USGS
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USGS Mineral Resources Program

Platinum-Group Elements—So Many Excellent Properties

As part of a broad mission to conduct research and provide information on nonfuel mineral resources, the U.S. Geological Survey (USGS) supports science to understand

- *How and where PGE resources form and concentrate in Earth's crust*
- *How PGE resources interact with the environment to affect human and ecosystem health*
- *Trends in the supply of and demand for PGE in the domestic and international markets*
- *Where undiscovered PGE resources might be found*

Why is this information important? Read on to learn about PGE and the important role they play in the national economy, in national security, and in the lives of Americans every day.

Photograph from http://earthobservatory.nasa.gov/IOTD/view.php?id=4414.

The platinum-group elements (PGE) include platinum, palladium, rhodium, ruthenium, iridium, and osmium. These metals have similar physical and chemical properties and occur together in nature. The properties of PGE, such as high melting points, corrosion resistance, and catalytic qualities, make them indispensable to many industrial applications.

Pre-Columbian peoples found naturally occurring platinum and platinum-rich alloys in stream deposits in Colombia and Ecuador and used them to make jewelry. In the 1500s, Europeans described platinum from the New World as "a substance which it has not hitherto been possible to melt by fire or by any of the Spanish arts." The Spaniards found platinum grains intermingled with gold nuggets they recovered from stream deposits and called the metal "platina." The metal had no known use and was considered worthless. Small samples of platinum-enriched nuggets from South America reached Europe during the 1740s. Platinum was described as a new metal in 1750, followed by iridium and osmium in 1803, palladium and rhodium in 1804, and ruthenium in 1807.

How Do We Use PGE?

Although platinum is well known for its use as jewelry and as an investment commodity, the major applications of PGE are industrial. Their leading use is in catalytic converters, which decrease hydrocarbon, carbon monoxide, and nitrous oxide emissions in automobile exhaust. The chemical industry uses platinum or platinum-rhodium alloys to manufacture specialty silicones and to make nitric oxide, the raw material for fertilizers, explosives, and nitric acid. In the petrochemical industry, platinum-supported catalysts are needed to refine crude oil and to produce high-octane gasoline. In the electronics industry, PGE components increase storage capacities in computer hard disk drives and are ubiquitous in electronic devices, multilayer ceramic capacitors, and hybridized integrated circuits. The glass manufacturing industry uses PGE to produce fiberglass and liquid-crystal and flat-panel displays. PGE alloys are exceptionally hard and durable, making them the best coating for the industrial crucibles used to manufacture chemicals and synthetic materials, including the high-purity sapphire crystals used to make light-emitting diodes. Because platinum does not corrode inside the human body and allergic reactions to platinum are rare, it is used in medical implants such as pacemakers. PGE are also used in cancer-fighting drugs.

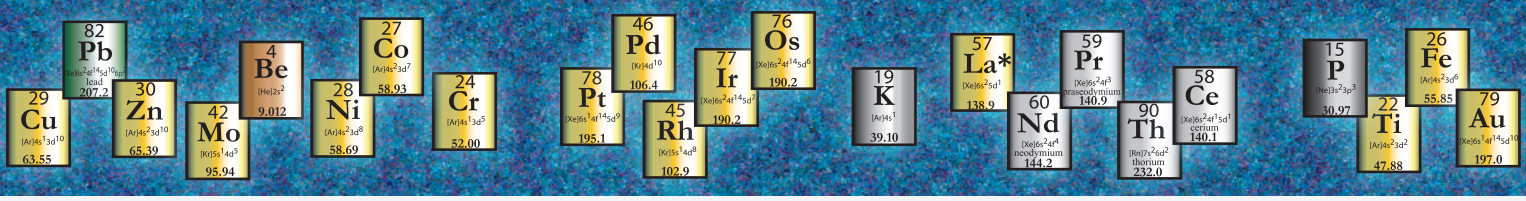
The PGE could play a crucial role in fuel cell technology, which could revolutionize clean energy production for cars, homes, and businesses. From http://www.platinum.matthey.com/about-pgm/image-gallery/.

Their white coloration, strength, and tarnish resistance make platinum alloys an ideal choice for jewelry. Platinum, palladium, and rhodium are used for investment in the form of coins and bars, and as stocks, mutual funds, or exchange-traded funds.

Where Do PGE Come From?

PGE are among the rarest metals on earth; the upper crust of the Earth contains about 0.0005 parts per million (ppm) platinum. Today, the average grade of PGE in ores mined primarily for their PGE concentrations range from 5 to 15 ppm. Over 100 minerals contain PGE as an essential component. In most rocks, platinum-group minerals are very small, ranging in size from less than a micron to a few hundred microns in diameter. Geologists can spend a lifetime working on rocks enriched in PGE and never see a platinum-group mineral in a hand specimen, so the presence of PGE must be confirmed by laboratory analysis.

Most of the world's PGE are concentrated in magmatic ore deposits, which form during the cooling and crystallization of magma. If mafic to ultramafic magmas become saturated in sulfur, an immiscible sulfide liquid will separate from the silicate magma and form globules that naturally concentrate metals like copper, nickel, and PGE. As the magma cools, the PGE-enriched sulfide globules accumulate and crystallize to form PGE mineral deposits. Most magmatic copper-nickel-PGE deposits are found with volcanic and plutonic rocks that form where large volumes of mafic magma move from the Earth's mantle into the crust. Erosion of PGE-enriched rocks and physical concentrations of heavy mineral particles, by the action of moving water, can produce PGE-enriched placer deposits.



Worldwide Supply of and Demand for PGE

Until 1920, almost all of the world's PGE production came from placer deposits in Russia and Colombia. Most PGE produced today are from mineral deposits discovered in Siberia in 1919 and in southern Africa in the 1920s. Significant development of these deposits did not begin until the 1960s, when industrial demands for PGE increased. From 1900 to 2011, approximately 14,200 metric tons of PGE were produced, with roughly 95 percent of the production having occurred since 1960. An analysis of production statistics reveals that approximately 90 percent of global PGE production came from South Africa and Russia, with Canada, the United States, and Zimbabwe accounting for 5, 2, and 1 percent of production, respectively.

A secondary supply of platinum, palladium, and rhodium is obtained through the recycling of jewelry, electronic equipment, and catalytic converters taken from vehicles. Recycling volumes are sensitive to PGE prices, with higher prices typically leading to higher recycling volumes. Recycled platinum, palladium, and rhodium provide a significant proportion of total world supply, closing the gap between mine production and consumption. For example, in 2011, recycling accounted for about 24 percent of the total platinum and palladium supply and about 27 percent of the total rhodium supply.

Platinum nugget weighing 0.444 kilograms from Sverdiovsk Oblast, Russia, in the Ural Mountains (catalog number NMNH 73736 00 from the Smithsonian National Museum of Natural History).

Exploration and mining companies have found approximately 104,000 metric tons of PGE (with minor gold) in mineral deposits around the world that could be developed. For PGE, almost all known production and resources are associated with three geologic features: the Bushveld Complex, a layered mafic-to-ultramafic intrusion in South Africa; the Great Dyke, a layered mafic-to-ultramafic intrusion in Zimbabwe; and sill-like intrusions associated with flood basalts in the Noril'sk-Talnakh area, Russia.

In the United States, the Stillwater Complex, a mafic-to-ultramafic igneous intrusion in Montana, has a deposit that has produced roughly 305 metric tons of platinum and palladium since 1986. Drilling estimates indicate another 2,200 metric tons are present. Mining has progressed to depths of 900 m below the surface, but the bottom of the ore deposit has not been reached. Rough geological estimates suggest another 1,000 to 6,200 metric tons of PGE could be present at depth. In the future, PGE may be produced from deposits found near the base of the Duluth Complex, another group of igneous intrusions in Minnesota.

Did you know... ***The largest platinum nuggets ever found were discovered in stream deposits in the Ural Mountains, Russia. The largest was found in 1843 and weighed 9.635 kilograms.***

How Do We Ensure Adequate Supplies of PGE for the Future?

PGE are strategic and critical materials for many nations because they are essential for important industrial applications but are mined in a limited number of places and have no adequate substitutes. The United States' net import reliance, as a percentage of apparent consumption, is about 90 percent. The availability and accessibility of PGE supply could be (and have been) disrupted by social, environmental, political, and economic events.

To help predict where PGE supplies might be located, USGS scientists study how and where PGE resources are concentrated in the Earth's crust and use that knowledge to assess the likelihood that undiscovered PGE deposits may exist. Techniques used for assessing mineral resources were developed by the USGS to support the stewardship of Federal lands and evaluate mineral resource availability in a global context. The USGS also compiles statistics and information on the worldwide supply, demand, and flow of PGE. These data are all used to inform U.S. national policymakers.

The world's highest grade PGE deposit occurs in the Stillwater Complex of Montana, where grades are as high as 23 grams per ton (g/t) PGE. In comparison, ore grades in the Bushveld Complex of South Africa typically range from 6 to 10 g/t PGE.

Did you know... ***Virtually all electronic devices, including cell phones and computers, contain PGE in their circuitry. Approximately 2 to 6 grams of PGE are used in automobile catalytic converters.***

For More Information

- On production and consumption of platinum: http://minerals.usgs.gov/minerals/pubs/commodity/platinum/index.html#mcs
- Deposit models: http://pubs.usgs.gov/of/2012/1010/ http://pubs.usgs.gov/of/2010/1179/
- Assessment report on southern Africa PGE: http://pubs.usgs.gov/sir/2010/5090/q/

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Ring image from http://www.platinum.matthey.com/about-pgm/image-gallery

The USGS Mineral Resources Program is the principal Federal provider of research and information on PGE and other nonfuel mineral resources. For more information, please contact:

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ISSN 2327–6932 (online)
http://dx.doi.org/10.3133/fs20143064