Earth-Science Reviews 131 (2014) 1–21

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Platinum in Earth surface environments

F. Reith [a,b,*], S.G. Campbell [c], A.S. Ball [d], A. Pring [e], G. Southam [f]

[a] Centre for Tectonics, Resources and Exploration (TRaX), School of Earth and Environmental Sciences, The University of Adelaide, North Terrace, Adelaide, SA 5005, Australia
[b] CSIRO Land and Water, Environmental Biogeochemistry, PMB 2, Glen Osmond, SA 5064, Australia
[c] Department of Earth Sciences, The University of Western Ontario, London, Ontario N6A 5B7, Canada
[d] School of Applied Sciences, Royal Melbourne Institute of Technology University, Bundoora, VIC 3083, Australia
[e] Department of Mineralogy, South Australian Museum, Adelaide, SA 5000, Australia
[f] School of Earth Sciences, The University of Queensland, St Lucia, QLD 4072, Australia

A R T I C L E I N F O

Article history:
Received 22 September 2012
Accepted 18 January 2014
Available online 24 January 2014

Keywords:
Platinum
Cycling
Geochemistry
Mobility
Geobiology
Anthropogenic

A B S T R A C T

Platinum (Pt) is a rare precious metal that is a strategic commodity for industries in many countries. The demand for Pt has more than doubled in the last 30 years due to its role in the catalytic conversion of CO, hydrocarbons and NO_x in modern automobiles. To explore for new Pt deposits, process ores and deal with ecotoxicological effects of Pt mining and usage, the fundamental processes and pathways of Pt dispersion and re-concentration in surface environments need to be understood. Hence, the aim of this review is to develop a synergistic model for the cycling of Pt in Earth surface environments. This is achieved by integrating the geological/(biogeo)chemical literature, which focuses on naturally occurring Pt mobility around ore deposits, with the environmental/ecotoxicological literature dealing with anthropogenic Pt dispersion. In Pt deposits, Pt occurs as sulfide-, telluride- and arsenide, native metal and alloyed to other PGEs and iron (Fe). Increased mining and utilization of Pt combined with the burning of fossil fuels have led to the dispersion of Pt-containing nano- and micro-particles. Hence, soils and sediments in industrialized areas, urban environments and along major roads are now commonly Pt enriched. Platinum minerals, nuggets and anthropogenic particles are transformed by physical and (bio)geochemical processes. Complexation of Pt ions with chloride, thiosulfate, ammonium, cyanide, low- and high molecular weight organic acids (LMWOAs and HMWOAs) and siderophores can facilitate Pt mobilization. Iron-oxides, clays, organic matter and (micro)biota are known to sequester Pt-complexes and -particles. Microbes and plants are capable of bioaccumulating and reductively precipitating mobile Pt complexes. Bioaccumulation can lead to toxic effects on plants and animals, including humans. (Bio)mineralization in organic matter-rich sediments can lead to the formation of secondary Pt particles and -grains. Ultimately, Pt is enriched in oceanic sediments, where Pt is commonly concentrated in manganese (Mn) oxides. When these sediments are subducted, Pt re-enters the magmatic cycle. In conclusion, this review demonstrates that geological, geochemical as well as biological and most recently anthropological processes are strongly interlinked in driving the cycling of Pt in surface environments.

Contents

* Corresponding author at: CSIRO Land and Water, PMB 2, Glen Osmond, South Australia 5064, Australia. Tel.: +61 8 8303 8469; fax: +61 8 8303 8550.
E-mail address: Frank.Reith@csiro.au (F. Reith).

0012-8252/$ – see front matter.
http://dx.doi.org/10.1016/j.earscirev.2014.01.003

1. Introduction

Platinum is one of the rarest elements in the Earth's crust (Fig. 1; Wedepohl, 1995). It is one of six platinum group elements (PGEs), which also include osmium (Os), iridium (Ir), palladium (Pd), ruthenium (Ru), and rhodium (Rh). PGEs are highly sought after because of their unique physical and chemical properties (Macdonald, 1987). Platinum is a non-reactive refractory metal with high boiling- and melting-points, which makes it resistant to oxidation and corrosion (Bond, 1991). Hence, Pt compounds are commonly used as catalysts in (de)hydrogenation-, dehalogenation-, isomerisation- and oxidation reactions (Bond, 1991). Currently, the most important use of Pt is in automobile catalytic converter units (Fig. 2). But Pt is also required as catalyst in fuel cells, the production of petroleum and other petrochemicals from crude oil, and the oxidation of ammonia (Fig. 2C). In addition, Pt is used in resistance thermometers and thermocouples, glassmaking, jewelry, dentistry, prosthetics and anticancer drugs (Brenan, 2008). Because of these widespread industrial uses and its rarity, Pt has become a strategic commodity for many countries, e.g., the USA, China and the Euro-zone countries (Fig. 2; Koek et al., 2010; Mudd, 2012).

The Republic of South Africa and the Russian Federation control more than 95.9% of the 80,000 t known PGE reserves (Fig. 2B; Koek et al., 2010). With their large deposits in the Bushveld Complex and Norilsk they also account for more than 90% of the annual global production (Mudd, 2012). Production in other countries is limited to the mining of smaller deposits including placers, refining of Pt from Ni-rich secondary lateritic deposits and recycling of Pt from industrial wastes (Mungall and Naldrett, 2008; Mudd, 2010). To break the South

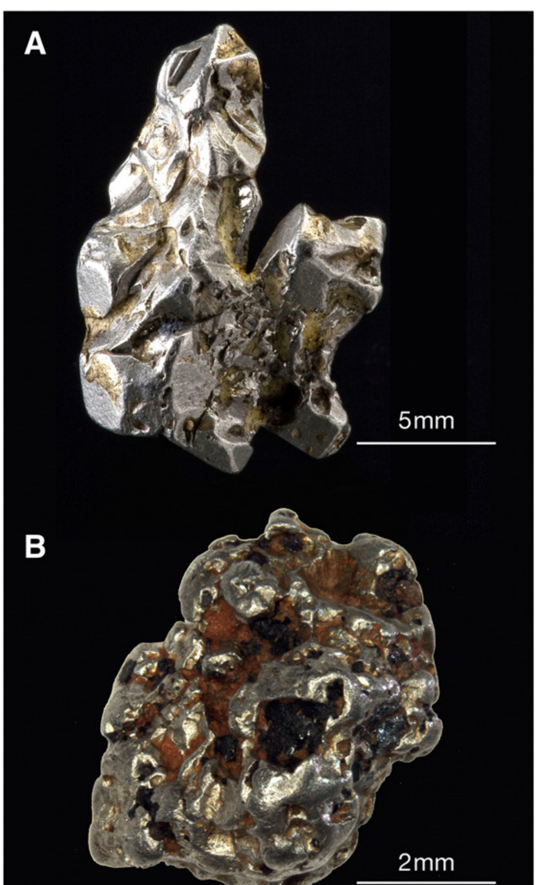

Fig. 1. Optical micrographs of Pt nuggets. (A) Cubic primary nugget from the Kondyer Massif, Siberia, Russia; (B) subhedral surface transformed placer nugget from Platina Deep Lead, Fifield, New South Wales, Australia.
Panel A is after Cook (2011); image J. Budd.

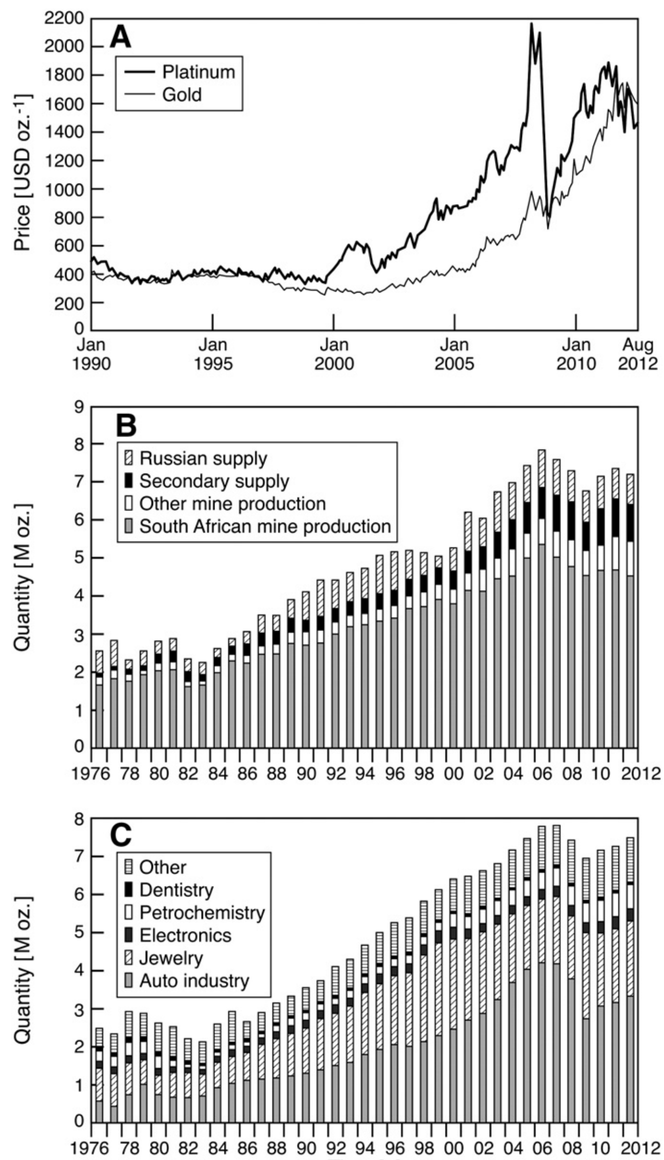

Fig. 2. Economics of Pt. (A) Comparison of Pt and Au prices from 1990 to August 2012; world production (B) and demand of Pt by industry (C) since 1976.
After Butler (2012) and CPM-Group (2012).