Review Article

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Refractory Raw Materials of Pakistan Beyond the Year 2000

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Pakistan refractory bricks industry is in infancy stage despite the fact that domestic demand of these bricks is growing fast and good quality refractory minerals are abundantly available in the country. Most of the refractory bricks requirements by local steel, glass, ceramics, oil refinery and other industries are being met through import. Important refractory minerals occurring in Pakistan include large deposits of chromite, magnesite, dolomite, bauxite, fire clay, kaolin, dunite and quartzite. This paper briefly reviews the quality and size of major refractory mineral deposits and various legal, financial, technical and other factors necessary for the development of refractory bricks industry in Pakistan.

Key words: Refractory materials, Brick industry, Minerals.

Introduction

Growth of steel, cement, glass and other industrial mineral sectors have created a great demand for sophisticated refractory bricks in Pakistan. At present most of these requirements are being met through imports. Throughout the industrial world, the refractory market is governed by the requirements of traditional heavy industries: iron-steel, cement and allied industries, glass and non- ferrous metals, and minerals including alumina, chemicals, adhesives, petroleum, power and ceramics together with a multitude of miscellaneous product requirements.

Important refractory raw materials include bauxite, beryl, chromite, dolomite, graphite, magnesite, olivine, dunite, pyrophyllite, quartz , zircon, kyanite, andalusite, sillimenite, fire clays, kaoline or China clay and wollastonite (Lorenz 1991). The country is served by a large number of private refractory bricks producers using abundant local mineral resources but imports still remain very high (Griffiths 1987). The imports of refractory bricks by Pakistan in 1992-93 and 1993-94 were Rs. 1.1 billion and Rs. 2.22 billions respectively (Foreign Trade Statistics 1994). Pakistan's steel mills, cement, glass, ceramics, chemical and petroleum refining industries are importing most of these refractory bricks. This paper reviews the current situation of each of the refractory raw materials available in Pakistan and the factors that affect their supply. Suggestions for improvement in raw material supply in future and an assessment of factors to encourage private investment in new refractory industries in Pakistan are also made.

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Principal varieties of refractories and minerals. There are several varieties of refractory materials used in many metallurgical processes and miscellaneous furnace linings Bateman (1950). Varieties of refractory minerals which occur in Pakistan in good quality and quantity are briefly reviewed (Table 1).

Magnesia Refractories. Magnesite: Pakistan has two large magnesite occurrences in the North West Fronteir Province (NWFP) and Balochistan. In NWFP, important magnesite deposits occur in the Kumhar area near Sherwan, 30 km north west of Abbottabad, in a 3 km^2 area and consist of 13 lense shaped bodies (Ghaznavi *et al* 1995). The quality of the ore is not uniform throughout the deposit, 15 magnesite samples from lenses number 1 and 2 of the Kumhar deposit show an average of 45.76%, MgO; 1.79%, CaO; 1.43%, Al_2O_3; 0.76%, Fe_2O_3; 3.42%, SiO_2; 46.54%, L.O.I.; and total 99.76% (Junaid 1992). An average of nine magnesite samples from Kumhar (Kaifi *et al* 1998) also shows the same range of chemical composition (Table 2). The Kumhar magnesite deposits are hydrothermal types formed by progressive replacement of dolomite and dolomitic limestone through solutions associated with igneous rocks. The reserves of the Kumhar magnesite deposits, estimated as 11 million tons (Siddiqi and Alam 1968), are presently being mined on a small scale by open cast method by the Pakistan Industrial Development Corporation to meet local demand for low quality refractory bricks and other local industries (Kaifi *et al* 1998).

Important magnesite deposits also occur at Nasai (30°-0.50 N→68°- 0.02E') and localities near Muslimbagh (30°-0.47 N'→ 68° 0.03 E') in the Zhob district Balochistan (Gauhar 1966;

Bilgrami 1974). The deposits are cryptocrystalline (amorphous) vein and replacement types generally affiliated with serpentinized ultramafic rocks formed as enrichment and fissure filling deposits of hydrothermal origin. These deposits appear to have formed from hydrothermal alteration and enrichment of serpentinized rocks (Vloten 1962; Bilgrami 1974). The average percentages of chemical composition of Muslimbagh magnesite is SiO_2 0.26, FeO 0.30, Al_2O_3 2.95, CaO 2.15, MgO 42.50, LO.I 52.85 and total 100.01.

The Muslimbagh magnesite deposits are large but their reserves remain unestimated by earlier workers. These deposits have been mined for decades by open cast methods for domestic use. In 1984-85, Muslimbagh produced about 20,000 tons of magnesite, which is 61% of the country's total production (Griffiths 1987). According to Kaifi *et al* (1998) magnesite deposits of Muslimabagh are also high grade with average MgO content of 42% (Table 3).

Dolomite: Large deposits of dolomite occur in the provinces of Punjab, Sindh and NWFP. In Punjab, about 900 million tons of mineable dolomite occur near Mianwali, in beds averaging 89 meters in thickness (Gauhar 1966). In the southern lower Indus Basin near Jhampir in Sindh several million tons of dolomite have been discovered. In the northern part of the Axial Belt, very large deposits of good quality dolomite occur near Haripur, Havelian, Abbottabad and at several places in the Khyber Tribal Agency and other areas in the North West Frontier Province (Shah 1977; Khan *et al* 1997). Detailed studies about extent and quality of reserves of dolomite deposits occurring throughout Pakistan are still very much lacking.

About one sixth of Pakistan's dolomite requirements are obtained from Punjab province, The quarry has reserves in excess of 1.25 million tons with an annual output of about 20,000 tons for production of refractory bricks at the Pakistan Steel Mill, Karachi (Griffiths 1987). Typical analysis of Mianwali dolomite is MgO 21.10%, CaO 31.20%, Fe_2O_3 0.38%, Al_2O_3 0.38%, SiO_2 70%, L.O.I 47.20% with a total of 100.96%.

Chromite: Important chromite deposits occur at Muslimbagh, 75 miles north of Quetta. The chromite bearing rocks extend over large areas spreading to Gawal, Khanozai and Nasai localities in Muslimbagh. The chromite bodies occur as disseminated crystals in veins, lenticular mass and pod like bodies of varying shapes and sizes (Ahmad 1970). These deposits are Alpine types formed in highly deformed regions by liquid magnatic injections. The chromite bodies occurring in this district are generally smaller in size and extremely irregular in shape occurring mostly in folded and faulted ultramafic rocks specially serpentine and dunite. As a result reserve estimation is difficult.

Total chromite production in this province comes from Muslimbagh district, where a large number of small and medium scale mining companies have been engaged for the last 70 years. Chromite mined from Muslimbagh is mostly exported to Japan, Korea, China and some other countries. Limited chromite production from Muslimbagh is also used domestically. In 1984-85, Balochistan produced 30090 tons of chrome. The chromite in these podifrom deposits is generally friable. About 5-6 major companies produce high grade (Cr_2O_3 48%) as well as low grade (Cr_2O_3 40-46%) chromite at Muslimbagh (Griffiths 1987). In reviews by Rait (1950) and Yoshino (1985) of the chemical composition of the world chromite ores, Pakistani chromites were indicated as ideal raw material for refractory bricks.

In the Malakand district of NWFP, lenses and veins of chromite are found associated with dunite, hurzburgite and pyroxenite. The chromite is of variable grade and deposits are small (Cr_2O_3 35-40%) having iron to chrome ratio of 1: 25 (Griffiths 1987). Chromite deposits also occur at Shinkai near Boya (North Waziristn Agency, NWFP). The Cr_2O_3 content ranges from 32- 52%. The average Cr / Fe ratio of 21 chromite samples is 1.48, indicating that chromite from the Shinkai area could be exploited for metallurgical purposes. In the Shinkai area, about 12 chromite bodies are located in an area of 104 km^2 and both the Malakand and Shinkai deposits are being mined at small scale and sold domestically and internationally.

High alumina refractories. Bauxite and fire clay: The most important bauxite and fire clay deposits occur in the Salt Range, district of Sargodha and Kalachitta Range near Attock. Bauxite occurs in the Salt Range as blankets and lenticular bodies measuring half to seven meters in thickness with significant variation in mineral and chemical composition within the same deposit (Cheema 1974). The reserves have been estimated as 134 million tons but known resources may be around 1000 million tons (Khan and Husain 1970).

Important deposits of fire clay occur in Datta Formation near Attock city. Its reserves have been estimated as 50 million tons (Husain and Naqvi 1973). Extensive deposits of fire clay also occur in Sindh as roof shale above Lakhra and Jhampeer coal fields near Hyderabad city and are Paleocene and Eocene in age. Thickness of the clay beds varies from 2 to 2.5 meters covering an area of about 300 km^2. The fire clay reserves have been estimated at 112 million tons (Ahmad 1986) and the known resources may be up to 1000 million tons (Baqri 1989). The chemical composition of important Pakistani fire clays is given in Table 4 (Husain *et al* 1992).

Kaolin or China clay: Important deposits of kaolin occur in Precambrian granitic rocks at Nagar Parker Sindh. These clay deposits occur in pockets and lenticular bodies in varying thickness (Ahmad and Bahar 1992). About 4 million tons of reserves of kaolin have been proved at Nagar Parkar (Baqri 1990). The medium sized kaolin deposits also occur near Shaidu Sharif near Swat (NWFP), formed by alteration of the plagioclase rich leuco-quartz-diorite (Husain *et al* 1992). Reserves of these deposits have been estimated as about 2 million tons. The chemical analysis of representative samples from Nagar Parker and Shaidu Sharif China clay deposits is given in Table 5. (Husain *et al* 1992). These deposits are being mined for making ceramics sanitary and other products by a few private and public sector ceramic factories located in Sindh and NWFP.

Silica refractories. Quartz and quartzite: There are no economic deposits of quartz crystals in Pakistan. However, quartz crystals occurring in veins are found at several places in Gilgit, Hazara and North Waziristan Agency of NWFP. On the other hand very extensive deposits of quartzite occur at dozens of places in NWFP (Table1). Detailed studies regarding their size, quality and modern industrial uses of quartzite have not yet been carried out in Pakistan. At present, quartzite is used on limited scale only in the local construction industry.

Miscellaneous materials. Graphite: In Pakistan, no economic deposit of graphite has been discovered. However, small deposits of graphite are reported from Gilgit, Chitral, Hazara and other places in NWFP (Table 1).

Olivine and dunite: Olivine rich dunite and serpentinized dunite rocks are widespread in the Axial Belt region at Muslimbagh and Lasbela districts of Balochistan and at several places in NWFP (Table 1). Pakistan's chromite deposits are also hosted in these ultramafic rocks. There is a need to carry out detailed studies on dunite rocks in Pakistn as partial substitute for chromite in refactory bricks industry (Bateman 1950; Lorenz 1991).

Discussion and Conclusion

Pakistan has large deposits of a variety of refractory minerals but most of them are still underdeveloped, under-exploited and underutilized. All important and known refractory mineral deposits in Pakistan e.g. magnesite, chromite, bauxite, dolomite and fire clay are being operated by small private mining groups which lack modern mining methods and up to date processing equipment and adequate finance. Lack of physical infrastructure and adequate supply of water and electricity in Pakistan's mineral districts have also hampered mining.

However, mining conditions are better in dolomite and fire clay districts of Punjab, which are being mined and marketed by the public sector Punjab Mineral Development Corporation (PUNJMIN). The development and mining of industrial minerals including refractory minerals have suffered due to following factors.

In Pakistan mining is not treated as industry. There is no clear-cut mineral policy similar to the petroleum policy of Pakistan. As industrial minerals development is a provincial concern, techniques and policies vary with respect to mine leasing, imposition of mine safety measures and collection of taxes. As a result, the mining industry in Pakistan remains very traditional and primitive with no substantial local and

Table 1
Chief refractory types and distribution of mineral raw materials in Pakistan

High alumina refractory	Used in making high alumina bricks for miscellaneous furnace linings
Bauxite	Mianwali, Khushab (Sargodha) Jhelum (Rawalpindi)
Fire clay	Attock, Lakhra and Jhampeer (Hyderabad)
Kaolin or China clay	Nagar Parker, Shaidu Sharif (Swat)
Silica refractory	Used in many metallurgical processes
Quartzite	Dir, Abbottabad, Haripur and many other localities of NWFP
Quartz	Gilgit, Chitral and many localities of NWFP
Magnesia refractory	Used in metallurgical furnaces, kilns and with corrosive materials
Magnesite	Kumhar (Abbottabad) Muslimbagh (Balochistan)
Dolomite	Mianwali (Punjab), Haripur, Abbottabad, Havelian (NWFP)
Chromite	Malakand and North Waziristan Agency (NWFP), Muslimbagh
Miscellaneous	Graphite is used both in natural and electric furnace products and olivine may replace chromite in steel furnaces and nonferrous furnaces.
Graphite	Gilgit, Chitral, Khyber Agency (NWFP)
Olivin and dunite	Muslimbagh, Lasbela (Balochistan), Malakand and N. Waziristan Agency

Table 2
Average chemical composition of nine Kumhar magnesite samples (wt %)

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	L.O.I	Total
0.98	0.91	4.49	1.54	41.93	50.66	100.57

Table 3
Average chemical composition of seven Muslimbagh magnesite samples (wt %)

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	L.O.I	Total
0.26	0.08	2.95	2.15	42.50	51.85	99.79

Table 4
Chemical composition of Pakistani fire clays (mass %)

	Khushab	Attock	Hyderabad
SiO_2	15.00	6.00	50.35
TiO_2	--	3.65	3.53
Al_2O_3	66.00	74.24	35.27
CaO	1.60	0.76	0.14
MgO	0.30	--	0.37
Na_2O	--	0.20	0.17
K_2O	--	--	0.40
Fe_2O_3	2.10	0.64	0.54
L.O.I.	14.40	14.51	10.12
Total	99.40	100.00	100.84

foreign private capital invested in this sector. Loans with low interest rates available to the agricultural and industrial sectors are not extended to mining companies to purchase equipment and to develop mining infrastructure. Thousands of small mining groups engaged in the exploitation of industrial rocks and minerals generally do not receive any technical assistance by the government and its agencies except in the field of mine safety. There are no training facilities for miners and mineral processors. Most of the work force engaged in the mining sector comprises of illiterate people who have learnt their skills from their elders. There have been no efforts by either provincial or federal governments to replace these workers by educated and skilled in the field of mining personnel. A poor network of metal roads and a shortage of both water and electricity are common in all provinces of Pakistan where refractory raw materials and other minerals occur abundantly.

There are no testing laboratories near the mines to regularly check the quality of mined refractory raw materials, which is necessary to produce standard refractory bricks. In Pakistan satisfactory calcining facilities are not available to produce and supply uniform refractory grade bauxite and magnesite to the brick industry. There is a need for basic investment in this sector and to create ware-housing facilities to keep refractory raw materials moisture free. Mineral transportation within the country is quite costly because all transport is by trucks. Railways that can move huge tonnage of mineral products cheaply are not playing any significant role in mineral transport in Pakistan. It is also difficult to export mineral commodities because of inefficient and expensive local transport that makes indigenous minerals more costly than imported Indian and Chinese equivalent products.

The government has no schedules or targets to develop refractory, fertilizer or other industrial raw materials in Pakistan. As a result, no measures have been taken by the provincial and federal governments to attract significant private, national or foreign investment capital from exploration, mining and processing of refractory minerals and to set up refractory brick industries to meet ever growing demand by local iron and steel, cement, glass and petroleum refining industries.

The refractory bricks industry in Pakistan has great potential and a bright future in view of the growing demand for this product by a variety of industries. At present, Pakistan meets most of its requirements by importing bricks from India and other countries despite the fact that major deposits of refractory raw materials occur in the country. Pakistan needs to attract major foreign joint venture partners to help explore and mine its local raw materials. The prospects of finding more magnesite, bauxite and chromite deposits are poor but local deposits of dolomite and fire clays are potentially very large and need further testing for their suitability as refractory raw materials. There is an urgent need to modernize both mining and processing of refractory raw materials and to increase their production to meet the demand of medium to

Table 5
Chemical composition of Pakistani kaolin or China clay deposits (wt %)

	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O	K_2O	L.O.I	Total
Nagar Parker	41.02	2.30	1.81	45.37	0.43	0.21	0.62	0.31	8.10	100.17
Swat	48.95	--	1.60	32.03	8.36	1.29	3.59	0.22	4.30	100.34

large refractory brick plants beyond the year 2000. These policies will help to curb expensive imports of bricks by fast growing heavy industries.

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