Applied research of shaking table for scandium concentration from a silicate ore

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Abstract. A poor magnetite iron ore is a super large independent scandium deposit with over the multi-billion potential utilizable value. Shaking table separation is very useful for impurities removing and scandium content increasing as a follow-up step of high-intensity magnetic separation. In the present study, a satisfactory index, namely scandium content of 83.10 g/t and recovery rate of 79.45 wt%, was obtained by shaking table separation. The good result was achieved under the conditions which the parameters were feed concentrate of 18 wt%, feeding quantity of 11 L/min, stroke frequency of 275 times/min and stroke of 17mm.

1. Introduction
Scandium is a soft and argentous transition metal, which the melting point and boiling point are 1541 °C and 2831 °C, respectively [1-2]. Currently, scandium has been used in laser (GSGG type laser), electric light source (scandium halogen lamp), alloy (Al-Sc alloy) and civilian use areas (Ga-Sc alloy cermet adhesive), etc [3-4]. Scandium is a typical dispersed lithophile element instead of a rare element. Because scandium is not affected by redox in nature, so it hardly forms a significant concentrate (ore deposit) and widely dispersed in various rock-forming minerals (especially magnesium and iron silicates) [5].

A super large independent scandium deposit is a poor magnetite iron ore in Yunnan, China, which is associated with 1.2 million tons of scandium oxide and prospective reserves could reach 4 million tons with over multi-billion potential utilizable value. The beneficiation of pre-concentration should be carried out to enhance scandium content and wipe out impurity elements, such as iron and titanium. The purpose was to reduce the difficulty and cost of subsequent leaching extraction process. A method contained gravity separation and magnetic separation was used in scandium concentration from this silicate ore. In the present research, the shaking table was used for concentrate scandium in the ore, this efficient process is expected to be environmentally friendly and provide economic benefit. Meanwhile, the research was significant and essential for its comprehensive exploitation and utilization.
2. Experiment

2.1. Study on the properties of samples

A scandium-bearing rare earth mine belongs to basic-ultrabasic intrusion. The ore is consisted of four kind minerals: sulfide, carbonate, oxide, and silicate accounted for about 89 wt% of the total mineral. The main occurrence minerals of scandium are diopside, mica, hornblende, and clay, which was formed by the alteration of silicate. The results of multi-elementary analysis were shown in Table 1.

Table 1. The multi-elementary analysis results of sample (wt%)

| Element | Fe   | TiO₂ | SiO₂ | MgO  | Al₂O₃ | Sc₂O₃ a |
|---------|------|------|------|------|-------|---------|
| Content | 10.26| 3.74 | 45.68| 8.91 | 10.44 | 55.72   |

*a how many grams in one-ton

Table 1 shows that the valuable elements are ferrum, titanium and scandium. Because the content of silicate minerals with poor preparability are relatively high and scandium minerals are more diffuse, this has decided that the beneficitation progress is very difficult.

2.2. Experimental scheme

Owing to most of the scandium is hosted in silicate by isomorphism or ion adsorption form, so beneficiation is very difficult to get a good result. In order to cut down the cost and workload of subsequent leaching process, the main purposes of beneficiation are improving the scandium content and remove the impurity elements (mainly iron, titanium). The process flow diagram showed in Figure 1 was an optimal beneficiation technique for this scandium-bearing silicate ore.

![Figure 1](image.png)

Figure 1. The beneficiation process flow of the scandium-bearing rare earth ore in Yunnan Province

The separating effect of shaking table used in this scandium-bearing silicate ore was emphatically discussed in this paper. The sample used in shaking table separation was obtained from high-intensity magnetic separation, which the content of scandium, iron, and titanium was 71.3 g/t, 19.21 wt%, and 10.74 wt%, respectively. According to the specific gravity, we found that the heavy minerals were mainly ilmenite, magnetite, and the light minerals were mainly silicate such as diopside, hornblende, etc. The rough titanium concentrates and titanium middlings showed in Figure 1 should be further processed to obtain qualified products. However, the scandium concentrate qualified for the subsequent leaching was shaking table tailings.

3. Results and discussion

The separation of shaking table was realized by the lateral and vertical flow on the bed [6]. The layer phenomenon of mineral particles based on specific gravity was achieved by flow and gravity. In the transverse direction, the light mineral particles on the upper layer were badly affected by the flow, but the lower heavy mineral particles were slight. The lateral velocity of light particles on the bed was
greater than the heavy particles. In the longitudinal direction, the differential movement of bed not only accelerate the loose layered of mineral particles but also made the heavy particles moving quickly in the longitudinal direction and the light particles moving slowly [7-9]. Eventually, the minerals were expansion in fan-shaped according to different move direction, and the different products were obtained by shaking table, such as concentrate, middlings, and tailings.

3.1. Experiment results of feeding concentration and feeding quantity

The speeds of particles’ layering and transportation on the bed of shaking table were directly influenced by feeding density and quantity [10]. When the feeding density and quantity were smaller, the viscosity of pulp increased and fluidity became worse. However, the small feeding density and quantity not only affected the processing capacity but also led to a mass loss of concentrate [11]. The results of feeding density and quantity shown in Figure 2 and Figure 3 were obtained under the conditions which the stroke and stroke frequency were 18 mm and 270 times/min, respectively.

![Figure 2](image2.png) ![Figure 3](image3.png)

**Figure 2.** Results of feeding concentration test during shaking table separation

**Figure 3.** Results of feed quantity test during shaking table separation

When the feeding quantity was 10 L/min, scandium content of concentrate declined continuously, recovery rate appeared a trend of rising first and then declining gradually (Figure 2). When the feeding concentration was 18 wt%, the satisfactory index of obtained concentrate was that the scandium content and recovery rate was 80.41 g/t and 75.64 wt%, respectively. The results showed in Figure 3 was obtained under the feeding concentration of 18 wt%. A good result could be obtained under the feeding quantity of 11 L/min, which the scandium content and recovery rate were 82.41 g/t and 80.41 wt%, respectively.

3.2. Experiment results of stroke frequency and stroke

The acceleration, speed and loose degree of particles on the bed were decided by the stroke frequency and stroke of shaking table [12]. The experiment results of different stroke frequency and stroke were shown in Figure 4 and Figure 5, respectively, which the feeding concentration and quantity were 18 wt% and 11 L/min severally.

![Figure 4](image4.png) ![Figure 5](image5.png)

**Figure 4.** Results of stroke frequency test during shaking table separation

**Figure 5.** Results of stroke test during table separation
As shown in Figure 4 and Figure 5, the peak of curve about scandium content appeared simultaneously when the stroke frequency was 275 times/min and stroke was 17mm. Meanwhile, the recovery rates at this moment were satisfactory. The best index in Figure 4 was that the scandium content and recovery rate were 82.31 g/t and 79.76 wt%, in Figure 5 was 83.21 g/t and 80.13 wt%. This phenomenon had demonstrated that the scandium-bearing minerals were gotten a good separation.

### 3.3. The experiment results of shaking table separation

The best conditions which were suitable for the separation of scandium silicate ore were determined based on the front condition experiments. When the feeding density was 18 wt%, feeding quantity was 11 L/min, stroke was 17 mm and stroke frequency was 275 times/min, the results about eliminating the effect of iron, titanium and enrich effect of scandium were shown in Table 2.

| Products                      | Yield (wt%) | Content of scandium (g/t) | Recovery rate of scandium (wt%) | Content of titanium (wt%) | Content of iron (wt%) |
|-------------------------------|-------------|--------------------------|---------------------------------|---------------------------|----------------------|
| Rough titanium concentrate    | 18.08       | 38.7                     | 9.83                            | 33.38                     | 36.72                |
| Titanium middlings            | 13.81       | 55.3                     | 10.72                           | 17.44                     | 27.06                |
| Scandium concentrate          | 68.12       | 83.1                     | 79.45                           | 3.37                      | 11.50                |

As shown in Table 2, the scandium content of rough titanium concentrate and titanium middlings were relatively higher for the decentralized distribution of scandium in different minerals. However, the shaking table was a useful beneficiation method for obtaining qualified scandium concentrate from strong magnetic products and efficiently removing of impurities such as iron, titanium. Eventually, the good beneficiation index was achieved, which the scandium content of obtained concentrate was 83.1 g/t and recovery rate was 79.45 wt%.

### 4. Conclusion

(1) This rare earth mine with scandium was a small iron ore and its average scandium content reached 55.72 g/t. And scandium was mainly hosted in the minerals in the form of homogeneous or ion adsorption, such as diopside, mica, hornblende and clay minerals altered by silicate.

(2) The products obtained from high-intensity magnetic separation was used for shaking table beneficiation experiments. When the feed concentrate was 18 wt%, feeding quantity was 11 L/min, stroke frequency was 275 times/min and stroke was 17 mm, a good beneficiation index was obtained which the scandium content of concentrate was 83.10 g/t and recovery rate was 79.45 wt%. Meanwhile, the impurities contained in scandium concentrate, mainly iron and titanium, was mostly removed.

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