

# Geology of Platinum Group Elements

CIM SPECIAL VOLUME 54: THE GEOLOGY, GEOCHEMISTRY, MINERALOGY AND MINERAL BENEFICIATION OF PLATINUM-GROUP ELEMENTS

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This CIM Special Volume 54 (publication) edited by Louis J. Cabri is the successor to the CIM Special Volume 23 first printed in 1981 and reprinted in 1989. It is an ambitious undertaking aimed at presenting a series of review papers on the platinum group elements (PGEs) rather than attempting to deliver results of the very latest research in the field. Of the 26 papers included, one is devoted to analytical methods, five to phase geochemistry and three to mineral processing and extractive metallurgy. The other contributions are review papers covering the full range of geological settings in which the PGEs occur.

Papers include reviews of the main PGE deposits comprising those associated with Sudbury (Canada), the Bushveld Complex (South Africa), the Stillwater Complex (U.S.A.), the Great Dyke (Zimbabwe) and Noril'sk (Russia). These papers have been prepared by workers with enormous experience of the deposits covered and incorporate the results of the key relevant contributions to the literature. As such they can be read in the confidence that they reflect the consensus that has emerged about the origin of the deposits and the primary controls of the mineralisation. This will be of particular benefit to professionals not expert in the field but who may need a balanced and authoritative description of these key primary magmatic deposits which currently provide virtually all the newly mined supplies of the PGEs.

Deposits associated with layered intrusions that are currently the focus of exploration in northern Finland and the Kola Peninsula in Russia are also covered, and a convenient description of their geological setting, characteristics and potential as major sources of PGE is provided by T. T. Alapieti and J. J. Lahtinen. The association of the PGEs with komatiitic-hosted nickel sulfide mineralisation is also recognised in a separate paper devoted to this topic, by C. M. Lesher and R. R. Keays. There

are also papers describing PGE mineralisation associated with minor magmatic deposits in the Kola Peninsula, by A. V. Dedeev and colleagues.

More exotic settings associated with hydrothermal fluids, contact mineralisation and placer mineralisation are the focus of several detailed reviews. The conclusion that can be drawn is that there remain many unanswered questions on the chemical and physical controls on these styles of mineralisation. The Platreef of the Bushveld Complex has demonstrated the importance of seeking an understanding of the underlying genesis of contact mineralisation. A robust model for the control of PGE mineralisation is needed to predict continuity of the ore zone as this underpins the integrity of resource estimation and grade control procedures during mining.

The paper on sample preparation and analytical methods by E. L. Hoffman and B. Dunn, should be compulsory reading for anyone embarking on PGE exploration – all too often projects considered to have high potential for hosting PGEs prove to be geochemically depleted in these metals when subject to geologically-controlled sampling and analysis by experienced laboratories. The paper provides insights into the importance of selecting the correct analytical procedures when determining PGE concentrations in geological material and matching these to the mineralogical characteristics of the host samples and also into the precision and accuracy required.

The commercial sensitivity and proprietary nature of downstream processing of PGE mineralisation is well known and the paper on the beneficiation of South African PGE ores, by R. K. W. Merkle and A. D. McKenzie, is a very useful review. While probably of limited value to a mineral process engineer for design purposes, it does demonstrate why new PGE projects are often established as joint ventures with existing producers

who have the necessary expertise in the field. The key role of process mineralogy is recognised in the publication and demonstrated in a paper on the mineralogy and behaviour of the platinum group metals during processing of the Noril'sk ores by M. Z. Komarova and colleagues.

The text runs to 844 pages and, surprisingly, it has no subject index. Furthermore none of the papers has an abstract which means that retrieval of information is not going to be easy for the casual reader. However, the CIM offers a CD-ROM containing the papers in PDF format and this allows a word search in the usual way. However, this is no substitute for a professionally compiled index. While clearly it must have been a formidable task securing all the contributions, arranging reviews and coordinating final versions, the editor would have produced a more useful volume if he

had been more proactive in the final production stage. It would, for example, have been helpful if in the Preface Cabri had explained how his own contribution on the platinum group minerals related to the role of process mineralogy where this was described in papers on beneficiation.

Nevertheless for geologists, chemists and mineral process engineers seeking a convenient format for obtaining background information on PGE projects the effort of working through the primary material would be well worthwhile.

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## Resin-Supported Palladium Complexes for Catalyses in Water

One of the aims of green chemistry is to switch from organic solvents to water for organic transformations, to reduce environmental problems and contribute to safety. Palladium (Pd)-phosphine complexes are highly active and widely used in organic catalyses, with organic solvents, although Suzuki chemistry can be performed in water/EtOH systems. Water-soluble phosphine catalysts are available, but as many substrates are insoluble in water, they have been received less attention. However, if Pd-phosphine complexes, combined with a solid support, could undertake catalyses in water, it would be a powerful tool in organic synthesis.

Now, Y. Uozumi from the Institute for Molecular Science, Okazaki, Japan, reports the preparation of Pd-phosphine complexes bound to an amphiphilic polymer resin, and their success as catalysts for various reactions in aqueous media (*J. Synth. Org. Chem., Jpn.*, 2002, 60, (11), 1063–1068).

Polystyrene-poly(ethylene glycol) (PS-PEG) is a commonly used resin, functionalised for attachments. PS-PEG resin beads show relatively uniform swelling in solvents of different polarities. A PS-PEG resin with an amino group was chosen as a support for phosphines. The resin-supported phosphines were then treated with excess  $[\text{PdCl}(\eta^3\text{-C}_3\text{H}_5)]_2$  (Pd:P = 1.2:1) to form a Pd monophosphine complex.

The Pd-phosphine-PS-PEG resin was successfully tested for various transformations in water, such as allylic substitution, hydroxycarbonylation of aryl halides, the Heck reaction, cross-couplings of aryl halides and allyl acetates with arylboron reagents, asymmetric allylic substitution, etc. The catalyst could be recovered and reused without significant loss of activity and selectivity. A novel chiral *P,N*-ligand was prepared on PS-PEG, and with Pd, in water, gave  $\pi$ -allylic substitutions of cyclic and acyclic substrates of enantioselectivity up to 99% ee.

## Red-Light Emission Using Iridium

A team from the National Tsing-Hua University, Taiwan, report a new route to design electroluminescent polymers (X. Chen, J.-L. Liao, Y. Liang, M. O. Ahmed, H.-E. Tseng and S.-A. Chen, *J. Am. Chem. Soc.*, 2003, 125, (3), 636–637). They grafted high-efficiency green  $\text{Ir}(\text{ppy})_3$  and red  $\text{btp}_2\text{Ir}(\text{acac})$  phosphorescent complexes as dopants and carbazole (Cz) charge transport moieties onto alkyl side chains of fully conjugated polyfluorene polymers, for polymer light-emitting diodes (PLEDs).

The fabricated PLEDs emitted red light with high efficiency,  $2.8 \text{ cd A}^{-1}$  at 7 V and  $65 \text{ cd m}^{-2}$ , and can emit broad band light having blue, green and red peaks ( $2.16 \text{ cd A}^{-1}$  at 9 V). Incorporating Cz significantly increases the efficiency and lowers the turn-on voltage.