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Rationalization of the up-grading circuit of celestite for advanced applications

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ABSTRACT

The conversion of celestite into other strontium compounds, mainly strontium carbonate, is a necessary step for many industrial applications. However, the impurities need to be removed to achieve a suitable celestite grade (>90% $SrSO_4$) for the conversion process.
Therefore, this paper is aimed at celestite separation from calcite using gravity separation (i.e., jig and shaking table). The jig was used to deal with coarse sizes (−15 + 2.0 mm) while shaking table was used to deal with finer sizes (−0.5 + 0.080 mm) or cleaning the jig tailings after further regrinding to −0.5 mm. Moreover, the shaking table separation was evaluated in terms of its operating parameters using statistical design of experiments. Starting from the primary crushed −0.5 + 0.080 mm fraction contains 44.91% SrO (79.58% $SrSO_4$), a celestite concentrate 51.88%SrO (91.93% $SrSO_4$) was produced at optimum conditions; i.e., 25%, 3 cm, 25 l/min, and 6 degree for pulp density, stroke length, water flow rate, and table slope, respectively.

1. Introduction

Over 95% of celestite ($SrSO_4$) is consumed by chemical industries for conversion to other strontium compounds; mainly strontium carbonate and strontium nitrate. The converted celestite has versatile advanced applications such as: television tubes and computer monitor tubes, pyrotechnic industry in manufacturing of safety flares and tracer bullets, greases, soaps, alloys, anticorrosive paints, pigments, driers, fillers, ceramics, pharmaceuticals, capacitors, resistors, sugar refining, drilling fluids, superconductors, cast iron, fuel cells, medical applications, and magnesium alloys [1].

The presence of impurities in celestite ores requires various beneficiation steps to meet the chemical specifications for conversion to other important strontium salts. The ore is mainly processed by gravity separation techniques to remove calcite and silica [2–14]. In Iran, a combination of jigging and shaking table or spiral were used to upgrade Zagros celestite ores. Relatively fine size fractions were treated with Mozley multi-gravity separator and a concentrate with 90–95% $SrSO_4$ was obtained, however, the recovery was low (up to 40 %) [3].

In Turkey, up-grading studies of celestite ore using Mozley multi-gravity separator were conducted [4]. A concentrate of 94% $SrSO_4$ with 87% recovery was obtained at the optimum separation conditions (i.e., wash water flow rate, amplitude, frequency, tilt angle, and pulp density) [5].

In previous study for the authors, the jigging process was used to separate celestite from calcite into two size fractions −15 + 2.0 mm and −2 + 0.5 mm. A concentrate, contains 92% $SrSO_4$ with 60% recovery, was obtained at optimum conditions; i.e., 3.1 mm diameter of one layer bed thickness, and 15 min jigging time [6].

This paper, as a continuation of previous efforts, aims at the concentration of celestite ore using the shaking table to reach a concentrate of >90% $SrSO_4$ with a higher recovery due to the increase in the liberation in finer fractions. The X-ray diffraction (XRD), chemical analysis, liberation study, and mineralogical investigation were used to show the main components of the ore and their interaction and the liberation degree which significantly affects the separation results in terms of grade and recovery. In addition, the statistical design of the experiments was used to optimize the process and to investigate the main parameters affecting the separation process. Furthermore, the cleaning of the previously obtained jigging tails was investigated.

2. Experimental

2.1. Preparation and characterization of feed samples

A representative sample from Wadi-Essel locality, Egypt, was subjected to crushing by a "Denver" jaw crusher to −15 mm. The mineralogical examination by X-ray diffraction (XRD) and chemical analysis were used to identify the mineral phases and the chemical composition of the feed sample and separation products. Dry size analysis using a series of ASTM standard sieves i.e. 11.2, 8.0, 6.68, 3.327, 2.0, 1.65, 1.19, 0.71, 0.50, 0.25, and 0.08 mm, was applied. After

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Table 1
2^4 Factorial design (FD) experimental runs and factor levels.

Parameter	Unit	Symbol	(−)	(+)
Water flow rate	L/min	A	15	25
Pulp density	Solid %	B	5	25
Tilt angle	Degree	C	2	6
Stroke length	cm	D	1	3

Table 2
Chemical analysis of representative celestite sample.

Constituent	wt.%
$SrSO_4$	66.80
$CaCO_3$	27.71
SiO_2	2.05
L.O.I.	11.90
Total	100.00

screening, each size fraction was collected, weighed, and chemically analyzed for SrO% and L.O.I.%.

The degree of liberation was investigated, according to the particle size, using two techniques. The counting technique was used for sizes larger than 2 mm and the sink–float technique, by BDH methylene iodide (sp.gr.3.32 g/cm^3), for sizes less than 2 mm. All separated size fractions were collected, weighed and chemically analyzed. Mineralogical examination of the different samples was carried out.

Primary crushed fractions, −15 + 2.0 mm, and −2.0 + 0.50 mm were directed to concentration via Jigging technique. A scavenging processing using the shaking table technique for the −15 + 2.0 mm jigging tailing was conducted after further regrinding to −0.5 mm using "Denver" rod mill. On the other hand, the primarily crushed size fraction −0.5 + 0.08 mm was directed to shaking table.

2.2. Shaking table optimization—factorial design (2^4)

A factorial design, 2^k, where $k=4$ (the number of studied operating parameters), was used to optimize the most significant factors that affect the tabling process using a "Wilfley" shaking table [15]. The experiments were carried out at feed particle size −0.5 + 0.08 mm. The design matrix with 19 experimental runs and the levels of each factor is shown in Table 1. For each run, the assay and distribution of SrO in concentrates were determined.

3. Results and discussion

3.1. Characterization of the studied samples

XRD pattern shows that celestite and calcite are the main mineral phases, Fig. 1. On the other hand, Table 2 shows the chemical analysis of a representative sample. It indicates that the sample contains 66.8% $SrSO_4$. Meanwhile, the $CaCO_3$ is the sole gangue mineral, reaching 27.7%, Table 2.

Table 3 illustrates the chemical analysis and liberation characteristics of the primary crushed sample. The liberation behavior of different size fractions using the counting technique as well as Methylene Iodide heavy liquid (sp.gr.3.32 g/cm^3) is shown in Table 3. It is clear that the finer the size, the higher the liberation. It is noticed that not only the wt.% of the heavy fraction increases but also its SrO % with increasing the fineness. Another indication of the liberation increase with fineness is the change of the middling fraction in −15 + 11.2 mm and −3.35 + 2.0 mm from 31.82% to 6.61%, respectively. As shown in Table 3, the size fraction that was used in shaking table

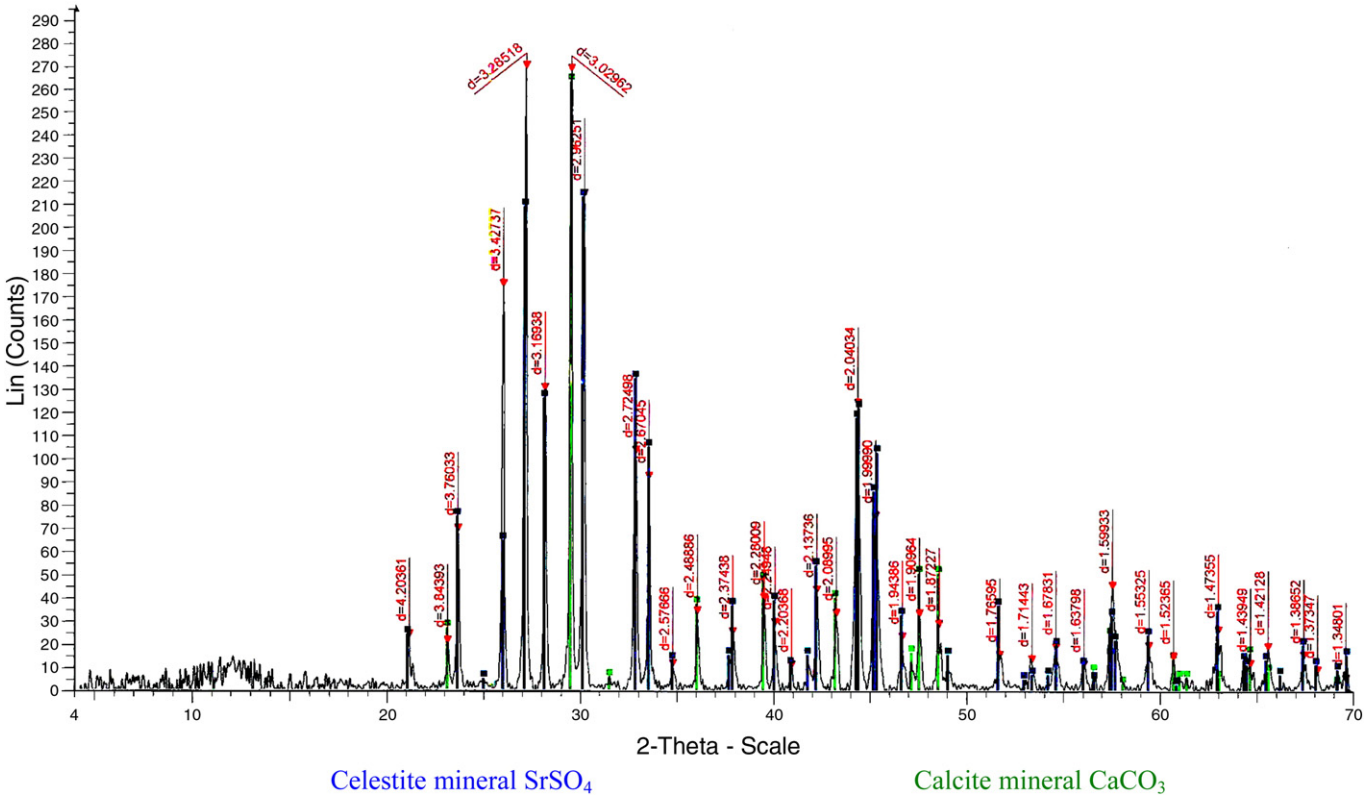

Fig. 1. XRD pattern of original celestite sample.