



Russian PGM

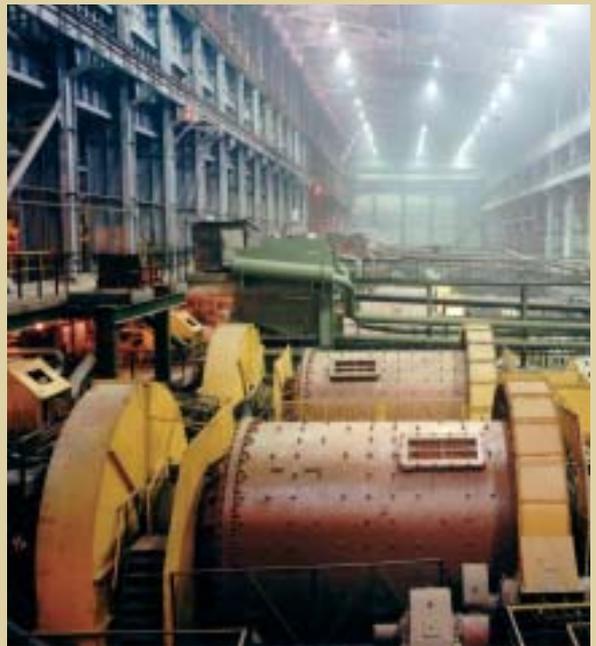
PGM Mining in Russia

Russia currently accounts for over 40 per cent of global annual mine production of palladium and approximately 15 per cent of platinum production. Despite the importance of the Russian pgm mining industry to global pgm markets, hard facts on reserves, production and sales have historically been difficult to come by, as data was deemed confidential under the Russian state secrecy law.

In recent years, however, Norilsk Nickel has been able to disclose more information regarding its base metals operations, and the group has been pushing for the freedom to publish details of its pgm reserves, production and sales. These efforts bore fruit in late 2003 when a bill to declassify pgm information (with the exception of government stocks and sales) was passed by both chambers of the Russian parliament and was signed by President Putin.

The bill took effect in February 2004 but the publication of pgm data appears to have been delayed by regulatory procedures that have to be completed by several ministries. Release of pgm information is now not expected until the final quarter of 2004 at the earliest.

In the meantime, this article describes the structure and mining operations of Norilsk and the alluvial pgm producers in Russia, and provides estimates of current platinum and



View of part of the ore milling circuit at Norilsk Nickel's Tainakh concentrator.

palladium output. The latter are based on data from a wide range of sources, including visits made by Johnson Matthey staff to the facilities described.

Map of Russia showing location of pgm mining districts and pgm refineries.





Russian PGM

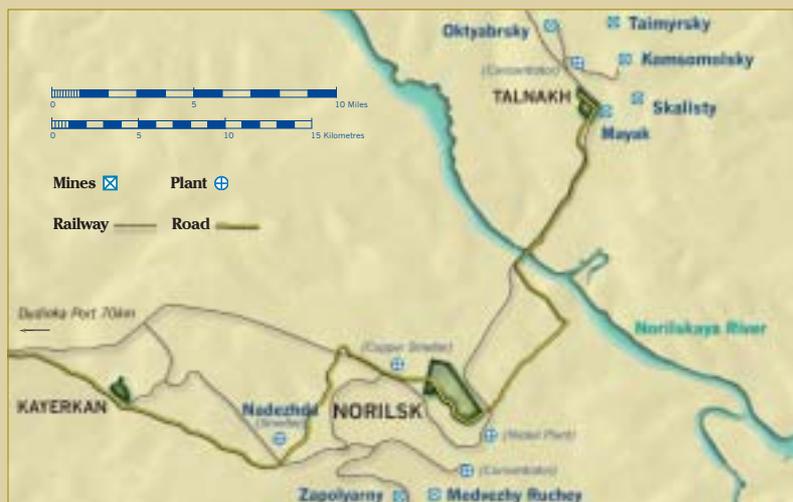
Norilsk Nickel: a pgm powerhouse

Norilsk Nickel dominates Russian pgm output, producing platinum, palladium and minor pgm from its copper-nickel mining and smelting complex in northern Siberia. Small volumes of pgm are also produced from its copper-nickel mines in the Kola Peninsula.

Detailed exploration and research into the copper-nickel ore deposits in the Taimyr Peninsula in northern Siberia began in the 1920s. Development of the Norilsk Combine began under the aegis of the Soviet security services in 1935, utilising political prisoners and convicts as labour. Initially adits were dug to exploit the Norilsk copper-nickel-pgm deposit and the first copper-nickel matte was produced in March 1939 from a pilot facility. Two open pit mines were established in the 1940s and by 1953 the combine was producing 35 per cent of the Soviet Union's total nickel output, 12 per cent of its copper, 30 per cent of its cobalt and 90 per cent of its platinum group metals.

Over the next three decades the mines and associated processing facilities at Norilsk underwent several major expansions. Crucial to the area's development was the discovery in 1960 of huge, high-grade ore resources at Talnakh, approximately 25 km north of Norilsk. Production expanded rapidly during the 1960s and 1970s with the construction of new mines and a concentrator to process the Talnakh ores. This was followed in the early 1980s by the establishment of a smelting complex at Nadezhda. By the late 1980s palladium output exceeded 4 million oz per year.

Following the break up of the Soviet Union in 1991, the operations at Norilsk experienced a difficult period – with a lack of capital for investment the mining and processing infrastructure deteriorated, whilst domestic demand for base metals and palladium slumped. Consequently, by 1996 palladium output was estimated to have fallen below 2 million oz.



In 1997 a controlling share in the company was acquired by Uneximbank through an associated investment company. The access to new capital enabled Norilsk to pay off substantial debts to the state pension fund and resume investment in its facilities. Revenues were also boosted by the devaluation of the rouble in 1998 and, over the next three years, by the increasingly rapid rise in the palladium price, which encouraged an emphasis on improving recoveries of the metal. As a result palladium output at Norilsk climbed to an estimated 2.7 million oz by 2000 and has remained fairly close to this level since then.

Map of local area of Norilsk showing location of copper-nickel-pgm mines and processing facilities.

The Norilsk Nickel group today consists of three main operating divisions, two of which concern copper-nickel-pgm production, the other relates to gold. The Polar Division, located on the Taimyr Peninsula in northern Siberia, operates seven nickel-copper mines and associated metallurgical plants, and is the source of most of the company's pgm production. The Kola Mining and Metallurgical



Drilling underground at Norilsk Nickel's Oktyabrsky mine in northern Siberia, source of much of the company's pgm production.



Russian PGM

Company on the Kola Peninsula mines and processes lower grade nickel-copper deposits containing small amounts of by-product pgm, and also processes some high-grade matte that is shipped in from the Polar Division. Finally the group has a rapidly expanding gold division, which incorporates the Olimpiada mine in the Krasnoyarsk region, operated by ZAO Polyus, and majority shareholdings in the Matrosov (Magadan) and Lenzoloto (Irkutsk) deposits.

Polar pgm

The scale of Norilsk Nickel's Polar Division operations is impressive – especially in view of the remote location and the hostile conditions. The town of Norilsk is located inside the Arctic Circle, where the average daily temperature in February is -32° Celsius, and it is completely isolated from Russia's road and rail systems. The Yenisey River, which links the Norilsk area with Krasnoyarsk some 1,500 km to the south, is navigable during the summer but in winter the site is accessible only by air or via the northern sea route (kept open with ice-breakers) between Dudinka and Murmansk on the Kola Peninsula.

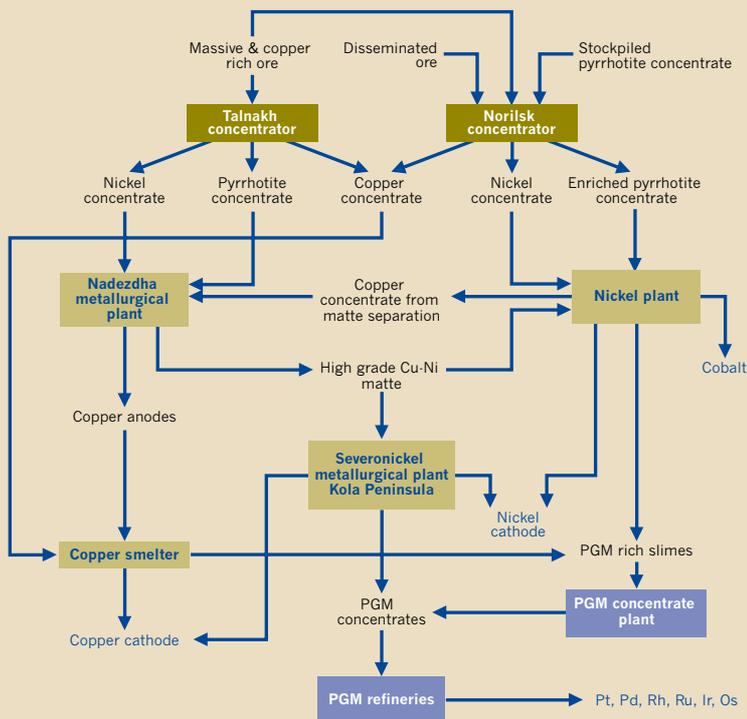
Despite these challenges, in 2002 (the last year for which official data are available) the Polar Division mined and processed just over 13 million tonnes of ore from its six underground mines and one



Tapping molten palladium at the Krastvetmet PGM refinery in Krasnoyarsk

open cast operation at Norilsk-Talnakh. We estimate that total pgm output reached 650,000 oz of platinum, 2.7 million oz of palladium, and 60,000 oz of rhodium. These figures include small amounts of pgm from Norilsk Nickel's operations on the Kola Peninsula, but the volumes are understood to be negligible – probably no more than 20,000 oz per annum in total.

Norilsk Nickel Polar Division - Simplified Processing Flowsheet



A unique suite of pgm deposits

The deposits mined by Norilsk Nickel's Polar Division are unique in their size and are unusually rich in pgm. We estimate that head grades at Norilsk-Talnakh mines average between 10 and 11 grams per tonne pgm – more than twice the typical grade of ore mined in South Africa – in addition to high base metal values of around 1.8 per cent nickel and over 3 per cent copper.

The Norilsk-Talnakh ore bodies occur as large sheets or pods associated with a sequence of layered igneous intrusions. The deposits are considerably wider than the narrow, continuous reefs mined in South Africa, but are much more variable in grade and composition. Consequently, even within a single mine, pgm grades can vary widely.

Three types of ore are mined:

Massive sulphide ores occur in lens-shaped ore bodies typically between 1 and 40 metres thick, and are the richest in nickel. They can also contain extremely high pgm values – up to and beyond 100 g/t in some areas – though a more typical grade would be 12-14 g/t pgm with a palladium to platinum ratio of between 3:1 and 4:1.

Copper-rich ores form a halo around the massive sulphide lenses. They tend to be significantly richer in copper than the massive sulphide ore, but with a relatively low nickel grade. They



Russian PGM

often contain large amounts of platinum and palladium; indeed, grades for these metals can be as high as those in the massive ores.

Wide zones of **disseminated ores**, up to 40 to 50 metres thick, are also associated with the intrusive bodies. These are less rich in both base and precious metals but nevertheless can contain grades of between 5 and 15 g/t pgm.

Mining at Norilsk-Talnakh

There are currently five operating mines at the Talnakh deposit, all of which are underground, and two at the older Norilsk-I deposit including one open cast operation (see map on page 17).

The jewel in Norilsk's crown is the **Oktyabrsky** mine, which in 2002 accounted for 36 per cent of the ore mined by the Polar Division but 49 per cent of the nickel and 53 per cent of the platinum and palladium. This mine extracts some 4.7 million tonnes of ore per annum, of which around 4 million tonnes are rich, massive sulphide material with a high pgm content – probably averaging 13-14 g/t. It also mines small but increasing quantities of copper-rich ore, and a little disseminated ore.

There are two other full-scale mines exploiting the Talnakh deposit: the **Taimyrsky** mine, which in 2002 mined only massive sulphide ore, and the **Komsomolsky** mine, which extracts mainly copper-rich ore. In addition, smaller contributions to production are made by the **Mayak** mine, the oldest and smallest operation at Talnakh, and the new **Skalisty** mine which is exploited via the Komsomolsky infrastructure. The latter is currently building up to full production, expected to be around 1 million tonnes per annum of pgm-rich massive sulphide ore. Both Mayak and Skalisty are now managed as part of the overall Komsomolsky operation.

At the Norilsk-I deposit the massive sulphide ore has long been exhausted, and only disseminated ore is mined, via the **Zapolyarny** underground mine and the **Medvezhy Ruchey** open pit.

From ore to metal

Norilsk Nickel's Polar Division operates two 'enrichment plants' (concentrators) and three metallurgical plants (incorporating smelting, base metal refining and the upgrading of pgm residues). A simplified outline of the processing flow sheet is shown opposite.

The Talnakh Enrichment Plant, which came into operation in 1980, processes the majority of the massive sulphide ores and some copper-rich material to produce nickel, copper and pyrrhotite (iron sulphide) concentrates. Between 1980 and the late 1990s, much of the pyrrhotite concentrate was stockpiled, as the company's metallurgical plants could not treat it effectively. This had quite a significant impact on production, as around 10 per cent of the nickel and quite substantial amounts of pgm were lost through association with the pyrrhotite fraction.

More recently Norilsk Nickel has been treating all current arisings

of pyrrhotite concentrate via an oxidative leach process at the Nadezhda Smelter. It has also begun to upgrade some of its pyrrhotite stockpile through the Norilsk Enrichment Plant – 750,000 tonnes were processed in 2002, although very large stocks are still believed to exist. The Norilsk concentrator (the older of the two, parts of which date from the 1940s) also treats the remaining disseminated, massive and copper-rich ores to produce nickel and copper concentrates.

Nickel and pyrrhotite concentrates from the Talnakh Enrichment Plant are sent to the Nadezhda Smelter, while the Norilsk concentrator's output is sent to the Nickel Smelter. Copper concentrates from both plants are processed at the Copper Smelter. Adjacent to the latter is the precious metals concentrate production area, which upgrades slimes from electrolytic refining operations at both the Nickel and Copper plants. The resulting product, now rich in platinum group metals, is sent for toll refining at independent precious metals refineries, primarily the Krastsvetmet refinery in Krasnoyarsk. Traditionally most of Krastsvetmet's pgm output was in the form of ingots but since 1999 a significant portion of production has been as sponge.

Production Plan to 2015

In March 2003, Norilsk Nickel published its Production Plan to 2015. The aim of the plan is to enable the company to respond to market demand for its metals, while increasing efficiencies and limiting the environmental impact of its operations. The company's



Pouring molten copper-nickel matte at Norilsk Nickel's Nadezhda smelter.



Russian PGM

At Kondyor pgm-bearing river sediments are broken up with high pressure water jets. Lighter clay and sand particles are washed away over screens, leaving the heavier platinum grains behind.



increase in ore production at Norilsk-Talnakh, combined with the shift towards copper-rich ore, will boost pgm output in excess of the growth in base metals production.

A further increase in pgm and base metal output is possible. Norilsk Nickel has stated that it could increase ore production from the Norilsk-Talnakh mines to 20 million tonnes per annum if market conditions were

immediate goal is to increase production from the Norilsk-Talnakh mines to around 14 million tonnes of ore per annum, which represents a 7 per cent increase compared with the 13.06 million tonnes extracted in 2002. Output from the Kola Peninsula operations will fall to 6 million tonnes, keeping the overall level of production stable at 20 million tonnes.

Between 1998 and 2002, the mining of disseminated ore at the older Norilsk-I mines increased by 40 per cent, as the surge in palladium prices made it economic to mine this ore for its pgm values (it is marginal when considered as a base metal ore). However, the new production strategy will reverse this trend, with output of disseminated ore declining in favour of a modest increase in mining of massive sulphide material and a significant jump in the extraction of copper-rich ore. Output of the latter was below 1 million tonnes per annum in 1998, reached almost 3 million tonnes in 2002, and is planned to expand to 5 million tonnes in 2005 under the current Production Plan.

As a result of the planned change in the mix of ores mined, nickel output from the Taimyr Peninsula is expected to rise to 200,000 tonnes per annum from 185,000 tonnes in 2002, an increase of 8 per cent. The company has stated that pgm production will remain approximately constant, but we think it likely that the overall

favourable. However, this would require substantial additional investment, not only in the mines but also to overcome capacity constraints at the concentrators. A decision on whether to commit funds to such an expansion is likely to be made in 2005. The company could also accelerate the rate at which it processes stockpiled pyrrhotite concentrate but again this would require additional investment in processing capacity.

On the metallurgical side, Norilsk Nickel plans to upgrade its smelting facilities at Nadezhda and the Copper plant, which will permit the closure of the smelter at the Nickel plant. Not only will this result in lower smelting costs, it will also help reduce sulphur dioxide emissions substantially.

Research is currently underway to assess further possible investments in processing infrastructure. These include new flotation technology with the potential to increase recoveries by up to 5 per cent and the introduction of high-grade matte leaching-refining technology at Nadezhda.

Rivers of platinum: alluvial mining in the Far East of Russia

In recent years significant quantities of platinum have been produced from two alluvial operations in the Far East of Russia. The larger of these, Kondyor, is located in a crater-like bowl surrounded by mountains in the Ayano-Maisk region of Khabarovsk (see map on page 16). The Koryak deposit is found on the Kamchatka Peninsula. Both operations are remote and experience harsh winter weather; consequently, mining takes place only during the summer season, usually from May to September.

The existence of platinum at **Kondyor** was first confirmed in 1957 but it was initially calculated that the deposit contained just 2 tonnes of metal and, given the remote location, was therefore uneconomic. As a result it was more than 20 years before the potential of Kondyor was fully appreciated. In 1978 and 1979 a detailed re-evaluation of the area's platinum potential resulted in the collection of numerous platinum nuggets. This was followed by a

Recovery of egg-sized nuggets of platinum is not uncommon at Kondyor; the largest nugget recovered from the operation to date weighed a massive 3.52 kg.





Russian PGM

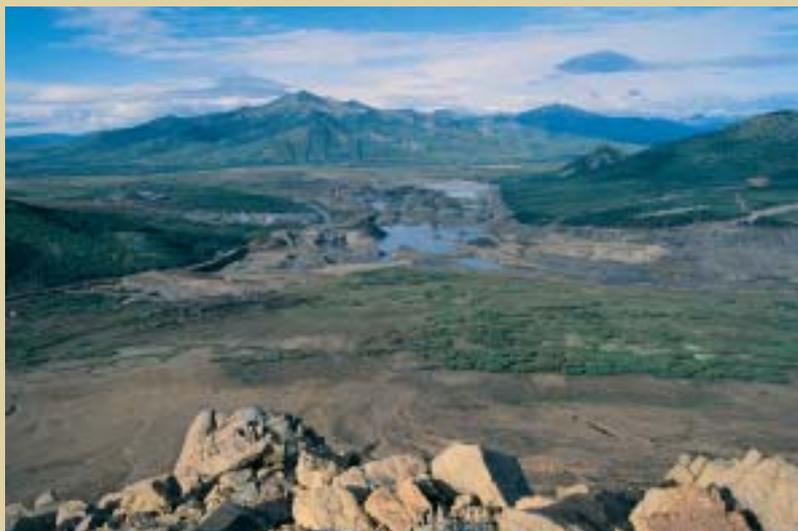
trenching and sampling campaign in 1980 and 1981 that was undertaken by a local gold mining company, the Amur artel. Commercial exploitation of the deposit by Amur began in 1984 with the extraction of 60 kg of platinum; by 1987 production had reached 1 tonne. According to the company, the level of production has been more or less stable since 1990 at around 3 tonnes (~95,000 oz) of platinum per annum, although recent reports suggest that output may have risen to closer to 4 tonnes (~130,000 oz) in 2003. It is thought that production in the range of 3 to 4 tonnes per year is sustainable for some years to come.

The processing method at Kondyor is relatively simple because the platinum occurs in discrete grains. Bulldozers scrape out the bottom of the riverbed and drive the material to sluices in which hydraulic guns break up and wash the ore allowing heavier particles to fall through a mesh into collectors. The artel currently has 14 of these hydraulic units in operation. There follows further on-site washing stages to separate out the precious metal grains (in effect, panning on an industrial scale). These are collected and are passed through a final gravity concentration stage and a shaking table to separate pgm and gold concentrates. The platinum grains can be extraordinarily large: the largest nugget found so far weighed 3.522 kg (around 110 oz) with a metal content worth in the region of \$100,000 at today's prices.

The Koryak alluvial operation is located on the Pustaya river system, which drains an area of pgm-bearing zoned ultrabasic rocks in the Kamchatka Peninsula in the Far East of Russia. Prospecting took place from 1990 and in 1994 the Chaibukha Mining Artel won a tender to enter into a 25 year mining licence agreement with Koryakgeologodobycha (KGD). Trial mining at two sites began that year and full-scale operations started in 1995.

The mining and processing operations at Koryak are similar to

River sediment at Koryak is channelled down sluices, allowing dense platinum grains to settle out. These are collected manually before undergoing further washing prior to bagging and dispatch by air to a pgm refinery.



View across the Pustaya river valley in Kamchatka, source of KGD's alluvial platinum.

those at Kondyor, encompassing mining of river gravels by bulldozer followed by a series of washing and gravity separation stages to concentrate the platinum grains.

Production peaked in 1998 at close to 7 tonnes of platinum but then halved the following year after a dispute between Chaibukha Mining and KGD resulted in their agreement being dissolved. Chaibukha subsequently transferred its mining equipment from Koryak to gold projects in Irkutsk. KGD continues to mine the Koryak alluvial platinum deposits but output is believed to have fallen to between 2 and 3 tonnes (65,000 to 95,000 oz) annually. The reserves at Koryak are understood to be smaller than those at Kondyor, with the richest deposits having already been depleted.

The Urals – potential from the past

Large alluvial platinum deposits were discovered in the central Ural Mountains in 1823 and mining in the area grew rapidly. By the end of the 19th century the alluvial deposits of the central Urals had become the world's dominant source of platinum. The most easily accessible high-grade placer deposits, however, had largely been exhausted by the end of the 1920s and mining has since dwindled to a handful of small-scale dredging operations producing very modest volumes of platinum.

The Urals region remains of interest, however, as a potential future source of platinum. Exploration is examining the possibility of exploiting alluvial platinum in the central Urals area that was too fine-grained to have been recovered by former mining operations. Previously unmined placer deposits that have been buried under sediment may also exist, whilst the poorly explored northern Urals area offers the potential to host as yet undiscovered alluvial platinum fields.

Estimated Russian Mine Production of Platinum and Palladium in 2003
'000 oz

	Pt	Pd
Norilsk	650	2,700
Amur artel, Kondyor	130	0
KGD, Koryak	90	0
Urals	10	0
Total	880	2,700

