CHARACTERIZATION OF TALC-CARBONATE ROCK OF MINGORA EMERALD MINES, DISTRICT SWAT, KHYBER PAKHTUNKHWA, PAKISTAN.

Nisar Mohammad*, Mohammad Mansoor Khan* Noor Mohammad*

ABSTRACT

In present research characterization/ pre-concentration investigations study was done for low-grade talc- carbonate rock of Mingora emerald mines located in District Swat, Khyber Pakhtunkhwa (KP), Pakistan. These rocks host emerald crystals and the debris are dumped after excavation and extraction of emerald crystals. Present research work was undertaken for devising a suitable and commercial processing technique for the said talc carbonate rocks. Thorough investigations were conducted using SEM-EDX, X-Rays Diffraction (XRD) , Thermal Gravimetric Analysis (TGA), and Heavy Media Separation to determine talc content in the original rock. Petrographic study was made to know the nature of associated mineral impurities. Chemical composition and elemental impurities were determined by XRF spectrometer analysis. Grinding optimization study of the host rock using rod mill was also done. Whiteness of original talc carbonate rock and its magnetic content was also determined. The investigations reveal that talc content in the talc carbonate rock ranges from 60 to 70% with carbonates like magnesite and calcite as associated impurities. Optimum grinding time at which talc particles get liberated from gangue is 60 minutes and whiteness of the original rock is 50 to 60%.

KEYWORDS: *Talc, Whiteness, Mingora emerald mine, beneficiation, Heavy media separation*

INTRODUCTION:

Pakistan is endowed by nature with a plenty of mineral wealth. As per report of Geological Survey of Pakistan (GSP) (Ref: website of GSP) about fifty-five commonly used minerals metallic, non-metallic and precious stones are known to exist in our country. These minerals must be profitably exploited to enhance national economy, living standard of the society and to inculcate self-reliance. Unfortunately due to the lack of research and technological development, only a few of the existing indigenous minerals are properly exploited and the rest of the minerals demand is met through import of either minerals or mineral based products[1]. Through maximum utilization of our mineral resources, foreign exchange being spent on import of minerals and their products will be saved and the share of Mining industry in the Gross Domestic Product (GDP) may be increased. Industrial minerals like limestone, dolomite, gypsum and marble etc, has maximum contribution in the GDP as compared to metallic minerals. The industrial minerals therefore need special attention.

Despite this fact that both metallic and non-metallic minerals are known to exist in various parts of our country but we failed to exploit these deposits on scientific basis. The reason is that most of the minerals are not of the required quality which can be used directly in the industry as raw material. Therefore it is necessary to conduct detailed laboratory and pilot plant tests in order to find suitable and economical processes of beneficiation and subsequent utilization of these minerals.

Lack of research and development propoer utilization of low and medium grade indigenous mineral deposits is not contributing to improve national economy, for example Pakistan importing considerable quantity of talc worth millions rupees annually to meet its own industrial demand in addition to imports of talc products. The cost of cosmetic talc in international market is more than 10 times as compared to locally available low grade talc (United States Geological Survey report).

The local talc can therefore be upgraded with less cost as compared to the cost incurred on imported talc. The minerals processing cost normally ranges from Rs.1000 to Rs. 1500 per ton depending upon ore characteristics and the technique adopted. The price of raw talc is Rs. 3500 to Rs.4000 per ton.

The difference of anticipated price of processed indigenous talc which can be about Rs. 5000 per ton and the price in the international market (about Rs. 20,000 per ton) clearly indicates significance of the present research work.

* *Department of Mining Engineering, University of Engineering and Technology, Peshawar, Pakistan*

EXPERIMENTAL WORK:

MATERIALS, METHODS AND EQUIPMENT USED

Excavated talc carbonate samples, weighing about 50Kg were collected from Mingora emerald mine, District Swat, KP with the help and cooperation of Directorate General Mines and Minerals, KP. The same sample was used through out this research. Equipment and testing facilities used in the research are present in Table 1.

A. MINERLOGICAL STUDY

1. X-Rays Diffraction Analysis

Two random Talc carbonate samples were analyzed by XRD equipment. The x- ray diffraction patterns of the analyzed samples are presented in Figure 1 and Figure 2. The minerals were identified taking help of the Table 2.which shows main lines of these minerals in Amstrong (Å) and the ASTM Card numbers[2]. The minerals identified were talc, magnesite, dolomite, quartz, magnetite, muscovite and serpentine. According to the data of X- ray diffractographs talc represent the abundant mineral in the samples followed by magnesite which is in conformity with petrographic study.

2. Thermal Gravimetric Analysis

Thermal Gravimetric analysis is an alternate method of determining mineralogical composition of rocks/ores.

Table 1: Equipment and testing facilities used in the research

S.No	Equipment	Purpose of use	Laboratory/Organization
1.	Jaw Crusher & Roll Crusher	Crushing Talc carbonate lump samples	Mineral Testing Laboratory, Hayatabad Peshawar
2.	Rod Mill, Model D.R , AMDEL Australia, Sr.No BRD – 104	Grinding of crushed ore to desired size	--------do--------
3.	Vacuum Filter Model B52208, Sr. NO 31441, UK.	Dewatering of grinding products	--------do--------
4.	Sieve Shaker, Model ACTAGON 200, UK	Sizing of ground ore	--------do--------
5.	Electric Oven , Model A-9VC, UK	Drying the wet sieving products	--------do--------
6.	XRF Spectrometer, Model S4 Poineer 7kp1060, Bruker Company Germany	Chemical analysis of original ore, flotation and leaching products	Pakistan Council of Scientific and Industrial Research (PCSIR) Laboratories Complex, Peshawar
7.	XRF Spectrometer, Regaku Japan	Chemical analysis of original ore, flotation and leaching products	Centre of Excellence in Geology, University of Peshawar, Peshawar
8.	Scanning Electron microscope(JSM 5910, Jeol Japan) with EDX (INCA 200/oxford instruments UK)	Chemical & mineralogical analysis of original ore, flotation and leaching products	Centralized Resource Laboratory, University of Peshawar, Peshawar
9.	Thermo Gravimetric and Differential Thermal Analyzer (TG/DTA) (Perkin Elmer Diamond Series , USA)	Mineralogical analysis of Talc carbonate ore	--------do--------
10.	SHIMADZU XRD Equipment Model XRD 7000S, Shimadzu corporation Kyoto Japan.		Industrial Engineering Deptt. University of Engineering &Technology Peshawar
11.	Data Color , Model SF 50X, USA made	Whiteness measurement	PCSIR Laboratories Complex, Peshawar
12.	Magnetic Separator, Model MWMS made by Makwell corporation of China.	Separating magnetic content from Talc carbonate	PCSIR Laboratories Complex, Peshawar

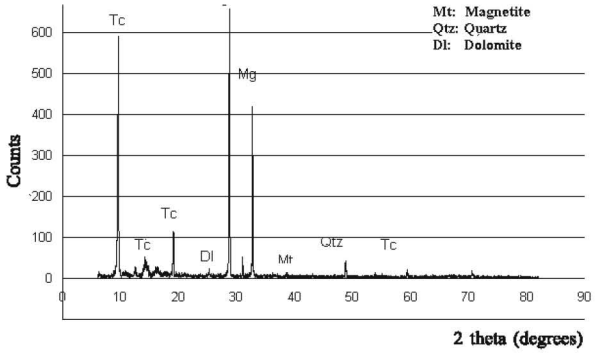

Figure 1: X-Rays Diffraction Pattern of Talc Carbonate Sample

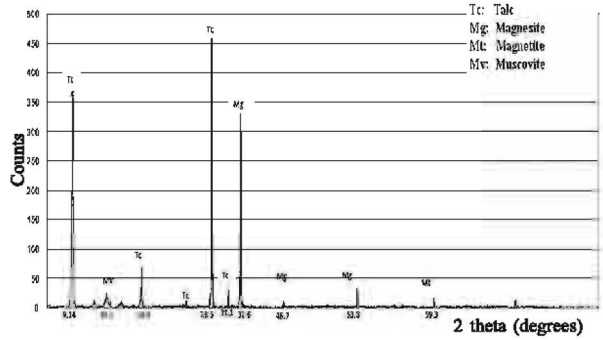

Figure 2: X-Rays Diffraction Pattern of Talc Carbonate

Table 2: Talc and its Associated Minerals, Their Main Lines in Å & ASTM Card Numbers

Mineral	Main Lines in Å	ASTM Card
Talc	9.34,4.66,3.12	13-358
Magnesite	2.74, 2.10,1.70	8-479
Dolomite	2.89, 2.19, 1.79	11-78
Quartz	3.34, 4.26, 1.82	5-0490
Magnetite	2.53, 1.48, 2.97	7-322
Serpentine	7.09, 3.56, 2.49	13-4
Chlorite	7.15, 3.59, 14.4	16-351
Hematite	2.69, 1.69, 2.51	13-534
Geothite	4.21, 2.69, 2.44	8-97

Mingora emerald talc carbonate rock mostly consisting of talc and carbonates as confirmed by chemical analysis and petrographic study. In carbonate content, calcite and dolomite are in minute quantities and magnesite is the major carbonate mineral associated with talc in the ore. Two samples collected from different points of the deposit were ground to -45 microns size which is talc liberation size. Then samples weighing 9.675 mg (sample 1) and 7.072 mg (sample 2) were taken from the ground ores

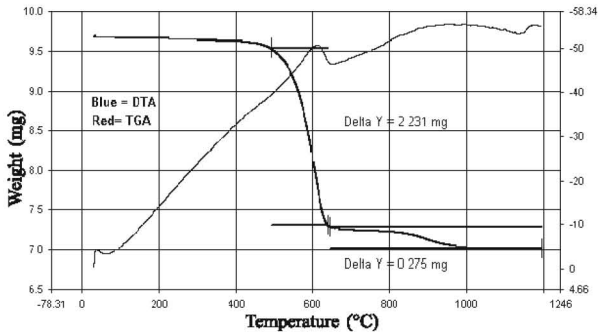

Figure 3: Thermogram of Sample-1 Showing Weight Loss on Heating

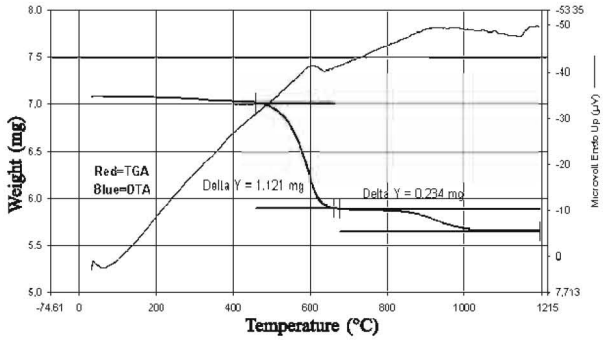

Figure 4: Thermogram of Sample -2 Showing Weight Loss on Heating

Table 3: Formula Weight and Theoretical Wight Loss of Talc and Associated Minerals

Mineral	Formula Weight	Theoretical Weight Loss(TW)
Talc	389.3	4.70
Chlorite	563.1	12.78
Magnesite	87.7	50.20
Dolomite	186.6	47.20

and analyzed by TG/DTA equipment. Samples were hold for 1.0 minute at 30°C and heated from 30°C to 1200 °C at a rate of 10°C/minute. Effect of heating and weight loss are depicted in thermograms as shown in Figure 3 and Figure 4 and Formula weight and theoretical weight loss are presented in Table 3.

Experimental weight loss at temperature range of 450°C to 650°C corresponds to % magnesite and from 650° C to 1100° C corresponds to % talc. Formula used by researchers for % phase by TGA analysis[3] is given

in Equation 1.

$$\%Phase = \frac{(L \times S.F)}{(TW \times W)} \times 10^4 - \quad (1)$$

Where L = length of thermogram step correspondence to weight loss of mineral considered (mm)

S.F =Scale factor (mg/mm) (measured from thermogram curve), TW= Theoretical weight loss (%) to be read from Table.3

W = Weight of original sample (mg)

Calculations:

Sample 1

For Magnesite

W = 9.675 mg, L = 150 mm

S.F = 2.231/150 = 0.014873 mg/mm, TW = 50.2%

$$\%Magnesite = \frac{150 \times 0.014873}{50.2 \times 9.675} \times 10^4 = \frac{2.23095}{485.685} \times 10^4$$

$$= 45.934\%$$

For Talc

L = 80mm, W = 9.675 mg, S.F for Talc = 0.275/80 =0.003437mg/mm

$$\%Talc = \frac{80 \times 0.003437}{4.70 \times 9.675} \times 10^4 = 60.47\%$$

Sample 2

For Magnesite

W = 7.072, L = 100mm, S.F = 1.121/100 = 0.0112mg/mm

$$\%Magnesite = \frac{100 \times 0.0112}{50.20 \times 7.07} \times 10^4 = 1.121 / 355.0144 \times 10^4 = 31.576\%$$

For Talc

W = 7.072, L = 75mm, S.F for talc = 0.234/75= 0.00312mg/mm

$$\%Talc = \frac{75 \times 0.00312}{4.70 \times 7.072} \times 10^4 = 0.234 / 33.2384 = 70.40\%$$

3. Dissolution Method

40gms of original talc carbonate ground to -45 microns size was put in beaker with leaching solution (HCl(10%) + $SnCl_2$(300ppm)). The beaker was placed on hot plate for about 1hr at 70°C. The suspension was then diluted with cold tap water and filtered. The acid insoluble / residue is considered as Talc content and the loss in weight is considered as carbonates content that get dissolved in the leach solution and goes into filtrate[4].

Weight of original talc carbonate sample taken = 40 gms
Weight of residue/Talc content = 26.70 gms = 66.75%
Weight of carbonates = 40 – 26.70 = 13.30 gms = 33.25%

4. Chemical composition of Original Rock and its Leached Product

Average MgO content in the talc carbonate rock was found as 36.0 % and in the leached residue it was found as 15%. As the MgO is contributed by talc and magnesite in the ore and MgO of magnesite is washed away by leaching therefore talc MgO in the sample will be (36-15) i.e 21%. Now in pure talc when talc content is 100%, MgO is 32% and when MgO is 21%, - the Talc content in the sample is 65.625%

5. Heavy Media Separation/ Phase Analysis[5]

Ground sample of -45 microns was passed through splitter and two split samples of 20 gms each were used for the process. Tetra bromo ethane (TBE) with specific gravity 3.0 was used as heavy media and acetone as diluting agent. Minerals associated with talc, their specific gravities and compositions[6,7] are presented in Table 4 and chemical composition of heavy media separation test products presented in Table 5.

One test was conducted using pure TBE with specific gravity 3.0 and the other at specific gravity 2.8 by diluting TBE with acetone. Time allotted for sink/float was 20 minutes, Tests results and test parameters are presented in Table 5. Specific gravity of talc is 2.6 - 2.7 and that of magnesite 3 - 3.2. The float product will be rich in talc and sink rich is magnesite which is confirmed by chemical composition of test products. Iron content in float fraction indicates that it also exists in talc lattice. Phase analysis gives very rough estimation of fractions

because other than specific gravity particles shape and its hydophobicity also have effect on sinking and float.

B. CHEMICAL COMPOSITION OF MINGORA TALC CARBONATE

1. X- Rays Fluorescence Studies

Three representative samples of original rock were analyzed by XRF in centre of Excellence in Geology University of Peshawar and two representative samples of original rock were analyzed by XRF in PCSIR laboratories Complex Peshawar. The analysis results were averaged together and presented in Table 6.

2. Scanning Electron Microscope (SEM) – EDX Studies

SEM microphotograph showing talc grains and elemental analysis peaks are presented in Figure 5 and chemical composition of talc carbonate sample presented in Table 6. All elements were analyzed and number of iterations was 4.

Table 4: Chemical Composition and Weight % of Heavy Media Separation Test Products

Specific gravity	Product	Weight (%)	Chemical Composition								
			SiO2	MgO	Fe2O3	CaO	Al2O3	Cr2O3	NiO	MnO	LOI
3.00	Float	61.0	51.33	32.72	7.08	0.49	0.30	0.29	0.38	0.16	7.07
	Sink	29,0	34.79	39.56	13.22	0.45	0.43	0.84	0.30	0.21	12.62
2.80	Float	66.50	47.73	31.26	7.46	0.43	0.23	0.35	0.34	0.16	11.72
	Sink	27.00	29.06	33.03	11.04	0.38	0.36	0.70	0.25	0.02	16.50

Table 5: Chemical composition of Mingora Talc carbonate

Sample No	Chemical Composition											
	SiO2	MgO	CaO	Cr2O3	Fe2O3	Al2O3	K2O	Na2O	NiO	PbO	MnO	TiO2	LOI
1	36.01	41.21	0.42	0.50	4.89	0.31	0.24	0.38	0.170	LLD	0.01	0.03	18.5
2	32.20	37.85	1.68	0.47	4.82	0.30	0.54	0.73	0.264	0.003	0.13	0.05	23.93
3	26.50	38.57	0.45	0.16	5.04	0.40	0.07	0.95	0.245	0.002	0.15	0.006	28.06
4	29.65	35.54	1.56	0,78	4.29	2.80	0.13	0.89	0.680	0.006	0.16	0.019	20.30
5	32.20	32.94	0.99	0.30	5.538	0.52	0.08	0.25	0.028	0.004	0.15	0.007	27.44
Average	**31.312**	**37.222**	**1.02**	**0.442**	**4.92**	**0.866**	**0.212**	**0.51**	**0.278**	**0.004**	**0.12**	**0.023**	**23.65**

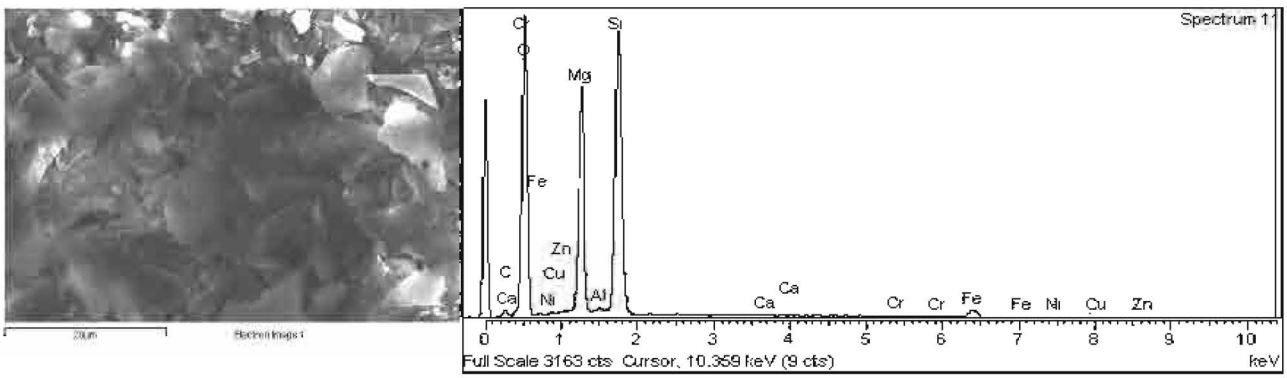

Figure 5: SEM microphotograph and SEM elemental Analysis Peaks

C. GRINDING OPTIMIZATION STUDY

Original ore sample was wet ground in rod mill after crushing in Jaw crusher with ½ inch product size and roll crusher with 2 mm product size with following fixed parameters.

Mill size = Length 255mm, diameter 190mm, No. of steel rods= 15 of 15 mm diameter and 23 mm length

Ore water ratio= 60: 40, Speed of the mill = 69 rpm, Grinding time was varied for 15, 20, 25 , 30,35,40, and 60 minutes Each time 500g ore was wet ground , filtered in vacuum filter then dried in electric oven and after coning and quartering by passing through splitter, 50 g was screened in sieve shaker. Weights on each sieve and their percentages were then recorded. Tables 7.i. to 7.vii. indicate grinding results. The recommended talc liberation size in the ore under study is -45 microns.

D. WHITENESS DETERMINATION.

Whiteness of talc is one of the desired physical properties for its specialized uses. Whiteness of the Talc carbonate rock was determined using whiteness measuring equipment. Pure magnesite is used as standard in the equipment with 100 whiteness. Monochromatic light rays of specific wave length are directed to fall on the sample whose whiteness is desired. Whiteness is the percentage of rays reflecting from the sample out of the total light rays intensity.

The whiteness of talc carbonate rock under study was found ranging from 50 to 60%. Mingora emerald mine talc contains traces of Fe, Ni, Cr and Cu in its body as confirmed by microprobe analysis[6,8]. These elemental

Table 6: Chemical Composition of Talc Carbonate Sample by SEM

Element	Weight%	Atomic%		
C K	5.43	8.52		
O K	54.18	63.79		
Mg K	16.58	12.85	MgO	27.63
Al K	0.11	0.07	Al2O3	0.21
Si K	20.44	13.71	SiO2	43.83
Ca K	0.10	0.05	CaO	0.17
Cr K	0.13	0.05	Cr2O3	0.38
Fe K	1.68	0.57	Fe2O3	4.80
Ni K	0.39	0.13	NiO	0.45
Cu K	0.58	0.17	CuO	0.72
Zn K	0.39	0.11	ZnO	0.48
Totals	**100.00**			

Table 7-i: Sieve Analysis Result of 15 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	13.30	26.60	26.60	73.40
63	240	4.90	9.80	36.40	63.60
53	270	3.50	7.00	43.40	56.60
45	325	5.30	10.60	54.00	46.00
45	-325	22.50	45.00	99.00	00.00

Table 7-ii: Sieve Analysis Result of 20 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	9.50	19.00	19.00	81.00
63	240	6.00	12.00	31.00	69.oo
53	270	3.40	6.80	37.80	62.20
45	325	2.10	4.20	42.00	58.00
-45	-325	29.00	58.00	100.00	00.00

Table 7-iii: Sieve Analysis Result of 25 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	7.50	15.00	15.00	89.00
63	240	4.00	8.00	23.00	81.00
53	270	3.80	7.60	30.60	69.40
45	325	2.80	5.60	36.20	63.80
-45	-325	31.50	63.00	99.20	00.00

Table 7-iv: Sieve Analysis Result of 30 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	6.90	13.69	13.69	86.31
63	240	3.60	7.16	20.79	79.21
53	270	2.20	4.37	25.16	74.84
45	325	3.50	6.96	32.12	67.88
-45	-325	33.80	67.60	99.72	00.00

Table 7-v: Sieve Analysis Result of 35 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	4.70	9.34	9.34	90.86
63	240	1.70	3.38	12.72	87.28
53	270	2.20	4.37	17.09	82.91
45	325	1.30	2.60	19.69	80.31
-45	-325	40.1	79.72	99.41	00.00

Table 7-vi: Sieve Analysis Result of 40 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	2.0	3.74	3.74	96.26
63	240	2.3	4.31	8.05	91.95
53	270	1.3	2.43	10.48	89.52
45	325	1,5	2.81	13.29	86.71
-45	-325	43,0	86.00	99.29	00.00

Table 7-vii: Sieve Analysis Result of 60 Minutes Grinding Time

Sieve Size		Weight Retained (g)	%Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative Weight Passing (g)
Microns	Mesh				
75	200	-	-	-	100
63	240	-	-	-	100
53	270	-	-	-	100
45	325	1.20	2.40	2.40	97.60
-45	-325	48.80	97.60	100.00	00.00

Table 8. Chemical analysis Result of Non magnetic and Magnetic Fractions

Fraction	L.O.I	MgO	SiO2	Fe2O3	Cr2O3	CaO	NiO	Al2O3	MnO	TiO2	ZnO
Non magnetic	27.44	32.94	32.2	5.54	0.23	1.0	0.28	0.19	0.15	0.00	0.02
Magnetic	23.14	32.196	27.9	14.02	1.39	0.63	0.24	0.23	0.19	0.02	0.01

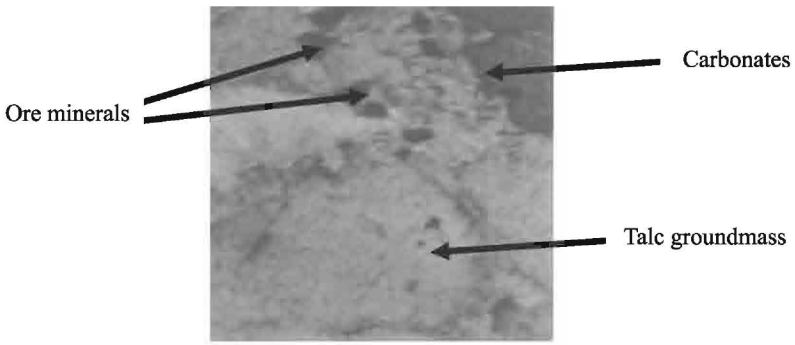

Fig 6: Photomicrographs of talc- Carbonate Thin Sections

impurities reduce the whiteness of talc and give it yellowish green color.

E. MAGNETIC CONTENT DETERMINATION

Magnetic materials particularly Iron bearing minerals reduces whiteness of talc and also restricts its use particularly in cosmetic products etc. Grind sample of -45 microns size was passed through magnetic separator. The regulating current was 5 amperes and magnetic intensity 0.8 Tesla. , Weight of original sample taken was 400 gms.

Weight of Non magnetic fraction collected after

passing through the magnetic separation stage was 353gms and weight of Magnetic fraction was 30gms, 17gms was associated with dust losses. Chemical analysis of non magnetic and magnetic fractions conducted by XRF in PCSIR laboratories complex Peshawar is given in Table 8. The microphotograph of thin section of talc carbonate showing ore/Iron bearing minerals in the rock is shown in Figure 6.

CONCLUSIONS

Talc content in original talc carbonate rock of Mingora emerald mine varies from 60 to 70% and carbonate content which is mostly magnesite ranges from about 30 to 40% as confirmed by different analytical techniques used in the study.

Traces of Fe, Ni, Cr and Cu in the body of talc grains reduce its whiteness. Presence of iron in talc grain lattice is confirmed by chemical analysis of sink and float products by heavy media separation of talc carbonate rock and magnetic separation test products.

Mineralogical composition of the mingora mine talc carbonate rock is not uniform. In some blocks talc content is dominant and in other magnesite content is high as indicated by chemical composition of original samples.

Optimum grinding time is 60 minutes to get maximum quantity of -45 microns product with the given fixed grinding parameters.

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