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RARE EARTHS IN ELLIOT LAKE ORE AND
IN MONAZITE

by

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SUMMARY

Analyses of a mill feed sample and a mill leach residue sample of an Elliot Lake ore show that while only about 20% of the total rare earths is extracted approximately 75% of the yttrium oxide is extracted. Analysis of a monazite sample concentrated from the mill feed shows that the contained rare earths consist mainly of the lighter rare earth elements, and yttrium oxide accounts for less than 1% of the total rare earth content of the monazite. These data indicate that rare earth extraction probably results mainly from the dissolution of minerals other than monazite.

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INTRODUCTION

The unpublished results of a mineralogical study, made in 1957, of the rare earths in Elliot Lake leach tailings showed that only a small proportion of the total rare earths was dissolved from the ore by acid leaching; although a considerable proportion of the yttrium was extracted, the cerium and lanthanum contents were essentially unchanged. Monazite appeared to be the main rare earth mineral in the leach residue. It was tentatively concluded that the small proportion of total rare earths extracted was due to the dissolution of brannerite, uraninite and possibly uranothorite.

To determine whether current leaching practice resulted in similar distribution of rare earths and yttrium, a typical ore sample and corresponding residue sample were obtained from an Elliot Lake mine for chemical analysis. Also, in order to confirm the suspected distribution of rare earths in individual minerals, the preparation of a monazite concentrate for detailed analysis was undertaken.

PROCEDURE AND RESULTS

Several hundred pounds each of the following two samples (our reference No. 9/67-1) were obtained from an Elliot Lake mine:

1. 11-day composite of rod mill feed
2. composite, collected over the same period, of cake from the drum filter of the uranium leaching circuit.

Representative samples were prepared of each composite and were analysed using a combination of chemical and X-ray spectrographic methods. The results are shown in Tables 1 and 2.

To effect a concentration of monazite from the mill feed material, several different series of separation techniques were employed. Sulphide minerals were removed by xanthate flotation. One sample was treated on a Wilfley table, prior to flotation, to eliminate gangue minerals. Closely sized fractions were treated, in varying sequences, on the Haultain Superpanner, on the Frantz Isodynamic Separator, and by sink-float in a heavy liquid of specific gravity 4.0. The concentrates of heavy minerals were used as source material from which the cleanest monazite grains were selected under a low-power stereoscopic microscope. The monazite concentrates thus prepared were combined and cleaned to eliminate obvious contaminants.

TABLE 1

Analyses of Feed and Residue and Approximate Extraction

	Approximate Wt %		Extraction * %
	Feed	Residue	
U ₃ O ₈	0.16	0.010	94
ThO ₂	0.038	0.018	53
P	0.050	0.047	6
RE ₂ O ₃	0.20	0.16	20
La ₂ O ₃	0.035	0.032	9
CeO ₂	0.072	0.067	7
Pr ₆ O ₁₁	0.0065	0.0062	5
Nd ₂ O ₃	0.024	0.021	12
Sm ₂ O ₃	0.0041	0.0034	17
Y ₂ O ₃	0.012	0.003	75

* Based on analyses of feed and residue.

TABLE 2

Rare Earth Distribution

Oxide	Approximate % of Total Rare Earths	
	Feed	Residue
La ₂ O ₃	17.5	20.0
CeO ₂	36.0	41.8
Pr ₆ O ₁₁	3.2	3.9
Nd ₂ O ₃	12.0	13.1
Sm ₂ O ₃	2.0	2.1
Y ₂ O ₃	6.0	1.9
Totals *	76.7	82.8

* Other rare earths (from europium to ytterbium) were not determined.

The chemical analysis of a 60-mg sample of monazite, concentrated as described from 150 to 270-mesh feed, is shown in Table 3. The rare earth precipitate from this analysis was then analysed by the X-ray spectrographic method and the results are shown in Table 4.

TABLE 3

Chemical Analysis of Monazite

Oxide	Approximate Wt %
U ₃ O ₈	0.204
ThO ₂	3.66
P ₂ O ₅	24.8
RE ₂ O ₃ *	58.8
Total	87.5

* See Table 4.

TABLE 4

Analysis of Rare Earth Precipitate

Oxide	Approximate Wt %
La ₂ O ₃	15.65
CeO ₂	26.42
Pr ₆ O ₁₁	2.22
Nd ₂ O ₃	6.78
Sm ₂ O ₃	0.89
Gd ₂ O ₃	0.20
Dy ₂ O ₃	<0.02
Er ₂ O ₃	<0.02
Yb ₂ O ₃	1.69
Y ₂ O ₃	0.57
Total	54.4 *

* Rare earths accounted for = $\frac{54.4}{58.8} \times 100 = 92.5\%$ of total RE₂O₃.

DISCUSSION AND CONCLUSIONS

The results of the analyses of feed and residue samples (Tables 1 and 2) show that the light rare earth elements, from lanthanum to samarium, comprise the bulk of the rare earth content of the ore: the oxides of these elements together comprise more than 70% of the total whereas the oxide of yttrium, considered to be one of the heavy rare earth elements, comprises only 6%. On leaching, while most of the uranium is extracted and over half of the thorium, only about 20% of the total rare earths is extracted. Less than 10% each of the lanthanum and cerium oxide is extracted but approximately 75% of the yttrium oxide is extracted. The phosphorus analyses indicate that only about 6% is extracted.

The analyses of the monazite concentrate (Tables 3 and 4) show that it consists of fairly pure monazite which contains mainly light rare earths. Lanthanum oxide and cerium oxide together comprise approximately 72% of the total rare earth oxides, and yttrium oxide accounts for less than 1%.

These data confirm the results of the earlier study and again indicate that monazite is refractory to acid leaching. In the absence of quantitative data on the proportions of the rare earth minerals (mainly monazite, uraninite and brannerite) in the ore and on the rare earth content of the minerals other than monazite, it is not possible to account unequivocally for the distribution of rare earths in the feed and leached residue. However the present results are not inconsistent with the theory that monazite contains the bulk of the rare earths present in the ore (and in the leach residue) and that the extraction of rare earths effected by leaching is due largely to the dissolution of uraninite and brannerite. This is indicated by the low extractions of phosphorus, lanthanum and cerium, which are major constituents of monazite, and by the high uranium extraction. The high extraction of yttrium can be accounted for by the probable concentration of this element in uraninite and brannerite of Elliot Lake ores, as compared to the relatively low yttrium content of monazite. This theory is substantiated by analyses of brannerites and of uraninites from other deposits which show that the rare earths in these minerals are mainly of the yttrium group ⁽¹⁾.

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REFERENCE

- (1) E. Wm. Heinrich, "Mineralogy and Geology of Radioactive Raw Materials", McGraw-Hill Book Company Inc., New York, p. 27, 29 (1958).

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