Qatar Univ. Sci. J. (1993), 13(1): 134 - 139

DISTRIBUTION AND MINERALOGY OF THE CLAY DEPOSITS IN SAUDI ARABIA

By

AHMED A. ALMOHANDIS
Geology Department, College of Science, King Saudi University, Riyadh, Saudi Arabia

توزيع معادن رواسب الطين في المملكة العربية السعودية

أحمد عبدالقادر المهندس

أن الهدف الرئيس من هذه الورقة العلمية هو تمييز رواسب الطين المعدنية في المملكة العربية السعودية وخاصة من حيث تركيبها المعدني والوضع الجيولوجي لها بالإضافة إلى استعمالاتها الممكنة . ولذلك فإن معظم التقارير والأبحاث عن رواسب الطين بالمملكة العربية السعودية قد روجعت وأعيد النظر فيها . وقد أمكن دراسة ثلاثة رواسب طينية رئيسية في المملكة وذلك بواسطة حيود الأشعة السينية ، والتحليل الحراري التفاضلي بالإضافة إلى التحليل الكيميائي . وتتكون رواسب الطين السعودية عموماً من معدن الكاولينايت كمعدن أساسي مع كميات صغيرة من معادن الطين الأخرى مثل معدني المونتموريلونايت والإلايت . وتحتوي معظم رواسب الطين السعودية عل معدن الكوارتز .

Key Words: XRD, DTA, Chemical analyses, clay, Kaolinite, quartz, mud stone, laterite.

ABSTRACT

The main goal of this paper is to characterize the mineral clay deposits in Saudi Arabia; especially their mineral composition, deposit size, geological setting and possible uses. Different published reports and papers on clay deposits of Saudi Arabia have been reviewed. Three major clay deposits have been studied by XRD, DTA and chemical analyses. Saudi clay deposits consist generally of kaolinite as a major mineral, and small amounts other clay minerals, such as montmorillonite and illite. Most of the Saudi clay deposits contain quartz. The paper concentrates on the cooperation and coordination between the Gulf Universities and institutes and industry to undertake a detailed studies on the clay deposits of the Gulf states for possible industrial uses and applications.

INTRODUCTION

Saudi Arabia is in a rapid process of development with an increasing demand for industrial minerals and construction materials. Thus the exploration and development of industrial mineral resources continues as part of the programme of the Deputy Ministry for Mineral Resources (DMMR). Clay is one of the very important industrial materials which can be used in the manufacture of ceramic products and in many other purposes (Patterson and Haydn, 1983).

The term "clay" is used to find a grain of less than 4 μm, while the term "clay mineral" refers to the fine-grained hydrated aluminosilicates with a layered structure (Grim, 1962). Clay minerals are the weathering and hydrothermal alteration products of feldspars and mafic minerals. The clay are the most common minerals of sedimentary rocks, constituting about 45% by weight or volume (Ehlers and Blatt, 1982). The main types of clay minerals are kaolinite, montmorillonite and illite. Other varieties include chlorite, vermiculite, glauconite, mixed-layer clay minerals, attapulgite and sepiolite. The formation of Kaolinite is favoured by an acid environment and free circulation which lead to a leaching of Na, Ca, Mg, and K. Such process occurs mainly in relatively humid climate (Keller 1956). Montmorillonite formation is favoured by neutral to alkaline conditions and by incomplete leaching (Keller, 1956). However, the formation of illite is favoured by retention of M(metallic) ions, especially K+ and Ca2+ and no excess of H+ ions with moderate rainfall and the presence of CaCO3 (Keller, 1956) and 1970).

Major clay deposits occur in many localities in the

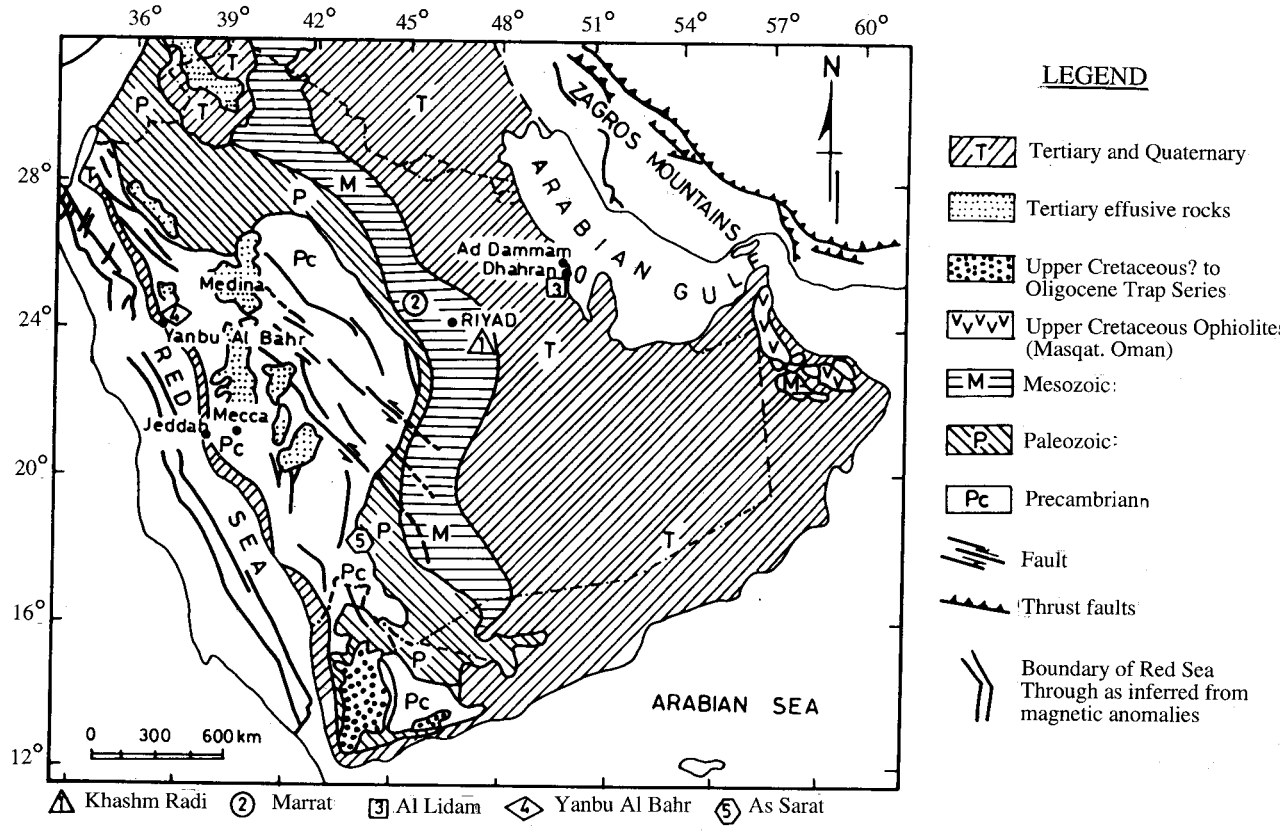

Fig. 1: Geological Map of the Arabian Peninsula showing some major Clay deposits in Saudi Arabia

Kingdom of Saudi Arabia. They are present in the Arabian shield which occupies the West-Central part of the country and in the sedimentary cover which overlies the Arabian shield (Fig. 1).

The purpose of this paper was to study and review briefly the distribution and mineralogical composition of major clay deposits in Saudi Arabia on a regional scale. Furthermore, this study will identify the suitable clay deposits for possible industrial uses.

METHOD OF STUDY

To prepare this study; different published reports and papers on clay deposits of Saudi Arabia have been reviewed. Some of these deposits have been studied using different technique. A visit to the Saudi Ceramic company in Riyadh was a good opportunity to appreciate its products of sanitary ware and tiles which are manufactured from local clay and feldspar materials.

Three major clay deposits areas have been selected for X-ray diffraction, differential thermal analyses and chemical analyses.

X-ray diffraction analyses were obtained using Philips PW 1050 diffractometer with CuKa radiation. The goniometer was set at a speed of one degree 2 0/min, with a chart speed on the recorder equivalent to 1 cm/min.

Differential thermal analyses (DTA) were recorded under the following conditions: whole rock samples were ground to <150 um, heating rate of 10 C per minute in an atmosphere of nitrogen gas flowing over the sample.

Chemical analyses for major oxides were done by wet chemical methods. Na and K were determined by flame photometry.

DISTRIBUTION OF CLAY DEPOSITS

Clay deposits are of secondary origin in the sedimentary formations of Saudi Arabia. Table 1 summarizes and characterizes the major clay deposits of Saudi Arabia. Seven major clay deposits were selected; these include the Khashm Radi area, the Marrat area, the Dhurmah area, Wadi Sallah, Al Lidam area, Yanbu Al Bahr area and the As Sarat laterite. However, other areas which has potential clay deposits include the Burayadh area where the Permian Sudair shale formation contains clay deposits. Moreover, at Tabuk and Al Jawf in the north of the Kingdom, reconnaissance survey has identified clay deposits suitable for structural clay products (Delhawi and Laurent, 1982).

RESULTS AND DISCUSSION

Figure 2 shows a typical x-ray diffractograms of the Khashm Radi clay, Marrat clay and Dhurmah clay. It indicates that such clays are dominantly composed of Kaolinite with subordinate quantities of quartz. However, other mineral such as little and hematite are present in the Marrat and Dhurmah clays. The DTA curves of clay samples from the Khashm Radi, marrat and Dhurmah areas are shown in Fig. 3. It illustrates the typical feature of kaolinite, where the endothermic reaction peaks around 100 C are assigned as dehydration of absorbed water at the surfaces of fine kaolinite particles and the endothermic peaks around 550 C are assigned as dehydration due to the thermal decomposition of the structural water of kaolinite.

Table 1
Major clay deposits of Saudi Arabia

Location	Brief Geological Setting	Deposit size and possible uses	Mineral Composition	References
The Khashm Radi area (Riyadh region).	The Wasia Formation consists of three clay beds with a limestone overburden. Exploitation of upper layer depends on the value of the overlaying limestone. The intermediate layer can only be used as a cleanser. The lower layer is the most accessibly exposed but its thickness has been reduced by erosion.	Large deposit. The kaolinite is not suitable for refractories but it is used, with an additive of K-feldspars for faience.	The white clay is very pure and well-ordered kaolinite. The other two beds are composed of kaolinite and quartz. Small amount of non-clay minerals such as feldspars and siderite are present.	Fujii, (1977)
The Marrat area (Riyadh region).	The Middle Marrat Formation (Lower Jurassic) is dark-red, massive sandstone and mudstone, with a maximum thickness of mudstones at and near the town of Marrat , about 200 km West of Riyadh.	Maximum thickness of about 57 meters of material with technical characteristics suitable for the manufacture of structural clay products and for alumina extraction. Estimated reserves may exceed 1000 million tons.	The x-ray diffraction and differential thermal analyses indicate that the Marrat mudstones are composed mainly of kaolinite with minor amount of illite and quartz.	Laurent and Al Habshi (1976).
The Dhurmah area (Riyadh region).	This area is an extension of the Marrat Clay-shale deposits, which crops out beneath a very thin overburden in a cuesta of Lower Jurassic rocks.	Large deposits can be used for a vitrified clay pipes and the manufacture of structural clay products and alumina extraction.	As the Marrat clay deposits.	Laurent and Al Habshi (1976).
Wadi Sallah (Riyadh region)	The deposits consists of clay beds separated by sandy limestone under thin overburden. The upper clay bed is the thickest and extends over 6 km. Aggregate clay thickness of 14.2 m of which 9.1 m belong to the upper bed. The deposit belongs to the Biyadh Formation.	Over 50 million tons. The clay is suitable for manufacturing structural clay products and possibly for the manufacture of ceramics. It is now being used for vitrified clay pipes.	Mainly kaolinite and quartz.	Villalard. (1977).
Al Lidam area (the Eastern region)	The deposit consists of two clay layers with combined thickness of 8 m separated by 1 to 3 m of sandstone. Both layers are similar but the overburden is thick. The deposit belongs to the Dam Formation.	About 20 million tons. Both clay layers meet quality standards for manufacturing of bricks.	X-ray diffraction analysis shows a remarkable similarity in the mineralogy of the two clay layers.	Roger and Al Habshi (1977).

Table 1 Contd.
Major clay deposits of Saudi Arabia

Location	Brief Geological ßetting	Deposit size and possible uses	Mineral Composition	References
			They contain mainly illite with accessory kaolinite and interstratified illite-smectite; they also contain minor amounts of dolomite and quartz.	
Yanbu Al Bahr area (the Western region)	The clay deposit is covered by a gravel conglomerate reaching up to 2 m in thickness. However, the clay deposit in the wadi plain is covered by a thinner layer of wadi sediments. The deposit belongs to the Raghma Formation (Miocene)	Not determined. Suitable for the manufacture of the structural clay products.	The clay deposit is composed mainly of montmorillonite and kaolinite, with small amounts of illite, chlorite and quartz.	Alabouvette, Le Chapelain, and Pellaton (1974) ElKholy (1977)
The As Sarat laterite (Asir region)	The clay deposit is the major part of the Tertiary laterite deposit of the As Sarat mountains. The area covered by laterite is about 1000 km^2. The deposit belongs to the Oligocene?	Not known. Suitable for the manufature of structural clay products and alumina extraction.	The x-ray diffraction and differential thermal analyses indicate that the As Sarat laterite is composed mainly of kaolinite with miner amounts of montmorillonite. Quartz is present in considerable amounts in many samples.	Overstreet and Others (1977)

Table 2
Chemical analyses of some major clays in Saudi Arabia (whole rock analyses)*

	Khashm Radi Clays			Marrat Clays			Dhurmah Clays		
SiO_2	59.30	42.04	47.09	43.62	44.40	43.78	48.90	47.82	48.74
TiO_2	1.40	1.12	1.18	1.80	1.75	1.65	0.98	0.91	0.87
Al_2O_3	20.35	33.97	29.80	22.31	23.01	22.40	20.50	21.47	20.72
Fe_2O_3	1.64	1.09	1.81	12.98	11.98	13.98	8.74	8.72	8.81
CaO	1.51	0.71	2.20	2.50	3.50	3.50	3.59	3.60	3.63
MgO	0.56	0.53	0.48	1.15	1.25	1.40	1.51	1.36	1.43
Na_2O	1.97	1.78	2.24	0.10	0.05	0.47	0.35	0.41	0.30
K_2O	0.37	0.36	0.16	2.10	2.20	2.30	2.74	2.61	2.76
MnO	0.02	0.01	0.02	0.09	0.02	0.01	0.04	0.03	0.04
P_2O_5	0.03	0.02	0.03	0.08	0.05	0.05	0.06	0.05	0.05
H_2O	3.79	3.10	1.75	1.38	1.52	1.24	1.57	1.53	1.34
L.O.I.	7.95	15.20	12.85	11.36	10.84	10.74	10.10	10.36	10.51

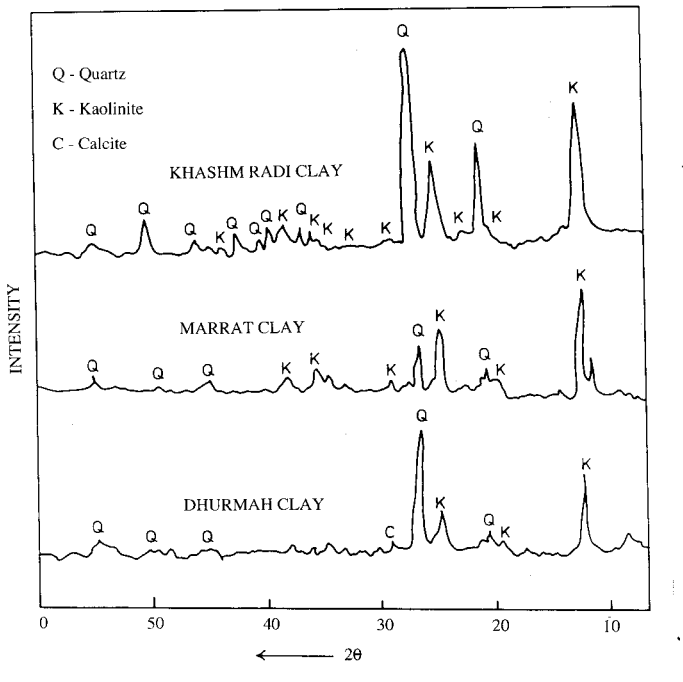

Fig. 2: X-ray diffractograms of the Khashm Radi, Murrat and Dhurmah Clays.

Table 2 presents the chemical analyses of selected clays from the Khashm Radi, Marrat and Dhurmah areas. The Khashm Radi clays are generally richer in Al2O3 and Na2O3 than the Marrat and Dhurmah clays, but they are poorer in Fe2O3CaO, MgO and K2O. This Table can also reflects the mineral composition and show that the Khashm Radi clays can be used for ceramic products. However, the presence of iron, alkalies are not desired for the necessary high fusion point. The quality of the Khashm Radi clays, according to laboratory tests, is quite suitable for production of ceramic products (Baudet, Habert and Mario, 1979).

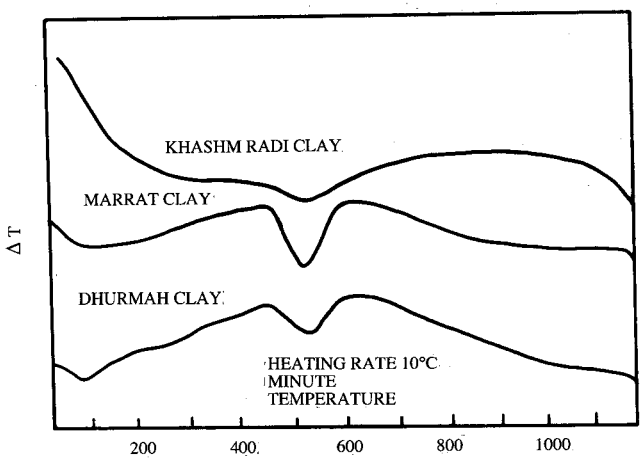

Fig. 3: Typical differential thermal curves for the Khashm Radi, Marrat and Dhurmah Clays.

As a result of the rapidly rising incomes and development of a market for ceramic tiles and sanitary ware, the Saudi Ceramic Company has been formed. Since 1979, its modern factory in Riyadh is producing ceramic tiles and sanitary ware for the public and private sectors. The company utilizes the Khashm Radi clays, 120 km South-East of Riyadh for the production of tiles and sanitary ware. The clay deposits contain kaolinite and ball clays. Other essential raw materials,

* Analysed at Chemistry Lab., Faculty of Earth Sciences, King Abdul Aziz University, Jeddah, Saudi Arabia.

such as feldspar, quartz sand and limestone are available in large quantities in the central region of Saudi Arabia.

CONCLUSION AND RECOMMENDATIONS

Saudi Clay deposits consist generally of kaolinite as a major constituents and small amounts of other clay minerals such as montmorillonite, and illite. Most of the clay deposits contain quartz.

REFERENCES

Alabouvette, B., J. C. Le Chapelain and **C. Pellaton, 1974.** Geology and mineral exploration of the Yanbu Al Bahr quadrangle, 24/38C: Bureau Recherches Geologiques et Minieres, Technical Record, 75 Jed 20.

Baudet, G., S. Habert and **M. Mario, 1979.** Khushaym Radi Kaolinitic clay ceramic aptitude test: Bureau Recherches Geologiques et Minieres, Technical Record, 79 Jed 4, 22 pp.

Delhawi, M. R. and **D. Laurent, 1982.** Industrial minerals and building material developments. Proc. Ind. Miner. Conf., Madrid, Spain, 01-13.

Ehlers, E. G., H. Blatt, 1982. Petrology: Igneous, Sedimentary, and Metamorphic Rocks. W. H. Freeman and Co., San Francisco, 732 pp.

El Kholy, M., 1977. Yanbu construction and industrial materials, geological study, TR - 1977-1, Jeddah, 61 pp.

Fujii, N., 1977. Reconnaissance of the Kaolin Clay deposit, Al Kharj district, Kingdom of Saudi Arabia. Directorate General of Mineral resources, Technical record, TR-1977-9, 17 pp.

Grim, R. E., 1962. Applied Clay Mineralogy. McGraw Hill, N. Y., 422 pp.

Keller, W. D., 1956. Clay minerals as influenced by environments of their formation, Bull. Am. Ass. Petrol. Geol., 40: 2689-2710.

Keller, W. D., 1970. Environmental aspects of clay minerals, J. Sedim. Petrol., 40: 788-813.

Laurent, D. and **A. Al Habshi, 1976.** Durmah-Marrat clay-shale deposit and its economic potential: Bureau Recherches Geologiques et Miniere, Open-file Rept. 76 Jed. 21, 23 pp.

Overstreet, W. C., D. B. Stoeser, E. F. Overstreet and **G. H. Goudarzi, 1977.** Tertiary Laterite of the A Sarat mountain, Asir Province, Saudi Arabia, Bulletin No. 21, DGMR, Jeddah, 30 pp.

Patterson, S. H., and **H. M. Haydn, 1983.** Clays in: Industrial Minerals and Rocks, AIME.

Roger, J., and **A. Al Habshi, 1977.** Al Lidam clay deposit, drilling and tests for structural clay products: Bureau Recherches Geologiques et Minieres, Technical Record, 77 Jed. 37, 20 pp.

Villalard, P., 1977. Wadi Sallah clay deposit exploration results, Bureau de Recherches Geologiques et Ministres Report 78 Jed 5, 15 pp.