Iraqi Bulletin of Geology and Mining *Vol.13, No.1, 2017* *p 99 – 106*

ASSESSMENT OF THE RUTBA FORMATION SILICA SAND AS ABRASIVE FOR GRINDING AND POLISHING GALENA: A CONTRIBUTION IN ORE MICROSCOPY

Salih M. Awadh[*1] and Rana A. Ali[1]

Received: 01/ 03/ 2017, Accepted: 20/ 07/ 2017
Key words: Silica sand; Abrasives; Polishing; Galena; Reflectance; Roughness

ABSTRACT

This study aims to assess the Iraqi silica sand collected from Rutba Formation as an abrasive for grinding and polishing galena surface for mineralogical study under the reflected light microscope. Grinding is performed using four-grain sizes of silica sand (68, 46, 30, and 18 µm) which are equivalent to 260, 325, 600, and 1200 mesh respectively. Polishing and buffing stages are done using two-grain size of diamond paste (7 and 2.5 µm). The reflectance (R%) values are inversely proportional to the grain size (the lower particle size, the higher the reflectivity), while the surface roughness (Ra) is directly proportional to the grain size. The reflectance is increased from 0, 5.4, 12.2, 16.4, 23.5, 28.3, to 32.3% and roughness is decreased from 57.2, 47.8, 35, 22.5, 8.4, 6.9, to 3.3 µm with grinding and polishing abrasives of grain sizes of 68, 46, 30, 18, 7, and 2.5 µm. The ideal reflectance of the polished surface of galena at 546 nm (air) is 43.1%, and 41.9% at 589 nm in air. The highest reflectance of 32.3% at 546 nm in air achieved by this study is adequate to diagnose galena and its texture intergrowth under the polarized reflected light microscope.

تقييم رمل السليكا لتكوين الرطبة كمادة صاقلة لتنعيم وصقل الغالينا: مساهمة في دراسة مجهرية الخامات

صالح محمد عوض و رنا عباس علي

المستخلص

تهدف هذه الدراسة الى تقييم رمل السليكا من تكوين الرطبة كمادة صاقلة لتنعيم وصقل وتلميع سطح معدن الغالينا لأغراض الدراسة المعدنية تحت المجهر العاكس للضوء. تم اجراء عملية التنعيم باستخدام اربع احجام حبيبية من رمل السليكا (68 و 46 و 30 و 18 مايكرون) والتي تكافيء 260 و 325 و 600 و 1200 مش على التوالي، فيما اجريت مراحل الصقل والتلميع باستخدام حجمين حبيبيين من معجون الماس (7 و 2.5 مايكرون). تناسبت قيم الانعكاسية عكسيا مع الحجم الحبيبي (حيث تزداد قيم الانعكاسية كلما قل الحجم الحبيبي للمادة الصاقلة)، فيما تناسبت خشونة السطح طرديا مع الحجم الحبيبي. إزدادت قيم الأنعكاسية من 0، 4.5، 12.2 ، 16.4، 23.5، 28.3، الى 32.3% وتناقصت قيم الخشونة من 57.2، 47.8، 35، 22.5، 8.4، 6.9، الى 3.3 مايكرون مع مواد التنعيم والصقل ذات الاحجام الحبيبية 68 و 46 و 30 و 18 و7 و 2.5 مايكرون. تبلغ الإنعكاسية المثالية لسطح معدن الغالينا المصقول عند 546 نانوميتر (في الهواء) 43.1%، وعند 589 نانوميتر في الهواء 41.9%. إن أعلى قيمة للأنعكاسية تم التوصل اليها من خلال هذه الدراسة عند 546 نانوميتر في الهواء هي 32.3% والتي بدت كافية لتشخيص معدن الغالينا وأنسجة نموه المتداخل تحت المجهر العاكس للضوء.

[1] Geology Department, College of Sciences, University of Baghdad, Baghdad, Iraq,
[*]e-mail: salihauad2000@yahoo.com

INTRODUCTION

Many common abrasives are routinely used for finishing targeted materials such as metals, alloys, and glasses. Carborandom (silicon carbide SiC), zirconia alumina (an aluminum oxide enhanced with approximatly 20% zirconium oxide), diamond abrasive (a synthesis diamond with high hardness of 10 on the Moh's scale), and emery are abrasives widely used to finalize polishing stages and reducing surface roughness. Silica (SiO_2) and Alumina (Al_2O_3) are good abrasives due to their composition with a Moh's scale hardness range 6 – 8 (Crage and Vaughan, 1981). Buffing abrasives are mostly composed of hard materials such as Al_2O_3, SiC and Fe_2O_3 which are used for producing shiny polished surfaces (Konstanty, 2005). The abrasives which are also commonly used consist of silica and sometime mixed with calcium carbonate in different ratios (Hefferren, 1976). Silica sand has widely been used for different abrasive processes such as wall cleaning, surface preparation for the paint and rust removal (Tator, 1998). Attempts were conducted by some researchers to manufacture abrasives from local raw materials. Quartz, coal, sodium carbonate, sawdust and sodium chloride from locally sourced raw materials in Nigeria were used for manufacturing of silica carbide abrasives (Odior and Oyawale, 2011). The substitute materials for silica sand in abrasive blasting such as coal slag, crushed glass, nickel slag, olivine, silica sand, dust suppressant specular hematite and staurolite had been evaluated in the abrasive plasting (Tator, 1999). This study is an attempt to test different sizes of silica sand as abrasive for galena. Most of ore minerals are opaque, so, they are studied under reflected light microscope. Hence, it is essential to prepare a polished section of the ore mineral that needs to be studied. In this study, the surface of galena section was tested to be polished using grinding, polishing, and buffing. The preparation of polished surface free from scratches and from relief is necessary for the identification of ore minerals and their textural interpretation (Graig and Vaughan, 1981). The aim of this study is to evaluate high purity silica sand from Rutba Formation for grinding and polishing galena surface. The Rutba Formation which was previously used for glass industry is exposed in the Western Desert of Iraq near the Jordanian border.

MATERIALS AND METHODS

- **Chemical and Mineralogical Analyses**

A total of ten samples were collected from various sites of the glass sand quarry within the Rutba Formation (Cenomanian – Early Cretaceous) located near Rutba town in the Western Desert of Iraq. For obtaining a representative sample, 25g from each sample was mixed together. The total volume of the sample was coned and quarted into four equal parts. Then, one part was coned and quartered again. By repeating the procedure five times, a homogeneous and representative sample was obtained. Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) was used for analyzing the major oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, MnO, P_2O_5, SrO, Cr_2O_3, BaO and L.O.I). The chemical analysis was carried out in ALS Laboratory Group, Analytical Chemistry and Testing Services, Mineral Division-ALS Chemex at Dublin in Ireland. The adopted procedure is ME-ICP06 code including a package of 13 element fused by lithium borate. 0.2g of the sample is added to 0.9g of lithium metaborate/lithium tetraborate flux, mixed well and fused in a furnace at 1000ºC. The resulting melt is then cooled and dissolved in 100 ml of 4% nitric acid, 2% hydrochloric acid solution (Pock, 1979 and Saikkonen, 1996). This solution is then analyzed by ICP-AES and the results were corrected for spectral inter-element interferences. Oxide concentration is calculated from the determined elemental concentration. The mineralogical analyses is conducted by scanning electron microscope (SEM) and X-ray

diffraction (XRD). XRD is performed at the Germany Lab, Department of Geology, College of Science, University of Baghdad. The analytical conditions are listed in Table 1.

Table 1: XRD conditions used for the silica sand run

X-Ray	Slit	Measurement
Target: Cu Wave: 1.54060 Voltage: 40 KV Current: 30 mA	Divergence: 1.0 deg Scatter: 1.0 deg Receiving: 0.15 mm	Axis: Theta- 2 Theta Scan mode: Continuous Scan Range: 5.0 – 50.0 deg Step: 0.05 deg Speed: 5.0 deg/min

- **Abrasive Preparation**

The representative sample of silica sand was washed by distilled water, dried at 80ºC for 2h and sieved to four grain sizes (68, 46, 30 and 18 µm) which are equivalent to 260, 325, 600 and 1200 mesh respectively. The procedures of abrasive and polished section preparation along with the grinding and polishing process had been conducted at the Department of Geology, College of Science, University of Baghdad.

- **Polished Section Preparation**

A small piece of galena was placed in the sample casting of 2.5 cm diameter, as most researchers find the circular polished sections of 2.5 or 5 cm to be adequate diameters (Graig and Vaughan, 1981). A metal mold casing of sample with a total thickness of 2 cm is used. A thin coating of a lubricating agent is used to help in removing the sample once the casting resin has hardened. A full procedure of Ramdohr (1969) and Graig and Vaughan (1981) is followed to prepare the polished section.

- **Grinding and Polishing Process**

Presto-press device (Figure 1A) and polishing device (1500 rpm) (Figure 1B) available in the Department of Geology are used in this study. A preliminary section of galena with a diameter of 2.5 cm is made by using the device shown in Figure 1A. Grinding is done by using four-grain size of silica sand (68, 46, 30 and 18 µm) which are equivalent to 260, 325, 600 and 1200 mesh. The purpose of grinding is to prepare a smooth surface for further work by reducing thickness, removing the casting resin that covers the sample and deformation resulting from the initial cutting of the sample, and removing surface irregularities (Bousfield, 1992). Gentle manual hand pressure is applied to the target piece (galena) on a disc machine. Drops of distilled water are continuously used as lubricant, cleaning and heat reducing to produce finer finishing. Each grinding duration is approximately 4 min. The speed of the rotating disc is 1500 rpm, where faster disc speed represents faster finishing times. After grinding processes, two polishing stages are done for sample buffing. Two polishing (buffing) stages are applied using diamond paste (7 and 2.5 µm).

- **Abrasive Evaluation**

The surface roughness (Ra nm) and reflectance (R%) are the two parameters used to evaluate the action of the silica sand abrasive. Roughness (Ra nm) is measured using PosiTector with a probe type SPG (Figure 2). The device is normalized with the standard roughness surface. Roughness reading (µm) is measured for ten points (n = 10) along a path on the galena surface. Minimum, maximum, average and standard deviation is recorded for each polishing stage, then the average is used for the abrasive evaluation. The reflectance

(R%) is measured at 546 nm in air performed by Laser Beam System composteed of laser beam, photoelectric cell and galvanometer for measuring electric current. Laser beam invokes to receipt signals to a photoelectric cell that send to measure the electric current to be read on the microampere. The reflectance of the specimen is measured in the Optical Lab, Laser Branch, Applied Science Department, University of Technology. Polarized reflected light microscope is used to examine each stage of grinding, polishing and buffing, then a micro-image is picked up for each stage. This procedure is done in the Department of Geology, College of Science, University of Baghdad.

Fig.1: Presto-press device (A) used for making polished section; Dp-U2, a rotary grinding and polishing machine disc (B)

Fig.2: PosiTector device with standard plate and glass for the device normalization used for measuring the surface roughness

RESULTS AND DISCUSSION

The scanning electron microscope (SEM) and XRD techniques are used in the silica sand analysis which proves that it consists mainly of quartz (Figure 3). The chemical composition of the representative abrasive silica sand sample is listed in Table 2. The grinding stages produced a level surface of galena. The first step of grinding is done with a coarser grain size of silica abrasive. The subsequent processes were applied to reduce the scratches yielded from the previous grinding. The finest grain size of abrasive improves the surface level and reduces its roughness by removal the scratches, pits and polishing lines. For assessing the silica sand as an abrasive for galena, two parameters (roughness and reflectance) are measured and the results are presented in Table 3. Silica sand is a hard material whose hardness is 7 on the moh's scale. The grains of silica sand have a sub rounded shape, while they tend to be sub-angular to angular shape when they are fine. For the purpose of evaluating the smoothness of the surface of galena, both roughness and reflectivity are measured. The roughness is measured on a path at ten points on the galena surface and then averaged, while reflectivity is measured at one point (Table 3).

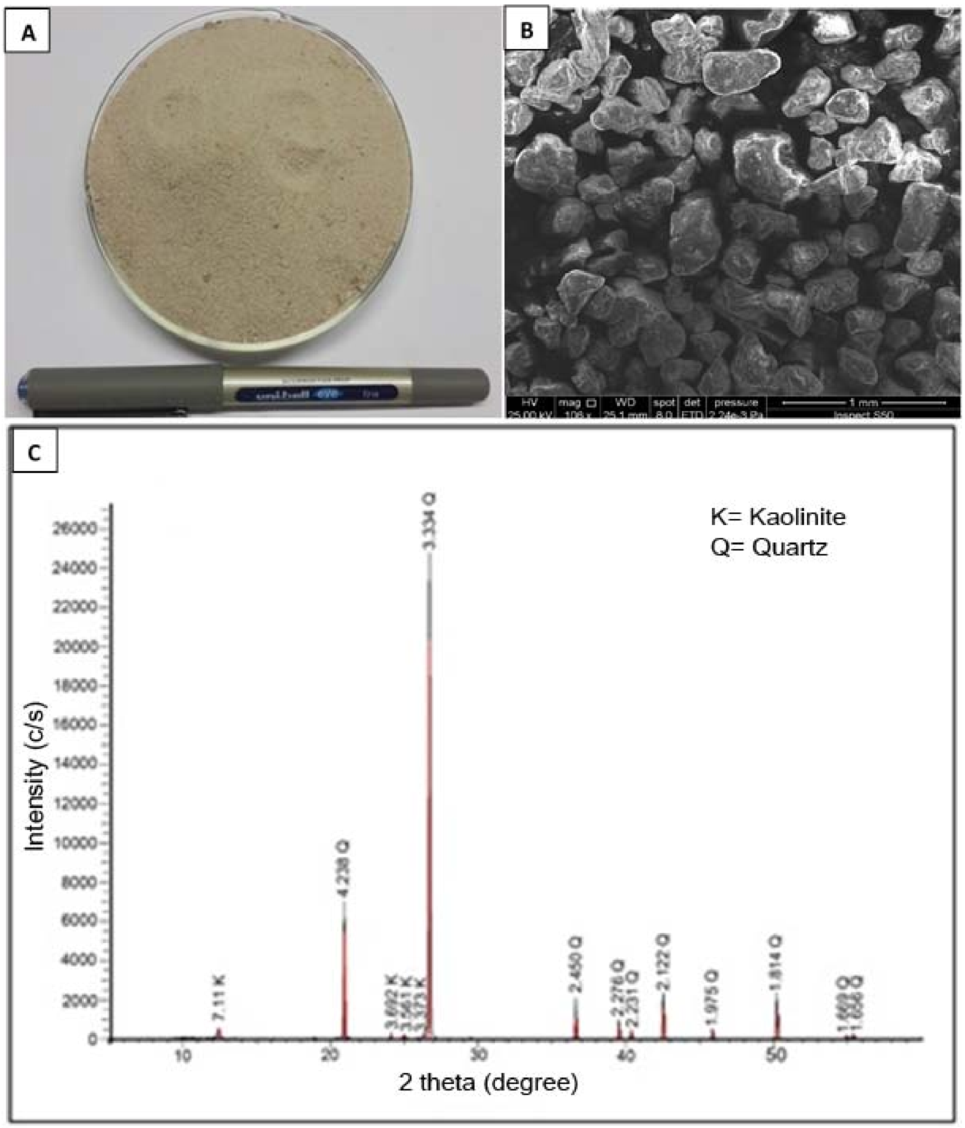

Fig.3: Silica sand sample; **A)** representative specimen; **B)** SEM image shows quartz grain; **C)** XRD diffractogram displays quartz as a main constituents

Table 2: Chemical composition (wt%) of the representative sample of silica sand

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	SrO	Cr_2O_3	BaO	L.O.I	Total
Silica sand	95.4	1.53	0.14	0.63	0.11	0.06	0.03	0.14	0.02	<0.01	<0.01	<0.01	<0.01	1.49	99.6

Table 3: Roughness and reflectance values measured on the galena surface for grinding, polishing and buffing stages using different grain size of silica sand as abrasive

Stage	Grain size (µm)	Approximate Mesh (grit size)	Measurements	
			Roughness (µm) n= 10	Reflectance (%) n= 1
Grinding by silica sand	120	100	57.2	0
	68	200	47.8	5.4
	46	325	35	12.2
	30	600	22.5	16.4
	18	1200	8.4	23.5
Polishing and buffing by diamond paste	7	3000	6.9	28.3
	2.5	8000	3.3	32.3

The grinding grain sizes are 120, 68, 46, 30 and 18 µm, and the diamond paste is used for the polishing and buffing stages with grain sizes of 7 and 2.5 µm. The values of roughness (57.2, 47.8, 35, 22.5, 8.4, 6.9 and 3.3 µm) decrease with decreasing grain size, whilst, the reflectance (0, 5.4, 12.2, 16.4, 23.5, 28.3, 32.3) increase proportionally (Figure 4).

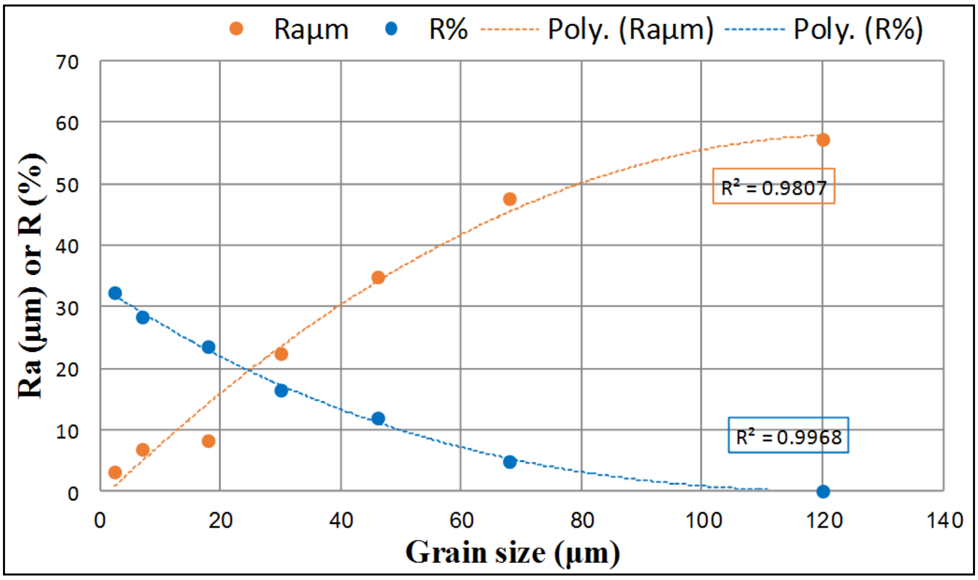

Fig.4: The relationship between grain size of abrasive (silica sand) and each of roughness (Ra µm) and reflectance (R%) values; Perfect positive proportional with the R%, but proportionally negative with Ra

Each stage of grinding and polishing has been examined, and then the surface of galena is gradually improved with decreasing the grain size of abrasive. The optical image analysis is recommended for ore petrography interpretation (Berrezueta and Castroviejo, 2007). Micro-images were taken for the galena surface under reflected light microscope for each grinding, polishing and buffing stage (Figure 5). The 30 µm or 600-mesh abrasive is needed for harder materials, whilst the 18 µm which is equivalent to 1200-mesh abrasive appears suitable for galena due to its softness. By using 18 µm abrasive, the rough polishing was more effective for removal of the surface deformation and deeper scratches from the galena surface. Grinding could be completed with 600 and 1200 mesh abrasive, and will be followed by polishing stages. Two polishing stages are applied with diamond paste on Napless Cloth. The first one is started with a diamond paste of 7 µm, while the second one is started with a diamond paste of 2.5 µm. The embedding permits the diamond grains to plane the surface without rolling, relief, irregular scratches and gouging (Craig and Vaughan, 1981). Scratches and pits begin to fade gradually as the particle size decreases. The typical reflectance of the polished surface of galena at 546 nm is 43.1%, and 41.9% at 589 nm in the air (Craig and Vaughan, 1981). The maximum reflectance (23.5%) is obtained in the case of 18 µm particle size of abrasive (silica sand), then it increases to 32.3% by using the 2.5 µm diamond as abrasive. With this reflectance, galena can be easily identified with its texture. Consequently, the silica sand is an effective abrasive for grinding and polishing galena surface to ready for testing under polarized reflected microscope.

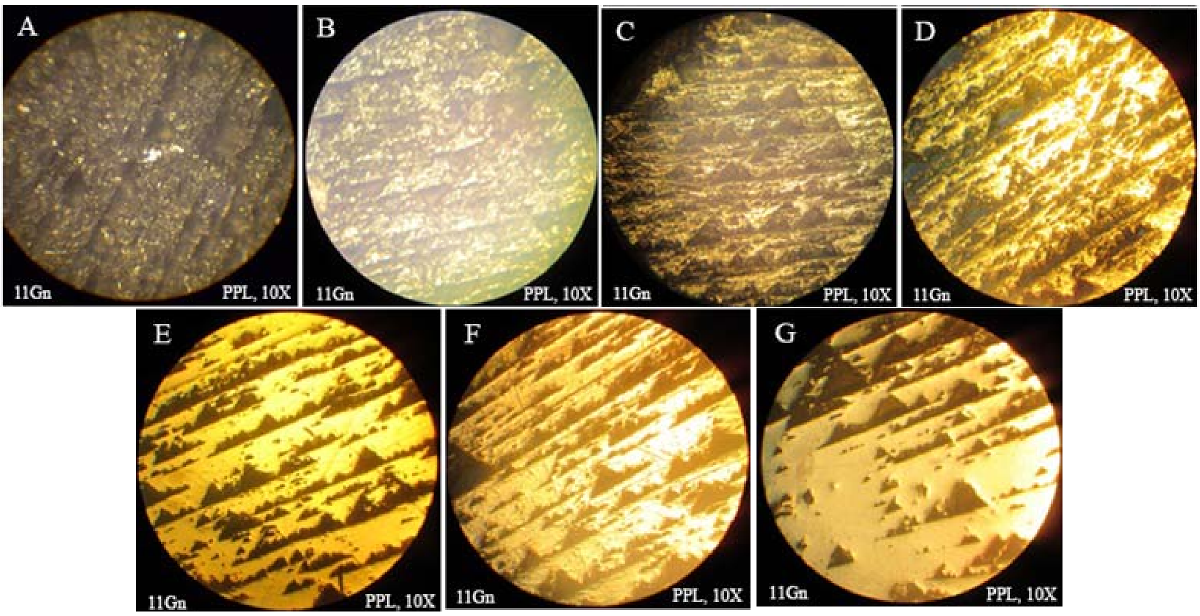

Fig.5: Photmicrographs for galena surfaces showing different grinding, polishing and buffing stages using different sizes of abrasive silica sand; A, B, C, D and E: display the grinding stages with 120, 68, 46, 30 and 18µm respectively; F and G represent the polishing and buffing stages with 7µm and 2.5µm diamond paste respectively

CONCLUSIONS

The following conclusions can be drawn from laboratory experiments on silica sand from Rutba Formation as abrasive for grinding and leveling the surface of galena molds:

1. The surface irregularities improve by polishing as the particle size decreases.

2. The final surface roughness of galena decreases from 57.2 µm to 8.4 µm by using sand grain sizes of 120, 68, 46, 30 and 18 µm.
3. The best polished surface is obtained by using 18µm (1200 mesh) size sand abrasive; the characteristic features and textures of galena are diagnosed under these conditions.
4. The time factor affects the abrasiveness of the target surface.

REFERENCES

Berrezueta, E., Castroviejo, R., 2007. Automated microscopic characterization of metallic ores with image analysis: A key to improve ore processing. I: Test of the methodology. Rev. Metal. 43, 294 – 309.

Bousfield, B., 1992. Surface Preparation and Microscopy of Materials. John Wiley and Sons, New York, 342pp.

Craig, J.R., and Vaughan, D.J., 1981. Ore Microscopy and Ore Petrography. John Wiley and Sons. New York, 406pp.

Hefferren, J.J., 1976. A laboratory method for assessment dentifrice abrasivity, J. Dent. Res., 55: 563 – 573.

Konstanty, J., 2005. Powder Metallurgy Diamond Tools. Powder Metallurgy Dept., University of Mining and Metallurgy, Krakow, Poland. Published by Elsevier Ltd.

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 2011, London, U.K., Vol.1.

Pock, R.A., 1979. Handbook of Decomposition Methods in Analytical Chemistry. New York; John Wiley and Sons, 444pp.

Ramdohr, P., 1969. The Ore Minerals and Their Intergrowths, 1st Edition, Pergamon Press, 1192pp.

Saikkonen, R., 1996. Chemical analysis of rocks and minerals new analytical methods developed for some major and minor components, Academic Dissertation submitted to the Department of Chemistry, Faculty of Science of the University of Helsinki. Espo, Geological Survey of Finland, Chemical Laboratory, 47pp.

Tator, KTA., 1998. Evaluation of substitute materials for silica sand in abrasive blasting. Contract No. 200-95-2946 prepared for Department of Health and Human Services Centers for Disease Control and Prevention National Institute for Occupational Safety and Health, 146pp.

Tator, KTA., 1999. Evaluation of substitute materials for silica sand in abrasive blasting, Contract No. 200-95-2946; prepared For Department of Health and Human Services Centers for Disease Control and Prevention National Institute for Occupational Safety and Health 115 Technology Drive Pittsburgh, PA 15275-1085, 68pp.

About the author

Dr. Salih M. Awadh, A professor of geochemistry, graduated from the University of Baghdad in 1986 with B.Sc. Degree in Geology; M.Sc. (1992) in Geochemistry; Ph.D. (2006) in Geochemistry and Economic Geology; and Post Doctorate degree (2014) from Warsaw University – Poland. He has over twenty seven years experience in Geochemistry, Organic Geochemistry, Ore Geology and Environmental Studies, includes more than twenty years as an academician staff. He is an Editor-in-Chief of the Iraqi Geological Journal, and a member of the Editorial Board of both of the Iraqi Bulletin of Geology and Mining, and International Journal of Earth Sciences and Engineering. ISSN 0974-5904, (Elsevier indexing). His publications exceeded 60 papers and 5 books, and supervised about 18 master's and doctoral theses.

e-mail: salihauad2000@yahoo.com