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PROCESSING OF EMERALD BEARING ROCKS OF GUJAR KILLI EMERALD MINE BY WASHING AND SCREENING

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The recovery process of talc and emeralds, contained in the emerald bearing altered talcose schists of Gujar Killi were found to be feasible at the bench and pilot plant scale. The various units required for the washing and screening plant were tested. A detailed investigation of size analyses of the head and ground samples, liberation and association of emerald/gangue particles, pulp density, product size analysis and optimisation of grinding were undertaken. A tentative block diagram was developed as a result of laboratory tests. The study conducted for the Gem Stone Corporation of Pakistan is encouraging and can be applied to the mechanical recovery of talc and emerald in the Gujar Killi emerald mine.

Key words. Emerald, Talc beneficiation, Pakistan.

Introduction

Pakistan is one of the Gem producing countries in the world. Emerald, ruby, topaz and other precious/semi precious stones occur in abundance in the country. The mining of gemstone is carried out with the normal tools like pneumatic picks, hand picks, hand showers etc. The Gem Stone Corporation has been engaged in the mining for the last 12 years using mostly manual methods. Very little has been done in Pakistan for processing and extraction of precious and semi precious stone due to the lack of processing technology. A preliminary processing plant established at the Swat Emerald Mine, Mingora, consists of jaw crusher, tumble mill and classifier. The plant however is not using the processing techniques on a commercial scale for the emerald bearing debris. As desired by the Gem Stone Corp. It was envisaged during the study to design a five tonnes capacity plant for processing, washing and screening of debris to recover emerald. It was also worthwhile to extract talc as a by product, from sample bearing higher talc percentage, as the total daily production of emerald debris in Gujar Killi mine, is expected to rise from the present 1.5 tonnes to 4 to 5 tonnes.

Experimental

The recovery of valuable minerals and emeralds, contained in the samples of Gujar Killi emerald bearing altered talcose schists, was investigated at the bench and pilot plant scale. The following tests were undertaken in this study.

(i) Size analyses of the original samples.
(ii) Specific gravity.
(iii) The bonding associated with emerald/gangue particles.
(iv) Determination of pulp density.
(v) Product size analyses and production, specification e.g. grind size analyses and optimisation of grinding.

Eleven samples were collected from eleven open pit mines by channel sampling. The samples were small and may not therefore, be truly representative but provided a lot of information required for mineral processing data.

The libration of talc from the gangue was studied both by grinding in a rod mill and by tumbling. The talc was analyzed chemically and were subjected to mineralogical studies by miroscopy, XRD and DTA. The samples collected for the processing studies were subjected to conning and quartering. Specific gravity tests, sieve analyses and tumble crushing tests were then conducted using rod type crusher with no rods, rotating at different speed. Optimum rotation speed was selected on the basis of the degree of the size reduction. The size reduction was based on the characteristics and nature of mineral and gangue associations in the emerald bearing debris.

Processing/sieve analysis test work. The sieve analyses are presented in the form of graphs (A, B, C) for all samples and in a table for one sample. The sieve analysis of the original samples indicated that in five out of eleven samples 94% of the material is minus 1" (25 mm) as indicated in sieve analysis test nos. MPS-15, MPS-16, MPS-19, MPS-21 (Fig. 1) and MPS-14 (Table 1). Analysis of sample no. MPS-17, MPS-18, MPS-20, MPS-22, MPS-23 and MPS-24 (Fig.2) indicate that the maximum size of the lumps from the mine is at 25 mm, 90% passing. The specific gravity head sample ranges from 2.66 to 3.28. This mean that there is great variation of gangue mineral in the production debris from the mines.

After grinding for 4 and 6 minutes the sample no.MPS-14 yielded material with 83.9 and 97% respectively, passing 6

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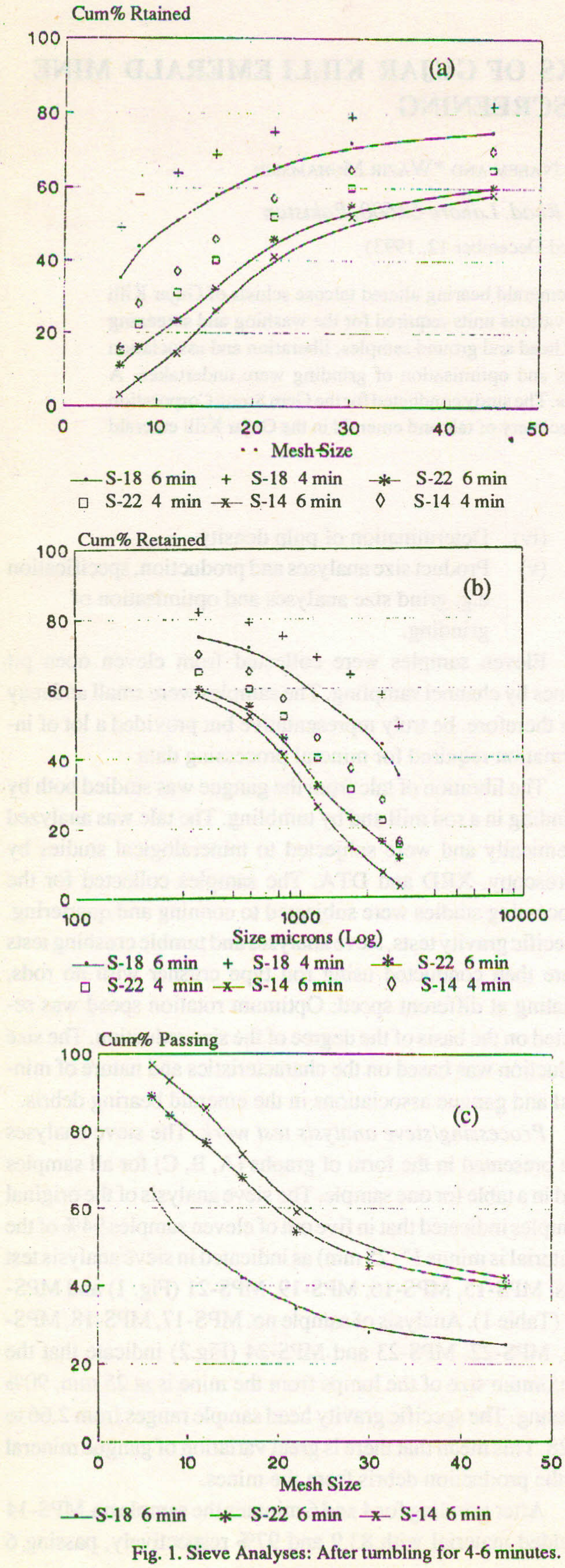

Fig. 1. Sieve Analyses: After tumbling for 4-6 minutes.

mesh (Table 3), MPS-15 gave 75.9 and 80.0%, MPS-16 gave 77.1 and 78.2%, MPS-17 yielded 60 and 63%, MPS-20 gave 70.3 and 79.8 %, MPS-23 gave 75 and 81.9%, MPS-24 gave 71.49 and 88.8% respectively.

The large variation in size fraction indicated that the structure and mineralization in size fractions indicated that the structure and mineralization differ from sample to sample. However, a specific crusing method was adopted which would be used before washing and classification of the waste. Because of variation in the specific gravity of the samples, it was necessary to vary the inclination angle of the sieves between 30 - 45. The study established that the emerald crystals could

TABLE 1. HEAD SAMPLE SIEVE ANALYSIS. SAMPLE NO.GKEM-92-AR-01 (OLD MINE BENCHES); LAB: CODE NO. GKEM/MPS-14; SPECIFIC GRAVITY 2.66.

Mesh size	Wt. (g)	Wt. (%)	Cum wt. passing
+ 1"/25.0 mm	101.1	5.05	94.94
+ 1/2"/12.5 mm	232.5	11.6	83.31
+ 1/4"/6.30 mm	466.8	23.3	59.97
+ 6#/3.35 mm	354.4	17.7	42.24
+ 8#/2.36 mm	123.3	6.22	36.02
+ 12#/+1.70	87.2	4.36	31.67
– 12#/-1.70 mm	633.2	31.67	00.00

TABLE 2. ANALYSIS OF SAMPLE NO.MPS-14 AFTER GRINDING. GRINDING TIME -04 MINUTES. PRM-01 PASSING SIZE 1/4" (6.30) SIEVE.

Mesh size	Wt.(g)	Wt.(%)	Cum wt.% pass
SIEVE ANALYSIS OF 04 MINUTES GRINDING			
+6 #	88.27	16.51	83.50
+8 #	61.00	11.40	72.10
+12#	48.50	9.10	63.00
+16#	49.45	9.30	53.80
+22#	57.95	10.48	42.90
+30#	43.05	8.10	34.90
+45#	27.51	5.20	29.70
-45#	158.77	29.70	00.00
SIEVE ANALYSIS OF 06 MINUTES GRINDING			
+6#	15.22	2.98	97.01
+8#	19.99	3.92	93.09
+12#	38.27	7.50	85.56
+16#	57.80	11.33	74.25
+22#	78.45	15.38	58.87
+30#	57.45	11.26	47.60
+45	32.67	6.40	41.19
-45#	210.06	41.19	00.00

be recovered on a 6 mesh screen, while talc was recovered in the minus 30 meash fraction of the samples.

Recovery and processing of talc. The talc was recovered in the process after passing it through a 30 mesh size sieve. The associated gangue minerals comprising of mica, calcite, quartz and less altered ferromagnesian minerals were preferentially retained on the sieve. In order to assess recoveries quantitatively, one kg representative samples were prepared from three types of samples selected on the basis of sieve analyses. Samples blended were GKEM/PMS-17 and 18 (coarse type), 14 and 15 (medium type) and 21 and 22 (fine type debris).

Sample from each of the representative stocks were ground for different specific times, and the product sieved through 6 and 30 mesh size screen (Table 4). In one set of experiments all the material passing 6 mesh sieve was collected and in the other only the material passing 30 meash sieve was collected. The talc was estimated using microscopic point counting and DTA methods. The results are given in Fig.2. It can be concluded from the Table 4. that pure talc of 92 - 99% grade can be obtained under 30 mesh screen. However the recoveries were low. Recoveries of 24, 27 and 45% were obtained in coarse, medium and fine type samples with talc contents of 92, 95 and 97% respectively.

The 6 mins grinding for materials passing 6 mesh size gave the recoveries of 65, 85 and 90% and talc contents of 88, 92 and 94% respectively. It can therefore be concluded that by

Table 3. Sieve Analysis of Head Sample After Grinding. RPM-10; Weight Approx. 500-550 g.

	Milling time 4 minutes Material passing (%)		Milling time 6 minutes Material passing (%)	
Sample	6#	45#	6#	45#
MPS-14	83.9	29.70	97.0	41.00
MPS-15	75.9	–	80.8	0.00
MPS-16	77.1	–	78.2	0.00
MPS-17	60.0	20.00	63.0	22.00
MPS-18	59.0	17.00	65.0	24.00
MPS-19	76.7	29.57	81.0	30.80
MPS-20	70.3	26.58	79.8	36.45
MPS-23	75.0	25.50	81.9	35.84
MPS-24	71.49	27.00	88.8	36.92

Table 4. Recovery of Talc.

	Time of grinding/tumbling					
	6 minutes		4 minutes		2 minutes	
	Talc%	Recovery%	Talc%	Recovery%	Talc%	Recovery%
I. Recovery of material passing 6 Mesh Sieve						
Coarse	88	65	91	53	95	45
Medium	92	85	94	73	96	55
Fine	94	90	95	82	97	68
II. Recovery of material passing 30 Mesh Seive						
Coarse	92	24	94	20	96	14
Medium	95	27	96	21	98	16
Fine	96	45	97	36	99	30

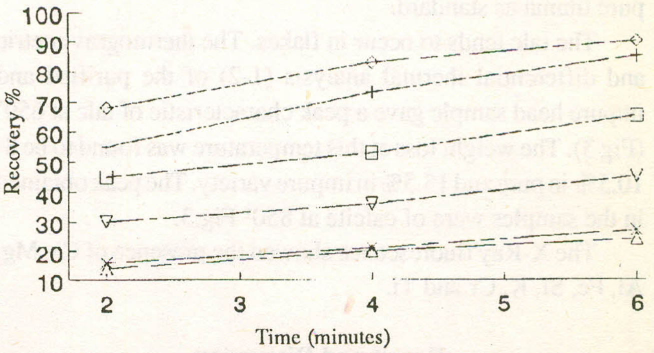

Fig. 2. Recovery of talc with time.

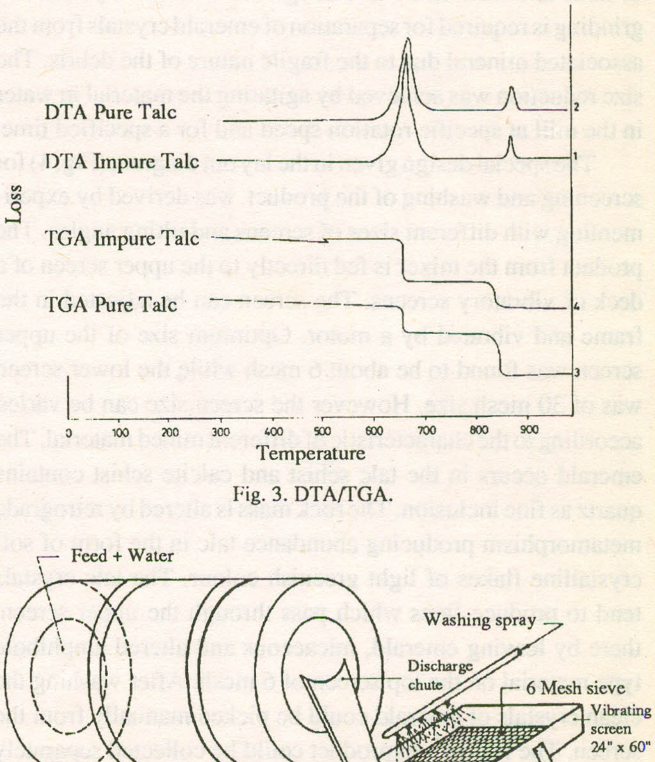

Fig. 3. DTA/TGA.

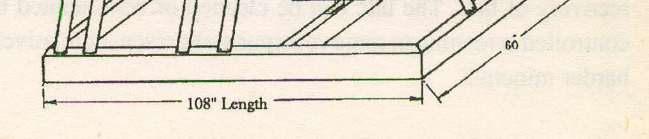

Fig. 4. Wet tumble mill 38" dia x 60".

controlling the grinding and sieving parameters the talc of desired composition can be recovered.

Properties of talc. Talc is a basic magnesium silicate of general formula $Mg_3 Si_4 O_{10} (OH)_2$. The talc in the samples is white with a light shade of green. The colour of the ground purified talc is white with a wihteness index of 60 - 70 using pure titania as standard.

The talc tends to occur in flakes. The thermogravimetric and differential thermal analysis (1-2) of the purified and impure head sample gave a peak characteristic of talc at 650° (Fig 3). The weight loss at this temperature was found to be 8-10.5% in pure and 15.5% in impure variety. The peak obtained in the samples were of calcite at 850° Fig.3.

The X-Ray fluorescence showed the presence of Ca, Mg, Al, Fe, Si, K, Cr and Ti.

Result and Discussion

The grinding tests conducted on the material using ball and rod mills, showed that excessive size reduction is achieved even when using small grinding times. Moreover, the impact of balls and rods tends to damage the emerald crystals. No grinding is required for separation of emerald crystals from the associated mineral due to the fragile nature of the debris. The size reduction was achieved by agitating the material in water in the mill at specific rotation speed and for a specified time.

The special design given in the lay out diagram (Fig. 4) for screening and washing of the product was derived by experimenting with different sizes of screens and tilting angles. The product from the mixer is fed directly to the upper screen of a deck of vibratory screens. The screen can be adjusted in the frame and vibrated by a motor. Optimum size of the upper screen was found to be about 6 mesh while the lower screen was of 30 mesh size. However the screen size can be varied according to the characteristic of different mined material. The emerald occurs in the talc schist and calcite schist contains quartz as fine inclusion. The rock mass is altered by retrograde metamorphism producing abundance talc in the form of soft crystalline flakes of light greenish colour. The talc crystals tend to produce fines which pass through the upper screen, there by leaving emerald, micaceous and altered amphibole type material on the top screen of 6 mesh. After washing the clean crystals of emerald could be picked manually from the screen. The talc as a byproduct could be collected separately at the discharge end of the vibrating screens. The plant can act as a production unit for emerald and as a pilot plant for the recovery of talc. The talc can be cleaned or beneficiated by controlled screening to remove impurities present as relatively harder minerals.

A tentative block diagram (Fig. 4) was developed as a result of the laboratory tests. It is hoped that the information will help in the process development for bulk scale screening, processing and for fabrication of plant that will be used by Gem Stone Corp. in Gujar Killi emerald mine. The processing studies have indicated the libration of talc from the gangue below 30 mesh size. The equipment which showed better results was a tumbler rotating at a sufficient speed to cause maximum agitation of the material without involving forced crushing usually encountered in ball rod mills. The use of water during is found necessary for smooth libration of loose particles. In experiments using optimum parameters, ore up to 1" feeding size was mixed with water in a weight ratio of 40:60. The mixer drum which was fitted with internal flanges was rotated at 8-10 rpm and the material was tumbled to dissociate the valuable mineral and emerald crystals. The rotation speed rpm was optimised after observing the damage to emerald crystals which occurred at higher speed. The sieve analysis indicated that original head samples is about 94% passing 1" mesh screen. The drum recommended for the plant was designed for smooth liberation (size reduction by agitation in water), and it can be fitted with a continuous charging and discharging system.

Conclusion

1. Bulk scale processing of emerald bearing rock debris is possible for the production of emerald concentrates and talc as byproduct, by employing tumbling and sieving techniques.

2. The feed size to the tumbling mill should be less than 1". The over sized lumps which are calculated to be 4% of the total weight of the debris.

3. The solid water ratio should be 40 - 60% (w/w) and slow grinding or tumbling is required to avoid the damage to the emerald crystals.

4. For screening the ground material the size of the top screen should be 6" which is necessary for the retention and the recovery of emerald crystals while 30% screen is required for the separation of gangue materials from the fine talc product.

5. The present daily production of emerald bearing debris is 1500 kg but the plant should be based on 5 tonne/day in view of the anticipated increase in the future production.

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