Cornell

ROLLA RESEARCH CENTER
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Project Title: Rare Earth Metals From Missouri Iron Mines

Subactivity: Minerals and Materials Science

Element: Minerals and Metals Essential to the Nation RMIS No.: 724

Sub-Element: _____ Proposal No.: _____

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DISCUSSION OF TECHNICAL PROGRESS

The memorandum of agreement with the Pea Ridge Iron Ore Company was finalized. The agreement provides for the company to provide samples and technical consultation as needed. It also provides for the space, utilities, water, compressed air, and maintenance to be furnished by the company if a pilot plant is installed on site.

Characterization of the Pea Ridge ore was conducted using light and electron microscopy to insure and confirm mineral identifications. The major rare earth occurrence was the mineral monazite [$(CeLaNdTh)PO_4$], with minor substitutions of Pr, Dy, Sm, and other light rare earth elements. The monazite accounted for as much as 75 pct of the rare earth values in the samples studied. The monazite grains occur as acicular (needlelike) grains, euhedral crystals, and as simple veins through the host quartz and alkali feldspar. The grain size for the monazite ranges from 4 mm for the massive euhedral crystals down to 1 μm for the individual needles. The monazite grains break easily and cleanly but the overall fineness dictates the need for a grind in the minus 74- to minus 37-μm range depending on the feed. The other common rare earth mineral found is xenotime (YPO_4). The xenotime also

shows a euhedral crystal form with grain size ranging from 20 to 40 μm. The grains break easily and the liberation grind necessary is similar to the monazite. In most cases, there are minor substitutions of other heavy rare earth elements or Si. Minor amounts of other rare earth minerals are also found. These include allanite [$(CaCe)(Fe^{2+}Fe^{3+})Al_2O(SiO_4)(SiO_7)(OH)$] and thorite ($ThO_2$). Some rare earth values are also found in apatite, substituting for Ca. Grain size is 20 to 25 μm and is found as inclusions in host quartz grains. Rare earth-bearing apatite is also found in the tailings from the Fe ore production. In this case, the rare earth values are present as a distinct monazite phase in the host apatite.

Ore samples for test work ranged in tenor from 2.0 pct total rare earth oxide (REO) to as high as 20 pct REO. Initial testing was done on the Bartles-Mosely vanner using gravity separation. Samples were stage ground to minus 37 μm in a batch ball mill. As would be expected, the final grade of the concentrate was directly related to the grade of the feed. It is interesting to note, however, that the enrichment ratios are much higher for the lower grade feed. Recoveries varied very little in these tests. Table 1 gives typical results from these tests.

TABLE 1. - Results from early one-pass gravity tests

Test No.[1]	Feed grade	Conc grade	Conc/feed ratio	Recovery, pct
1	4.13	43.04	10.42	78
2	20.42	55.71	2.73	79
3	21.32	60.71	2.85	76
4	2.12	23.34	11.01	75

[1]Concentrates 2 and 3 are commercial grade (>55 pct total REO).

Flotation tests were run on the same feedstock as that used in No. 4 in table 1. The tests were run at pH 7.0 with various collectors and additives.

In the first, the collectors, oleic and linoleic acid, were tested. The total grade REO was 7.25 pct for the oleic acid and 7.61 pct for the linoleic acid. Recoveries were 98 and 92 pct, respectively. In an attempt to increase the REO grade of the concentrate, sodium silicate was used as a quartz depressant. On the low-grade sample, the sodium silicate raised the concentrate grade to 13.7 pct at a recovery of 97 pct. On a high-grade sample grading 16.2 pct REO, a concentrate of 33.5 pct REO was produced at a recovery of 65 pct. Recoveries were increased to the 90 pct range with an additional scavenging step.

Both gravity separation and flotation were used to clean the rougher concentrates from flotation. The flotation cleaning was unsatisfactory but the gravity cleaning gave very good results. Table 2 gives the results of a rougher test, which was followed by gravity cleaning (the results of which are given in table 3).

TABLE 2. - Results of rougher flotation test

Product	Wt pct	Assay				Distribution			
		Ce	La	Y	Fe	Ce	La	Y	Fe
Conc.....	34	11.0	6.5	1.3	5.2	78	78	85	35
Tail.....	66	2.4	1.5	.1	5.0	22	22	15	65
Feed.....	100	5.3	3.2	.5	5.1	100	100	100	100

TABLE 3. - Results of gravity cleaning of concentrate from table 2

Product	Wt pct	Assay				Distribution			
		Ce	La	Y	Fe	Ce	La	Y	Fe
Conc.....	35	20.5	11.4	2.5	5.2	63	62	65	35
Tail.....	65	6.4	3.8	.7	5.2	37	38	35	65
Feed.....	100	11.3	6.5	1.3	5.2	100	100	100	100

Overall, REO grade of the concentrate in table 2 is 61.4 pct, in actuality, the tailing in table 3 (cleaner tail) would be recirculated to the feed in

table 1 (rougher feed), and the tailing from table 2 would be scavenged and the concentrate from the scavenger would be also recirculated to the rougher feed. Several tests of this nature were run to provide commercial-grade concentrate for evaluation by possible future customers for any Pea Ridge REO concentrate.

Pea Ridge Rare Earths

Occurence

To date the high grade RE's occur in the north east footwall of the magnetite orebody. The RE minerals are concentrated in pipes or veins.

Known RE occurences appear to top out near the 2275 and go to unknown depth. Probable reserves lie between the 2275 and 2475 levels (200 feet). Diamond drilling has shown downward extension to the 2675 level (400 feet).

Tonnage and Grade

It appears that three of the pipes (X11, V12 and X13) carry for at least 200 feet vertically. Each pipe would contain about 100,000 GT over this 200 foot interval.

It appears that about a 10% RE ore could be recovered.

The % of heavy RE's appears to rise with greater depth.

RE Minerals

Principal RE carrying minerals are monazite and xenotime. Some allanite has been identified.

Mapping

Detailed mapping has been carried on underground at Pea Ridge by the State of Missouri (DNR) for over a year. The State is working in cooperation with the USGS.

Concentration

The USBM Research Center in Rolla, Missouri is doing RE research on minerals, concentration, pilot plant process, and metal recovery from Pea Ridge RE ores.

55 to 60% REO concentrates have been made. The concentrate runs about 20% heavy RE's and less than 5% Th.

Other Metals of Interest

Although Not Economic On Their Own Gold and Tin May Be Economic As Byproducts Of RE Recovery.

There Is Some Indication That Below The 2475 Level Other Metals Such As Copper, Nickel, Cobalt and Silver May Show Up.

Mining

Within Two Years We Think That Open Stoping Some Of This Material From The FW Would Be Possible. This Would Minimize Dilution Of The RE Ore and Give Good Mining Cost.

Five High Grade RE Assays

Metal	2275 #3	2370 #1	2475 #26	2475 #27	2505 #14	Avg	%
Y	1.50	1.20	3.20	2.60	5.40	2.78	10.8
La	8.80	4.80	6.90	5.50	3.90	5.98	23.3
Ce	14.90	7.70	11.70	8.80	7.00	10.02	39.0
Pr	1.20	.80	1.00	.80	.68	.90	3.5
Nd	4.00	2.60	3.80	2.80	2.30	3.10	12.1
Pm	-	-	-	-	-	-	-
Sm	.54	.52	.81	.56	.47	.58	2.3
Eu	.06	.05	.08	.05	.04	.06	.2
Gd	.30	.27	.53	.35	.44	.38	1.5
Tb	-	-	-	.01	.06	.01	-
Dy	.36	.35	.81	.63	1.00	.63	2.4
Ho	.08	.06	.18	.13	.25	.14	.5
Er	.20	.14	.53	.36	.77	.40	1.6
Tm	.04	.03	.12	.07	.16	.08	.3
Yb	.32	.17	.75	.47	1.10	.56	2.2
Lu	.04	.02	.11	.06	.16	.08	.3
% Metal	32.34	18.71	30.52	23.19	23.73	25.70	100.0

Composite Assays From Four Pipes

Metal	PR 11-1	PR 12-1	PR 13-1	PR 14-1	Avr	%
Y	.70	.69	.67	.36	.60	5.0
La	4.45	2.70	2.95	2.05	3.03	25.4
Ce	8.00	4.50	4.95	4.05	5.37	45.1
Pr	.68	NA	.41	.34	.48	4.0
Nd	2.15	NA	1.50	1.10	1.58	13.3
Pm	NA	NA	NA	NA	NA	-
Sm	.42	NA	.33	.24	.33	2.8
Eu	.03	NA	.03	.02	.03	.2
Gd	.15	NA	.18	.08	.14	1.2
Tb	-	NA	NA	-	-	-
Dy	.19	NA	.18	.09	.15	1.3
Ho	.03	NA	.03	.01	.02	.1
Er	.09	NA	.09	.04	.07	.6
Tm	-	NA	-	-	-	-
Yb	.16	NA	.12	.06	.11	.9
Lu	.02	NA	.01	-	.01	.1
Th	.63	NA	.23	.41	.42	
% Metal	17.07	11.27	11.45	8.43	11.92 (12.34)	100.0

300,000 Ton Probable Reserves

Ton Conc / Year	Lifetime at a 5:1
1,000	60
2,000	30
3,000	20
4,000	15
5,000	12
6,000	10
7,000	8½
8,000	7½
9,000	6⅔
10,000	6

Reserves have been upgraded to over 600,000 tons.