Journal of Geology & Geophysics

Howari, J Geol Geophys 2015, 4:3 DOI: 10.4172/2329-6755.1000200

Research Article Open Access

Evaluation of Chemical and Petrographic Characteristics of Silica Sand from Tabuk in Saudi Arabia

Fares M Howari*

College of Sustainability and Human Sciences, Zayed University, PO Box 144534, Abu Dhabi, United Arab Emirates

Abstract

Silica sand is one of the most common varieties of sand, and it is used in industrial applications throughout the world. The application depends on the purity, grain size and chemical characteristics. In the present study, X-ray, chemical and petrographic analyses were used to study sand deposits from Tabuk area in Saudi Arabia. The collected samples from the site are composed of 98% quartz (SiO_2), with very minor traces of carbonate and dark minerals which account for the rest of the sample constituents. The examined individual quartz grains have excellent purity, and about 98% of the grains were white transparent pure silica. The grains are mainly rounded to sub-angular. The chemical analysis indicated that the percentages of major oxides of Si, Al, Cr, Fe, and Ti were 97%, 1.5%, % <0.006%; 0.035%, and 0.0531% respectively. The grains sizes are fine and their sizes concentrated mostly around the 0.155 mm. Due to its high quality, the inspected deposit meets the industrial standards.

Keywords: Silica; Sand; KSA; Petrographic; Grain size; X-ray

Introduction

High-grade silica sand is an essential raw material in many industries and is used in the manufacture of container glass, glass fiber, chemical products, and silicon metal; as filler for rubber, plastics, and ceramics; and in the construction business (SGS, 2009) [1]. The present report evaluated, for industrial purposes, silica sand deposit in a location close to Bin Hirmaz well area, Tabuk in Saudi Arabia. To consider this silica deposits as an industrial mineral, it should give products of at least 95% SiO_2. Also the silica deposit should meet certain grain sizes and optical characteristics. For example to be considered for glassmaking and ceramics it should be transparent-translucent and has a glassy-vitreous luster and it should not have significant portion of trace contaminants or impurities such as Cr or Fe. To achieve the major objectives of this report, fifteen spots (40 x 40 cm) were examined (both in field and lab), ten of them were made at a longitude transects on the study area, and the rest were randomly chosen. The collected samples were subjected to different mineralogical and textural analyses as will be given in the methodology section.

Weather Pattern and Topography

According to Al-Harbi [2], Tabuk region is one of the largest regions in Saudi Arabia which covers an area of 139,000 km², and corresponds to about 7% of the country's total area. The agricultural area of investigation is located in the north of Tabuk city and roughly is extended from latitudes 28°28′ to 28° 40′ N and longitudes from 36° 06′ to 36° 29′ E. The area of interest occupies 543.4 km². This area is dominated by rock structures of Tertiary Era. The Quaternary formations comprise alluvial deposits of silt and gravels while the mountainous areas are dissected by many internal valleys

The weather in this region is desertous continental weather with hot summers and mild winters. Temperatures in the summer are between 26 and 46°C, while in winter they are between -4 and 18°C, with widespread frosts. Snowing is common, with temperatures reaching low -6°C in some winters. Rainfall in Tabuk Area falls in the winter months from November to March, and precipitation ranges between 50 and 150 mm, with some not uncommon snow every 3-4 years.

The boundaries of Tabuk region extends from the Saudi-Jordanian border in the north to the north of Medina Al Munawwarah, and from the Red Sea on the west to the Hufa depression in the east. It lies at the junction of Hejaz mountain range and the plains of the north in the basin of sedimentary area. There is plenty of underground water and the area is surrounded by hills and wadis, the important of which are Wadi Al-Akhdar (the green valley), Wadi Damm and Wadi Asafir. The town of Tabuk is an important gateway in northern Arabia on the active pilgrimage and caravan trade routes.

Methodology

Field survey was conducted by inspecting possible contacts between possible lithologic formations. This is done by visually inspecting the rocks in the investigated area. Samples were collected and grain-size analyses were conducted for the samples using the sieving procedures given in the standard methods [3-7]. Two hundred grams of dry sand were sieved for 15 minutes using a mechanical sieving machine. Sieves used followed the whole phi-Wentworth system i.e. 63, 125, 250, 500, 1000 and 2000 µm. The sand that remains in each sieve was weighed and expressed as a percent of the total sample weight. Note that the logarithmic phi scale or value for the grain size (in base two) are calculated from particle diameter size measures in millimeters as follows:

$$\phi = -\log_2 d = -\left(\frac{\log_{10} d}{\log_{10} 2}\right)$$

where:

φ= particle size in φ units

d = diameter of particle in mm

Note: the negative sign is affixed so that commonly encountered sand sized sediments can be described using positive φ values.

X-ray diffractometery were used to identify the bulk sample composition using a Philips diffractometer with a Ni-filtered Cu-K α radiation run at 40 Kv and 30 mA [5]. Identification of mineral

***Corresponding author:** Fares M Howari, College of Sustainability and Human Sciences, Zayed University, PO Box 144534, Abu Dhabi, United Arab Emirates, Tel: 00971-2-5993111; E-mail: fares.howari@zu.ac.ae

Received March 14, 2015; **Accepted** April 14, 2015; **Published** April 16, 2015

Citation: Howari FM (2015) Evaluation of Chemical and Petrographic Characteristics of Silica Sand from Tabuk in Saudi Arabia. J Geol Geophys 4: 200. doi:10.4172/2329-6755.1000200

species was based on data of the American Society for Testing and Material (ASTM) and those published by the International Center for Diffraction Data (1995). The carbonate content was determined for all samples using standard method. A portion of the sample weighing c.100 gm was treated with warm HCl (10%), washed several times, dried and weighed.

Petrographic slides, thin sections, were prepared and examined under binocular and polarized microscope for mineralogy, optical properties, and for observing and confirming grain sizes. Roundness of quartz grains were also examined microscopically and described. Parallel traverses were made across each slide and 200 grains from each sample were described according to published literature. Since the visual inspection revealed that the heavy minerals contents in the samples were very trace, they were separated and quantified under the binocular microscope. Sorting which is a measure of how similar all the grains in a sample are to the mean was determined using Folk microscopic techniques. For cross checking other analyses and reports on the study area, samples from four locations were analyzed for major oxides and trace with the Inductively Coupled Plasma (ICP).

Field Observations

The visited location is 1535 m x 600 m, and it is about 35.3 km west of Beer Hermaz area in the vicinity of Tabuk, Saudi Arabiya. Close to the site several occurrences of rich, black crust that coats the underlying sandstone platform exist. The black crust looks like lava, but careful inspection indicated that is mainly highly oxidized silica may be due to hydrothermal water rich with iron. However, the site itself is free from this crust (Figures 1 and 2). The investigation revealed that the crust is younger than the sandstone, thus it is unlikely to exist underneath unless in the case of folding but there was no surface field evidences. The site has advantage of being exposed above the surface of about 60 m average in some locations. Thus offer more quantities or reserve of sand. The vein-like features appeared in Figure 2 are proved to be silica covered with weathering coat.

Figure 3 gives an overview of the investigated area. As can be observed the area is covered with unconsolidated sand which is a weathering product from the original formation and other contribution from nearby areas. The friable sand cover has quartz up to 90% and the rest portion accounts for rock fragments, carbonate and feldspar. The weekly consolidated sand, the formation of interest, under the friable or loose sand cover is white in color once break but has also very thin weathering product layer on top. Field reconnaissance and inspection revealed that the deposit itself is pure silica; and such weathering product is something natural in most if not all the other silica deposits.

The landscape of the entire area is gently slopes downward gradually to the east with little relief. Erosion by both fluvial and Aeolian processes has acted to transport the eroded materials from the relatively higher areas to the intervening basins. The nearby area is almost flat, which allows vertical movement of water through the weathering material. This topography will also aid (i.e. suitable) the expected quarry or mining activities. In general, the investigated area is a part of the western portion of the Arabian Peninsula which is underlain by a rigid land-mass of Precambrian igneous and metamorphic rocks of the Arabian Shield. Paleozoic sedimentary strata overlie the basement rocks and are represented by two formations (Figure 4); the Saq Sandstone and overlying Tabuk Formation [8,9].

The Tabuk formation dominates the geology in the vicinity of Tabuk city, where it outcrops in several hills within the town limits. It is a thick sequence of shale, siltstone and sandstone units that belong to marine and continental facies of Ordovician to Devonian age. Its maximum thickness is about 1070 m but diminishes gradually in the southeast direction. The base of the Tabuk Formation is marked by the Hanadir shale member which grades upward into sandstone, siltstone and shale. The older Saq Formation which is the groups of rocks that contain silica sand is about 800 m thick and outcrops at a distance of about 40 km to the west of Tabuk (Figure 4); it consists mainly of sandstone facies. The upper Saq Formation is composed of buff to white, medium to coarse-grained, well sorted sandstone. It is commonly cross bedded and poorly-sorted west of Tabuk [10].

Results and Discussions

Table 1 gives a relation between the different grain sizes scales, and Table 2 gives grain size analyses results of the collected samples as obtained from the mechanical sieving. In the inspected samples, the average percentage of grains sizes equal to 0.25 mm and 0.15 mm were 38 and 49% respectively (Table 2). Figure 5 shows the graphical re-presentation of the grain sizes. It can be observed that most of the sand concentrate around 0.25 mm and 0.125 mm. Grains that fall within a narrow size range (less than + 0.5 ø) are considered to be well sorted; a wider range (more than + 1.0 ø) is referred to as poor sorting (Tables 1 and 2). Grain size both determines and is a product of the mode of transportation either rolling, saltation and suspension, and is also indicative of the distance of transportation; the finer the size, the greater the distance. The micro-scale morphology of the quartz grain seems to pass through different cycles of sedimentation and natural washing as indicate from the shape and uniform extinction of the quartz. The studied samples are mainly composed of fine to very fine sand-sized grains with traces of silt size grains. In essence, the samples are white with very thin brown coating (< 0.5 mm), and consist of very poorly cemented to friable grains of rounded to subangular, translucent quartz.

In the studied sediments, 95% of the individual grains tend to be more equi-dimensional indicating that the grains have traveled long distances and have undergone significant abrasion. Thus this sand is not very recommendable as abrasive sands which used in sand blasting, grinding, and polishing without processing. Such sand requires the individual particles to be nearly the same size and somewhat angular with sharp edges.

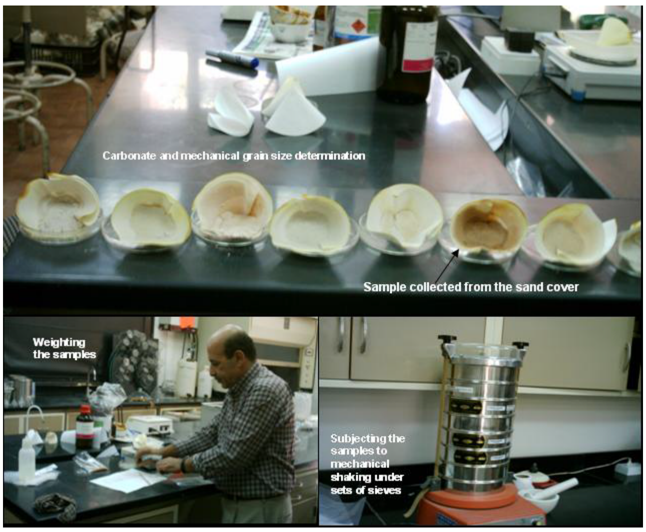

Figure 1: Preparing and processing the collected samples for petrographic and chemical analyses.

Citation: Howari FM (2015) Evaluation of Chemical and Petrographic Characteristics of Silica Sand from Tabuk in Saudi Arabia. J Geol Geophys 4: 200. doi:10.4172/2329-6755.1000200

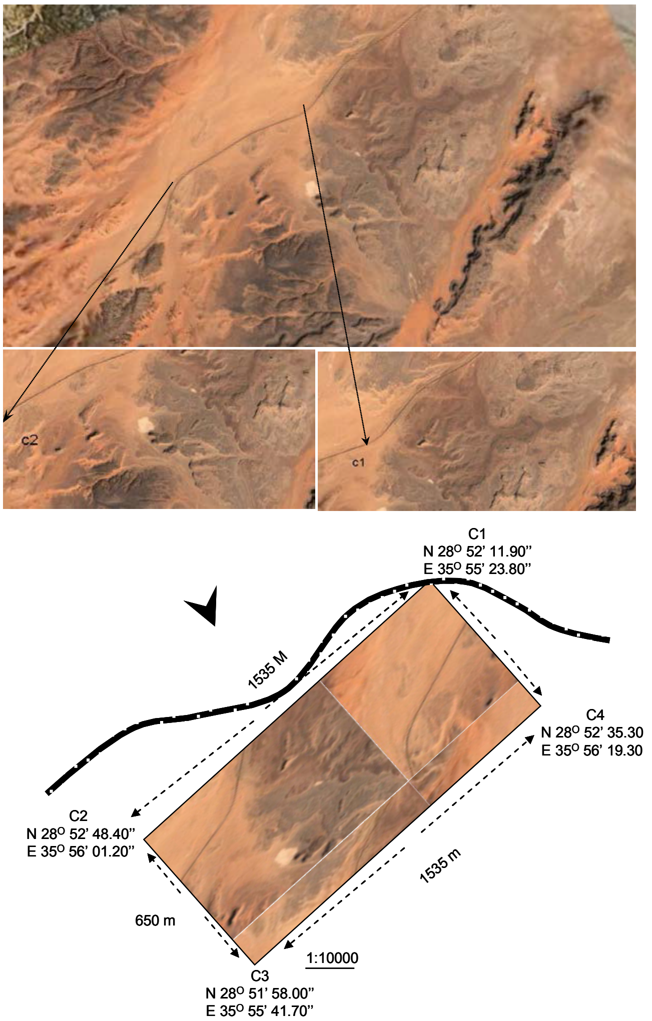

Figure 2: Location map and landscape of the area of interest.

Overall, the color of the tested samples was constant as being white clear sand. There were no evidences or observation of purple, pink gray or brown quartz grains however, minor or traces of rock fragment and dark mineral was observed in some samples, especially those collected near the sand cover. The luster of the quartz ranged from glassy to vitreous. All the tested samples were transparent with some translucent grains. Mechanical disintegration of the samples yielded a white product with fine sand size and specific gravity 2.5. Industrial minerals, such as silica or glass sand, are often associated with deleterious iron minerals. Iron oxides and other contaminants impair transmission in optical fibers, affect the transparency of glasses. The mineral phases with iron content in the studied samples were less than 1%. Thus the inspected deposit meets the industrial standards. It would provide the essential SiO_2 component of glass formulation to produce flat glass for building and automotive use, container glass for foods and beverages, and tableware. In its pulverized form, this silica is required for production of fiberglass insulation and reinforcing glass fibers. Specialty glass applications include test tubes and other scientific tools, incandescent and fluorescent lamps, television and computer monitors are other possible uses.

The micrographs presented in Figure 6 show an example of the dark but very trace mineral phase, also show the weathering coat that covers the white silica which is obvious on the first upper-right picture. The degree of good to moderately sorted sediments and grain sizes as observed under the microscope are also shown. The microscopic

Figure 3: Field view of some of the studied locations.

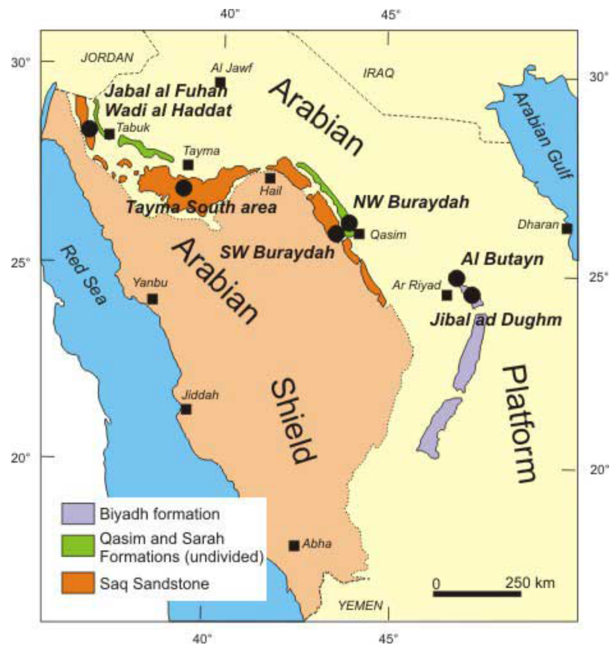

Figure 4: Geological map showing the sand deposits (Saq Sandstone) in Tabuk area, KSA (source, Saudi Geological Survey).

scale	Size range (metric)	Size range (approx. inches)	Aggregate name (Wentworth Class)	Other names
<−8	>256 mm	>10.1 in	Boulder	
−6 to −8	64-256 mm	2.5-10.1 in	Cobble	
−5 to −6	32-64 mm	1.26-2.5 in	Very coarse gravel	Pebble
−4 to −5	16-32 mm	0.63-1.26 in	Coarse gravel	Pebble
−3 to −4	8-16 mm	0.31-0.63 in	Medium gravel	Pebble
−2 to −3	4-8 mm	0.157-0.31 in	Fine gravel	Pebble
−1 to −2	2-4 mm	0.079-0.157 in	Very fine gravel	Granule
0 to −1	1-2 mm	0.039-0.079 in	Very coarse sand	
1 to 0	½-1 mm	0.020-0.039 in	Coarse sand	
2 to 1	¼-½ mm	0.010-0.020 in	Medium sand	
3 to 2	125-250 µm	0.0049-0.010 in	Fine sand	
4 to 3	62.5-125 µm	0.0025-0.0049 in	Very fine sand	
8 to 4	3.90625-62.5 µm	0.00015-0.0025 in	Silt	Mud
>8	< 3.90625 µm	<0.00015 in	Clay	Mud
>10	<1 µm	<0.000039 in	Colloid	Mud

Table 1: The numerical and verbal relations between the different grain sizes scales.

Sample No.		1	2	3	4	5	6	7	8	9	10
mm	Phi (φ)	wt. (gm)									
4	-2	0	0	0	0	0	0	0	0	0	0.41
2	-1	0	0	0	0	0	0	0	0	0.63	0.67
1	0	0	0	0	0	0	0	0	0	2.28	2.88
0.5	1	0.49	0.06	0.23	0	0	0.45	0.53	0.26	4.91	3.45
0.25	2	8.35	2.31	3.55	4.32	12.34	9.23	7.25	12.68	6.63	6.65
0.125	3	10.27	16.11	14.33	13.14	6.12	9.12	11.79	6.42	3.49	4.13
0.062	4	0.34	0.55	1.02	1	0.3	0.32	0.2	0.21	1.02	1.24
<0.062	>4	0.07	0.05	0.3	0.31	0.1	0.09	0	0.04	0.17	0.18
Total		19.5	19.1	19.4	18.8	18.9	19.2	19.8	19.6	19.1	19.6
wt. (%)											
Sample No.		1	2	3	4	5	6	7	8	9	10
mm	Phi (φ)	Wt (%)									
4 mm	-2	0	0	0	0	0	0	0	0	0	2.09
2 mm	-1	0	0	0	0	0	0	0	0	3.29	3.42
1 mm	0	0	0	0	0	0	0	0	0	11.92	14.69
0.5 mm	1	2.51	0.31	1.18	0	0	2.34	2.68	1.33	25.67	17.59
0.25 mm	2	42.78	12.11	18.27	23.02	65.43	48.05	36.67	64.66	34.66	33.91
0.125 mm	3	52.61	84.43	73.75	70.01	32.45	47.48	59.64	32.74	18.24	21.06
0.062 mm	4	1.74	2.88	5.25	5.33	1.59	1.67	1.01	1.07	5.33	6.32
<0.062 mm	>4	0.36	0.26	1.54	1.65	0.53	0.47	0	0.2	0.89	0.92
Wt. (%)		100	100	100	100	100	100	100	100	100	100
Texture											
Gravel %		0	0	0	0	0	0	0	0	3.3	5.5
Sand %		99.6	99.7	98.5	98.3	99.5	99.5	100	99.8	95.8	93.6
Mud %		0.4	0.3	1.5	1.7	0.5	0.5	0	0.2	0.9	0.9
Texture		Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand

Table 2: Grain size results of the test samples (mechanical sieving).

study (Figure 6) revealed that heavy minerals of the studied samples are almost negligible (less than 0.1%) and they could be magnetite or pyroxene. Below more petrographic description of samples collected from ten sampling spots in the investigated location.

The first spot consist from quartz grains formed about 100% of the sample, white clean glassy sand, sub rounded to sub angular grains, moderately sorted, no opaque minerals and Rock fragments appears. Some grains cemented by silica. It is fine to medium sand. The second spot is basically quartz grains formed about 100% of the sample , white clean glassy sand, sub rounded to sub angular grains, moderately sorted, no opaque minerals and rock fragments appears . Some grains cemented by silica, very fine to fine sand. Whereas, the third spot is made from quartz grains that are formed about 98% of the sample, some milky grains could be feldspar (albite). Grains white clean glassy sand, sub rounded to sub angular grains, moderately sorted, grains cemented with silica, no opaque minerals and rock fragments appears. Some grains cemented by silica. The grain sizes range from very fine to fine sand. The forth is quartz grains formed about 99% of the sample,

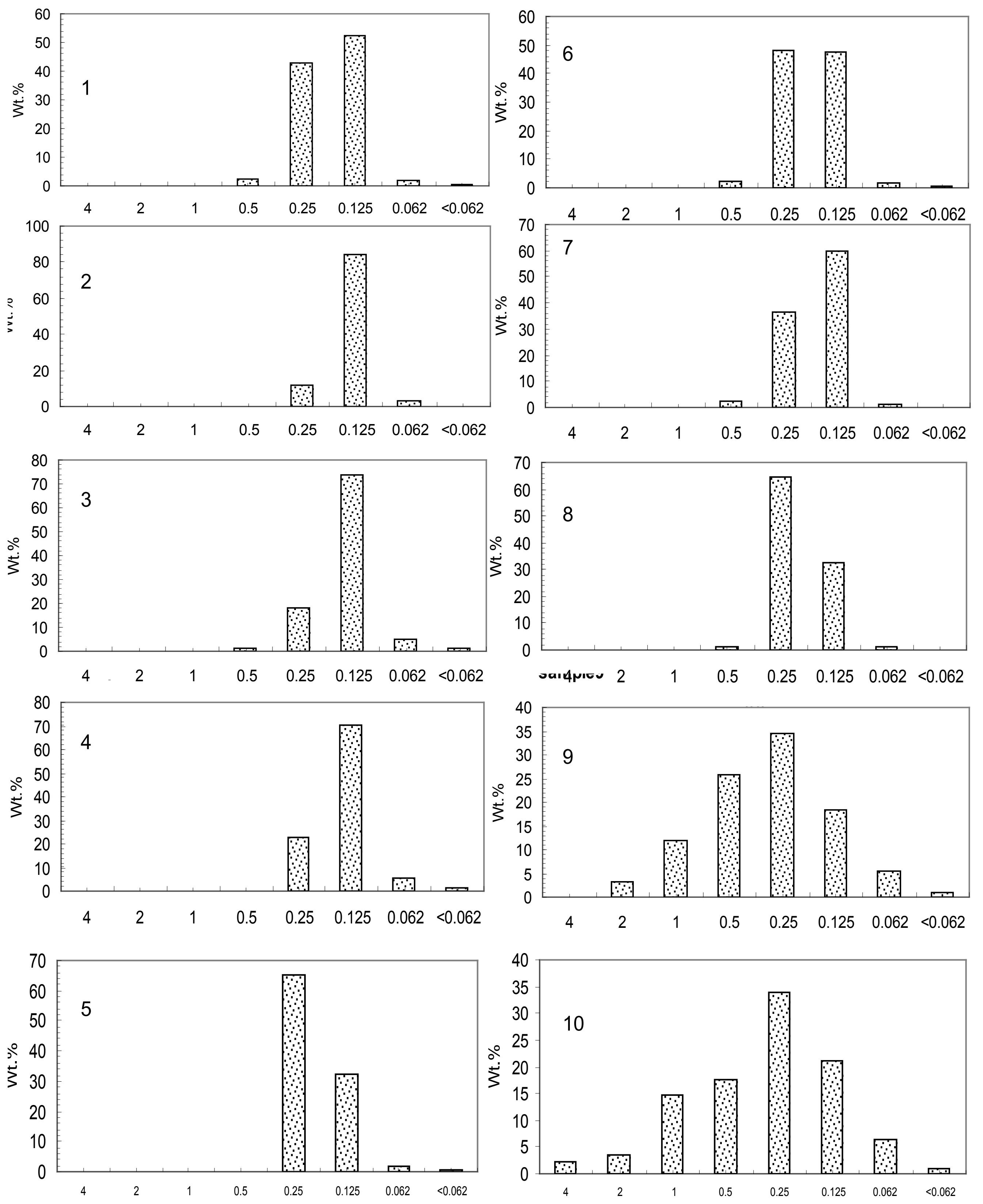

Figure 5: GMod of grain size distribution of the collected samples.

Citation: Howari FM (2015) Evaluation of Chemical and Petrographic Characteristics of Silica Sand from Tabuk in Saudi Arabia. J Geol Geophys 4: 200. doi:10.4172/2329-6755.1000200

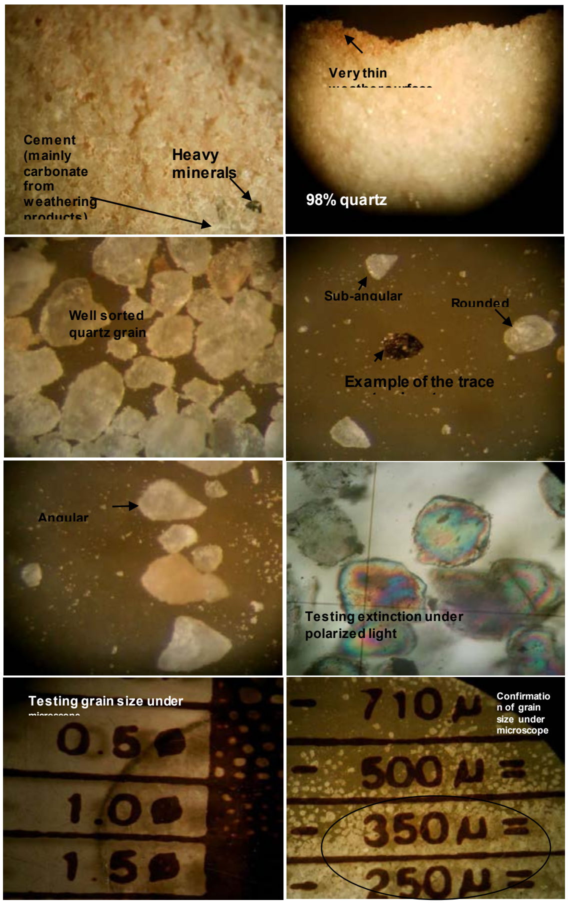

Figure 6: Micrographs showing the optical, mineralogy, and grain size characteristics of the investigated samples.

white clean glassy sand, with some grains stained by iron oxide gives brownish color appears. Some grains cemented by silica. The grains can be described as sub rounded to sub angular grains, moderately sorted with no opaque minerals and rock fragments appears. Some grains cemented by silica. The grain sizes range from very fine to fine sand. Spots five, six, seven, and eight are similar to each other, those has grain sized range from very fine to medium white clean glassy sand, sub rounded to sub angular grains, moderately sorted, no opaque minerals and rock fragments appears . Some grains cemented by silica. Meanwhile the ninth spot has brown to reddish brown color, mainly quartz about 98% stained by iron oxide, rock fragments about 2%, poorly sorted, very fine to granule size, sub rounded to well-rounded grains. The last inspected spot is similar to spot number 9 but it has some rock fragments about 1.5%

The noted earlier observation was confirmed by X ray analyses. Figure gives the X-ray profiles which confirm that quartz is the dominant mineral in the studied samples with very minor content of carbonate and other traces. Figure 7 and Table 3 give the carbonate content in the bulk samples. Note that sample number 5 is the friable cover sand sample. By excluding it the average carbonate content will be 1.6%. According to the Saudi Geological Survey, the nearby depositions are also well sorted and medium grained with 84% of the grains ranging 0.1-0.5 mm in diameter. Following heavy mineral removal, chemical analysis of 300 composite samples in the Tayma south area indicates that the 0.1-0.5 sand fraction of the crushed rock contains 96.3-99.18% SiO_2, 0.4-1.98% Al_2O_3, and 0.1-<0.05% Fe_2O_3, in other location the Jabal Fuhah-Wadi al Haddat area contains silica grading with 97.4-99.79% SiO_2, 0.05% Fe_2O_3, 1-2% Al_2O_3.

Graphical analyses for previous chemical data of major oxides indicated that the contents of pure silica are more than 98% SiO_2. These findings have been confirmed with new Inductively Coupled Plasma (ICP) analysis. As revealed from the ICP analyses, the percentages of SiO_2 range from 96.66 to 97.46% with an average of 97%, whereas Al_2O_3 ranged from 1.48%-1.539% with an average of 1.51%. According to the new analyses, the percentages of CaO, Cr_2O_7, Fe_2O_3, and TiO_2 were 0.5936% (range 0.56-0.627%), less than 0.006, 0.037% (range 0.034-0.037%), and 0.0531% (range 0.0539-0.0524%) respectively (Figures 8 and 9).

Sand from the deposits should be processed by crushing, washing, drying and screening before using as a raw materials. The specifications

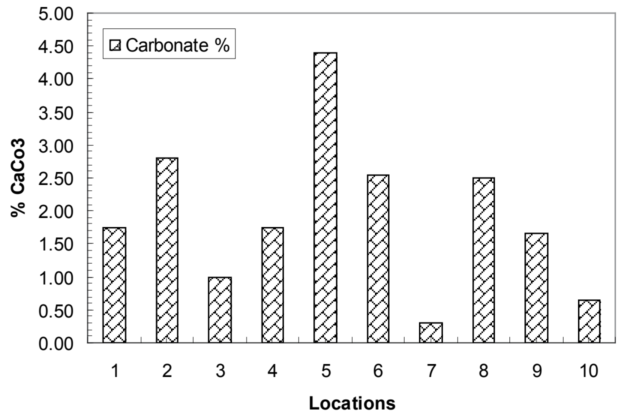

Figure 7: Distribution of carbonate contents in the investigated area.

S.No.	Sample (wt.)	W t. (F. paper)	Wt. (S+F) before	S+F after	Carbonate	I. R. wt.
	(g)	(g)	(g)	(g)	%	(g)
1	20	1.14	21.14	20.79	1.75	19.7
2	20	1.14	21.14	20.58	2.80	19.4
3	20	1.14	21.14	20.94	1.00	19.8
4	20	1.14	21.14	20.79	1.75	19.7
5	20	1.14	21.14	20.26	4.40	19.1
6	20	1.14	21.14	20.63	2.55	19.5
7	20	1.14	21.14	21.08	0.30	19.9
8	20	1.14	21.14	20.64	2.50	19.5
9	20	1.14	21.14	20.81	1.65	19.7
10	20	1.14	21.14	21.01	0.65	19.9

Table 3: Carbonate contents and associate insoluble residue of the tested samples.

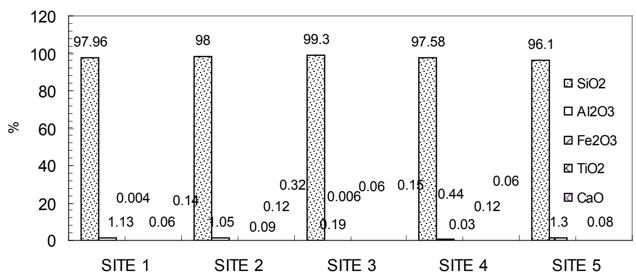

Figure 8: Percentages of major oxides in the sand of concern.

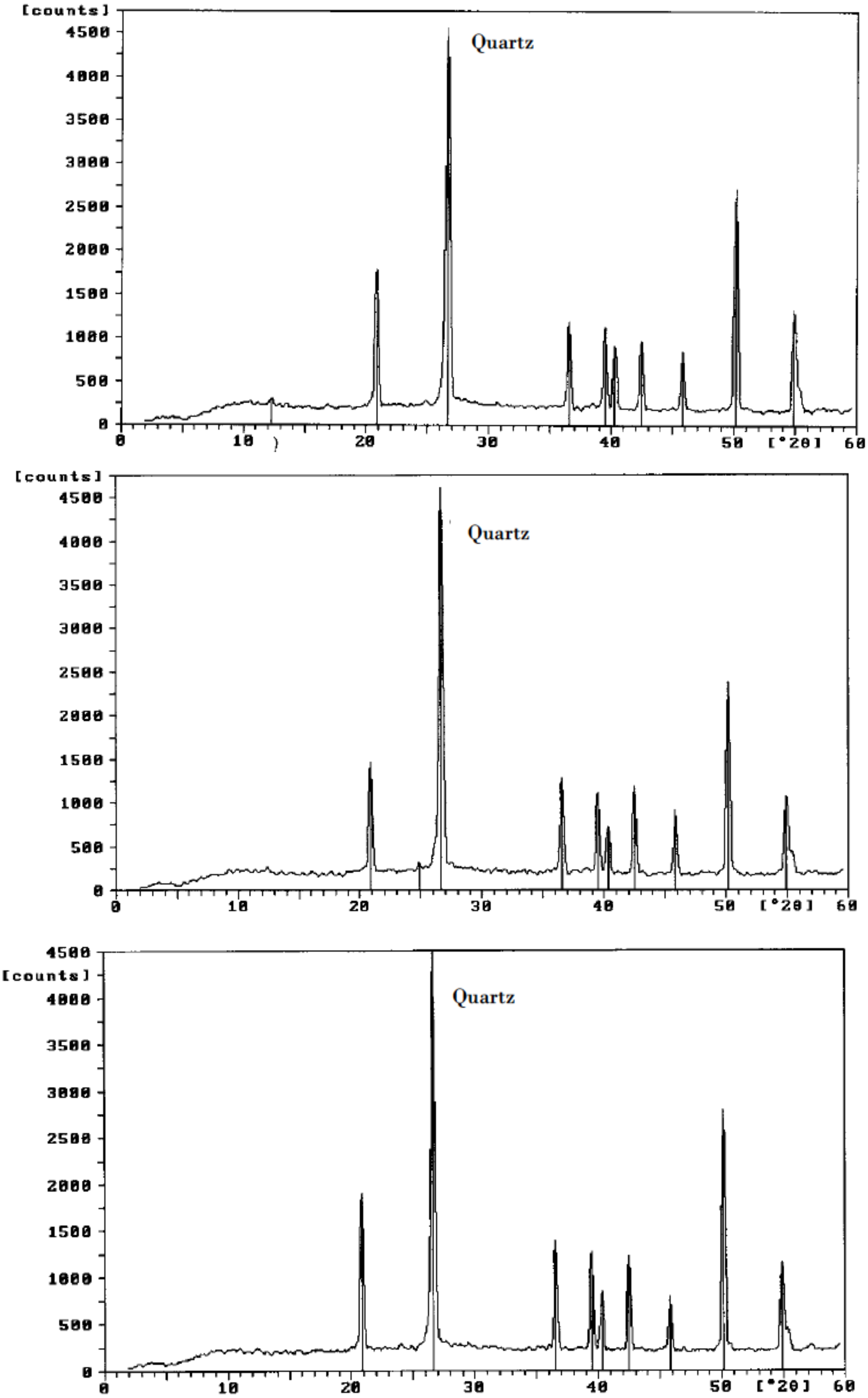

Figure 9: X-ray profile for selected samples.

of the processes depend on the application and the size of production. However, one of suitable applications is glass production. The silica sand used in making glass has the most rigid industry-based specifications. Tiny amounts of impurities, such as iron, manganese, chromium, calcium, or aluminum, can alter the color and/or physical properties of the resultant glass. Because of its high quality, the sand has potential applications in a variety of glass manufacture such as colored hollow glass, colored flat glass, colorless hollow glass, and fiber glass. It is also a potential source of filler in plastics, rubber, and ceramics. Oil and gas recovery, building products, ceramics and refractories, filtration and water production the most additional recommended industrial application for the studied deposits.

Conclusions

The average percentage of grains sizes equal to 0.25 mm and 0.15 mm were 38 and 49% respectively. The grain size analyses indicate that the size samples concentrate around 0.25 mm and 0.125 mm. Grains that fall within a narrow size range (less than + 0.5 ø) are considered to be well sorted; a wider range (more than + 1.0 ø) is referred to as poor sorting. In the studied sediments, 95% of the individual grains tend to be more equi-dimensional indicating that the grains have traveled long distances and have undergone significant abrasion. Overall, the color of the tested samples was constant as being white clear sand. The microscopic study revealed that heavy minerals of the studied samples are almost negligible, less than 0.1%, and they could be magnetite or pyroxene. Below more petrographic description of samples collected from ten sampling spots in the investigated location. The study found that the average carbonate content will be 1.6%. The percentages of SiO2 range from 96.66 to 97.46% with an average of 97%, whereas Al_2O_3 ranged from 1.48%-1.539% with an average of 1.51%. According to the new analyses, the percentages of CaO, Cr_2O_7, Fe_2O_3, and TiO_2 were 0.5936% (range 0.56-0.627%), less than 0.006, 0.037% (range 0.034-0.037%), and 0.0531% (range 0.0539-0.0524%) respectively. However, one of suitable applications is glass production. It is also a potential source of filler in plastics, rubber, and ceramics among other applications.

References

1. SGS (2009) http://www.sgs.org.sa/English/mineralresources/pages/default.aspx
2. Al-Harbi KM (2010) Monitoring of agricultural area trend in Tabuk region-Saudi Arabia using Landsat TM and SPOT data. The Egyptian Journal of Remote Sensing and Space Science 13: 37-42.
3. Folk RL, Ward WC (1957) Brazos river bar: a study of significant of grain size parameters. Journal of Sedimentary Petrology 27: 3-26.
4. Friedman GM (1979) Difference in size distributions of populations of particles among sands of various origins. Sedimentology 26: 859-862.
5. Howari FM, Baghdady A, Goodell PC (2007) Mineralogical and geomorphological characterization of sand dunes in the eastern part of United Arab Emirates using orbital remote sensing integrated with field investigations. Geomorphology 83: 67-81.
6. Jung HS, Lim D, Xu Z, Kang JH (2014) Quantitative compensation of grain-size effects in elemental concentration: A Korean coastal sediments case study. Estuarine Coastal and Shelf Science 151: 69-77.
7. Islamic Medical Association of North America (IMA-NA) (2004).
8. Powers RW, Ramirez LF, Redmond CD, Elberg Jr EL (1966) Geology of the Arabian Peninsula: Sedimentary geology of Saudi Arabia. United States Geological Survey Professional Paper 560-D: 147p.
9. Sabatan AA (2005) Geotechnical properties of expansive clay shale in Tabuk, Saudi Arabia. Journal of Asian Earth Sciences 25: 747-757.
10. NISA (2014) What is Industrial Sand? Wisconsin National Industrial Sand Association.