Technology Section

Pak J Sci Ind Res 1998 **41** (1) 57-62

Geochemical Characterization of Important Magnesite Deposits of Pakistan for their Modern Industrial Application

Zafar Kaifi[a], Viqar Husain[ab], M A Qaiser[a] and Aurangzeb[b]*

[a]*PCSIR Laboratories, Jamrud Road, Peshawar, Pakistan*

[b]*PCSIR, PPI Building, Kamal Ataturk Road, Karachi, Pakistan*

(Received 5 May 1995; accepted 20 September 1997)

Magnesite occurrence in Pakistan appears to be a part of Himalayan Orogenic System as all magnesite deposits occur along the Axial Belt. Two major genetic types of magnesite have been recognised in Pakistan. Crystallin and replacement magnesite hosted in carbonate rocks and cryptocrystalline (amorphous) magnesite hosted in ultramafics. Commercially both types of deposits occurring in Kumhar and Muslimbagh are important but the reserves of Kumhar are large. Magnesite desposits in Pakistan are being mined by open cast method and the production is only few thousand tons per annum. This paper discusses briefly the quality and size of these magnesite deposits and their possible modern industrial applications.

Key words : Geochemistry, Magnesite, Pakistan, Industrial Applications.

Introdution

Important magnesite deposits of Pakistan occur along the Axial Belt-Abbottabad (Hazara), Malakand and Waziristan in the north and Muslimsagh (Zhoab), Khuzdar and Lesbela in the south. The only carbonate rock hosted replacement or crystalline type of magnesite deposits of the country occur 20 km north west of Abbottabad near Kumhar and Sherwan villages (43 F/4). Whereas, all other magnesite deposits reported from NWFP and Balochistan occur as veins in serpentinized ultramafics which also host Pakistan's important chromite deposits (Figs. 1,2). Among these veins or cryptocrystalline type deposits occurring in ultrabasic igneous rocks only Muslimbagh or Zhoab valley magnesites are of commercial importance and have been mined continuously since the second half of 20th century.

The Kumhar magnesite deposits occur in dolomitic limestone of Abbottabad Formation of Early Paleozoic age. Abbottabad is the main city of Hazara region which has complex geological history. It is a part of Indo-Pak plate and Lesser Himalayas. Interestingly largest rock phosphate, magnesite and soapstone deposits of the country occur in the same stratigraphic sequence. These magnesite deposits were discovered in 1968 and have been developed recently. The estimated reserves of Kumhar are over 11 million tons. Small scale open cast mining has also been undertaken recently to meet partial domestic demand of low quality refractory bricks and some other industries.

Major magnesite deposits occur at Nasal (30 47 N, 68 03 E) and few other localities near Muslimbagh in Zhoab district of Balochistan (34 N/13-14). The magnesite deposits also occur in some more areas of Khuzdar and Lasbela districts of Balochistan alongwith chromite hosted in ultramafic intrusives (Fig.2)

Most of the world's magnesite production is consumed by the refractory industry and 70-75% of the refractories are used by the iron and steel industry. Despite the fast increasing industrial importance of magnesite in the world for the last twenty years, comprehensive studies and literature on magensite deposits of Pakistan have been lacking. As a result, these deposits remain underdeveloped and underutilized.

Earlier workers have carried out detailed geological mapping and geochemical studies on Kumhar magnesite (Siddiqui and Alam 1968; Alam 1972; China-PIDC report 1975) and proved that good quality mineable reserves of Lense No. 1 and 2 are 3 million tons (Fig. 3). Experiments have also been carried out by these workers on their suitability for magnesite and magnesite chrome refractory bricks, which are being imported by Pakistan at huge price every year. Twelve more lenses of Kumhar magnesite deposits require detailed geological investigations, chemical and technological tests, topographical mapping and ultimately mining (Anon 1980). Among other workers who contributed to the better understanding of these deposits include (Khan and Qazi 1982; Husain *et al* 1990; Junaid 1991). However, no study has yet been made to assess their suitability for preparing magnesium chemicals.

The available literature on Muslimbagh magnesite deposits

* Author for correspondence

[b] Present address

is also very scanty and old (Vloten 1962; Bilgrami 1964; Gauhar 1966; Vlöten 1967; Ahmad 1969; Griffiths 1987; Husain *et al* 1993). Present study is therefore, aimed at reviewing all unpublished work on magnesite deposits of Pakistan focussing mainly on their physico-chemical characterization, size and quality of deposits, origin and modern industrial applications. An attempt has also been made to carry out laboratory scale experiments for preparing chemicals from the magnesite samples collected from Kumhar magnesite deposits.

Materials and Methods

Geologic Setting. Kumhar Magnesite: These magnesite deposits are located near Abbottabad city of Hazara division constituting northern part of Pakistan. The Hazara area has very complex geological history as it is a part of Indo-Pak plate and Lesser Himalayas (Ghaznavi *et al* 1975).

The Kumhar magnesite deposits occur in the Abbottabad formation which is in contact with the underlying Tanawal Formation by an E-W trending thrust fault (Table 1). The quality of the ore is not uniform throughout the area. The northern lenses are good in quality (due to low silica content) as compared with southern lenses (Ghaznavi *et al* 1975).

The Kumhar magnesite is white, compact, coarsely grained and at some places has greyish and brownish patches. Its specific gravity is 3.0 and hardness ranges from 3.5 to 4.0. Considering the factors such as voids, porosity, fracture and mining losses, the volume tonnage factor has been determined as 12 cubic ft per ton (Alam 1972). The ore mainly constitutes magnesite, calcite, dolomite and small amounts of quartz, haematite, limonite, epidote, sphene and clays (Anon 1980).

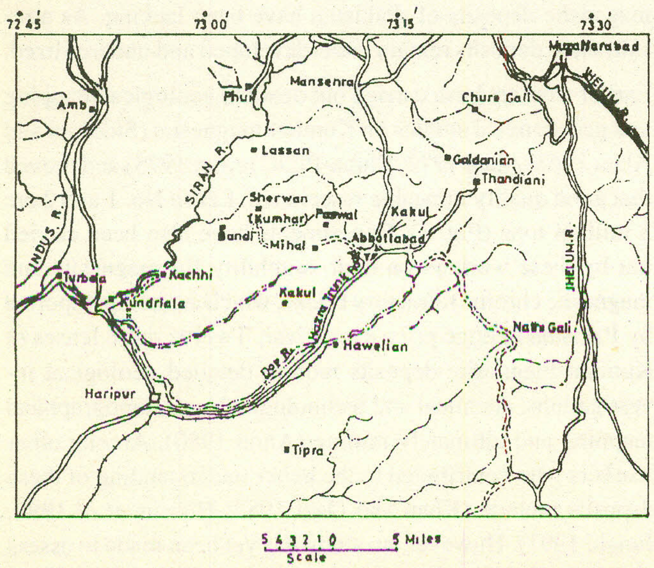

Fig. 1. Location map of Sherwan (Kumhar).

Muslimbagh Magnesite. The Muslimbagh massif lies in the chain of mountains which borders the Indo-Gangetic Plain and forms the westward extension of the Himalayan mountain system. It is situated in the Alpine-Himalayan geosynclinal belt, in which marine sediments were deposited during Paleozoic to Tertiary period. This belt was folded during late Cenozoic time and the ultramafic and mafic eruptive rocks were intruded along the Axial Belt of the geosyncline (Anon 1960; Vloten 1967). Detailed geological sequence of the Muslimbagh area by Bilgrami (Bilgami 1964) is mentioned in Table 1.

In the hand specimen the Muslimbagh magnesite bearing rock is milky white in colour, very fine grained and extremely tough. Angular fragments of serpentine in the process of alteration to magnesite can be observed in a number of specimens. The hardness ranges from 4 to 5. Magnesite is euhedral in form and shows extreme birefringence (Bilgrami 1964).

Experimental. The representative magnesite samples were collected from Kumhar and Muslimbagh magnesite deposits (Tables 2, 3). The chemical analysis of magnesite for major elements was carried out by conventional methods (Scott 1979).

The trace elements were determined by preparing all solutions with analytical grade chemicals. A gram of each magnesite sample was dissolved in 100 ml of concentrated HC1 and digested on sand bath; added 1:1 HC1 and heated again. Filtered the solution and the total volume of the solution of

Table 1

Stratigraphy of Kumhar (Sherwan), Abbottabad

Age	Formation	Lithologic Unit
		Quartzite
		Schist
Cambrian	Tanawal Formation	Quartzite
		Phyllite
		Fleshy coloured quartzite
Lower Cambrian	Abbottabad Formation	Thin bedded limestone
		Quartzite
		Dolomitic
		Limestone (magnesite)
-------------Thrust fault-----------		
		Phyllite
		Quartzite
Cambrian	Tanawal Formation	Schist
		Quartzite
-------------Unconformity-----------		
Pre-cambrian	Hazara Formation	Slates etc.

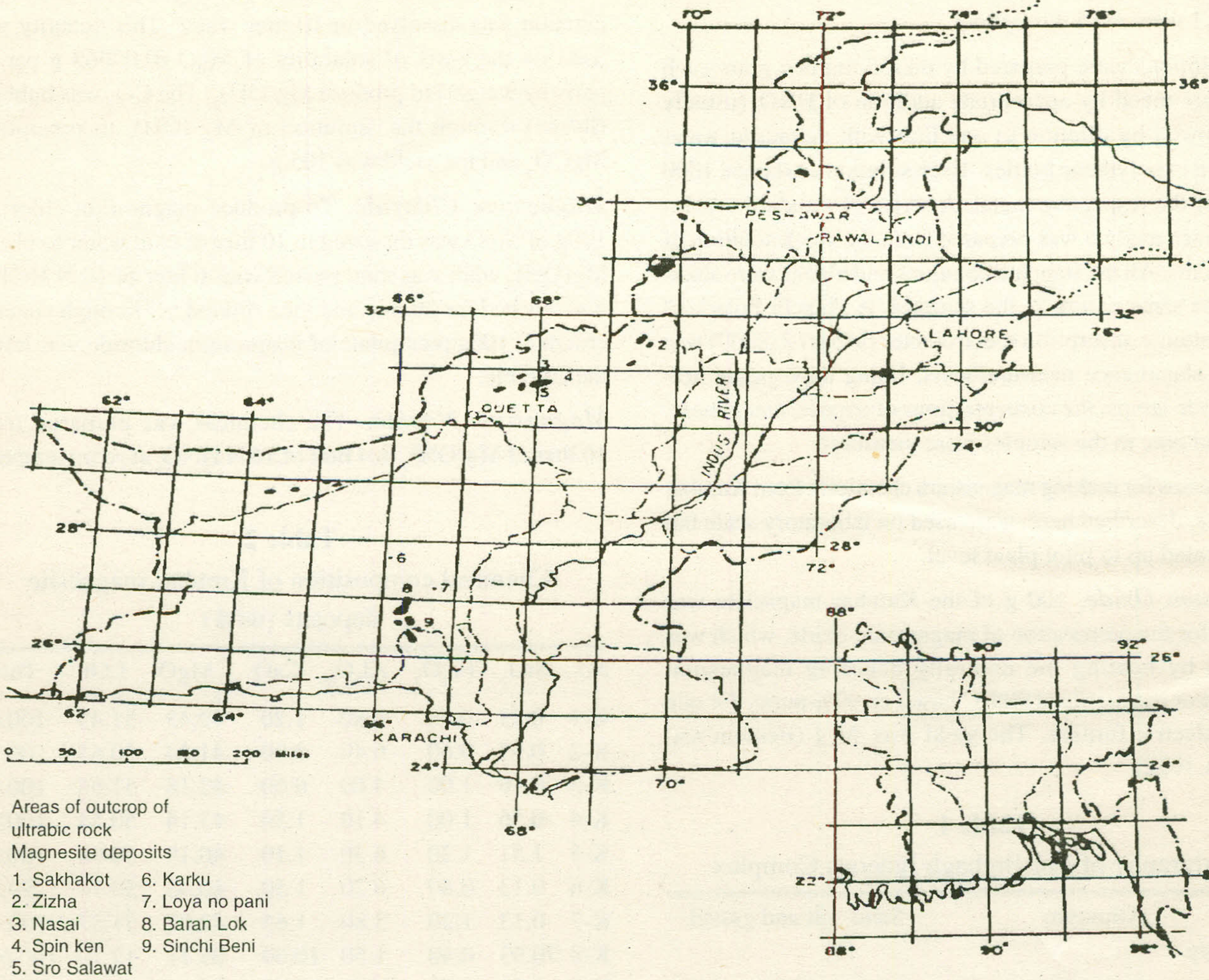

Fig 2. Index map of Pakistan showing areas of outcrop of ultrabasic rocks and the locations of magnesite deposits. (After Vloten 1962)

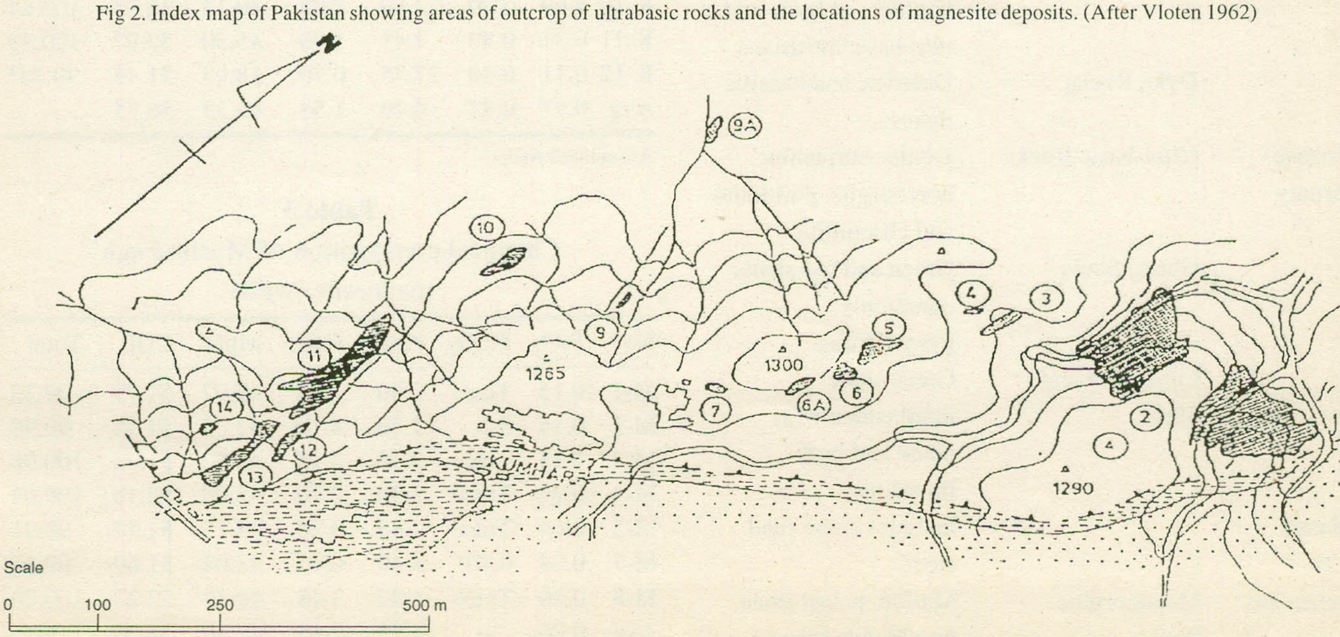

Fig 3. Map showing the magnesite lenses of Kumhar magnesite deposits (After Ghaznavi *et al* 1995).

each sample was made up to 250 ml. Deionised water and 10N HC1 were used throughout.

Stock solutions were prepared by dissolving one gram each of the pure metal by appropriate addition of HNO_3 (usually 1:1) followed by dilution to one litre with deionised water and stored in polythene bottles. Each solution contained 1000 $\mu g/ml^{-1}$ of the respective metal. A series of standard solutions of each analyte was prepared from the stock solution of the elements. All the standard solutions and blanks were acidified to the same extent as the samples. A Hitachi Polarized Zeeman atomic absorption spectrometer (Model Z-8000) was used for absorbance measurements. Using appropriate hollow cathode lamps, the concentrations of copper, manganese, nickel and zinc in the samples were measured.

The processes for making magnesium chemicals from Kumhar magnesite, described here, were used on laboratory scale but can be scaled up to pilot plant level.

Magnesium Oxide. 100 g of the Kumhar magnesite was calcined for the preparation of magnesium oxide, which was obtained by heating the naturally occuring magnesium carbonate or magnesite at 900°C based on 90% purity for one h in an electric furnace. The yield was 44 g (Bessem and Koborich 1932).

Table 1

Stratigraphy of Muslimbagh Igneous Complex

Quaternary	Alluvium	Sand, silt and gravel
	Conglomerate	Inludes pesbles and boulders of basic and ultrabasic intrusives
	Dyke Rocks	Doleritic and basaltic dykes
(Eocene) Tertiary	Ultra-basic Rocks	Dunite, serpentine horzburgite, peridotite and chromitite
	Ghazij Shale	Green and red shale, commonly gyspsiferous
	Limestone and Shale	Green shale interbedded with black and buff limestone
Triassic to		includes some sand stone
Cretaceous	Metamorphic Rocks	Marble, baked shale. hornblende schist.

Pure Magnesium Carbonate. The MgO obtained by calcination was dissolved in 10 liter water. This quantity was used on the basis of solubility of MgO (0.00062 g per 10 parts by weight) to produce $Mg(OH)_2$. The CO_2 was bubbled (lb/sec) through the solution of Mg $(OH)_2$ to precipitate $MgCO_3$ and the yield was 105 g.

Magnesium Chloride. To produce magnesium chloride, 100g of MgO was dissoved in 10 liter of cold water to obtain $Mg(OH)_2$ whih was then treated with 6 liter of 10 N HC1. It was leached for 36 min and then filtered off through sintered crucible. 100g precipitate of magnesium chloride was left in the crucible.

Magnesium Nitrate. The chemical was prepared from 10 liter of $Mg(OH)_2$ in 4 liter of 16 N HNO_3 at room tempera-

Table 2

Chemical composition of Kumhar magnesite deposits (wt%)

No.	SiO_2	Fe_2O_3	Al_2O_3.	CaO	MgO	LOI	Total
K-1	0.28	0.80	4.80	1.20	42.43	51.45	100.96
K-2	0.97	0.60	6.40	0.90	41.24	50.65	100.76
K-3	0.16	1.00	4.60	0.60	42.18	51.66	100.20
K-4	0.56	1.00	4.10	1.50	43.14	50.54	100.84
K-5	1.51	1.20	6.30	1.10	40.19	50.08	100.38
K-6	0.13	0.80	6.20	1.50	40.48	50.74	99.85
K-7	0.13	1.20	3.80	1.65	42.07	51.57	100.42
K-8	70.93	0.40	1.50	10.00	05.11	12.70	100.64*
K-9	1.91	0.60	20.80	14.00	12.14	51.59	100.84*
K-10	4.69	0.80	2.80	4.05	40.15	48.35	100.84
K-11	0.31	0.80	1.41	1.40	45.50	50.97	100.39
K-12	0.11	0.40	27.75	0.70	18.93	51.45	99.34*
Avg	0.97	0.93	4.46	1.58	46.33	50.75	--

Associated rocks.

Table 3

Chemical composition of Muslimbagh magnesite (wt%)

No.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	LOI	Total
M-1	0.15	Trace	2.50	1.85	42.97	51.79	99.33
M-2	0.15	0.2	1.70	4.10	42.05	51.78	99.98
M-3	0.25	Trace	3.30	2.25	42.50	51.78	100.08
M-4	0.26	Trace	2.90	2.70	42.00	52.18	100.04
M-5	0.64	Trace	2.85	0.20	44.75	51.47	99.91
M-7	0.28	0.40	3.40	0.45	43.02	51.69	99.24
M-8	0.10	Trace	4.00	3.48	40.19	52.23	100.00
Avg.	0.26	--	2.95	2.15	42.50	51.85	--

ture, which was later evaporated and crystallized to get $Mg(NO_3)_2$.

Results and Discussion

Geochemistry. The chemical composition of the raw Kumhar magnesite is: SiO_2 0.11-4.69%, Fe_2O_3 0.40-1.20%, Al_2O_3 1.41-6.40%, CaO 0.6-4.05% and MgO 40.15-45.50% (Table 2). On the other hand, chemical composition of Muslimbagh magnesite is: SiO_2 0.10-0. 64%, Fe_2O_3 0.2-0.4%, $Al_2 O_3$ 1.7-4.0% CaO 0.2-4.1% and MgO 40.19-44.75% (Table 3).

Comparative study of chemical constituents of Kumhar and Muslimbagh magnesites show that their magnesium contents are similar. However, impurises like SiO_2, Fe_2O_3, Al_2O_3 and CaO are relatively less in Muslimbagh ore. The Fe_2O_3 content in Kumhar magnesite is higher than Muslimbagh as the former occurs in the Ca-Mg-Fe carbonate host (Gupta and Mukherjee 1988).

Table 4

Trace elements of Kumhar magnesite (ppm)

No.	Cu	Mn	Ni	Zn
K-1	5	278	3	13
K-2	7	325	5	15
K-3	5	533	--	13
K-4	2	785	--	13
K-5	7	688	--	13
K-6	5	475	--	16
K-7	5	693	--	10
K-8	7	293	3	18
K-9	10	232	3	18
K-10	8	260	--	17
K-11	8	390	--	18
K-12	5	253	--	13
Avg.	6	434	--	15

Table 5

Trace elements of Muslimbagh magnesite (ppm)

No.	Cu	Mn	Ni	Zn
M-1	7	675	28	13
M-2	8	295	63	17
M-3	3	193	20	10
M-4	5	65	--	13
M-5	5	88	25	13
M-6	5	170	22	15
M-7	5	250	40	10
Avg.	5	248	28	13

Among the trace elements determined from both Kumhar and Muslimbagh magnesite deposits, only manganese is of some importance ranging from 65 to 785 ppm (Table 4, 5), other trace elements occur in low concentration and are very close to the detection limit. However, nickel in cryptocrystalline or amorphous type Muslimbagh deposits is upto ten times higher than crystalline and replacement type of Kumhar magnesites (Liavsky *et al* 1991).

Origin. The crystalline type Kumhar magnesite deposits appear to have been formed by the progressive replacement of dolomitic limestone through hydrothermal solutions associated with igneous rocks. In the field, irregular ore bodies, undigested patches of host carbonate rock and varying grades of magnesite ore suggest hydrothermal origin for these magnesites. The Muslimbagh magnesite deposits on the other hand are cryptocrystalline (amorphous) vein and replacement type genetically 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 serpentized rock (Vloten 1962; Lorenz 1991).

Industrial uses. The international standard specifications for the dead burnt magnesite and refractory bricks are that the ore should contain minimum 41-45% MgO, and maximum SiO_2 content as 4.5 to5.5% with 2.5% CaO. The excessive proportion of SiO_2 Fe_2O_3 and CaO reduces the refrectoriness of the bricks (Gupta and Mukharjee 1988; Russel 1991). The major element composition of magnesite ores from both these deposits meet international specifications required for making magnesite refractory bricks with the exception of CaO.

The magnesite deposits of Kumhar are large, which can ensure long term supply for refractory bricks plant, which is proposed to be set up in Hattar 60 km *south of Kumhar.* Chinese consultants (China-PIDC report 1975) have also carried out successful experiments for making magnesite and chrome magnesite refractory bricks using Kumhar magnesite and chromite of Malakand, which is located 100 km north of Kumhar.

The Kumhar ore can also be successfully used for making magnesium oxide, carbonate, chloride and nitrate. These ores may also be used for manufacturing caustic calcined magnesia which is utilized in making such diverse products as magnesium oxychloride; paper pulp, rubber, rayon, fertilizer, magnesium metal and alloys, insulating material and drugs or other chemicals (Coope 1987; Lorenz 1991).

At present, there is not a single unit in the country producing magnesium chemicals and total reliance is on imports. Substantial amount of foreign exchange is being spent in Pakistan to meet the requirements of its domesitc industry. Further, if Pakistan pays attention towards magnesite refractory bricks and chemical industries, it will help in reducing its imports of such products and provide scope for exporting these items to Bangladesh, Sri Lanka and other Asian countries.

Conclusions

The appraisal of geoscientific and physio-chemical studies of Kumhar magnesite deposits indicate that additional search of magnesite bodies in down dip direction is certainly required. Detailed geological and industrial testing studies for proving more mineable reserves in Kumhar and Muslimbagh should be carried out alongwith the feasibility studies for magnesite, magnesite-chrome bricks and magnesium based chemicals. These studies show that both Kumhar and Muslimbagh magnesite deposits should be systematically developed, mined and utilized in modern industries.

References

Ahmad Z 1969 *Directory of mineral deposits Rec.* Geol Surv Pak Quetta, pp 15.

Alam S 1972 *Geological report on Kumhar magnesite deposits Hazara NWFP.* Published by Pakistan Industrial Development Corporation (PIDC) Karachi.

Bassem W and Kobarich F Z 1932 *Physical Chemistry* (P 7 323) Ency of Chem Tech 8.

Bilgrami S A 1964 *Minerology and Petrology of the Central Part of the Hindubagh (Muslimbagh) Mining District.* Zhoab Valley Pakistan RcGeol Surv Pak **10** part 2-6 Quetta.

Anon 1997 *Experimental Report on Manufacture of Magnesite Bricks and Magnesite-chrome Bricks with Kumhar Magnesite and Malakand Chromite deposits of Pakistan.*

Coops B 1983 Magnesia markets/magnesia producers. *Industrial Minerals* **191** 57-88.

Gauhar S H 1966 *Magnesite Deposits in Pakistan.* Geol Surv Pak 57.

Ghazanvi M I Hasan M T, Karim T 1995 *Geology and Economic Minerals of Abbottabad area.* A field guide book for UNESCO -- IGCP Project 325 and SEGMITE International Symposium and Field Workshop Abbottabad, Pakistan.

Gupta D K S, Mukherjee S K 1988 Minerological Study of Jhiroli magnesite Almora distriot Up India. *Indian Jour Min Met and Fuels.* pp 150-156.

Griffiths J 1987 Pakistan's mineral potential: Prince or pauper. *Industrial Minerals London July* 20-43.

Husain V, Jan N, Siddiqi F 1990 Mineralization of Kumhar magnesite, Hazara NWFP. *Pak J Sci Ind Res 33 (9):* A 325.

Husain V, Bilqees R, Abbas G 1993 Pakistan's Industrial mineral resources for 21st contury. *J Society resource Geology **16*** 263-270.

Anon 1960 *Reconnaissance Geology of Part of West Pakistan.* Colombo Plan Co-operative Project, Toronto, Govt. of Canada. Hunting Survey Corp. Ltd. Canada.

Ilavsky J, Turan J, Turanova L 1991 Magnesite deposits and occurrences in the West Capathians of Czechoslovakia. *Ore Geology Reviews* **6** 537-561.

Anon 1980 *Report on Feasibility Study Geological Exploration of Kumhar Magnesie Deposits Hazara NWFP Pakistan.* Minkoh Japan and PIDC Pakistan.

Junaid M 1991 *Modern Industrial Applications of Kumhar Magnesit.* M.Sc. thesis Geology Dept Univ of Peshawar Pakistan.

Khan I H, Qazi M A 1982 *Report on Minerological and Investigations on Kumhar Magnesite Deposits.* PCSIR Lahore Pakistan.

Loranz W 1991 Criteria for the assessment of non-metallic mineral deposits. Geol J b A **127** 299-326.

Russel A 1991 Indian's Industrial Minerals, Completing the Picture. *Industrial Minerals* 45-55.

Scott W W 1939 *Standard methods of chemical analysis.* Vol 1 Van Nestrand Company Inc. Newyork.

Siddiqi N A, Alam S 1968 Preliminary Study of Kumhar Magnesite Deposits. PIDC Karachi Pakistan.

Vloten R V 1962 *Magnesite in Pakistan.* CENTO symposium on industrial rocks and minerals Lahore 211-215.

Vloten R V 1967 Geology and chromite deposits of Nasal Area, Hindubagh (Muslimbagh) mining district. *Geol Surv Pak issue No 2.*