

The Role of Near-Earth Asteroids in Long-Term Platinum Supply

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The Lewis Model

- 2km Metallic Asteroid
- \$20 Trillion Valuation (pgm, iron, nickel)
 - 1995 metal prices
 - assumes products sold in terrestrial markets
 - \$6 Trillion - PGM (388K ton)
 - \$14 Trillion - Fe/Ni (25B ton)
- Ignores mining costs, market size, price collapse

Q: What is the platinum market really like?

Platinum Demand Factors

- Major metal uses
 - Industrial uses: emissions-control catalysts, chemical refinery components, electronics and hard disks
 - Precious metal uses: jewellery, investment products
- International consumption trends: \$2-3B/y
- Substitutes for platinum: Pd, Rh, Au
- The link between platinum and high technology: Fuel Cells and Electronic Components

Platinum end use by category

(thousand oz, Johnson-Matthey, 1999)

	1998	1999
Autocatalyst	1,415	1,220
Jewellery	2,410	2,730
Industrial	1,250	1,340
Investment	315	200
Total Global Demand (k oz)	5,390	5,590

Platinum Supply

- Primary mine production (1999)

Noril'sk 800,000 oz

Stillwater 206,000 oz

Hartley 150,000 oz

South Africa

Amplats 928,000 oz

Impala 1,065,000 oz

Lonmin 564,000 oz

Northam 333,000 oz

- Smelters and refineries

- Rustenberg, Germiston and Lohrno, *South Africa*; Krasnoyarsk and Monchegorsk, *Russia*; Acton and Royston, *England*; Kristiansand, *Norway*; Metallurgie Hoboken-Overpelt refinery in *Belgium*; Englehard mill, New Jersey, *U.S.A.*

- Byproduction and coproduction

- Recycling

Platinum supply by country

(thousand oz, Johnson Matthey, 1999)

	1998	1999
South Africa	3,680	3,820
Russia	1,300	800
North America	285	275
Other	135	165
Total Supply	5,400	5,060

Note: 430,000 oz will be recovered from autocatalysts in 1999

Global Platinum Reserves (USGS, 1980)

- Merensky Reef (Bushveld) - 333 Million troy ounces / 0.25 opt
- Great Dyke (Zimbabwe) - 139 Million oz / 0.10 opt
- Noril'sk (Russia) - 50 Million oz
- Stillwater (Montana) - 7 Million oz / 0.6 opt
- Lac de Iles (Ontario) - 3 Million oz / 0.125 opt
- Byproduction at Sudbury, Ontario and in Chile
- Estimated worldwide platinum reserves total **513 Million ounces**

What about those Asteroids?

The Geology of NEAs

- LL Chondrites ~ 8% of total NEAs
- Population -vs- Size
 - ~2,000 estimated at >1km size
 - ~100,000 estimated at >100m size
- Geologic Inference from Meteorite Samples
- Radar Mapping
- Spectral Analysis
- Spacecraft

PGM concentrations by meteorite class

(ppm – Kargel, 1996)

	Avg. LL Chon.	90 th % Fe	98 th % Fe
(precious metals)			
Ge	1020	70	35
Au	4.4	0.7	0.6
(platinum group)			
Re	1.1	1.1	2.4
Ru	22.2	20.7	45.9
Rh	4.2	3.9	8.6
Pd	17.5	2.6	1.2
Os	15.2	14.1	31.3
Ir	15.0	14.0	31.0
Pt	30.9	28.8	63.8

LL Chondrite size –vs- contained platinum

(spherical model, projected revenues at a platinum price of \$500 per ounce, assumes complete recovery of platinum from an LL chondrite with a specific gravity of 3.0g/cc and platinum grade of 30.9 g/ton)

Diameter (m)	Mass (k ton)	Contained Pt		Value (\$B usd)
		(ton)	(k oz)	
20	13	0.4	12	0.006
40	101	3	99	0.050
100	1,571	49	1,553	0.777
200	12,566	388	12,426	6.21
400	100,531	3,106	99,405	49.7
1000	1,570,795	48,538	1,553,202	777
2000	12,566,360	388,301	12,425,617	6,213

Mining Options

- Option I: Return the whole asteroid
 - use Current launch vehicle technology
 - 20 meter (13,000 ton) = upper limit for practical orbital transfer
 - PGM revenue estimate for 20m asteroid = \$6 Million
- Option II: Regolith mining and concentration In-Situ
 - 1 kilometer or larger LL Chondrite
 - 1M ton of ore per meter of mined regolith (spherical model)
 - Implies roughly \$500 Million revenue /meter at 100% recovery
 - Higher risk than Option I due to operational complexity

- Both options for mining asteroidal platinum *lack economic justification* based on PGMs alone!
- If other products provide the primary incentive for mining, asteroidal platinum will significantly alter the long-term characteristics of the terrestrial platinum market

Marketing Considerations

- Limit price volatility through *marketing agreement* with existing sellers
- Space-manufactured & consumed products:
 - ISS, MIR, Orbital business parks
- Specialized *niche-market products*: exotic alloys, metallic-foam based catalysts, high-purity &h electronic components.

Got Other Products Than Platinum?

(Option I revisited)

- Capture & return a 20-meter asteroid (LL Chondrite: 10% water, 7% iron, 30% hydrocarbons, significant silicates)
- Current launch price = \$10,000 per kilogram to LEO (remarkably close to the price of gold!)
- Implies that the entire asteroid may be valued as if it were made of gold (\$126 Billion!)
- Significant caveats exist:
 - First, there are no existing markets for the other products that could be extracted.
 - Second, the technology for material handling and product fabrication has not been developed.