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Identification and characterization of the quality of silica sand resources from Munda Gucha, district Mansehra, in glass making

SYED HAMIDULLAH, M. TAHIR SHAH & M. ASIF KHAN

National Centre of Excellence in Geology, University of Peshawar, Pakistan

ABSTRACT: *The silica sand deposit of Munda Gucha area occurring in the quartzose rock of Tannawal Formation, district Mansehra, has been mapped and sampled for identification and characterization of its quality for glass making. Petrographic, geochemical and field studies show that the Munda Gucha silica sand deposit has tremendous potentials as a source of silica sand for glass, steel, soap and ceramic industries. With previous studies suggesting an inferred reserves of 70 million metric tones and an average SiO_2 between 90-95%, the present data has enhanced the average SiO_2 to 95.21%. Samples collected from the snow white zone of Bela Sukian block along Munda Gucha-Jacha road have maximum SiO_2 content of 99.78% and those from Mohri have 98.84%, proving to be useful in manufacturing of first quality optical glass. On the basis of grain size (0.3 to 0.5 mm in diameter) the Munda Gucha silica sand stands the best standard known in Pakistan. It is concluded that the deposit has tremendous potentials as a source of silica sand for glass, steel, soap and ceramic industries. Simple or very dilute acidic washing is suggested for the removal of tFe_2O_3 because of its occurrence as surfacial iron leaching.*

INTRODUCTION

Silica sand is one of the important industrial minerals of Pakistan. It is used mainly by glass, ceramics, steel and soap industries in the country. Important known silica sand deposit occur (a) in Datta Formation of the lower Jurassic age, between Makarwal and Musakhel in Mianwali district, and at Pezu and Panyala in D.I. Khan district and (b) in Abbottabad Formation of possible Devonian to Permian age, near Munda Gucha in Mansehra district (Figs. 1a, b). The deposits of Mianwali district are used by many private companies, however, those of the Mansehra district have so far not been widely utilised. The quality of the commercial glass produced (e.g. strength, color, clarity and degree of imperfection) are highly dependent on mineral raw material used in the process. Silica sand utilized by the glass industry, not only has to fulfil the requirement of a specific compositional range but also of a particular grain size. The present study funded by USAID was lunched to survey the selected potential silica sand resources in Pakistan. This paper describes the silica sand deposits at Munda Gucha, district Mansehra, with respect to purity, mineral content and extent for its use, especially, in the glass making industry.

GENERAL CHARACTERISTICS OF SILICA SAND

Silica sand can be defined as quartz sand of such a high purity that the rock almost becomes monomineralic. The type and percentage of impurities can vary according to the requirement of the consumers including glass, ceramic, steel,

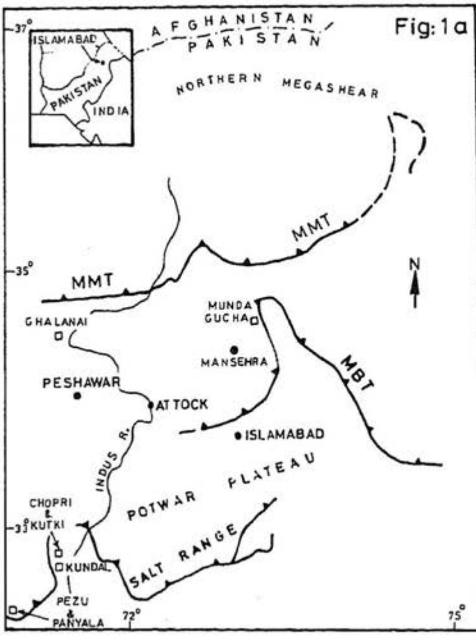

Fig. 1a. Location map of silica sand deposits in northern Pakistan.

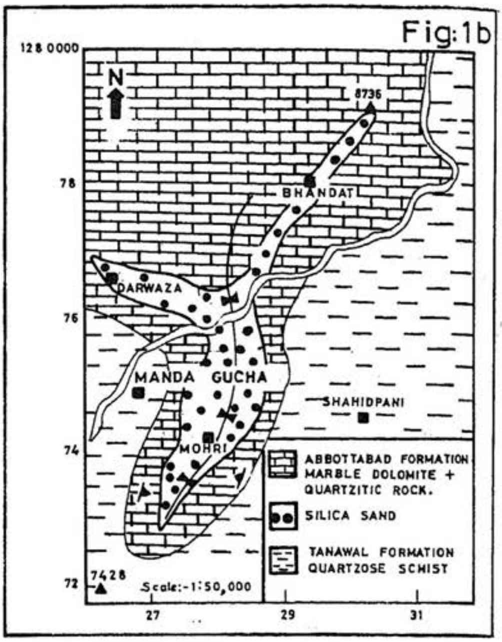

Fig.1b. Geological map of Munda Gucha silica sand deposit, Mansehra district (modified after Khan, 1990).

soap and other industries. Grain size can be a requirement for different uses. Silica sand normally forms as a result of shearing of quartzite and sandstone which are rocks formed due to the erosion of acidic rocks. The major types of silica sand deposits are fluvial marine, lacustrine, glacial and residual and windblown or loess. It is mainly used in glass making, abrasive, metallurgical (steel industry in particular), soap making (formation and sodium silicate), refractory and miscellaneous. In glass making industry the quality of glass is mainly dependent on the amount of silica, iron and alumina as well as on the grain size of silica sand.

For various types of glass the percentage of SiO_2 can vary between 85 and 99%. Tables 1 and 2 show the allowed limits recommended by various international organizations including the Manufacturer Federation London (1974), the American Ceramic Society and American National Bureau of Standards. Iron and chromium impart colors to the glass, with the latter having higher intensity than the former type at a given proportion. Similarly due to Al_2O_3 the melting temperature of silica sand tends to rise and also the final product loses its transparency. In silica sands, therefore, heavy minerals like the oxides of iron and chrome-and alumina-bearing minerals are unwanted ones. Allowed limit of Al_2O_3 in the best optical flint glass container is between 0.1-0.55%.

Apart from chemical imposition, silica sand can be also graded on the basis of grain size. A grain size of [-20#] - [140#] is considered to be acceptable for glass making. Uniformity of grain size promote melting and, therefore, it is also considered an important factor. Very fine grain size sand can blow into the checker-work of the

TABLE 1. SILICA SAND COMPOSITIONS AND THE RELATED PRODUCTS (SOURCE: MANUFACTURING FEDERATION, LONDON, 1974: 1 IS THE BEST QUALITY)

	Soda-lime silica glass	Colorless Containers	Colored Containers	Tableware	Clear flat glass	Glass fibre insulation	Ideal silica
Quality→	7	6	5	4	3	2	1
SIO_2	72.2	98.9	97.6	99.6	99	94.5	100
TiO_2	0	0	0	0	0	0	0
Al_2O_3	1	0.15	0.15	0.2	0.5	3	0
Fe_2O_3	0.1	0	0.2	0.1	0.1	3	0
MgO	3.6	0	0	0	0	0	0
CaO	7.1	0	0	0	0	0	0
Na_2O	14.8	0	0	0	0	0	0
K_2O	0.2	0	0	0	0	0	0
B_2O_3	0.5	0	0	0	0	0	0
Totals	99.5	98.95	97.95	99.9	99.6	100.5	100

TABLE 2. SILICA SAND CLASSIFICATION RECOMMENDED BY AMERICAN CERAMIC SOCIETY AND NATIONAL BUREAU OF STANDARDS

Quality→	1	2	3	4	5	6	7	8	9
	First quality optical glass	Optical flint glass container	Flint glass	Sheet rolled & polished glass	5th quality	Screen widows	Green glass	8th quality amber glass	9th quality amber glass
SiO_2	99.8	98.5	95	89.5	95	98	95	98	95
TiO_2	0	0	0	0	0	0	0	0	0
Al_2O_3	0.1	0.5	4	0.5	4	0.5	4	0.5	4
Fe_2O_3	0.02	0.035	0.035	0.06	0.06	0.3	0.39	1	1
MgO	0.05	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25
CaO	0.05	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Totals	100.02	99.235	99.535	99.56	99.56	99.3	99.89	100	100.5

regenerators, to the flue or coalesce up on the hot surface and thus effecting the life of the melting tank. Fine dust of silica sand can chock the chimney of the furnace and thus reducing its life span. An excessive coarser grain size can be a problem for melting with larger grains surveying in the melt. Roundness of the grain is a negative factor in melting. The higher the roundness of the grains, the lower the speed of melting.

TECHNICAL DESCRIPTION OF THE PRESENT WORK

Studies by previous workers (Allauddin & Nasreen, 1987; Nasreen et al., 1987; Nizami and Farooqi, 1990) indicate that a major problem, faced by the glass industry in Pakistan is the high iron content in silica sands from D.I. Khan (tFe_2O_3 = 0.0 - 0.14 wt.%) and Mansehra (tFe_2O_3 = 0.45 - 0.98%), due to which manufacture of colorless glass is difficult and only sheet glass of greenish tint can be produced easily. Therefore, under this project, in consultation with Khwaja Glass, Hasanabdal, activities were directed to the silica sand deposits of Munda Gucha area in district Mansehra, to locate zones of consistent compositions having low iron content and to suggest possible low cost benefaction methods, if necessary.

METHODOLOGY

Field mapping and sampling were carried out in August 1993 around Munda Gucha in Mansehra district. The laboratory studies included the application of petrographic and geochemical techniques for characterization of the deposits. Specific activities included chemical analyses followed by grain size study to discard those deposits or sections which are not appropriate for use in glass making, on the basis of chemical composition and grain size (c. 60-150 BSM). Also deposits or section of the deposits which were very hard to be used by the glass industry were also discarded. Mineralogical and geochemical studies were performed simultaneously concentrating on the nature of minerals other than quartz (impurity bearing minerals) and their textural details to know whether such minerals are in granular or cement form. Mineralogical studies have been performed by using polarizing microscope and X-Ray Diffractometer and the chemical analyses by using Atomic Absorption Spectrophotometer at the National Centre of Excellence in Geology, University of Peshawar.

MUNDA GUCHA DEPOSIT, MANSEHRA DISTRICT

The Munda Gucha silica sand deposit of Hazara division occurs along the Siran river 50 Km NNE of Mansehra Town (Toposheet No. 43 F/16; also see Fig. 1b). Khan and Ali and Khan of the Geological Survey of Pakistan performed preliminary studies of these silica sand deposits in 1949 and 1964, respectively (see Khan, 1990). Offield and Abdullah (1964) published an initial geological map of the area. Khan (1990) worked in further detail and presented a report for Sarhad Development Authority (SDA). Silica sand is part of the quartzite and quartzose sand stone of the Abbottabad Formation which also contains marbles and dolomite (Fig. 1b).

The deposits can be accessed by an all weather road with metalled part up to Nawazabad and onward on an unmetalled road. Large area of the deposit is covered under forest, vegetation, alluvium. Silica sand is mainly exposed along the Siran river between altitude of 1680 and 2750 meters. The highest peak of the area, Musa Ka Mosalla, is 4280 meters above the sea level. Under the steep slopes and high altitude conditions the streams form a dendritic pattern.

General geology

Low grade regionally metamorphosed rocks cover the area around Munda Gucha. These rocks are metamorphosed pelites, psammites and calcarious rock units of Abbottabad and Tannawal formations. Tannawal Formation of possible Cambrian age is the dominant rock type in the area, comprising of quartzite and quartzitic schist with interbedded quartzite veins and bands. This formation overlies the Salkhala Formation of possible Precambrian age and is overlain by the Abbottabad Formation of possible Devonian to Permian age (see Offield & Abdullah, 1964).

The Tannawal Formation consists of dark green and grayish green garnet-biotite muscovite-quartz schist with quartz 70-90% in the rock. Muscovite occurs more commonly than biotite while the porphyroblast of garnet are also noticed. White bands of quartzite also occur in Tannawal Formation.

The Abbottabad Formation comprises of marble, quartzite, quartzose sand stone with local amphibolite and calcarious quartz schist. The latter is in direct contact with the Tannawal Formation. Dolorite dykes and sills have intruded into the calcarious quartz schist (see Khan, 1990). The silica sand of Munda Gucha has formed due to the shearing, folding and faulting of quartzite and quartzose sand stone (Fig. 2a). Quartzite is thin to medium bedded. It is jointed and fractured and has a white colour. It is stained and encrusted by reddish brown ferrugineous material. Silica sand is mainly represented by friable snow white sandstone called quartzose sand stone by Khan, (1990; Fig. 2b, c). Sporadic amphibolite outcrops occur in quartzite and silica sand deposit. Recrystallized limestone is also reported from the northern and north-eastern side of Munda Gucha village by Khan (1990).

The marble of the Abbottabad Formation is medium-to coarse-grained in texture and light grey to dark green in color but white bands are

Fig. 2a. Shearing in rocks of the Abbottabad Formation. Quartzite turns into silica sand due to this. phenomenon.

also found. In the basal portion of the Munda Gucha Syncline (Fig. 1b) numerous bands of white and hard quartzite occur.

The age of the Abbottabad Formation is uncertain but due to its field relationship with Tannawal Formation of possible Silurian-Devonian age underlying it, and with rocks of possible Triassic and Jurassic age overlying it, Offield and Abdullah (1964) have suggested a Devonian to Permian age for the Abbottabad Formation.

Field data and petrography

Silica sand deposit of Munda Gucha occurs in the quartzose rocks of Tannawal Formation (Fig. 1) as a trough of a doubly plunging syncline which trends N20°E and crosses Siran river east of Munda Gucha. It extends 6-8 km in length along the strike (Khan, 1990). The overall out crop of silica sand is about 152 meter thick. Thin section study indicates a variable quartz content from 60-100%. Calcite and feldspar are the other important minerals varying between 0-40%, and 0-10%, respectively. Phlogopite and muscovite occur as accessories. Zircon, magnetite, rutile and apatite are also accessary minerals reported by earlier workers (Ali & Khan, 1964). Silica sand beds are normally formed due to folding and shearing of quartzose rocks. Color variation from reddish-yellow and pinkish red to snow-white are noticed (Figs. 2a-c). Color intensity is generally associated with iron oxide lamination in silica sand.

Chemistry

Chemical data of 48 samples analyzed by Khan (1990) from various localities around Munda Gucha including Mohri, Darwaza, Bela, Nallah, Bhandar, Jacha, Battangan Sukian, Biar and Duna are shown in Figure 3. Twenty samples show SiO_2% above the line showing SiO_2 requirement for glass fibre insulation (i.e. 94.5%). Also one sample from Nulla Luga Gali block of Mohri (MGJMSS168; Fig. 3) has SiO_2 content of 96% and has a CaO content as high as 2.15%. However, the average of various samples from this area is 95% SiO_2, 0.1 tFe_2O_3, 0.67% Al_2O_3 and 0.23% CaO+MgO. Such a composition can be directly used for green glass and 8th and 9th quality amber glass. Considering the allowed limit of tFe_2O_3 (0.3%) by the American standards, a little washing treatment can make it even useful for screen and window glass.

Samples collected during the present investigation were also analyzed for the same elements. It is interesting to note that the snow white zone of Bela Sukian block along Munda Gucha-Jacha road (cf. Fig. 2a-c) has a maximum SiO_2 content of 99.78% (Table 3; Fig. 4). This proves to be first quality optical glass,

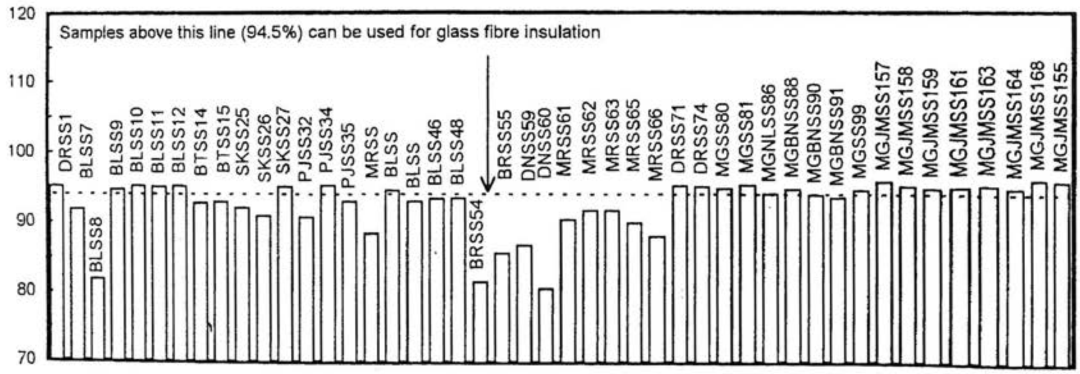

Fig. 3. SiO_2 bar diagram for Munda Gucha deposit (data from Khan, 1990).

TABLE 3. SILICA SAND COMPOSITION FROM MUNDA GUCHA AREA, MANSEHRA, ANALYZED DURING THE PRESENT STUDY, SS 14, 15 & 18 ARE FROM MOHRI BLOCK, OTHERS ARE FROM BELA SUKIAN BLOCK

Samp. No.	SS-5A	SS-14A	SS-19	SS-16	SS-18	SS-13B	SS-15	SS-14	SS-13C
SiO_2	89.33	97.26	98.62	98.65	98.84	89.14	97.95	97.41	99.78
TiO_2	0	0	0	0	0	0	0	0	0
Al_2O_3	0.68	0.48	0.13	0.21	0.13	0.57	0.32	0.12	0
Fe_2O_3	0.54	0.22	0.11	0.11	0.16	0.3	0.18	0.89	0.12
MgO	2.48	0.22	0.13	0.18	0.21	2.68	0.23	0.27	0.03
CaO	3.78	0.48	0	0.14	0.13	23.89	0.4	0.35	0
Na_2O	0.02	0.12	0.09	0	0.08	0.12	0.08	0.12	0
K_2O	0.03	0.16	0.11	0.13	0.04	0.09	0.03	0.1	0
Ig. loss	1.32	0.32	0.14	0.21	0.14	1.78	0.2	0.18	0
Totals	98.18	99.26	99.33	99.63	99.73	98.57	99.39	99.44	99.93

with maximum tFe_2O_3 content of 0.12 which can be easily washed out, because of its occurrence as surfacial iron leaching. Other samples in the vicinity (Fig. 2c) also reach the range of third quality flint glass. These silica sands can be directly used for sheet rolled and polished glass as well as for screen and windows.

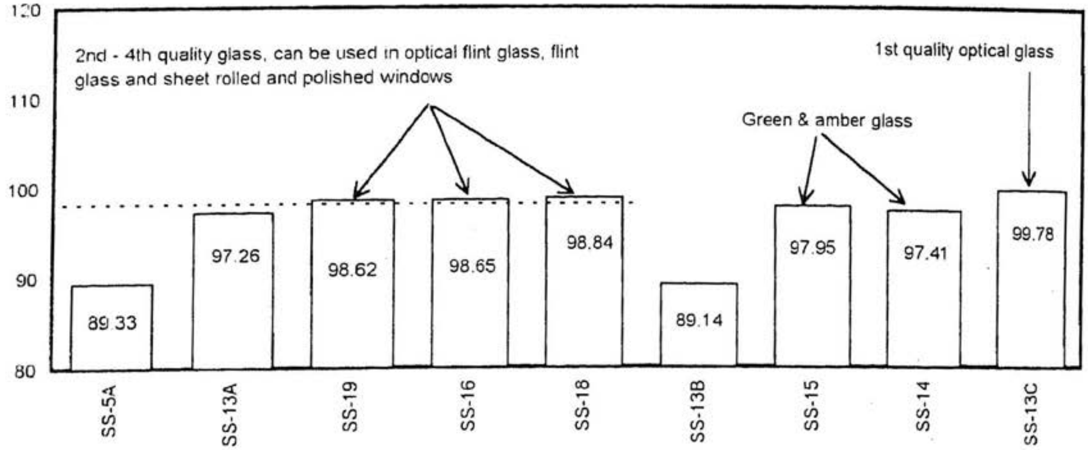

Fig. 4. SiO_2 bar diagram for Munda Gucha silica sand analyzed during the current study.

Samples collected from Mohri also show much higher SiO_2 content then reported by SDA (Khan, 1990). A maximum SiO_2 content of 98.84% was obtained, with several other samples showing SiO_2> 98%. Such silica sands can be easily used for optical flint glass, flint glass, sheet rolled and polished windows as well as for screen and windows. CaO, MgO and Ignition Loss show a negative correlation with SiO_2 in these samples, indicating that calcite/dolomite is replacing quartz in SiO_2-poor varieties (Fig. 5). Total Fe_2O_3 and Al_2O_3 vs SiO_2 plots are scattered (Figures not represented) which reflect the presence of these elements in minerals other than quartz in various proportions.

Grain size

As far as the grain size of the Munda Gucha silica sand is concerned, it stands the best standard known in Pakistan. These are sugary grains ranging in size from 0.3 to 0.5 mm in diameter.

Reserves

The total inferred reserves of the various blocks of silica sand at Munda Gucha are 70.35 mm. tonnes. This comprises of 6 mm. tonnes of Bala Sukian block, 18.75 mm. tonnes of Paja Mohri block, 20.25 mm. tonnes of Mohri Sunda Guli, 11.11 mm. tonnes of Behkar Darwaza and 14.25 mm. tonnes of Nulla Luga Guli. SDA has reported an overall average composition of SiO_2= 90.58%, tFe_2O_3= 0.2%, MgO= 1.5% and CaO= 3.94% for the deposit. However, the present data (Table 1) with much high SiO_2 content enhances the overall average composition of the deposit (SiO_2= 95.21%) and strongly supports the recommendations proposed by SDA. To prove the inferred reserves, further study including trenching, pitting, under ground editing, core drilling and bulk sampling for chemical analyses are needed to be done. It is however, emphasized that high quality silica sand with SiO_2> 99% is always a rare commodity and the glass manufactures must realize that the high quality zones of Munda Gucha may be mixed with low quality for obtaining a reasonable average grade for glass making. Utilization of high quality zones solely for very special products is, however, recommended.

DISCUSSION AND CONCLUSIONS

The Munda Gucha silica sand deposits have tremendous potentials as a source of silica sand for glass, steel, soap and ceramic industries. The five different blocks have an inferred reserves of 70 million metric tones, with an average SiO_2 between 90-95% (Khan, 1990). Inclusion of the present data has enhanced the average SiO_2% to 95.21%. Detailed economic feasibility has been worked out for the most accessible Bala Sukian Block by Khan (1990) with 6 mm. tonnes; with

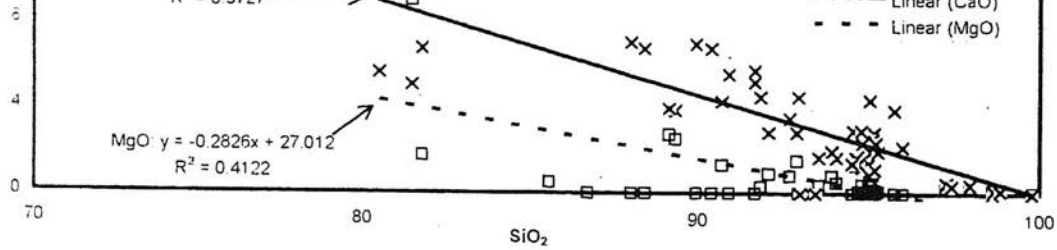

Fig. 5. MgO and CaO vs SiO_2 plot of Munda Gucha silica sand deposit; both, data from Khan (1990) and the current ones are used.

a further exploration cost of Rs. 5 million, a mine capacity of 150 tonnes/day, yearly capacity of 45000 tonnes/anum (300 working days), a price of Rs. 150/tonne, a production cost of Rs. 50/ tonne, annual revenue of Rs. 6.75 million/year (including taxes of Rs. 2 million), a mine life of 66 year and a pay back period of two years. As the deposit is very friable, slight primary crushing is needed to get the required material before screening it to get the appropriate grain size.

Further work is needed to be carried out on other blocks, particularly the Mohri block, where the snow-white silica sand covered with considerable overburden in Bela Sukian block, is well exposed. Road construction of about 3-4 km is needed prior to the actual exploitation of this block.

As the Bela Sukian block is generally coarse-grained with an average diameter of 0.3-0.5 mm, friable silica sand is well in the range of the requirement of glass industry. Low cost washing with simple and/or acidified water can easily improve its quality and thus making it feasible for use in high quality glass products.

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