Area

Legend

Minnig Right

Exploration_Request

Geology

KS Kumob Sandstone

Topography

villages

Contour

Road < 5 m

Road > 7m

Road 5 - 7 m

Ticks outside the neatline indicate the Palestine_1923_Belt