Economic Evaluation of Magnesite Deposits of Khuzdar, Balochistan, Pakistan

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Abstract: The cryptocrystalline magnesite deposits of Khuzdar region are Kraubath-type and are hosted within serpentinized harzburgites. Mineralogical studies (XRD) revealed high magnesite in association of dolomite, calcite, Mg-calcite, artinite, huntite, brucite and Fe-magnesite in variable quantities. These deposits have average 84.56% $MgCO_3$, 11.57% $CaCO_3$, 1.33% R_2O_3 (F_2O_3+Al_2O_3), and 2.12% SiO_2. The specifications for industrial applications in terms of Mg content are slightly less than the specified value (46.6%) and some impurities like CaO and SiO_2 are high. The magnesite ore of the study area is suitable to produce Mg metal, caustic, dead-burned and fused magnesia. It can also be utilized in cement, chemicals, fluxes, animal-feed, paper, insulation and pharmaceuticals industries.

Key Words: Magnesite, Economic evaluation, Bela Ophiolite, Khuzdar, Pakistan.

INTRODUCTION

Minerals are one of the principal natural resources essential for the economic development of any country. Presently, the mineral sector of Pakistan is not substantially contributing in the Gross National Products (GNP). The province of Balochistan has been generously bestowed by the nature with vast mineral resources. It has a great potential both for metallic and non-metallic minerals [1]. Considering the rich natural endowment and geo-strategic location, Balochistan has the potential to emerge as Pakistan's new economic frontier.

The magnesite deposits of Khuzdar region are Kraubath-type and are hosted within serpentinized harzburgites, associated with Bela Ophiolite of Cretaceous age. The deposits occur as cryptocrystalline veins of stockwork-type, possessing botryoidal and bone habits [2]. The Kraubath-type magnesite deposits of the study area are preferred in metallurgy and refractory producers because of its higher density and lower Fe, Mn and Ca content.

Economic utilization of magnesite is largely depends upon physical properties of mineral. The color is normally white but it can display tints of yellow, orange and buff on surface. The specific gravity ranges around 2.8 to 3.0 depending on accessory mineral inclusions. It is mainly used as chemically or thermally treated magnesite products in many industries and also as raw material. In modern industries, it becomes very important value added material. Magnesite is used in refractories which consumed primarily by the iron and steel industry [3]. In addition, Mg compounds are used in such varied materials as cement, rubber, fertilizers, insulation, chemicals, fluxes, animal-feed, paper and pharmaceuticals. Primary use of magnesium metal is in aluminum-magnesium alloys, which are used in products such as automobiles, aircraft and machinery [4].

The aim of this paper is to evaluate the quality and quantity of magnesite deposits of Khuzdar area. The present information assists miners, exploiters and industrialists in better utilizing magnesite ore in Pakistan so that the mineral sector can play its proper role in boosting the economy of the country. In the light of present findings, the economic feasibility of the magnesite ores in the area appears encouraging for export of raw material and to meet the domestic demands for metallurgical, chemical and other industrial uses.

MATERIALS AND METHODS

Samples of magnesite were collected from 24 different locations of Khuzdar area (Fig. **1** and Table **1**). Samples were crushed to 10mm size using Jaw crusher and pulverized (-200 mesh) in a Tema mill for chemical analysis. One-gram air free sample was treated with hot concentrated hydrochloric acid. Insoluble residue (IR), combined oxides (R_2O_3) and loss on ignition (LOI) were determined gravimetrically. Calcium and Mg were measured by EDTA titration. The XRD analyses of magnesite samples were carried out using a Bruker AXS 5000 X-ray diffractometer.

RESULTS AND DISCUSSION

Quality

Mineralogical study is essentially required for better evaluation of any ore deposit. The magnesite deposits of study area are cryptocrystalline in nature so that only x-ray

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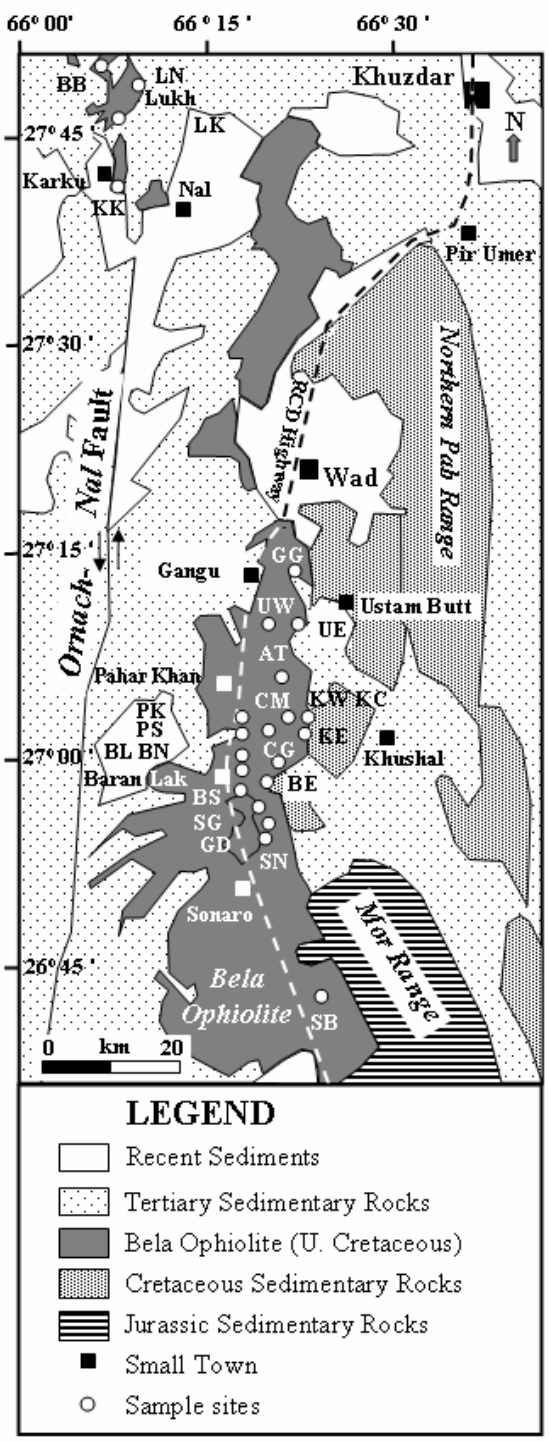

Fig. (1). Geological Map showing locations of studied magnesite deposits.

analysis is the valid technique. The XRD analysis of magnesite ore samples indicates that magnesite, dolomite and calcite are widespread distributed minerals; Mg-calcite and artinite are 24.13% (Fig. **2**), while huntite, brucite and Fe-magnesite are only reported from 4-5 localities. The quality of magnesite is good and it contains >76% while rest is occupied by other Mg-bearing minerals.

Table 1. Reserves, Volumes and Densities of Magnesite Deposits of Study Area

Locality	Volume (m3)	Density (g/cc)	Reserve (tons)
Sonaro (SN)	200	2.91	582
Godar (GD)	250	2.63	657
Sokand Ghar (SG)	310	2.78	862
Baran-Lak South (BS)	3250	2.74	8,905
Baran-Lak (BL)	7400	2.35	17,390
Baran-Lak East (BE)	8500	2.78	23,375
Baran-Lak North (BN)	7,200	2.74	19,728
Chokri Ghor (CG)	9,350	2.75	25,712
Pahar K. Bidrang south (PS)	1,250	2.69	3,362
Chrome Mine	1,400	2.74	3,836
Pahar K. Bidrang East (PE)	515	2.86	1,473
Pahar Khan Bidrang (PK)	9,750	2.66	25,935
Khushal East (KE)	790	2.73	2,156
Abui Ka Tang (AT)	50,000	2.67	1,33,500
Khushal West (KW)	3,550	2.65	9,407
Khushal Central (KC)	5,400	2.74	14,796
Ustam Butt West (UW)	14,700	2.82	41,454
Ustam Butt East (UE)	15,500	2.81	43,555
Gangu (GG)	3,00,000	2.72	8,16,000
Karku (KK)	11,500	2.78	31,970
Karku North (KN)	500	2.62	1,310
Lukh (LK)	480	2.64	1,267
Lukh North (LN)	750	2.82	2,115
Bhanbhori Na Kund (BB)	310	2.71	840

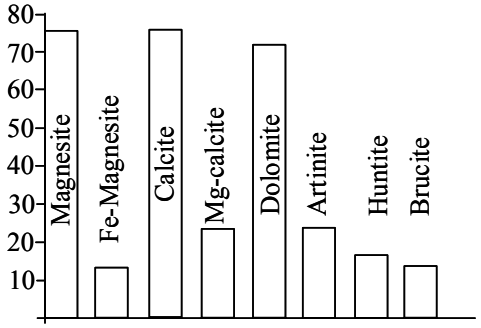

Fig. (2). Diagram illustrating the distribution of dominant minerals in the studied ore samples (all values are in %).

The proximate analysis of magnesites of Khuzdar reflects high amount of MgO (av. 40.43%) and loss on ignition (av. 49.22%). Silica (SiO_2), combined oxides (R_2O_3) and calcium (CaO) are present 2.12, 1.33 and 6.48% respectively as

impurities (Fig. **3**). Harben and Bates (1990) [5] mentioned the specification in terms of chemical composition of a good cryptocrystalline magnesite for used in different industrial applications as 46.6% MgO, 49.9% CO_2, 0.70% SiO_2, 1.35% CaO, 0.85% Fe_2O_3 and Al_2O_3. The samples of the study area show that the av. MgO content (42.66%) of different localities (Fig. **4a**) is slightly less than the specified values, except in the SN locality (av. 32.37%). Calcium is objectionable in many industries. In the studied samples, it ranges between 1.64-10.69% (Fig. **4b**), which is much beyond than 1.35% [5]. Silica is also high (Fig. **4c**) in comparison to 0.75% and combined Fe and Al-oxides in the northern area are within the specified range except BB locality. The southern localities contain relatively high proportion of R_2O_3 (Fig. **4d**).

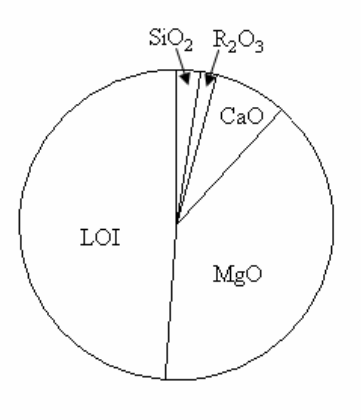

Fig. (3). Pie diagram illustrating the average concentration of major constituents of the studied magnesites.

Reserves

Considering the other industrial minerals of Balochistan, magnesite has low reserves. The Karubath-type magnesite occurs as veins of limited thickness and mostly they are confined in the upper horizons. In majority of cases, these veins have restricted lateral extension. In Baran Lak, Ustam Butt, Khushal, Abui Ka Tang and Gangu localities these veins run in hundreds of meter. In the study area, all magnesite deposits are mined by open-pit methods. Total reserves of the Balochistan area are not inadequately known. Kazmi and Abbas (2001) [6] have mentioned few small deposits in the study area. The annual production of magnesite in Balochistan Province is about 700 tons (2003-2004) which continually rises with the exploration of new deposits (1545 tons in 2004-2005). Recently the mining activities are increased but their exact production is not known. Reserves of the magnesite deposits of the study area have been calculated by considering area, thickness, specific gravity and tonnage factor [7]. The density of magnesite samples are determined by using steelyard method and the average of each locality is given in Table **1**. Area and thicknesses of the veins are calculated by simple measurement with the help of measuring tape. Present calculations are made on 5 to 10m depth, depending upon the individual case. Based on thickness, specific gravity and depth of mineralization, the reserves of individual deposits are estimated (Table **1**). The total probable reserves of these deposits are ~1.23 million tons.

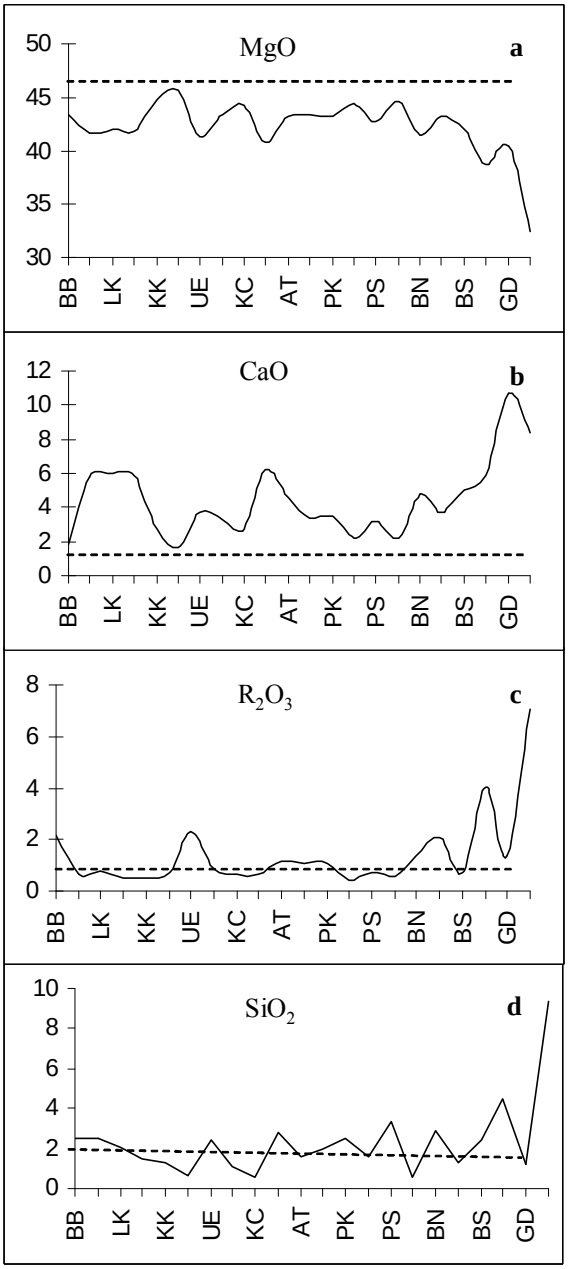

Fig. (4). Comparison of important constituents (av. wt.%) of magnesite ores in different localities. Broken line represents standard values of Harben and Bates (1990).

Processing of Magnesite Ore

The processing of magnesite ore begins with crushing, screening and washing (Fig. **5**). Magnesite is converted into magnesia by the application of heat which drives off carbon dioxide (CO_2), thereby converting the carbonate to the oxide of magnesium (MgO). When raw magnesite is heated

between 700-1000°C, produces caustic-calcined magnesia (caustic magnesia). It is both; an end product and an intermediary step in the chain of magnesia products (Fig. **5**). Caustic magnesia is able to absorb liquids and to absorb heavy metals and ions from liquid streams and is therefore useful in water treatment. When calcined magnesia is heated between 1530-2300°C, the product is non-reactive and exhibits exceptional dimensional stability and strength at high temperatures [8]. This product is known as dead-burned or sintered magnesia. It is mainly used as a refractory material because of its inertness and high melting point. Heating to this level drives off all but a small fraction of the remaining carbon dioxide to produce a hard crystalline non reactive form of magnesium oxide. When calcined or dead-burned magnesia is heated in excess of 2800°C in an electric arc furnace, electro-fused magnesia is produced. It has higher strength, resistance to abrasion and chemical stability than dead-burned magnesia. It is used in the manufacture of premium grade refractory bricks used in the high wear hot spots of basic oxygen furnaces, electric arc or similar furnaces where temperature can approach 950°C.

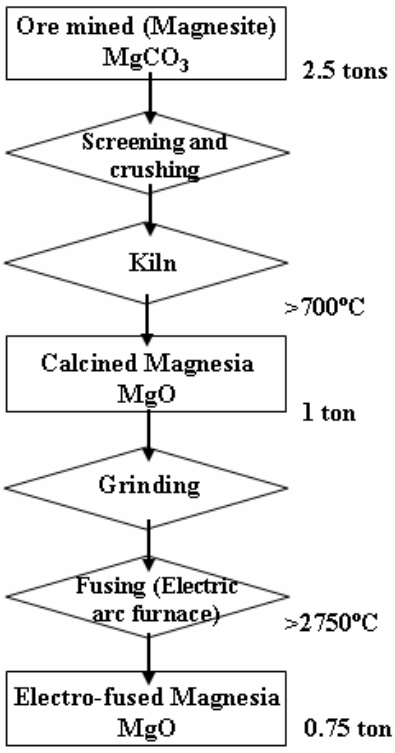

Fig. (5). Fused Magnesia Process Flow Chart (Hughes, 2008).

Uses and Applications

Magnesite is an important source of magnesium. Magnesite is used to produce magnesium metal, caustic, dead-burned and fused magnesia. There are a plethora of possible applications (Table **2**). These include: mobile telephones, car, truck, motorcycle, aircraft engines and other aircraft components and high impact resistance portable computer casings and parts [9]. The automotive market for Mg metal is expected to expand rapidly with current efforts to reduce the weight of vehicles to improve fuel economy and reduce harmful emissions. Magnesite can be used as a slag former in steel making furnaces, in conjunction with lime, in order to protect the magnesium oxide lining. In addition, Mg compounds are used in such varied materials as cement, chemicals, fluxes, animal-feed, paper, insulation, and pharmaceuticals [10]. It can also be used as a catalyst and filler in the production of synthetic rubber and in the preparation of Mg chemical fertilizers. Similar to the production of lime, magnesite can be burned in the presence of charcoal to produce periclase, an important product in refractory material. Magnesite insulating properties have been used in firebricks and emergency flares. Because Mg has a relatively high melting temperature it can be cast into most forms and into near finished shapes. Magnesite's incredible resistance to stress, wear and tear nature and its light weight are very useful. Its usefulness is far-ranging, from being a vital component of cement-like construction material to being used in the tiles covering the Space Shuttle. Almost 50% of all magnesium produced worldwide is used to strengthen aluminum engines.

The magnesite of the study area is of good quality magnesium carbonate and being used in many local industries. One of the most important uses is in Pakistan Steel, Karachi. Siddiqui *et al*. (1996) [11] has successfully used serpentine and magnesite in sintering process of steel production instead of dolomite. The deposits can be considered as future resources to fulfill the requirement in steel industry. In addition, the magnesite samples of study area shows complete calcinations which could be utilized as one of the important ingredient of refractory. Hirayama *et al*. (1995) [12] and Mononobi *et al*. (1992) [13], prepared a feasibility for refractory brick plant using magnesite from Kumhar mines, Khyber Pakhtunkhwa Province, Pakistan and also a plant to produce a new kind of fertilizer called as 'Fused magnesium phosphate'.

World Production and Marketing

Major reserve of magnesite is found in China, Korea, Russia, Turkey and Brazil [14]. China is the top producing country then Russia, Turkey, Slovakia and Korea respectively. Main exporters of magnesite are China, Slovakia and Turkey. Although, Slovakia is forth major producer but it is the second major exporter of the magnesite in the world. Pakistan contributes 0.05% of the world production. The total magnesite production of Pakistan varies between 4000-7000 tons per year.

The price of fused magnesia depends significantly on its quality. At the lower end of the scale, Chinese fused magnesia (97.5% MgO) is being sold at around US$300 per ton into Europe, whereas 98.5% material would sell at around US$450-550 per ton [8]. At the other end of the scale, highest quality fused magnesia with MgO contents of greater than 99%, would sell for around US$1200-1400 per ton. The

Table 2. Generalized Industrial Applications of Magnesite (Baymag, 2006 and Harben, 2008)

Uses	End User Industry	Product/ Function
Chemicals	Chemical manufacture	Feedstock, magnesium salts, magnesium metal and alloys.
	Fire retardants /wood preservatives	Feedstock
	Rubber	Catalyst and filler
	Pulp and Paper	Pulping liquors.
Refineries/ Refractories	Steel, Copper and Nickel Refining	Slag conditioners, insulators
	Fluxes (soldering, welding, & smelting)	Fluxing agent
Glass and ceramics	Fiberglass	Feedstock
	Specialty additives including frits, glazes, enamels	Additives
	Sealants & adhesives	Cements.
Building Compounds / Specialty Cements	Construction/ Building industry	Cements, typically used in the production of fireproof materials and coatings, wallboards, flooring and grinding wheels.
Pharmaceutics	Pharmaceutical industry	Medicines, disinfectants
Fertilizer/ Agriculture	Fertilizer	Secondary/micronutrients
	Animal feed	Nutritional minerals
Environmental, Water treatment, filtration	Waste & effluent treatment	Chemical additives
		FGD
Energy	Oil and gas	Drilling muds
Media	Electronics	Die-casting, mobile telephones, resistance portable computer casings and parts.
Automobile	Automobile/ Aircraft manufacturers	Engine alloys, car, truck, motorcycle aircraft Engines, light aircraft components.
Human Consumption	Cosmetics	Raw materials
		Active minerals
	Food	Filler/pigments
Miscellaneous	Miscellaneous Industries/ Processes	Used in various industrial processes as a pH modifier and precipitant. It also has a myriad of applications as a filler, desiccant, absorbent and flocculent

price of dead burned magnesia rose by over 25% in 2004, which was the first increase since the late 1990s.

CONCLUSIONS

The magnesite deposits of Khuzdar region are crypto-crystalline Kraubath-type and are hosted within serpentinized harzburgites, associated with Bela Ophiolite of Cretaceous age. The major mineral is magnesite with variable amount of dolomite, calcite, Mg-calcite, artinite, huntite, brucite and Fe-magnesite. The average chemical composition indicates MgO, LOI, SiO_2, R_2O_3 and CaO are 40.43, 49.22, 2.12, 1.33 and 6.48% respectively. The specifications for some industrial applications in terms of Mg content are slightly less than the specified values. The SiO_2, R_2O_3 and CaO are slightly high. Although the estimated reserves is not encouraging but it can be utilized in many local industries.

In general, the magnesite of the study area is of good quality magnesium carbonate and being used in many local industries. Magnesite is an important source of magnesium. It is used to produce magnesium metal, caustic, dead-burned and fused magnesia. Magnesium compounds are used in such varied materials as cement, chemicals, fluxes, animal-feed, paper, insulation, and pharmaceuticals.

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