

19 October 2004

Mak-32.341 MINING TECHNOLOGY AND ECONOMICS (2 cr, 3 ECTS)

EXAMINATION 20.10. 2004, 9.00 – 12.00

Questions without material

1. Describe shortly

- a) different sensitivity analysis methods 2p
- b) relationship between NPV and IRR, both in simple and discounted case 2p
- c) reasons for ore losses and dilution 2p

2. Ore reserve classification and estimation methods 6p

Questions with material

1. Zinkgruvan (see App.) hoisted 774 000 ton of ore in the year 2003. In-situ grades of the mined proven reserves were 9.9 % Zn, 5.2 % Pb and 103 g/ton Ag. Ore was processed to Zn-concentrate (Zn) and Pb-concentrate (Pb and Ag).

a) What are the estimated ore loss and waste rock dilution? Waste rock may contain some lead and silver, not zink. 2p

b) Calculate the amount of tailings and the grades of zink, lead and silver in tailings in the year 2003. 1 oz = 31.1 gram 4p

2. What is the net present value and internal rate of return of the proven reserves of the mine for Lundin Mining? Use purchase price + working capital as investment. The mining and milling costs in 2004 are 30 EUR/ton, and the fixed costs 4 MEUR/year. Inflation is expected to be 2 % and interest rate 7 %. For pricing, see Appendices. 6p

3. What is the pay-back period of the Zinkgruvan purchase? Calculate the break-even point and operating margin. 6p

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**RIO
TINTO**

ZINKGRUVAN LEAD AND SILVER MINE, SWEDEN

Exploiting a zinc-lead-silver orebody near Åkersund on Sweden's Lake Vattern, Zinkgruvan started underground mining in 1857. In the early 1990s, new technology and careful management cut mining and milling costs by about 50%, converting a high-cost operation to the sixth-lowest-cost zinc producer in the Western world by 1993.

Zinkgruvan has always been foreign-owned. Australian-based North Ltd purchased Ammeberg Mining from Belgium's Union Minière in January 1996, changing the Swedish entity's name to Zinkgruvan Mining AB in 1997. North subsequently made substantial investments in exploration, mine expansion and equipment, and concentrator improvements, prior to being acquired by Rio Tinto in 2000. In early 2004, Rio Tinto announced the sale of the operation to South Atlantic Ventures, subject to a definitive agreement. During the 1990s, employment was reduced from around 350 to 320, and is now approximately 300.

GEOLOGY AND RESERVES

The mine exploits a 5km-long, east-west aligned tabular deposit bounded at each end by sub-vertical faults. Sheet-like orebodies occur in a zone ranging from 2.0–2.5m-thick within an area of precambrian intrusive activity. Faulting divides the deposit into the eastern Nygruvan orebody and the western Burkland and Knalla mining areas.

Zinkgruvan has continued exploration in order to raise head-grades and, as of end-2003, proven reserves totalled 7.9Mt grading 9.9% zinc, 5.2% lead and 103g/t silver. Probable reserves were 1.6Mt at 9.3% zinc, 2.8% lead and 68g/t silver.

MINING

Some cut-and-fill but mostly single-lift bench and multiple-lift open stoping are employed, the open stopes being paste backfilled. A 1.4km-long horizontal rail haulage to the underground crusher and main hoisting shaft is at 800m while ore mined below this level is hauled to the crusher up ramps by two trolley electric trucks. The target rate for the expansion plan initiated by North was 850,000t/y of ore by 2003.

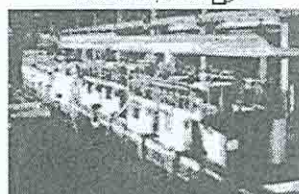
Drilling and almost all charging, scaling and rock bolting are mechanised, with electro-hydraulic production drilling now automated. Ore is hauled from the stopes by three 14t-capacity LHDs. Kiruna Electric truck hoisting was introduced in two phases: a 50t-capacity K1050E was delivered by ABB in 1989 and a

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The Zinkgruvan mine is located near Åkersund on Lake Vattern in central Sweden.

[Click To Expand](#)



Using new Svedala RCS flotation cells has expanded concentrator capacity at Zinkgruvan.

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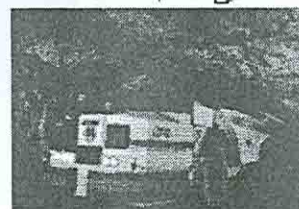
The Zinkgruvan mine, 240km west of Stockholm, has been in operation since 1857.

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A drilling jumbo underground at Zinkgruvan.

[Click To Expand](#)



Zinkgruvan's first Kiruna Electric truck

35t-payload K635E in 1995. The ramp will probably bottom out at 1,100m.

ORE PROCESSING


The concentrator was built in 1977 and capacity was later increased from 600,000–750,000t/y. Autogenous and ball mills liberate galena and sphalerite minerals, which are extracted by a rougher-scavenger flotation followed by pebble regrinding and cleaning. This bulk concentrate is separated into 74–78% lead and 55–58% zinc concentrates, the lead being cleaned in a fourth line of cells. To handle higher-grade feed, North decided to increase flotation retention time by replacing the existing cells with 22 larger Svedala Sala RCS cells, so avoiding the need to build new space. Recovery rates improved and the cells enabled Zinkgruvan to avoid silica content penalties previously exacted by customers. An ABB process control system was installed in 1999.

The concentrates are dewatered by Larox and Svedala pressure filters and trucked 100km to a port on Lake Vänern for shipping by bulk carriers to customers in Europe.


PRODUCTION

Milled tonnage has paralleled greater mine output, and zinc-in-concentrate production has been further increased by better recoveries. During the first-half of 2002, difficult mining conditions reduced production but in 2003 the concentrator treated 774,000t ore averaging 9.3% Zn, 4.7% Pb and 103g/t Ag to yield 119,200t of concentrate with 65,700t contained Zn (34% better than in 2002) and 45,000t lead-silver concentrate with 31,700t Pb (29% above 2002) and 1.84Moz Ag.

Typically, all of Zinkgruvan's output is sold on long-term contracts.


 [Click here for printable version](#)

was this K1050E with 50t payload.

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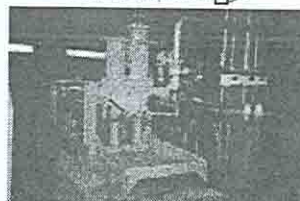
In 1995, Zinkgruvan acquired a smaller Kiruna Electric truck, the K635E, for the deepest part of the mine.

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Both the K1050E and the later K635E haul ore from mining areas below the main haulage level to the underground crusher.

[Click To Expand](#) 



Putzmeister seat valve pump HSP pumping slurry over a long distance.

SPECIFICATION

FEATURED SUPPLIERS

-  [ABB Automation Technologies - Mine Hoists \(Shaft Equipment, Winding and Winches\)](#)
-  [Dorr-Oliver Eimco - Flotation, Agglomeration and Filtering \(Flotation, Agglomeration and Filtering\)](#)
-  [Mine Site Technologies - Communications, Blast Initiation, Warning and Tagging Systems \(Communications Systems and Equipment\)](#)
-  [MineCom - Wireless Automation, Communications and Leaky Feeder Systems \(Communications Systems and Equipment\)](#)
-  [Minova International - Resin and Cement Capsules, Cementitious Foams and Grouts, Resin and Cement Injection Systems \(Support Technology and Strata Control\)](#)
-  [Putzmeister AG - Concrete, Paste, Slurry and Mortar Pumps \(Pumps, Compressors, Valves and Actuators\)](#)
-  [TIP TOP Industrie - Conveyor Belt Maintenance, Wear Protection and Corrosion \(Conveyors, Components and Accessories\)](#)

De Beers embraces South

WABUSH AGREEMENT

Cleveland-Cliffs Inc and members of the United Steelworkers of America union at the company's 26.83%-owned Wabush iron-ore mine and Pointe Noire shipping facilities in Labrador and Newfoundland, and Québec respectively have agreed a new labour contract. As a consequence, the workers have returned to work. They went on strike in July (MJ, July 16, p7). At the end of last month, workers at Iron Ore Co of Canada's operations also in Labrador and Newfoundland and Québec returned to work after approving a new three-year labour agreement.

ALCAN TRADER SALE

Alcan inc has sold the ores and concentrates business it acquired through its acquisition of Pechiney. The business has been sold to the existing management team and henceforth will be called Ocean Partners Holdings Ltd. It includes the net assets and commercial agreements of the copper, lead and zinc concentrate and secondary trading business which was operated through Pechiney World Trade (USA) Inc and Pechiney Trading Ltd. Ivernina Inc, which is developing the Magellan lead mine in Australia, said Ocean Partners will assume Magellan's exclusive sales agency contract for lead concentrates from Pechiney World Trade. Alan De'ath, Ivernina's chief executive, noted that the contract includes a US\$10 million inventory/trade facility.

ATACOCHA TAILINGS DAM

Cia Minera Atacocha SAA has solved the problem of finding a site for a new tailings dam, averting the potential closure of its zinc-lead mine near Cajamarquilla in Peru. According to the company's managing director, Juan Jose Herrera, Atacocha has managed to reach an agreement whereby the dam will be constructed on 13 ha of land owned by the town of Cajamarquilla. Atacocha had originally agreed to build the dam on land owned by 700 residents of the town of Tlacayan. However local leaders pulled out of the agreement (MJ, September 24, p3).

SASOL DEATH

South African synthetic oil producer Sasol reports that a hoist operator was killed at its Bosjespruit coal mine in Mpumalanga Province after being trapped between a tractor and trailer. South Africa's Department of Minerals and Energy has started an investigation into the incident.

DE BEERS this week agreed to incorporate South Africa's 'black economic empowerment' (BEE) requirements in its 'supplier of choice' rough-diamond sight-allocation process.

Moreover, in meetings with the South African Government, the world's largest producer and marketer of rough diamonds has "wholeheartedly embraced" the domestic beneficiation of rough diamonds, and invited the state to take a 50% stake in its Diamdel rough-diamond trading subsidiary.

"Never before has the South African Government and De Beers come this close to finding a common ground in pursuit of a healthy secondary diamond industry", said a visibly elated South African Diamond Board chairman Abbey Chikane.

The announcement came at the end of a two-day workshop, arranged by Minerals and Energy Minister Phumzile Mlambo-Ngcuka, to solicit diamond-industry input before submitting the final version of the Precious Metals and Diamonds General Amendments Bill to parliament.

Israel-based diamond consultant Chaim Even-Zohar acted as facilitator at

the workshop, and will be submitting the various recommendations to Mrs Mlambo-Ngcuka for consideration. Mr Even-Zohar told *Mining Journal* that De Beers' plans also include the introduction of jewellery-manufacturing operations in South Africa through its client manufacturers.

Furthermore, De Beers' Diamond Trading Co (DTC), which currently has 14 sight-holders in South Africa, has committed to increase this number substantially. These undertakings meet the government's goals of creating added value, and facilitating the entry of 'historically-disadvantaged South Africans' (HDSA) into the diamond business (without resorting to export taxes or the imposition of a compulsory diamond-supply regime).

In its present form, the draft bill calls for a 5% across-the-board tax on all rough diamonds exported from South Africa, and requires all diamonds mined in South Africa to be sold to the local market. The minister reiterated her commitment to "widen and improve access to diamonds for all South African citizens", and to optimise local beneficiation of diamonds, thus aligning the new

Diamond Act with the Mineral and Petroleum Resources Development Act (MPRDA) which was enacted this May.

De Beers director and DTC managing director Gareth Penny informed the government that the existing BEE requirements placed on mining companies through the MPRDA will now also be applied by De Beers to all of DTC's South African sight-holders. This means, effectively, that the supplier of choice initiative, which is based on comparative scoring on an agreed set of criteria among clients, will be amended to incorporate credits that reflect the level of diamond beneficiation in South Africa.

The diamond industry in South Africa employs some 28,000 people, of which 13,000 are in mining, 300 in sorting and valuing, 2,100 in cutting and polishing, 3,000 in jewellery manufacturing and around 9,000 in retailing. Local mined production is valued at about US\$1 billion; with rough supplied to the South African market valued at US\$550 million, and polished diamond exports amount to a similar figure.

There is consensus that there are sufficient rough diamonds on the local market but that there is a lack of cutting

Lundin looks forward at Zinkgruvan

LUNDIN Mining Corp's Zinkgruvan underground zinc-lead mine, about 200 km southwest of Stockholm in Sweden, has just completed its first full quarter under new ownership.

Lundin acquired the 147-year-old operation from the Rio Tinto group in June this year for US\$100 million in cash plus SK39.7 million for working capital. The company had previously been a minor copper-zinc producer (from the 37%-owned Storliden mine, also in Sweden) and explorer under its former name of South Atlantic Ventures Ltd. The change of company name was concurrent with a move from the TSX-Venture Exchange to the main Toronto Stock Exchange in August.

Mining is by panel stoping at between 300-1,000m depth, producing 800,000 t/y of ore. Paste back-filling, using tailings from the processing plant, helps to reduce the effects of high horizontal stresses in the mine.

The processing plant comprises autogenous grinding followed by flotation to yield a lead-zinc concentrate with average recoveries in 2003 of 95% for zinc, 88% for lead and 73% for silver. The concentrates are separated before shipment to smelters in northern Europe via



the port of Otterbäcken. Production in 2003 was about 66,000 t of zinc, 32,000 t of lead and 1.8 Moz of silver.

Zinkgruvan is a metamorphosed ore deposit, the genesis of which is the subject of debate between those favouring either a volcanogenic or a sedimentary-exhalative origin. Concordant massive ore and veins are hosted within volcanic siltstones, and limestone-dolomite skarn.

Ore mineralogy comprises sphalerite and galena and proven and probable reserves are estimated at 9.5 Mt at

9.8% Zn, 4.8% Pb and 97 g/t Ag, sufficient for 11 further years of operation.

The majority of historical production came from the Nygruvan orebody, and a certain amount of reserves still remain in this area, but grades are decreasing. The bulk of proven and probable reserves are located in the Burkland orebody. Measured and indicated resources are estimated at 2.1 Mt at 8.6% Zn, 2.4% Pb and 82 g/t Ag. Inferred resources estimated at 8.3 Mt at 10% Zn, 4.3% Pb and 103 g/t Ag are mainly located in the Cecilia, Borta Bakom, Dalby, Mellanby and Sävsjön zones, plus a down-dip extension of the Burkland zone. However, additional ventilation will be required to access the Cecilia and Borta Bakom zones.

Additionally, an indicated and inferred copper-rich resource, estimated at 3.5 Mt at 3.1% Cu (2.7 Mt at 3% Cu, 0.5% Zn and 52 g/t Ag in the indicated category), is located in the hangingwall of the Burkland orebody. Investigations into plans to increase output using this copper resource are in progress, with initial capital cost estimates of about US\$15 million. The main hoisting shaft has excess capacity, as it is capable of handling 1.4 Mt/y.

- › Statistics
- › Daily observations on exchange rates

Exchange rates

Euro exchange rates published by the ECB on
18 October 2004 at 15:15

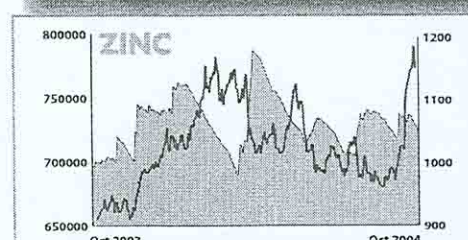
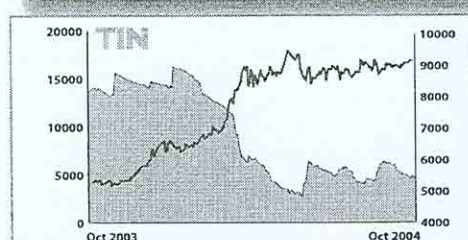
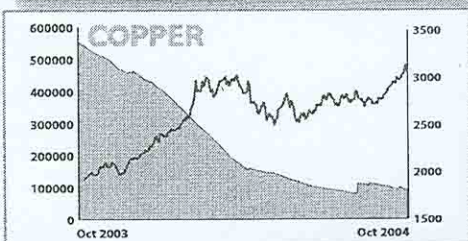
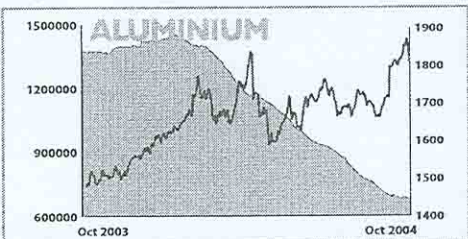
	Currency		currency : EUR
USA	dollar	USD	1.2474
Japan	yen	JPY	136.51
Denmark	krone	DKK	7.4387
United Kingdom	pound	GBP	0.69185
Sweden	krona	SEK	9.0985
Switzerland	franc	CHF	1.5382
Iceland	krona	ISK	87.12
Norway	krone	NOK	8.2390
Bulgaria	lev	BGN	1.9559
Cyprus	pound	CYP	0.57570
Czech Republic	koruna	CZK	31.398
Estonia	kroon	EEK	15.6466
Hungary	forint	HUF	247.35
Lithuania	litas	LTL	3.4528
Latvia	lats	LVL	0.6686
Malta	lira	MTL	0.4297
Poland	zloty	PLN	4.2902
Romania	leu	ROL	41257
Slovenia	tolar	SIT	239.9000
Slovakia	koruna	SKK	39.955
Turkey	lira	TRL	1848000
Australia	dollar	AUD	1.7103
Canada	dollar	CAD	1.5658
Hong Kong	dollar	HKD	9.7183
New Zealand	dollar	NZD	1.8124
Singapore	dollar	SGD	2.0943
South Korea	won	KRW	1426.65
South Africa	rand	ZAR	7.9846

Table 1. General pricing data of common concentrates.

Concentrate	Deduction unit	Payment	Refining charge		Smelting charge \$ / tonne
			\$ per unit		
Cu-concentrate					95 - 120
- Cu (%)	1,0	95 - 98	0,09 - 0,12	lb	
- Au (oz/t)	0,03 - 0,05	90 - 95	5,00 - 6,00	oz	
- Ag (oz/t)	1,0	95	0,30 - 0,50	oz	
Pb-concentrate					145 - 175
- Pb (%)	1,5 - 3,0	95	-		
- Au (oz/t)	0,02 - 0,05	95	6,00	oz	
- Ag (oz/t)	0,5 - 0,2	95	0,30 - 0,35	oz	
- Cu (%)	-	(< 40)			
Zn-concentrate					185 - 200
- Zn (%)	8 (Zn< 53%)	85 (Zn> 53%)			
- Au (oz/t)	0,01	80 - 85	6,00	oz	
- Ag (oz/t)	3,0 - 4,0	70	0,30 - 0,50	oz	
- Cd (%)	(0,1 - 0,2)	(60 - 70)	(1,00)	lb	
- Pb (%)	(3,0)	(50)			
- Cu (%)	-	-			

LME METAL STOCKS AND PRICES

Stocks (t) Three-months price US\$/t (rhs)



LME PRICES

	US\$/t	% change on week	% change on year
Aluminium			
Cash	1,747.5	-5.5	17.0
Three-months	1,701.3	-8.2	14.2
Aluminium-alloy			
Cash	1,567.5	-1.9	11.3
Three-months	1,592.5	-1.8	13.5
Copper			
Cash	3,042.5	-4.4	60.2
Three-months	2,908.5	-3.9	52.1
Lead			
Cash	969.3	-4.2	57.6
Three-months	921.5	-2.6	57.1
Nickel			
Cash	13,697.5	-14.9	21.6
Three-months	13,647.5	-15.0	22.0
Tin			
Cash	8,720.0	-5.2	64.9
Three-months	8,682.5	-4.3	63.9
Zinc			
Cash	1,077.5	-4.5	19.6
Three-months	1,095.8	-4.4	19.4

Source: Bloomberg, LME

LME OFFICIAL AVERAGES

Sep (US\$/t)	Settlement	Cash	3-mths
Aluminium	1,724.00	1,723.60	1,730.33
Alum-alloy	1,536.36	1,533.75	1,560.43
Copper	2,894.86	2,894.30	2,826.09
Lead	935.45	934.92	887.88
Nickel	13,277.27	13,270.91	13,166.48
Tin	9,019.55	9,009.66	8,949.43
Zinc	975.18	974.83	993.23
Settlement	£/US\$	US\$/£	€/US\$
exchange rates	1.7931	110.0800	1.2218

Settlement is the average of the cash sellers' price. Cash and three-months are the average of the buyers' and sellers' price.
Source: LME

EXCHANGE STOCKS

	t	% change on week	% change on year
LME aluminium	700,425	2.5	48.9
Comex aluminium	17,533	-42.0	-86.0
Comex			
aluminium pieces*	43,442	12.2	
Total aluminium	761,400	1.2	
LME aluminium-alloy	42,460	3.9	-17.9
LME copper	88,575	-7.1	-84.1
Comex copper	41,408	-4.3	17.5
Total copper	129,983	-6.2	-78.1
LME lead	50,975	-1.1	-67.1
LME nickel	15,366	-5.5	-52.3
LME tin	4,710	1.3	-66.3
LME zinc	721,000	-1.2	3.6

* Assuming 0.75 t per Comex aluminium piece
Source: Bloomberg, LME, Comex

COMEX PRICES

	Copper (US\$/c/lb)	Aluminium (US\$/c/lb)
October (spot)	127.4	84.6
November	127.2	84.7
December	126.9	83.6

Source: Bloomberg, Comex

COPPER CONCENTRATES

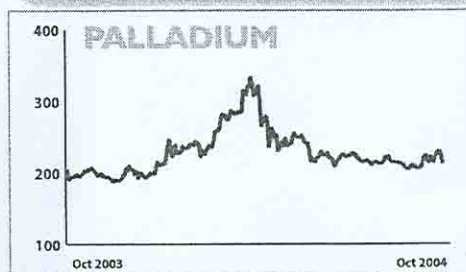
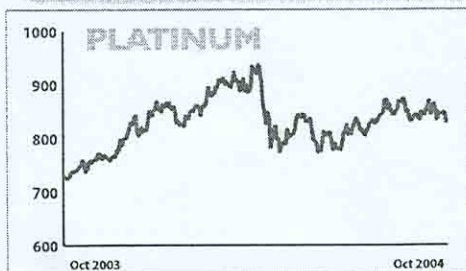
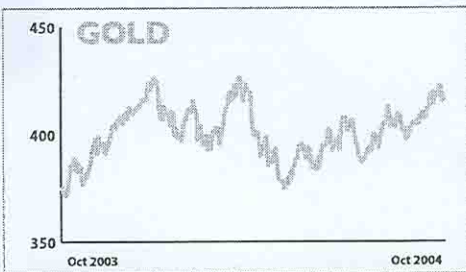
Spot TC/RCs, clean 30% copper concentrates, of Shanghai
Payable copper 96.7%, recovered 97.0%, free to smelter 0.3%

	Current	Last month	Year ago
Mine spot sales			
TC (\$/dmt)	105	80	15
TC (c/lb equiv)	16.4	12.5	2.3
RC (c/lb)	10.5	8	1.5
TC/RC (c/lb)*	26.9	20.5	3.8
Smelter spot purchases (Shanghai)			
TC/RC (c/lb)**	29.5	24.4	5.1
Unpaid Cu (c/lb)	0.4	0.4	0.3
Cu Premium (c/lb)	4.8	3.6	4.1
Total (c/lb)	34.7	28.4	9.5
Cu Premium of Shanghai (\$/t)	100	70	90

* Late quotational period ** Early quotational period

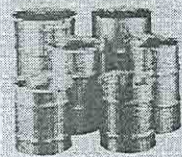
PRECIOUS METALS

	US\$/oz	% change on week	% change on year
Gold (last fix)	414.65	-0.8	11.0
Silver (spot)	6.97	-3.0	41.7
Platinum (last fix)	838	-0.8	14.8
Platinum (J Matthey)	842	-0.9	14.7
Palladium (last fix)	216	-4.0	5.9
Palladium (J Matthey)	218	-6.4	6.3
Iridium (J Matthey)	195	-2.5	116.7
Osmium (free market indication)	425	0.0	0.0
Rhodium (J Matthey)	1280	-1.5	156.0
Ruthenium (J Matthey)	82	0.0	148.5



ORES & OXIDES

	US\$/lb	% change on week	% change on year
Molybdenum oxide (conc 55-57%)	20.0	0.0	215.0
Tantalum oxide (60% N Euro port)	40.0	0.0	0.0
Vanadium (98% V ₂ O ₅)	5.5	3.8	205.6
Wolframite	50.5	0.0	18.8



Mining Journal's Nickel Day November 30, 2004

Eight companies profiled, entry is free.

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