Platinum-Group Elements: Mineralogy, Geology, Recovery

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CHAPTER 1

Introduction

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Introduction

1.1. Preface

The six platinum-group elements (PGE), ruthenium, rhodium, palladium, osmium, iridium and platinum, have long been considered, when grouped with gold and silver as the "precious metals". Unfortunately, in contrast to gold and silver, a veil of secrecy has prevailed, until recently, on the mineralogy, geochemistry and geology of the PGE. International symposia such as the International Platinum Symposium of the *Society of Economic Geologists*, held in Denver in 1975, and that on Nickel-Sulphide and Platinum-Group-Element Deposits of the *Mineralogical Association of Canada* in Toronto in 1978, have been instrumental in encouraging and stimulating more open research; especially because both symposia were followed by refereed special publications within a year. The 3rd International Platinum Symposium in Pretoria (July, 1981) should also provide significant contributions.

Desborough and Leonard (1976) made the point that it is not possible for symposium papers to be distributed to all authors so that "there is now the opportunity for someone to write the definitive paper based on all the papers" resulting from the Symposium. This suggestion, after some fermentation, evolved in 1978, prior to the Toronto Symposium, into a concept for a book. It was clear that a single definitive paper could not be written because of the range of material to be covered. However, a series of chapters, with the participation of leaders in the field, would be a useful contribution, a reference source representative of the explosion of PGE information that has been published in the 1970s, as well as a base for developing and encouraging future research.

Quality books, on specialized subjects, produced by commercial publishers are becoming extremely costly and can be afforded by fewer individuals. Traditionally, books published by professional and technical societies are sold with a smaller mark-up that is due, in part, to smaller advertising budgets and volunteer workers. This is one of the reasons I sought and obtained the support of the Geology Division of The Canadian Institute of Mining and Metallurgy (CIM), in April 1979, for publication of this special volume on the PGE. We are grateful, indeed, for the support of the Geology Division of CIM and to CIM for publication of this special volume.

The chapter manuscripts have all been critically reviewed by at least two experts, listed in Table 1, and the revised and edited manuscripts were submitted to CIM for publication between June 1980 and February 1981. We are extremely grateful for the careful, helpful and very prompt reviews and we trust that this volume will be timely and remain a useful reference, world-wide.

1.2. Terminology

Reference to the platinum-group elements (PGE) and the platinum-group minerals (PGM) in the literature is inconsistent and misleading. The earliest, and still common, term is "precious metals" or PM. This is, unfortunately, misleading because the geochemistry of silver and gold does not correlate with that of the PGE. Another misleading term used is "platinoid". It is erroneous on two grounds. Firstly, the suffix "oid", derived from the Greek "-οε ⌊δήs" i.e. "-ο-" meaning "of preceding element or connective" plus "-ε ⌊δήs" meaning "having the form of or like". The well-known usage, as in humanoid, for example, illustrates the fallacy of using "platinoid". A second, and equally important reason is that it is sometimes difficult, if not impossible, to determine if an author is referring to the PGE or the PGM. A matter of considerable significance! Unfortunately, although there is nothing wrong with reference to the PGE as the platinum-group *metals,* it is to be discouraged because the abbreviation for the latter may be confused with that used for platinum-group *minerals.*

TABLE 1. Technical reviewers*

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1.3. Contents

Selection of material to be covered in individual chapters was based on what was considered to be useful to those engaged in academic and government research, mineral exploration and exploitation of PGE mineral deposits. Constraints imposed included the paucity of information on exploration geochemistry and a planned desire not to cover meteorites nor the extractive metallurgy of the PGE, but to conclude with mineralogical factors influencing the beneficiation of different types of PGE mineralization (Chapter 11). Duplication of some material was unavoidable in order to make chapters coherent entities, permitting different chapters to be read separately.

The inorganic chemistry of the PGE is a very large and active area because of the importance of industrial applications and their predominance over use in jewellery during the last 30-40 years. Chapter 2 covers those aspects of the inorganic chemistry thought useful to geochemistry. Besides material from the literature, the reader is directed to several Eh-pH diagrams, some of which are new or are considered to be improvements over previously published diagrams.

Chapter 3 includes data pertinent to the physical chemistry and phase relations of the PGE and the compounds they form with elements selected for their known or potentially important mineralogical significance. These data are dispersed in the chemical, mineralogical and metallurgical literature, and have been collected up to 1979. Some 1980 references are also included. The tabular presentation was selected as the most efficient manner of handling the subject matter; it is accompanied by various solubility and phase diagrams. There is no doubt that this chapter will provide the encouragement and data base for realization of the authors' suggestion that: "Careful, systematic studies of ternary and quaternary compounds together with the phase relations between them will add immeasurably to our knowledge of the mineralogy and geochemistry of the PGE".

The wealth of trace-element geochemical data, mainly derived in the last decade by radiochemical neutron activation analysis (RNAA), is covered in Chapter 4. While it is evident that the range of elements analyzed and the low levels of detection have resulted in tremendous progress, there is much more work required for a definitive understanding of PGE distribution in the source rocks of ultramafic and mafic magmas.

Because of the scarcity of PGE and their often erratic distribution in nature, a discussion of sample preparation techniques is provided in Chapter 5. These techniques range from sampling in the field through to mineral separation techniques in the laboratory.

The analytical methods of PGE, described in Chapter 6, include mineralogical, assay and neutron activation. It is quite clear that, while many of these techniques may be routinely performed on PGE-bearing materials, the methods, in detail, are not routine and deserve careful study for consistently reliable results.

The numerical explosion of newly named PGM, demonstrated graphically most recently by Cabri (1981a), is ascribed to the application of the electron microprobe. Although these new PGM have been discovered during the course of more extensive mineralogical studies, it is important to appreciate fully the significance of careful characterization of new species. Where would mineral deposits geology, milling and extractive processes be without a proper understanding of the mineralogy of, say, copper deposits? Does copper occur as chalcopyrite or is it in the form of secondary sulphides such as chalcocite or covelline? Perhaps it occurs as oxidized minerals such as malachite or as related and more complex minerals. No such easy identification for the PGM has been possible until now. It takes years, if not decades, for textbooks on ore microscopy to provide a comprehensive and up-to-date coverage of rarer mineral groups such as the PGM. Chapter 7 is an attempt to fill this void in the literature and includes a critical appraisal of some dubious, named minerals. It also demonstrates the pitfalls in relying on four-wavelength reflectance data, and points to the significance of quantitative colour values based on good spectral data. Chapter 7 also nitpicks through the Powder Diffraction File cards on PGM and I am delighted to note that the majority of critical comments made in Chapter 7 are already being attended to by the JCPDS International Centre for Diffraction Data (P. Bayliss, pers. comm., 1981). It is evident, however, that there is no detailed knowledge of PGE oxides, hydroxides, chlorides, etc. This is an area of PGE mineralogy that will receive more attention in the near future as evidenced by the important discovery of unnamed $Pd_4Bi_5Cl_3$ by Karpenkov *et al.* (1981).

Because the confirmation of a PGM's identity is so dependent on electron microprobe analysis, Chapter 8 has been designed to provide the analyst with tabular data on representative PGM analyses from most PGE deposits and occurrences in the world. These tables include the ideal composition and reported elemental substitutions, all in weight per cent. Chapter 8 also includes a critical assessment of minerals reported to contain minor or trace quantities of PGE. This area of analysis is very important, because such data can be effectively used in metal balance calculations aimed at maximizing metal recoveries (Cabri, 1981b). Analytical developments for sub-ppb levels, such as reported by Rucklidge (1980), are significant. Much remains to be done here.

A new systematic approach for recording unnamed PGM is introduced in Chapter 9. Unnamed PGM from 1959, when the electron microprobe was first applied to PGM, to 1979 are recorded, detailed and critically commented upon. The author would appreciate knowing whether he has missed any published unnamed PGM reported in that period.

Wagner's (1929) classic book on platinum deposits would not have been reprinted in 1973, word for word, if an up-to-date book on South African PGE deposits had been published by then. Although Mertie's (1969) monograph is an excellent compilation of what was known of the mineralogy and geochemistry of PGE deposits prior to the 1970s, and will remain a valuable reference, it could not include the wealth of PGE data relevant to mineral deposits the publication of which was triggered by the 1975 Denver Symposium. Chapter 10 covers the major and many minor PGE deposits with a view to establishing a systematic and comprehensive classification. In addition, PGE concentrations in magmatic sulphide ores are examined from analytical and geochemical grounds with a view to modelling and understanding the genesis and the individual characteristics of these deposits.

Chapter 11 is an attempt to gather information on the application of a mineralogical and geochemical data base to the exploitation of PGE and PGE-bearing deposits. The generally poor PGE recoveries experienced in producing mines are attributed to lack of definitive mineralogical and geochemical data because of past secrecy on the subject. The organization of the chapter is based on a combination of deposit-type and recovery process. This is an area currently receiving more attention by mining companies, in their attempts to maximize metal recoveries.

Finally, the Index, possibly more detailed than usual for books of this type, is provided to help persons from diverse disciplines to track down areas of interest.

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