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Assessment of Magnetite Polishing by Using Tigris River Stream Sediments in Baghdad: An Ore Microscopy Application

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Abstract

This aim of this study is to assess the Tigris River sediments and utilize them as a new abrasive for the preparation of polished surface of magnetite ore to be studied under reflected light ore microscope. Such polishing process was tested using 250, 125, 71, 45, 25 and 18µm grain sizes of the river sediments. For the completion of the polishing and to obtain a glossy perfect polished surface, the 7 and 2.5 µm sized standard diamond pastes were used. After each polishing stage, the reflectance and roughness of these surfaces were measured as an evaluation step for the polishing efficiency. The reflectance values (R%) of the magnetite surface were found to be reversely proportioned to the abrasive grain size; while the surface roughness values (Ra) showed positive relationship with the grain size. The polished surface showed gradual improvement with decreasing grain size of the abrasive. The reflectance increased at a rate of 0, 0, 0.3, 1.2, 2.5, 3.7, 9.3, 20% with reducing grain sizes from 250, 125, 70, 45, 25, 18, 7 and 2.5 µm; at the same time, the roughness reduced at a rate of 72.2, 51.8, 23.7, 17.2, 10.9, 7.5, 6, 3.8 with reducing grain size. The 18 µm abrasive grain size of river sediments was found to be the best. Buffing by 2.5 µm diamond paste as the last stage, improved the polishing efficiency and resulted in 20% reflectance. Based on the obtained results, the Tigris sediments can be considered as fine-grained granules with the ability of preparing a flat, homogeneous surface with little roughness and reasonable degree of reflectivity.

Keywords: Ore; Abrasives; Magnetite; Reflectivity; Surface roughness.

تقييم صقل المغنتايت باستخدام رواسب مجرى نهر دجلة في بغداد: تطبيق في مجهرية الخامات

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الخلاصة

تهدف هذه الدراسة إلى تقييم رواسب نهر دجلة واستخدامها كمواد كاشطة جديدة لتحضير سطح مصقول من خام المغناتايت يصلح لاستخدامه في الفحص المجهري للمعادن تحت المجهر الخامات العاكس للضوء. تم عملية الصقل باختبار الأحجام حبيبية 250 ، 125 ، 71 ،45، 25 و 18مايكرون من ترسبات النهر. ولغرض اكمال عماية الصقل والحصول على سطح لماع، فقد تم استعمال الاحجام الحبيبية المعيارية من معجون 7 و 2.5 ميكرون. بعد كل مرحلة صقل ، تم قياس الانعكاسية وخشونة تلك الاسطح كخطوة تقيمية لكفاءة الصقل. تناسبت قيم الانعكاس (R٪) لسطح المغناتايت عكسيا مع الحجم الحبيبي للمواد الكاشطة، في حين تناسبت قيم خشونة السطح (Ra) للمغنتايت إيجابيا مع الحجم الحبيبي للمادة الكاشطة. يتقدم الصقل لسطح المنغتنايت بشكل مستمر ويتحسن تدريجيا مع تقليل الحجم الحبيبي للموادة الكاشطة. إن قيم الانعكاس

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لسطح المغنتايت المصقول والمسجلة (0 ، 0 ، 0.3 ، 1.2 ، 2.5 ، 3.7 ، 9.3 الى 20%) تزداد مع تناقص الحجم الحبيبي للمادة الكاشطة 250 ، 125 ، 71 ، 45 ، 25 ، 18 ، 7 و 2.5 ميكرون على التوالي. بالإضافة إلى ذلك ، انخفضت قيم خشونة السطح (72.2 ، 51.8 ، 23.7 ، 17.2 ، 10.9 ، 7.5 ، 6 ، 3.8) بتناغم مع تناقص الحجم الحبيبي. أعتبرت هذه الدراسة ان افضل حجم حبيبي للمادة الكاشطة هو18 ميكرون. استخدمت مرحلة التلميع كمرحلة أخيرة لتحسين كفاءة الصقل وقد نتج عنها سطح ذا انعكاس 20% باستخدام عجينة الماس (2.5 ميكرون). ومن ثم يمكن اعتبار الحبيبات الناعمه من رواسب نهر دجلة ذات قدرة على إعداد سطح مستوٍ ومنتظم مع خشونة قليل جدا، ودرجة معقولة من الانعكاسية.

1. Introduction

Magnetite is one of the main iron ores, with the chemical formula of Fe_3O_4 and belongs to the spinel group. It is a black, opaque, submetallic to metallic mineral. The hardness of magnetite ranges from 5.5 to 6.5 on the Mohs hardness scale with density of 5.18 g/cm3 [1]. It is typically found in natural terrestrial rocks formed under igneous, metamorphic, and all varieties of sedimentary environments [2]. Many common abrasives used for polishing targeted materials such as metals, alloys, glasses and stones are expensive including carborundum (silicon carbide), zirconia, alumina, diamond, emery, and silica [3]. Some authors have resorted to using some alternatives like quartz, coal, sodium carbonate, sawdust and sodium chloride from locally sourced raw materials [4]. Buffing abrasives are generally composed of hard materials such as Al_2O_3, SiC, and hematite which are utilized for creating shiny polished surfaces [5]. Some attempts were conducted by many researchers to prepare and manufactured abrasives from distinctive raw materials. The preparation of polished surface free from scratches and relief is vital for the identification of ore minerals and their textural interpretation [3].

The aim of this study is to test Tigris River sediments, which are accessible in huge amounts and cheap, and assessing their polishing efficiency for magnetite ore surface. The Tigris River carries sediments to central Iraq where the capital Baghdad is located as a sand composed of different types of light mineral, heavy minerals and rock fragments. These sediments were tested as abrasives for magnetite surfaces based on measuring the roughness surface and light reflectance.

2. Materials and Methods

2.1 Field Work and Techniques

Three accessible sites of river sediments of the Tigris River in Baghdad were chosen for sampling. The river sediments were collected from the bank of the Tigris River near the Al-Sarafiya Bridge at the Atifiyah side. It is located between latitudes (33° 21′ 29″N) and longitudes (44° 22′ 17″ E) as shown in Figure-1. More than ten kilograms were collected by manual shovel. These samples were merged together in one plastic container. The samples were dried by exposure to the sunlight for two days and then placed in oven of 80°C. A representative sample was selected using quartering process and described based on Folk classification. Fractions of a representative sample of river sediments which are medium sand, fine sand, very fine sand, coarse silt, medium silt, fine silt and clay were studied by x-ray diffractometer (XRD) to identify the mineralogical composition as well as the magnetite sample to be tested. The major oxides (SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3, K_2O, P_2O_5, SO_3 and L.O.I), and trace elements (V, Cr, Mn, Co, Ni, Cu, Zn) were analyzed in each abrasive and target using x-ray fluorescence (XRF) technique. The roundness and sphericity of the abrasive grains were studied under scanning electron microscope (SEM).

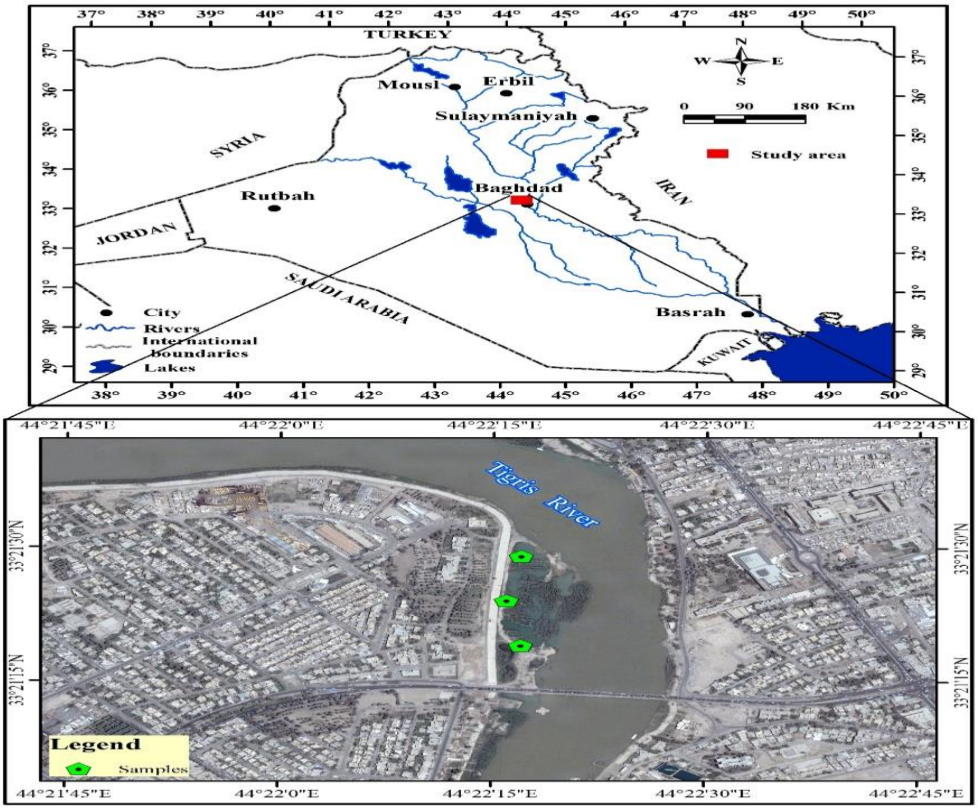

Figure 1-Location map of the study area (map from Google Earth).

2.2 Preparation of Abrasives and Polished Section

The studied abrasive sample was separated into six fractions using sieve analysis. These fractions are medium sand (500-250 µm), fine sand (250-125 µm), very fine sand (125-62 µm), coarse silt (62-31 µm), medium silt (31-16 µm) and fine silt and clay (16-1 µm)] according to [6] (Figure-2). These fractions were used for polishing the surface of magnetite sample using the method stated in [3]. For identifying any opaque mineral, a polished section for that opaque mineral should be prepared. Accordingly, a polished section was prepared for a small piece of magnetite based on [7, 3] (Figures-3A, B).

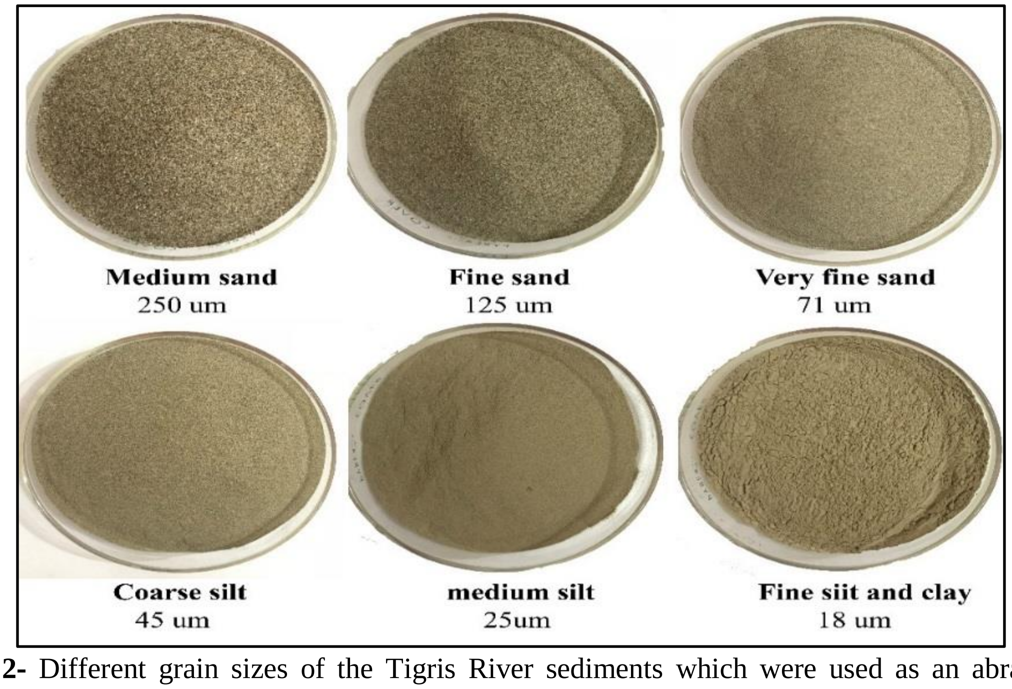

Figure 2- Different grain sizes of the Tigris River sediments which were used as an abrasive for magnetite surface.

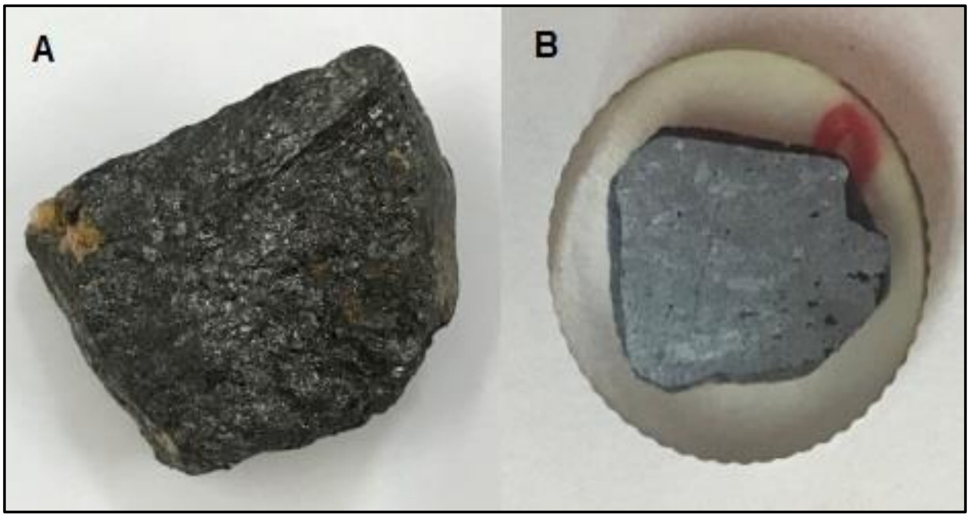

Figure 3- A Hand specimens of a magnetite displays a normal surface, B: section of magnetite used for testing the efficiency of the abrasive in polishing process.

2.3 Polishing Procedure

The magnetite polishing process was accomplished through the use of various sizes of river sediment in the workshop of the Department of geology at the College of Science at the University of Baghdad. The main purpose of the magnetite polishing is to prepare a fine brightening surface of this ore mineral so that it can be studied under reflected light microscope. The polishing provides a smooth surface of the target which can be used for a further work [8]. Polishing stages were conducted by utilizing the following six-grain sizes: 250, 125, 71, 45, 25, and 18μm of river sediments which are equivalent to 60, 120, 200, 325, 600 and 1200 mesh, respectively. The polishing process was carried out using a specialized rotary-disc device with controllable rotation speed. The followed procedure is placing the section of magnetite on the rotating disc with a speed of 1100 rpm and adding drops of water to reduce the strength of friction and to facilitate sliding the section on the rotating disc. Ten minutes or less is an ordinarily total time required to get a shining magnetite surface. Finally, buffing process was also used to obtain a glossy surface which was conducted by using a diamond paste of 7 and 2.5 μm grain size. For the assessment of the efficiency of abrasion, the reflectance and roughness were measured on the polished magnetite surface after each stage of polishing and buffing; thereafter the polished surface was also investigated by using reflected light ore microscope.

2.4 Abrasive Evaluation

The evaluation of the abrasives include measurement of three factors: roughness (Ra μm), reflectance (R%) and scratching using reflected light microscope. The surface roughness (Ra μm) and reflectance (R%) are the two parameters used to evaluate the action of the river sediment abrasive. Roughness (Ra μm) is measured using PosiTector Surface Profile Gage (SPG) which is shown in Figure 4A. It has a probe which give results digitally in micron. The device was standardized to smooth piece of glass before it using it for measurement. Ten points (n = 10) were measured on the magnetite surface. The statistical results are presented as minimum, maximum, average and standard deviation for each polishing stage. Laser Beam System which have a photoelectric cell and galvanometer was used for the measurement of the reflectance (R%) at 546 nm in air (Figure-4B). These measurements were conducted at the Optical Lab, Laser Branch, Applied Science Department, University of Technology in Baghdad.

Figure 4- A) PosiTector device with a digital screen and probe type SPG used to measure the roughness of the magnetite surface; B) Laser Beam System used for measuring the reflectance (%) of the polished magnetite surface.

2.5 Microscopic Study

The light and heavy minerals in the river sediment abrasive were identified under the transmitted polarized microscope, whereas the polished surface of the magnetite was assessed at each polishing stage by using the reflected light microscope. Scanning electron microscope (SEM) was also used for identifying the mineralogy of the abrasive. The bromoform heavy liquid of 2.89 specific gravity was used for the separation of heavy minerals from the whole sample based on the standard procedures [9, 10]. Mineralogy of the abrasive was studies in many slides which were prepared from medium sand, fine sand and very fine sand according to [11].

3. Results and Discussion

3.1 Geochemistry and Mineralogy of Abrasive

The chemical composition of abrasive and magnetite is presented in Table-1. The river sediment abrasive is generally siliceous in composition which is chemically composed of SiO_2 (34.3%), CaO (17.5%) Al_2O_3 (6.46%), Fe_2O_3 (5.12%), MgO (2.93%), K_2O (1.03%), P_2O_5 (0.54%), SO_3 (0.22%) and LOI (30.6%), and mineralogically consist of quartz, calcite, dolomite, kaolinite and feldspar based on XRD analysis as well as some minor minerals. The mineralogy of the abrasive and magnetite is displayed in Figures-5(A and B). More detail study of the abrasive mineral components was conducted using scanning electron microscope (Fig. 6). The relative value of hardness is considered as a controlling factor of the abrasion process [12]. The Mohs hardness of quartz, feldspar, dolomite, calcite, and kaolinite is 7, 6, 3.5-4, 3, and 1.5-2, reflectively. The tested abrasive is mainly composed of quartz which form 45.4% in the medium sand, 46.5% in fine sand and 48.9% very fine sand (Table-2). Feldspar composes only 5% of the medium sand and 6.9% of fine and very fine sand. The rock fragments form 49.5% from the medium sand, 46.4% from the fine sand and 44% from the very fine sand. The petrographic composition of the abrasive as illustrated in Figure-6 can be expressed as $Q_{46.9}F_{6.3}R_{46.6}$ (Table-2 and Figure-7). The heavy mineral suite form 3.53% of the whole composition of abrasive, while the average light minerals form 96.46% (Table-2). The low content of the heavy minerals in the abrasive minimizes its effect on the polishing process. The magnetite used as a target in this study was identified by the XRD (Figure-5B) and confirmed by XRF which showed it is relatively of very high Fe_2O_3 (94.26%) content and has low content of other oxides.

Table 1- Chemical composition (wt%) of the river sediment abrasive and magnetite.

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	SO_3	L.O.I	Total
Abrasive	34.3	6.46	5.12	17.5	2.93	1.03	0.54	0.22	30.6	99.8
Magnetite	2.30	1.03	94.26	0.26	1.45	0.001	0.42	0.009	0	99. 7

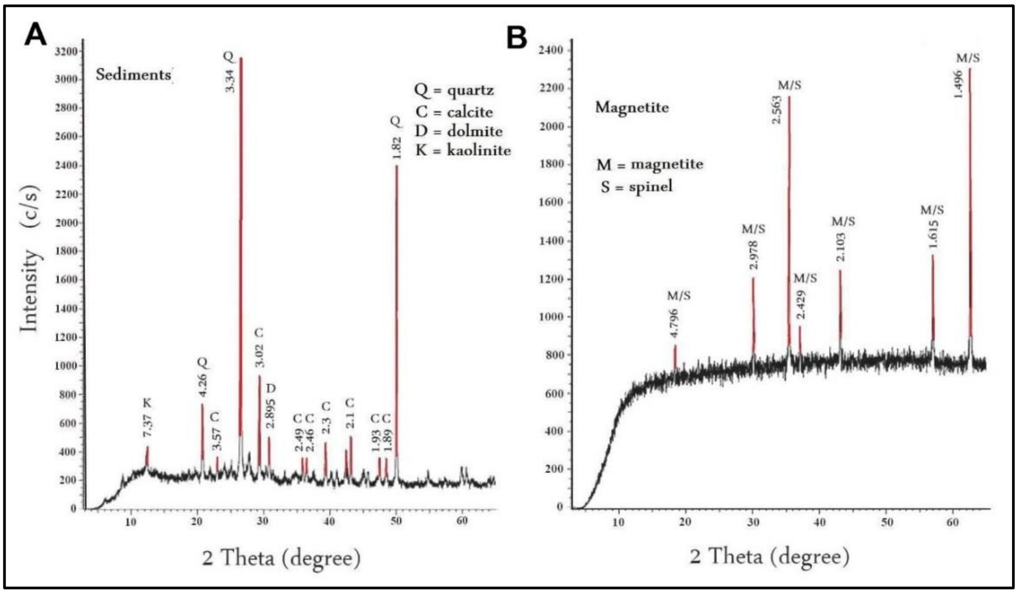

Figure 5- A) X-ray diffractograms displaying the main mineralogical composition of the river sediments and magnetite.

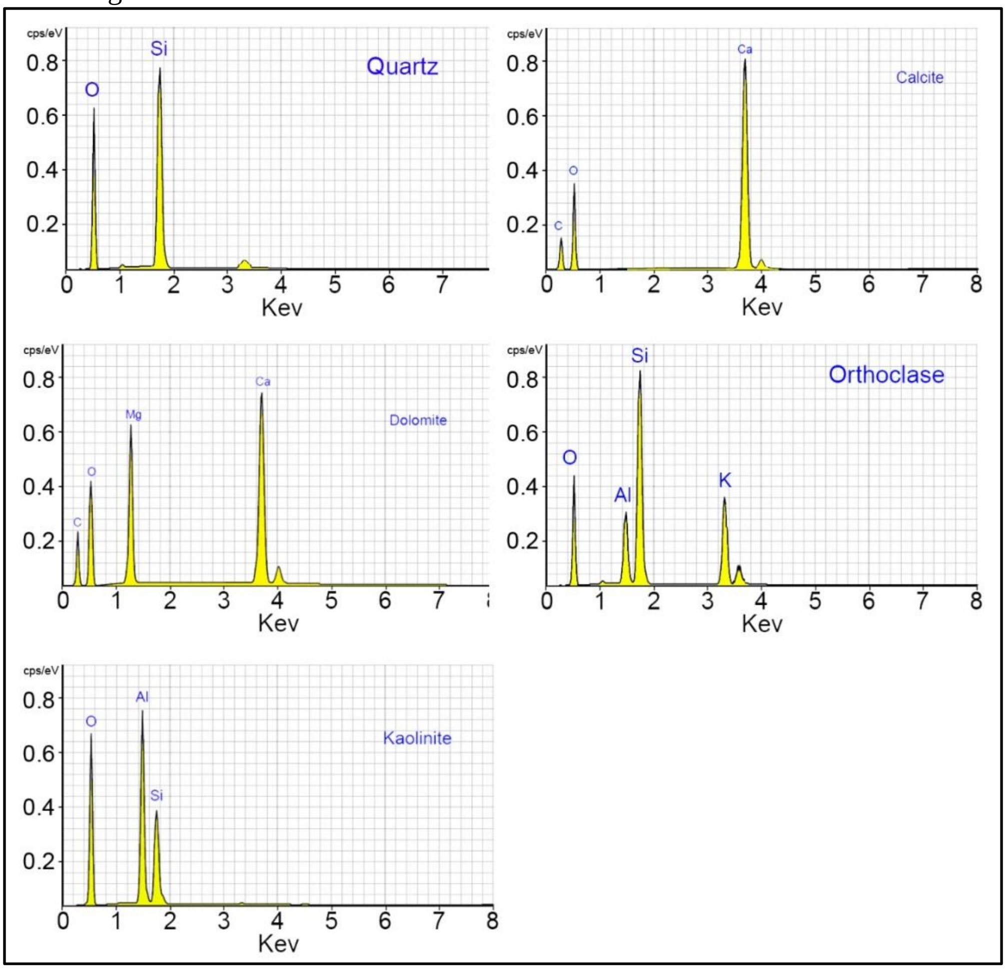

Figure 6- SEM spectra showing the mineralogy of the Tigris river sediment abrasive.

Table 2- Light and heavy mineral composition of the Tigris river abrasive in different grain sizes

River sediments	Wt. (gm)	L.M. (gm)	H.M. (gm)	L.M. %	H.M. %	Q (%)	F (%)	RF%
Medium sand	25	24.19	0.81	96.76	3.24	45.4	5	49.5
Fine sand	25	24.18	0.82	96.72	3.28	46.5	6.9	46.4
Very fine sand	25	23.98	1.02	95.92	4.08	48.9	6.9	44
Average	25	24.12	0.88	96.46	3.53	46.9	6.3	46.6

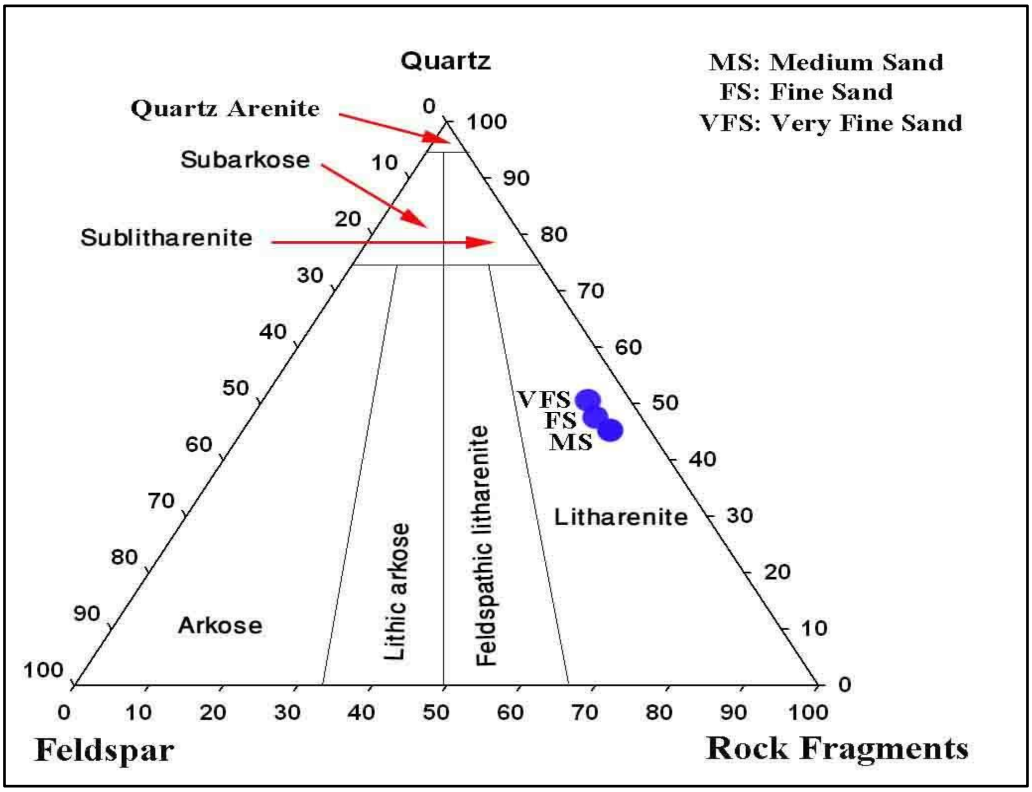

Figure 7- Folk diagram showing the petrographic composition of the Tigris river sediments [13].

3.2 Abrasive Particle Shape

The shape of the abrasive particle is one of the fundamental factors affecting the polishing process [14, 15]. In this study, a scanning electron microscope (SEM) was used in investigating the sphericity and roundness of abrasive in medium sand, fine sand, very fine sand, coarse silt, medium silt and fine silt and clay (Figure-8). The grain shape was checked again the standard sheet given by [16]. Grains of medium sand to very fine sand are characterized by angular shape with high sphericity of 0.7 and roundness of 0.5, but the grains of coarse silt to fine silt and clay are characterized by sub-rounded shape with low sphericity of 0.5 and roundness of 0.7. The shape of grains affects the polishing process; the rounded grains have a more uniform effect than the angular grains [17]. The ultra-fine grains of 18 µm look more homogenous, more rounded and has less sphericity [18]. The coarse grains (45 -250 µm) seems to be agglomerated and have less action of polishing and reducing grooves throughout a polished surface.

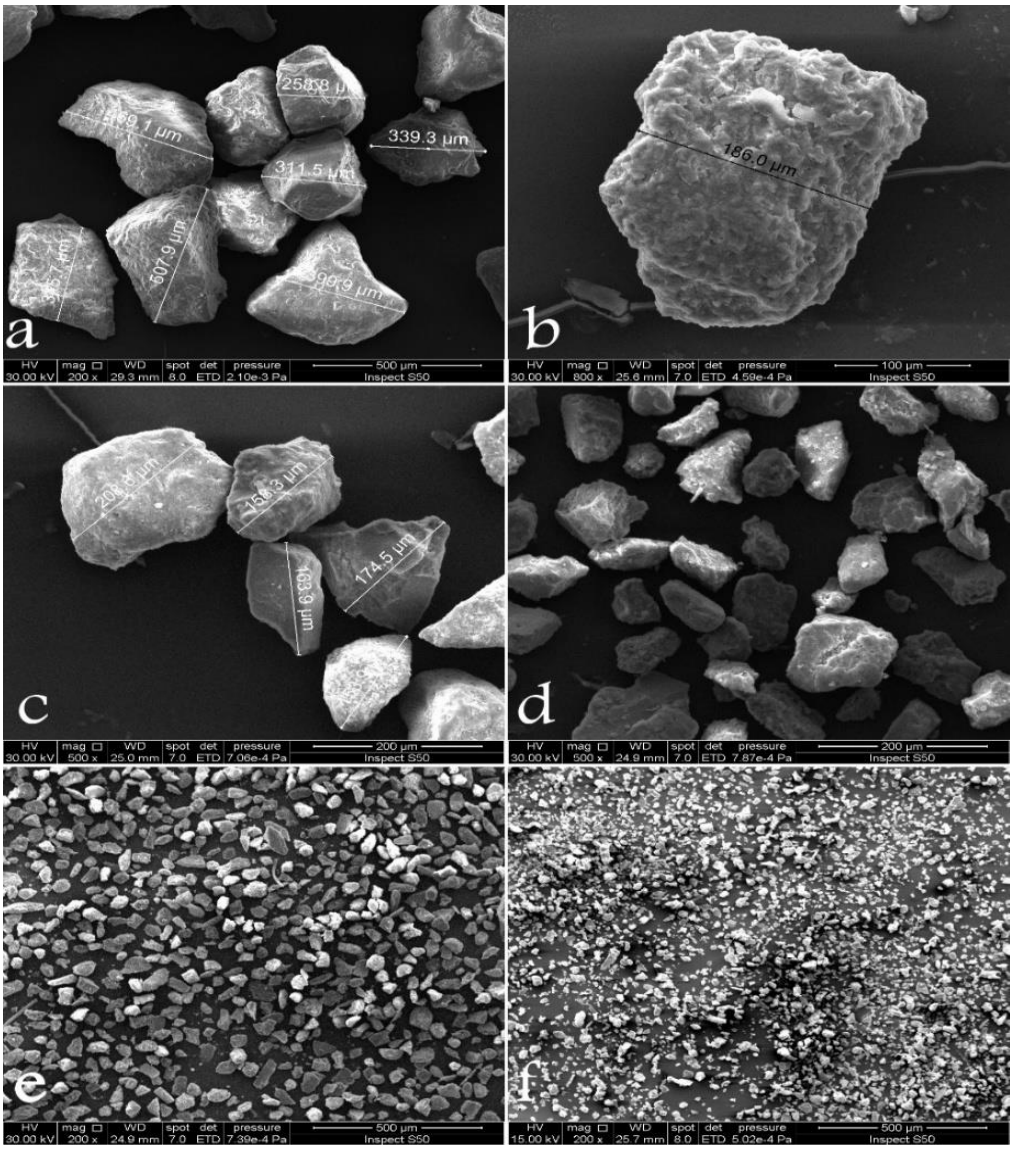

Figure 8- SEM images of different grain sizes of the abrasive; A) Medium sand; B) Fine sand; C) very fine sand; D) Coarse silt; E) Medium silt and F) Fine silt and clay.

3.3 Polishing Process and Assessment

The river sediments were used as an abrasive starting with the coarse grains and ending with the fine grains (250, 125, 71, 45, 25 and 18 µm). This was followed by using 7 and 2.5 µm sized diamond paste for buffing and final polishing process. This application helps to reduce the scratches and grooves gradually. The roughness (Ra) and reflectance (R%) were investigated and measured at every polishing stage (Table-3). The surface roughness of the magnetite decreased systematically in the order of 72.2, 51.8, 23.7, 17.2, 10.9, 7.5, 6 and 3.8 µm, proportionally with decreasing grain size, but reversely with reflectance which increases in the order of 0, 0, 0.3, 1.2, 2.5, 3.7, 9.3 and 20%. The relationship between grain size of river sediment abrasive and each of roughness (Ra µm) and reflectance (R%) values is displayed in Figure-9. The use of 18 µm sized abrasive grains yields highest reflectance (3.7%) and lowest roughness (7.5 µm). So, the finest grain-sized abrasive of 18 µm can be used for improving the irregular surface and refining the roughness of the magnetite surface. On the other hand, polishing by the coarse grains resulted in a surface roughness of 72.2 µm with low reflectivity of ~0%.

Table 3- Roughness and reflectance values measured on the magnetite surface for polishing and buffing stages using different grain size of river sediments as abrasive. G.S.: Grain size; Ra: Roughness; R: reflectivity

Abrasive (Sediments)				Measurements	
Stage	**G.S. (µm)**	**mesh (grit size)**	**Fraction type**	**Ra (µm) n = 10**	**R (%) n =1**
Polishing by Sediments	250	60	M. Sand	72.2	0
	125	120	F. Sand	51.8	0
	71	200	V.F. Sand	23.7	0.3
	45	325	C. Silt	17.2	1.2
	25	600	M. Silt	10.9	2.5
	18	1200	F. Silt & Clay	7.5	3.7
Buffing by Diamond paste	7	2000	----	6	9.3
	2.5	5000	----	3.8	20

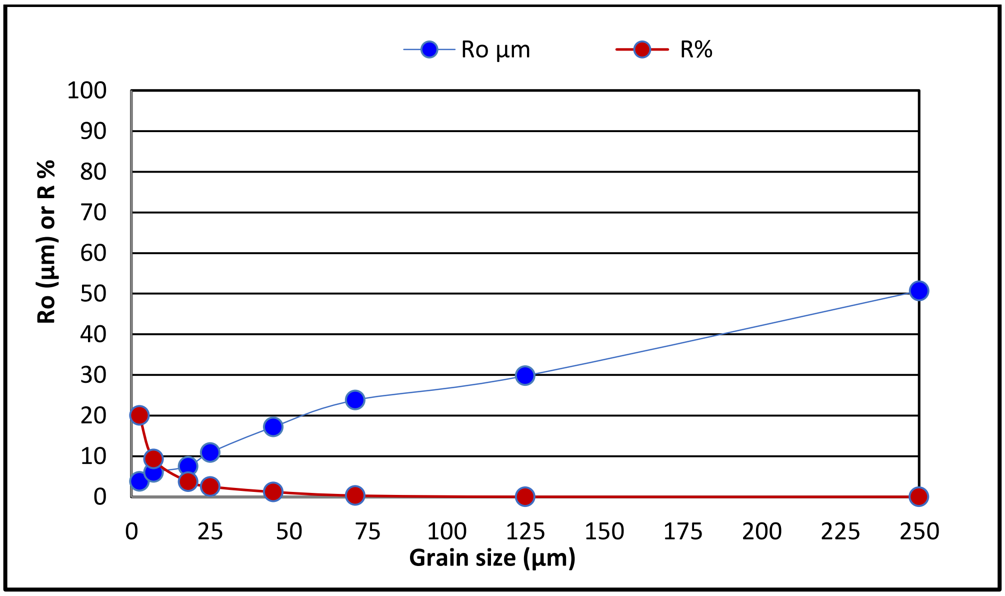

Figure 9- The relationship between grain size of river sediment abrasives and each of roughness (Ra µm) and reflectance (R%) values showing perfect positive proportionality with the R%, but negative one with Ra

In addition to the evaluation of the efficiency of the polishing processes by measuring the reflectivity and roughness of the magnetite surface, the magnetite was also studied under the reflected light microscope to check on the degree of success of polishing process. This process is done by studying the magnetite surface and observing the softness of the surface and the rate of reduction of the number of scratches and pits. Photomicrographs were snapped under microscope for the documentation of the efficiency of abrasive at each stage of the polishing process (Figure-10). The coarse grain sizes of 250, 125µm are recommended for polishing hard materials; for example: the coarse granules produced a scratched surface which increased the roughness values to 72.2 and 51.8 µm, respectively, and decreased reflectance values to zero. The fine grained abrasive of 18 µm look to be preferable for polishing magnetite, it produces a magnetite surface of only 7.5 µm roughness and 3.7% reflectance. For further improvement of polishing of the surface of magnetite and give it more gloss, it was buffed by diamond paste starting with grain sizes 7 μm and then 2.5 μm. The diamond grains are capable to produce a perfect level surface without scratches and gouging [3]. The typical reflectance of the polished surface of magnetite is 20% [3]. This study produced 3.7% reflectance by using 18 μm particle size of abrasive, and improved to 20% by using 2.5 μm diamond paste. Consequently, the tested river sediments can be considered as a preliminary effective abrasive capable of removing good deal of scratches and produce satisfactory polished surface for magnetite, ready to be followed by polishing and buffing with 7 μm and then 2.5 μm diamond paste which result in a polished surface than can be studied under reflected polarized microscope.

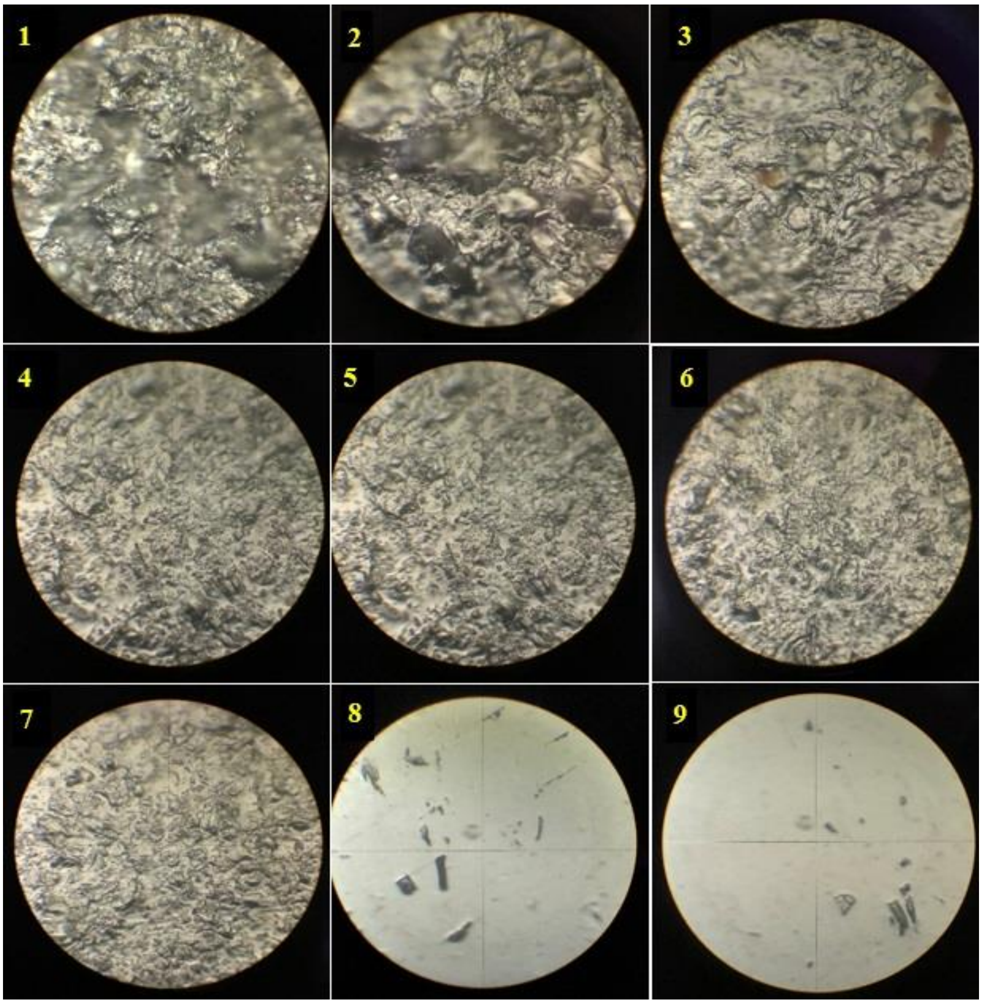

Figure 10- Photomicrographs displaying the progressive development of magnetite surface polishing causing the roughness to decrease from 1 to 9.

4. Conclusions

The following conclusions can be drawn from laboratory experiments conducted on magnetite ore sample smoothing and polishing using the Tigris River sediments collected from an area in Baghdad city.

1. The experimented Tigris river sediments are litharenite of $Q_{46.9}F_{6.3}R_{46.6}$ mineral composition.
2. Mineralogically the abrasive is composed of 96.46% light minerals and 3.53% heavy minerals. The finest grains are relatively rich in feldspar, while the coarse grains are rich in rock fragments that consist of calcite, dolomite and minor amount of kaolinite.
3. Geochemically, the abrasive is a siliceous sand, composed of SiO_2 (34.3%), CaO (17.5%) Al_2O_3 (6.46%), Fe_2O_3 5.12%), MgO (2.93%), K_2O (1.03%), P_2O_5 (0.54%), SO_3 (0.22%) and LOI (32%).
4. The quartz is concentrated in the very fine sand fraction of the abrasive, feldspar in the fine and very fine sand fraction, while the rock fragments in the medium sand fraction.

5. Grain shapes played an important role in polishing process where the angular grains played a different role than the rounded grains. The coarse grains within the medium , fine, and very fine sand are angular of high sphericity of 0.7 and roundness of 0.5; meanwhile the finer grains in the coarse-, medium- and fine-silt fractions and clay seem to be of sub-rounded and of low sphericity of 0.5 and roundness of 0.7.
6. The coarser grains abrasives 45, 71, 125 and 250 µm tend to be accumulated which has reduced its effectiveness.
7. The 18µm size abrasive is recommended for preparing and polishing the magnetite surface, while the 250, 125 µm sizes are not suitable.
8. The Tigris river sediments used as abrasive can be considered as fine-grained granules with the ability to prepare a flat, regular surface with little roughness and a reasonable degree of reflectivity.

5. Acknowledgments

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6. References

1. Cornell, R.M. and Schwertmann, U. **1996.** *The iron oxides.* Weinheim, Germany. VCH Press.
2. Thomas-Keprta, K. L., Bazylinski, D.A., Kirschvink, J.L., Clemett, S.J., McKay, D.S., Wentworth, S.J., Vali, H., Gibson, Jr. and Romanek, C.S. **2000.** Elongated prismatic magnetite crystals in ALH84001 carbonate globules: potential Martian magnetofossils. *Geochemist Cosmochim Acta*, **64**: 4049-4081.
3. Craig, J.R. and Vaughan, D.J. **1981**. *Ore Microscopy and Ore Petrography*. John Wiley and Sons. New York, 406 P.
4. Odior, A.O. and Oyawale, F.A. **2011**. Formulation of silicon carbide abrasives from locally sourced raw materials in Nigeria, Proceedings of the World Congress on Engineering, London, U.K., Vol. 1.
5. Konstanty, J. **2005**. *Powder Metallurgy Diamond Tools.* Powder Metallurgy Dept., University of Mining and Metallurgy, Krakow, Poland. Published by Elsevier Ltd.
6. Wentworth, C. K. **1922**. A Scale of Grade and Class Term for Clastic Sediments: *Jour. Geology*. **30**: 377-392.
7. Ramdohr, P. **1969**. *The Ore Minerals and Their Intergrowths,* 1st Edition, Pergamon Press.
8. Bousfield, B. **1992**. *Surface Preparation and Microscopy of Materials*. New York. John Wiley and Sons.
9. Carver, R. E. (edit.), **1971**. *Procedures in Sedimentary Petrology,* New York, Wiley- Interscience.
10. Mange, M.A. and Maurer, H.F. **1992**. *Heavy Minerals in Color*. London, Chapman Hall.
11. Moreland, G.C. **1968**. *Preparation of Polished Thin*-Section, In Hutchison, laboratory handbook of petrographic techniques, Wiley Inter. Science.
12. Awadh, S. M. and Rana A. A. **2017.** Assessment of the Rutba Formation silica sand as abrasive for grinding and polishing galena: contribution in ore microscopy. *Iraqi Bulletin of Geology and Mining,* **13**(1): 99-106.
13. Folk, R. **1974**. *Petrology of Sedimentary Rocks*. Hamphill, Texas, 182 P.
14. Barrett, P.J. **1980**. The shape of rock particles, a critical review. *Sedimentology*, **27**: 291-303.
15. ISO. **2006**. *Representation of results of particle size analysis.* Part 1-6. Part 6: Descriptive and quantitative representation of particle shape and morphology. Draft International Standard ISO/ DIS 9276, Geneva.
16. Krumbein, W.C. and Sloss, L.L. **1963**. *Stratigraphy and Sedimentation*. 2nd Ed, W.H. Freeman and Company, San Francisco.
17. Ramdohr, P. **1966**. *The Selection of Ore Specimens and the Preparation of Polished Sections.* In, H. Freund, Ed., Applied Ore Microscopy, Macmillan Company, New York.
18. Sin, H., Saka, N. and Suh, N.P. **1979**. Abrasive Wear Mechanism and The Grit Size Effect. *Wear* **55**: 163-190.