Fizykochemiczne Problemy Mineralurgii, 19 (1987) 195—204

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THE RECOVERY OF TUNGSTEN MINERAL FROM GRANITE ROCK — — A NON CONVENTIONAL APPROACH

Indian resources of tungsten, a strategic metal, are limited. Substantial quantities of tungsten metal and concentrates are imported by the country every year. (522 tonnes of concentrates and 41 tonnes of metal were imported during 1983-84).
India's reserves of tungsten are estimated at 1.2 million tonnes of ore assaying over 0.1% WO_3. About 45 million tonnes of leaner ore in the range of 0.01% to 0.02% WO_3 are also available. If a process for recovery of tungsten from these lean ores is developed, the country's workable resources will undergo a manifold increase. The indigenous production of tungsten metal meets only 5% of our requirement. Therefore, the development of a suitable technology for the treatment of low-grade Indian tungsten deposits is imperative.
This paper describes a novel approach to the development of a technology for the recovery of tungsten from non traditional sources.
Three granite samples assaying in the range of 0.07% to 0.09% WO_3 were beneficiated to yield concentrates assaying about 65% WO_3. The process used was very simple: tabling-flotation-magnetic separation, a combination which yielded concentrates of about 50% WO_3. This concentrate was further enriched by Mozley separation to a grade of 65% WO_3. The recoveries were further improved when pre-concentration by spiral was added to the above process set-up. Test work has established the possibility of concentration to a grade of 65% WO_3 with very good recoveries. The results are far better than those from non-granitic sources.

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Introduction

It is unfortunate that the known deposits in India are the lowest in the world. The grade of ore treated in India is very much below the tailings of beneficiation plants in the rest of the world. The deposits in India are very small and complex in nature, requiring a rather complex process schedule.

Indian Bureau of Mines has been testing a large number of samples from the existing mines and prospects for a long period. The Regional Ore Dressing Laboratory & Pilot Plant, IBM, Ajmer, which has been in operation since 1982, has so far conducted about 40 investigations on samples of Degana and Sirohi. While attempting detailed test work on the sample from Degana, it was observed that about 90% of the sample is only granite. Some thought was given to separating granite rock from the bulk so as to enrich the ore, and to simultaneously rejecting the bulk hard granite rock. At this juncture, granite rock was separated and assayed for tungsten (when the presence of tungsten in the granite rock was reported), and the test programme for establishing the recovery of tungsten from granite rock was initiated, which led to the very interesting results presented in this article.

Test Results

In order to establish the recoverability of tungsten from granite rocks, three samples of granite rock from three localities of the Degana Tungsten Project were investigated.

The mineralogy of the samples, nature of mineralisation, process attempted and the results obtained are presented.

The main process adopted for the three granite samples is identical, i.e., grinding the ore to minus 65 mesh, classification cum tabling; combined table concentrate to flotation followed by magnetic separation of flotation tailing. The feebly magnetic fraction is the final concentrate (granite no. 3, tabling at minus 35 mesh).

In the case of sample of granite no. 1, the feebly magnetic fraction assayed 53.0% WO_3 at a distribution of 37.50% (Wt% 0.061). In the case of granite sample no.2, the concentrate assayed 40.14% WO_3 at a distribution of 31.12% (Wt% 0.053), and in granite no. 3, the concentrate assayed 43.99% WO_3 at a distribution of 54.98% (Wt% 0.119).

The granites contained much lower values of tungsten: less than 0.1%. Pre-concentration by means of spirals was attempted in the case

Table 1

A comparative study of various beneficiation investigations conducted on granite rock samples of Degana Tungsten Project (for M/S Rajasthan State Tungsten Development Corporation Ltd., Jaipur) (Mineral Analysis)

Sample no.	Granite-I	Granite-II	Granite-III
SOURCE/LOCATION	R.O.M. Ore from underground working after hand picking vein quartz mineralisation	From underground working & devoid of vein quartz mineralisation	
WO_3 %	0.09	0.07	0.09
MINERALOGY Rock type Ore mineral	 Hard-compact granite Wolframite (Traces)	 Hard-compact granite Wolframite (Traces)	 Hard-compact granite Wolframite (Traces)
Gangue Mineral Essential (Major)	Quartz 45% Mica 20% Feldspar 12-20%	Quartz 45-50% Mica 20-25% Feldspar 10-15% Topaz 15%	Quartz 50-55% Feldspar 20-25% Mica 10-15% Topaz 10%
Minor	Topaz 3-5% Amphibole 2% Chlorite 2% Fluorite 1-2% Pyrrhotite 2-3% Pyrite 1-2%	Fluorite 1% Chlorite 1%	Fluorite 1% Pyrrhotite 1% Pyrite 1%
Trace Minerals	Apatite, Garnet, Carbonates, Tourmaline, Hematite, Goethite, Chalcopyrite, Sphalerite, etc.	Apatite, Garnet, Tourmaline, Amphibole, Carbonates, Pyrite, Iron oxides Pyrrhotite, Chalcopyrite, Covellite, Arsenopyrite, etc.	Carbonates, Amphiboles, Chlorite, Tourmaline, Apatite, Chalcopyrite, Arsenopyrite & Iron oxide.

Table 2

(Nature of tungsten mineralisation)

Granite - I	Granite - II	Granite - III
Wolframite is very fine-grained in nature (0.01mm to 0.18mm size but usally present as very fine, descrete, disseminated grains (0.01mm to 0.03mm) within the ground mess of silicate gangue minerals.	Wolframite is very fine-grained in nature (0.03mm to 0.6mm size). Wolframite grains are elongated as well as irregular in shape. Usually occurs as fine disseminated grains or as cavity fillings along the open spaces (craks) fracture planes of associated silicate gangues.	Wolframite is very fine-grained in nature (0.03mm to 0.36mm size). Wolframite grains are irregular as well as leth in shape. It usually occurs as cavity fillings along the intergranular spaces, cracks. cleavages or fracture planes of silicate gangue minerals. It also occurs as fine disseminated grains within the groundmass of silicate gangue. Wolframite grains are generally interlocked or associated with quartz, mica and feldspar.
Wolframite grains are mostly associated or interlocked with quartz grains and also occur as cavity filling along open space and fracture planes of associated gangue minerals.	Wolframite grains are generally interlocked or associated with quartz, and, at a few places, cracks/fractures present in wolframite minerals are filled with silicate gangue minerals.	Pyrrhotite and pyrite are the main sulphide-bearing minerals, followed by arsenopyrite (trace amounts). They usually occur as fine-to--coarse grained (0.12mm to over 1.0mm) dissemination or as patches and thin veinlets within the groundmass of silicate gangue.
Wolframite grains were seldom observed to occur interlocked with other associated gangue, viz. sulphides, topaz, etc.	Among the sulphides, pyrite and pyrrhotite are the main minerals. The sulphide minerals generally occur as patches/small veinlets belbs. They also occur as fine disseminated grains (upto 0.07mm) within the groundmass of silicate gangue minerals. The sulphide minerals are associated or interlocked with each other.	Quartz is the main predominant gangue and usually occurs as fine-to-coarse grains (0.2mm to over 1mm size) in association with mica, feldspar, topaz and wolframite.
Pyrrhotite and pyrite are the main sulphide minerals and usually occur as patches (thin veins) veinlets along the open space of silicate gangue. Sulphide minerals are usually associated or interlocked with each other.	Quartz is the predominant gangue, occurring medium-to-coarse grains (0.25 to 1.0). It is mainly associated with mica, topaz, feldspar and wolframite. Some of the quartz grains also carry fine inclusions of topaz, fluorite and opaque minerals.	Topaz is present as very fine-to--coarse grains (0.06mm to 0.6mm size), usually associated with quartz.
Quartz occurs as fine-to-coarse grains (0.18mm to 2.00mm) and is usually associated with mica, feldspar topaz, fluorite and wolframite, Quartz grains also carry extremely fine inclusions of sulphide, iron-oxide and wolframite minerals.	Topaz occurs as fine-to-medium grains (upto 0.5mm), usually associated/interlocked with quartz & mica.	
Topaz occurs as fine-to-medium grains along the cracks/fracture planes of associated gangue minerals, mainly quartz and mica.		

Table 3

(Test Results)

Sample number	Granite-I	Granite-II	Granite-III
PROCESS ATTEMPTED PRE-CONCENTRATION	i) Tabling at minus 35 mesh ii) Tabling at minus 65 mesh	i) Tabling at minus 35 mesh ii) Tabling at minus 65 mesh	i) Spiral cum tabling at minus 35 mesh ii) Tabling at minus 35 mesh
Mineralogy of the Pre-Concentration			
Wolframite	3-5%	3-5%	3-5%
Pyrrhotite	25-30%	3%	25%
Pyrite	10-15%	2%	15%
Arsenopyrite	Tr.	Tr.	5%
Topaz	52-55%	65%	45-50%
Mica Quartz	2-3%	5%	3%
	NOTE: In all the gravity pre conc. the wolframite is free from its associated gangue (over 90%).		
CLEANING OF PRE CONC.			
I.	Dry High Intensity Magnetic Separation	Dry High Intensity Magnetic Separation	Dry High Intensity Magnetic Separation
II.	-	Mozley Separation of FM fraction	Mozley Separation
III.	Flotation cum Magnetic Separation	-	Flotation cum Magnetic Separation
IV.	-	-	Flotation cum Mozley Separation

of granite no. 3. The spiral concentrate was cleaned on table, the table concentrate floated for sulphides, and the flotation tails were subjected to magnetic separation. The feebly magnetic fraction assayed 58.36% WO_3, which was further upgraded to 64.64% at a distribution of 48.87% by Mozley separation. The results can be futher improved in a continuous operation.

Table 4

(Final Process Results of Sample No. GRANITE-I)

Suitable Process; Tabling cum flotation cum magnetic separation process at minus 65 mesh size.

Product	Wt%	% WO_3	
		Assay	Dist.
TABLING			
Comb. T.Tails	91.337	0.040	41.66
Comb. T.Midd.	7.564	0.091	7.90
Comb. T.Conc.	1.099	4.020	50.44
FLOTATION			
Float	0.366	0.43	1.82
Tails	0.733	5.72	48.62
MAGNETIC SEPARATION			
HM	0.023	0.68	0.19
MM	0.015	6.29	1.09
FM	0.061	53.01	37.50
NM	00.634	1.34	9.84
Head (Calc.)	100.00	00.067	100.00

Table 5

(Final Process Results of Sample No. Granite-II)

Suitable Process; Tabling cum magnetic cum Mozley separation process at minus 65 mesh size

Product	Wt%	% WO_3	
		Assay	Dist.
TABLING			
Comb. T.Tails	93.283	0.038	50.00
Comb. T.Midd	5.922	0.088	7.34
Comb. T.Conc.	0.795	3.830	42.66

Contd (table 5) on the next page

MAGNETIC SEPARATION			
HM	0.013	1.92	0.36
MM	0.008	19.63	2.30
FM	0.053	40.14	31.12
NM	0.721	0.84	8.88
MOZLEY SEPARATION OF FM			
Moz. Conc.	0.026	59.04	23.24
Moz. Tails	0.027	19.26	7.88
Head (Calc.)	100.00	00.071	100.00

Table 6

(Final Process Results of Sample No. Granite-III)

Table 6a

Suitable Process: Table cum flotation cum magnetic separation process at minus 35 mesh size

Product	Wt%	% WO_3	
		Assay	Dist.
TABLING			
Comb. T. Tails	89.906	0.831	29.67
Comb. T. Midd.	8.598	0.184	9.25
Combined T. Conc.	1.496	3.950	61.87
FLOTATION			
Float	0.437	0.490	2.25
Tails	1.059	5.290	58.82
MAGNETIC SEPARATION			
HM	0.035	0.35	00.12
MM	0.008	2.73	00.23
FM	0.119	43.99	54.95
NM	0.897	0.37	3.49
Head (Calc.)	100.00	0.097	100.00

Table 6b

Spiral cum table cum flotation cum magnetic separation process at minus 35 mesh size

Product	Wt%	% WO_3	
		Assay	Dist.
SPIRAL TEST			
Spiral Tails	42.749	8.02	10.19
Spiral Slimes	13.072	0.06	9.35
Spiral Pre. Conc.	44.179	0.164	80.46
TABLING			
Comb. T. Tails	40.841	0.027	13.15
Comb. T. Midd.	2.702	0.125	4.01
Comb. T. Conc.	0.636	8.350	63.30
ROUTE-I; FLOTATION CUM MAGNETIC CUM MOZLEY SEPARATION			
Float	0.215	0.61	1.59
Tails	0.421	12.06	61.71
NM	0.266	1.35	4.36
HM	0.067	0.26	0.21
MM	0.007	8.02	0.68
FM	0.081	57.35	56.46
Mozley Conc. I	0.054	65.60	43.05
Mozley Conc. II	0.027	40.85	13.41
Head (Calc)	100.00	00.084	100.00

Route-II; Flotation cum magnetic cum mozley separation at minus 65 mesh sample

Product	Wt%	% WO_3	
		Assay	Dist.
FLOTAT	0.292	0.39	1.37
TAILS	0.344	15.02	61.33
NM	0.251	1.22	3.68
HM	0.008	10.08	1.84
MM	0.004	11.36	0.54
FM	0.081	58.38	58.67
Moz. Conc. I	0.063	64.64	48.67
Moz. Conc. II	0.019	36.12	7.80
Head (Calc)	100.00	00.084	100.00

It is seen from the above tables that the results obtained in the sample No. Granite-III are quite interesting. Pre-concentration followed by tabling, magnetic separation and Mozley yielded unbelievably good results. The final concentrates by this technique assayed around 65% tungsten with a recovery of 43%. It can been seen from the results presented in the tables that the recovery of final concentrates can still be improved considerably, as Mozley Concentrate II assays around 40% WO_3 with considerable distribution. The results can and will be bettered by continued pilot plant test work.

Conclusion

The resources of tungsten in India are very limited. The country produces very nominal amounts of tungsten in relation to its requirements. Since this is a strategic mineral, methods of recovering tungsten resources from leaner, marginal, sub-marginal and non-conventional materials are to be developed.

In Degana, the granite rock in the tungsten project contain wolframite at levels of 0.1% and below. Three rock samples have been investigated for the recovery of tungsten. The results are;

(Final concentrates)

Sample	WO_3 % Original	Wt %	WO_3 %	
			Assay	Dist.
Granite-I	0.09	0.060	53.01	37.50
Granite-II	0.07	0.053	40.14	31.12
		or	or	or
		0.026	59.04	23.24
Granite-III	0.09	0.119	43.99	54.96
		or	or	or
		0.063	64.64	48.67
		or	or	or
		0.054	65.60	43.05
		or	or	or
		0.081	50.30	56.67

It is clear from these results that the wolframite in the granite can be recovered. The concentration can reach a level of 65% at recoveries of about 43%. The process adopted for these three samples is identical, i.e., tabling-flotation-magnetic separation, which yielded concentrates to a level of about 50% WO_3. When these concentrates subjected to Mozley separation, they are fruther enriched to about 65% WO_3. The recoveries are further improved where a pre-concentration step is incorporated in the above process set-up. Test work has established the possibility of producing concentrates of 65% WO_3.

STRESZCZENIE

Sengupta A.K., Haragopal A.S.S.S., Jagdish Lal, Rao G.M., Satyanarayana K., 1987. Próba niekonwencjonalnego wydzielenia minerałów wolframu ze skał granitowych. Fizykochemiczne Problemy Mineralurgii 19; 195-204

Poddano przeróbce trzy próbki granitu zawierającego około 0.08% WO_3 i otrzymano koncentraty o zawartości 65% WO_3. W wyniku wzbogacania na stole koncentracyjnym, metodą flotacji oraz separacji magnetycznej otrzymano koncentraty o zawartości 50% WO_3. Dalsze wzbogacanie w separatorze Mozley'a dały 65% WO_3 w koncentracie. Podwyższono także uzyski, gdy do stosowanego schematu wzbogacania dodano wstępne wzbogacanie za pomocą spiral. Przeprowadzone badania wykazały możliwość otrzymania koncentratów o zawartości 65% WO_3 z dobrym uzyskiem. Otrzymane wyniki są dużo lepsze niż otrzymane dla próbek ze złóż innych niż granitowe.

СОДЕРЖАНИЕ

А.К.Сенгупта, А.С.С.С.Харагопал, Ягдиш Лялъ, Г.М.Рао, К.Сатьянараяна, Попытка неконвенционального выделения минералов вольфрама из гранитных скал, Физикохимические вопросы обогащения, 19; 195-204.

Подвергнуты обогащению три пробы гранита, содержащего около 0.08% и получены концентраты содержимостью 65% WO_3. В результате обогащения на концентрационных столах,флотации, а также магнитной сепарации, получены концентраты содержанием 50% WO_3. Дальнейшее обогащение в сепараторе типа Мозли дали 65% WO_3 в концентрате. Повышены также извлечения, когда в начале применяемой схемы обогащения додано вступительное обогащение при помощи винтовых сепараторов. Проведенные исследования показали возможность получения концентратов, содержащих 65% WO_3 с положительным извлечением. Полученные результаты являлись гораздо лучшими, чем полученные для проб из других залежей, чем гранитных.