STUDIES ON QUARTZITE AND GANISTER - RAW MATERIALS FOR REFRACTORIES FROM N.W.F.P. AND PUNJAB

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ABSTRACT

Quartzite and ganister have been located and studied from different areas of NWFP and Punjab for the manufacture of silica refractories. Brief geology of silica bearing rocks of those areas is given and discussed. In the laboratory the samples were studied and analysed for their mineral constituents and oxide components. Furthermore, their physical properties have been evaluated for stuitable uses for the manufacture of silica refractories. It is found out that quartzite from Attock and Haripur area is one of the best for refractory purposes while ganister from Musakhel and quartzite from Swabi and Tarbela can be used for making semi-silica bricks.

INTRODUCTION

Quartzite, ganister, novaculite etc. are considered to be raw materials for the manufacture of silica refractories. Quartzite is a metamorphosed bonded sandstone with secondary silica cementing the quartz grains together so strongly that breakage will occur across the grains. Ganister is a sedimentary sandstone, the quartz grains of which are cemented also by secondary silica. Novaculite is a hard compact rock of almost pure silica of sedimentary origin having deposited from water solution as siliceous spicules from sponge.

Characteristics such as microstructure, chemical composition, refractoriness, porosity, mechanical strength and susceptibility to firing (variation in specific gravity and porosity) are important for the assessment of the raw materials. One of the most essential properties of raw materials in determining their suitablity for making silica refractories is their refractoriness being 1750° C. They show little softening below their melting point and thus retain resistance to load at high temperature.

Dense structural cement quartzite having appropriate properties are prefered for making silica bricks. Such types are thought to be suitable since they contain quartz and basal cement of very fine structure, degenerating more rapidly and helping the formation of high temperature modification of silica i.e. tridymite and crystabalite.

High quality silica bricks should contain at least 97% silica, Al_2O_3 should be less than 1% and alkalies less than 0.3%. In other words, the material should consist essentially of quartz and the impurities like feldspar, muscovite, sericite etc. should be minimum. Second quality silica bricks can comprise of less silica and some Al_2O_3. Then semi-silica bricks contain 88-93% silica and some 3-4% Al_2O_3.

Silica bricks are extensively used in steel and glass industries. These bricks also find utility in electric furnace roofs, coke-ovens, open-hearth furnaces, copper refining furnaces, acid bessemer gas works, blast furnaces and glass melting furnaces.

During field investigations only quartzite and ganister have been met with in Peshawar, Mardan, Hazara, Campbellpur and Mianwali areas while novaculite has got to be discovered which according to Parmelee (1935) is a crypto-crystalline material with 0.05 to 0.10 micron grain size, the grains of which invert to crystobalite at a much lower temperature which means an advantage in the manufacture of silica refractories.

Occurrence.

The quartzite and ganister occur as large deposits in the Peshawar, Mardan, Hazara, Campbellpur and Mianwali areas in the north-western part of Pakistan. The quartzite crop-out in thick and considerably extensive beds near Hissartang, Swabi, Haripur, Tarbela, Sobrah Gali and Abbottabad. Ganister is exposed in Nammal Gorge near Musakhel of the Salt Range.

Hissartang Area: In this area of Peshawar district, the beds of quartzite crop out just north of Darwazai and continue westwards passing through Amirah, Mirkalan villages and are traceable beyond Jalalasar forming southern face of Attock-Cherat Range. Tahirkheli (1970) has mapped quartzite as a separate unit giving it a name Hissartang Formation of lower to upper Cretaceous age. The quartzite in this area is overlain by limestone. Throughout nearly 30 miles of this long range the thickness of the bed varies between 50 to 150 feet. This formation is also exposed across the Indus for a distance of two thousand feet near Dakhner in Campbellpur district.

The quartzite of Hissartang formation is white, light grey, mottled grey and rusty-brown on the joints. In this formation Tahirkheli has distinguished a white quartzite band 5 to 12 feet thick and forms a conspicuous horizon but it looks somewhat porous in hand specimen as compared to grey quartzite which is compact and dense. The whole formation is thin to thick bedded, hard, fine-grained with intercalations of shaly material.

Swabi Area: Martin et al (1962) has described quartzite in the Swabi-Chamla sedimentary group. The quartzite is abundantly present in and around Swabi i.e. in Kala, Rangli Kandao, Maneri and Pihur. The quartzite in these localities is white, light-grey and compact and gritty. The outcrop in the above-mentioned localities are isolated and do not show any physical relationship with one another but are possibly, of the same age and type. Davies et al (1963) had assigned it the Permocarboniferous age on the basis of notiliouds found in the associated limestone near Kala. At all other places quartzite is associated with marble and dolomite.

Haripur-Tarbela Area: Quartzite occurs in the said area around Seri, Garhi Maira and Tarbela localities of the Gandghar Range. The outcrops are found on the two limbs of the folded range and approach to the area is easy and economical. According to Tahirkheli (1971), the maximum thickness is over 350 feet on the western flank and about 180 feet on the eastern flank. He has named this quartzite as Tarpakhi which is white to light grey, dark-grey and sometimes it gives yellowish line. In hand specimen, it is fine to medium-grained and occasionally coarser. The quartzite occurs as thin to thick beds. The thickness of bands is from a two feet to over eight feet. The rocks are very compact and mostly free from argillaceous materials.

Abbottabad Area: In this area the quartzite rocks are well exposed near Kakul, Sobrah and Sarbon (Marks et al., 1961) on the roads cut. The quartzite is a part of the Abbottabad formation. The quartzite is white, grey and red with cross-bedding. It is coarse, gritty or sugary in nature.

Musakhel Area: Quite extensive bed of well-sorted gritstone is seen in the Nammal Gorge of the Salt Range near Musakhel. This bed is a part of Jurassic rocks. Thickness of the bed at this place is about 300 feet, and is exposed for more than a mile. Its extensions were not searched though its occurrence is mentioned in the literature by Wadia (1953) and Gee (1944). This rock is quite compact and consists wholly of quartz. In the far-past, people used this gritstone for their flour-mills. The whole formation is gradded from fine to medium-grained sandstone to gritstone. This is very light-grey to cream coloured.

Petrography.

Hissartang Area: Two types of samples were studied from this area. One of them (A-1) is white to very light grey and the other one is grey and somewhat rusty-brown. The sample A-1 is composed of equigranular and equidimensional grains of quartz which are compact and sintered, often strained and contain tiny inclusions of muscovite tablets. About 80 per cent grains are 0.4 to 0.6 mm in size. A few grains are somewhat coarser upto 1 mm. Some 15 per cent are 0.1 to 0.2 mm and rest of them are even finer than 0.1 mm. Amongst the accessories, magnetite, sphene, leucoxene, muscovite, sericite and apatite are recognizable. All of them are haphazardly distributed while sericite is present in the interstices of the quartz grains.

Sample A-2 shows equigranular quartz grains which are com-compact, sintered, angular and often-strained. Like A-1 quartzite, it also contains tiny muscovite tablets. Some chalcedony fragments are also prsent at places. Ninty per cent of the grains are 0.2 to 0.25 mm. About 4 per cent are upto 0.5 mm, and the rest of them are 0.1 to 0.15 mm. Accessory minerals are tourmaline, magnetite, muscovite and sericite.

Haripur Area: There are two to three types of quartzite in the Seri locality, some 10-12 miles west of Haripur. One of them is very dense while the second one is banded with intercalations of shaly material and the third one is intermediate. Only slate-free types were studied in detail, namely, H-1 and H-2; H-1 consists of inter-locking sharp angular grains of quartz. Some of the grains are strained. The intersticial grains are also of quartz with crenulated boundaries. About 80 per cent grains are 0.3 to 0.8 mm in size, about 8 per cent grains are 0.15 to 3 mm and the rest of them has size less than 0.10 mm. Accessories include plagioclase, sphene, aplite and a very fine ore dust.

H-2 is composed of foliated banded quartz grains, much of them are strained. The quartz grains are inter-locked like H-1. The intersticial grains are mostly of quartz with sericite and clay at places. The coarser grains about 70% are mostly 0.4 to 1.1 mm in size. The finer grains about 15% are less than 0.1 to 0.5 mm. All the coarser and finer grains have aligned along foliation plane. Accessory minerals are tourmaline, magnetite, sericite and apatite.

Tarbela Area: Three types of samples were studied from Tarbela area namely T-3, T-4 and T-6. Samples T-4 and T-6 are of very poor quality as they contain too much objectionable impurities. Their quartz grains are mostly 0.1 to 0.3 mm and some of them are occasionally upto 0.5 mm in size. The grains are thoroughly bonded by sericite. Rocks are somewhat foliated having angular to sub-angular and somewhat rounded grains. Sericite(about 6 to 8 per cent) is possibly an alteration product of feldspar. Other less abundant minerals are tourmaline, about 0.5 per cent, and feldspar 1.50 per cent. Sample T-3 is comparatively pure as accessories are hardly more than 2 per cent, consisting of sericite, ore, tourmaline, apatite and feldspar. Quartz grains are more or less of the same size and shape but without sericite as intersticial grains, except at one or two places. Quartz grains are rather welded together to form a compact rock.

Abbottabad Area: This area includes the outcrop on Abbott-abad-Havelian road, Abbottabad-Mansehra road and Abbottbabad-Sherwan road. Petrographic studies were made on Abbottabad-Mansehra road, sample "M", which consists of unequigranular grains of quartz and some fragments of chalcedony. The rock is sintered at places. Some of the grains are strained and they contain inclusions of tiny muscovite grains. The coarsest grains are 1 to 1.5 mm (30) per cent, 0.4 to 0.6 mm (40 per cent), 0.05-0.20 mm(20 per cent) and the rest of them less than 0.1 mm. Accessories are sphene, magnetite, limonite and tourmaline.

Swabi Area: R-1 type of rocks come from Tangli Kandao near Swabi. The quartzite is unequigranular rock as grain size varies from 0.1 to 0.6 mm. and occasionally upto 1 mm. Quartz grains are encircled by sericite and clay minerals and at some places there are aggregates of about 0.2 to 0.4 mm. Accessories (18 per cent) are oligoclase, sericite, tourmaline and fragments of chalcedony.

Musakhel: Ganister consists essentially of quartz with mostly coarser grain, 0.5 to 1.5 mm. and sometime upto 2.5 mm. The finer grains are 0.3 to 0.5 mm. with occasionally very fine grains of 0.1 mm. size. Other minerals are feldspar, ore, and limonite.

Results and Discussion.

Chemical Composition: According to Davies (1948) the raw material for the manufacture of high quality silica bricks should contain at least 97% SiO, whereas Al_2O_3 should be less than one per cent. Higher amount of alumina and alkalies destroy immiscibility and leads to a steady drop in refractoriness. Alkalies should be less than 0.3%.

Fourteen samples were analysed by routine classical methods. The quartzite with minimum impurities were analysed most extensively for SiO_2, Al_2O_3, TiO_2, Fe_2O_3, P_2P_3, MnO_2 CaO, MgO, Na_2O and K_2O. The rest of them were formally analysed for SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO.

Out of the selected quartzite samples, A-1, A-2, H-1, H-2 and M are the best ones. Their SiO_2 content ranges from 96.09 to 97.33 percent, Al_2O_3 is 0.77 percent in A-1 and 1.0 percent in M, while A-2, H-1 and H-2 contain, 1.69, 1.59 and 1.35 percent Al_2O_3, respectively. The alumina of these three samples could be further decreased by washing the crushed samples with water as some micaceous and earthy material usually present in the interstices and the micro joints. TiO_2 ranges between 0.14 to 0.15 percent in A-2, H-1 and H-2 while it is 0.42 percent and 0.49 percent respectively in A-1 and M-. According to Baron (1940) about 2 percent TiO_2 lowers the refractoriness upto 0.5 cone as compared to 0.5 to 1.5 percent Al_2O_3 or Fe_2O_3 to 1-2 cones. Moreover, the deformation temperature is not affected by TiO_2 even utp 3.0 percent, P_2O_5 is negligible. Fe_2O_3 was determined as total iron oxide which is 0.99 percent, 1.19 percent, 1.19 percent, 1.39 percent and 1.59 in the samples studied. This much iron can lower the refractoriness from 1-2 cones but the deformation temperature of the refractories will be less as compared to alumina. CaO is in small quantities from 0.11 to 0.24 percent in all the samples. It is less than 1 to 2.50 percent which is generally added as a bond (Chesters, 1957 P. 75). Smaller amounts of lime tend to give weak bricks both in dry and fired state. Both lime and iron oxides have a relatively small effect on the melting point of SiO_2 if present in reasonable proportion — a phenomenon explained in terms of immiscibility of the liquid formed by reaction between these materials.

In some less important quartzite samples only partial analysis was done. As is clear from microscopic examination the content of impurities is high in most of them, 7.50 per cent in R, 8 per cent in T-3, 2 per cent in T-4 and 11 percent in T-6 samples. SiO_2 in these rocks is 91.52, 91.70, 94.26 and 95.52 per cent repsectively in the above-mentioned samples. Al_2O_3 is 7.37 percent, 4.63 percent, 3.04 per cent and 3.46 per cent respectively while other oxides are hardly 1 to 1.4 per cent. Comparing with the specification given above, it is possible to usethese rocks in the manufacture of semi-silica-bricks.

The ganister type of rocks of the Salt Range near Musakhel, are to be further studied for chemical and mineralogical investigations. On the basis of one sample collected from that area it could be ascertained that due to high content of Al_2O_3 (about 4-5%) and low content of SiO_2 (85-90%) this could be used in the manufacture of semi-silica bricks.

Physical Properties: The variation in specific gravity is an important factor in determining the rate of degeneration of quartzite when fired at 1460°C for one hour. According to standard classification, quartzite having specific gravity form 2.4 to 2.45, iron from 2 to 2.5 and 2.5 are grouped as average degenerating, slow generating and extremely slow degenerating quartzites respectively. Rapidly degenerating quartzite should have specific gravity of 2.4 after firing at the said temperature. Now, quartzite samples A-1, A-2, H-1, H-2 and M after firing at 1460° C for one hour had specific gravity of 2.425, 2.515, 2.442, 2.498 and 2.63 respectively (Table-2). All these quartzites show specific gravity more than 2.4, thereby confirming that they have average, slow and very slow degenerating rates. Such quartzite, under appropriate conditions of firing are considered to be the best raw material for the manufacture of silica refractories.

Apparent porosity (Table-2) of A-1, A-2, H-1 and H-2 remains in the range of good quality quartzites. Moreover, the apparent porosities of A-1, A-2, H-1, H-2 and M, after firing at 1460° C for one hour should not increase more than 9 to 10 percent. From Table-2, excepting M, the figure remains in the permissible range and so again confirm the worth of quartzites of A-1, A-2, H-1 and H-2.

Similarly the apparent porosity of the raw quartzites ranges between 0.05 to 1.67 percent while water absorption ranges between 0.022 and 0.65 percent. According to standard evaluation, dense and very dense quartzites, having apparent porosity upto 1.2 and 4% are grouped to be the best ones. In case of water-absorption, quartzites having value upto 0.5 and 1.5 per cents are grouped as good ones. From the data given in Table-2, it is evident that the various quartzites are dense and very dense and can successfully be used for good quality silica bricks.

Refractoriness is an important property of quartzites as it determines its suitablity for making quality refractories. Quartzite with refractoriness upto 1750°C are considered to be the best while of lower refractoriness (1730°C) are used as additives. The refraceriness (Table-2)of our quartzites, A-1, A-2, H-1,H-2 and M is above 1700°C and thus they are worth of utility for the manufacture of good quality silica bricks.

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CHEMICAL ANALYSIS
Table-I

	A-1	A-2*	H-1*	H-2*	M*	R-1	T-3	T-4	T-6
SiO_2	97.33	97.01	96.84	97.06	96.09	91.51	91.70	94.26	95.52
TiO_2	0.42	0.14	0.15	0.14	0.49	..	0.06	0.06	0.00
Al_2O_3	0.77	1.69	1.59	1.35	1.00	7.37	4.63	3.04	3.46
Fe_2O_3	0.99	1.19	1.19	1.39	1.59	0.29	1.03	0.76	0.07
MnO	Traces	Traces	Traces	Traces	Traces	..	..	..	..
MgO	Traces	0.02	Traces	0.02	0.01	0.17	0.43	0.14	0.16
CaO	0.21	0.11	0.22	0.15	0.24	0.23	1.00	1.42	1.23
P_2O_5	0.10	0.06	0.13	0.09	0.17	..	..	..	..
Na_2O	0.02	0.01	0.03	0.02	0.03	0.32	0.36	0.30	0.10
K_2O	0.03	0.01	0.02	0.01	0.02	0.36	0.12	0.16	0.06
Loss	0.10	0.13	0.19	0.22	0.48	0.36	0.20	0.70	0.28
	99.97	100.37	100.36	100.45	100.12	100.62	99.53	100.84	100.88

**Analyst*: M. Ashraf.

PHYSICAL PROPERTIES

Table-2

	Specific grvity		Porosity		Water absorp- tion	Firing affect	Cone equivalent
	Raw	*Fired at* 146°C	*Raw*	*Fired at* 1480°C			
A-1	2.667	2.442	0.20	5.587	0.09	Two cracks	+1700°C
A-2	2.555	2.498	0.84	4.346	0.33	No Crack	+1700°C
H-1	2.664	2.425	0.056	5.219	0.02	No Crack	+1700°C
H-2	2.647	2.515	0.16	3.941	0.06	One Crack	+1700°C
M	2.502	2.463	1.67	10.636	0.65	One Crack	+1700°C