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OPPORTUNITIES FOR A PLATINUM-GROUP-ELEMENT RESOURCE APPRAISAL OF THE UNITED STATES

By

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OPPORTUNITIES FOR A PLATINUM-GROUP ELEMENT RESOURCE ASSESSMENT OF THE UNITED STATES

Introduction

This Open-File Report is a summary of a talk presented at the 93rd Annual Convention of the Northwest Mining Association on December 4, 1987. It describes a program being developed by the U.S. Geological Survey (USGS) that would conduct an assessment of the platinum-group element (PGE) resources of the United States. The preliminary compilation described in this talk was produced as a poster to be used as an administrative document, therefore, only slides of the final product are available. However, geographic locations and generalized geology for the slides can be obtained by projecting them on the 1:2.5 M scale geologic maps of the conterminous United States and Alaska (King and Beikman, 1974; Beikman, 1980).

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Text of talk presented at 93rd Annual Convention of the Northwest Mining Association.

Advances in our understanding of the geochemistry of the platinum-group elements and the many environments in which they occur, together with current economic and political conditions, have created a need for a comprehensive assessment of the PGE resources of the United States. The USGS is developing a program to: (1) identify and describe known PGE localities, (2) expand existing deposit models, and to develop new ones, (3) produce an up-to-date PGE-occurrence map, (4) produce a digital map showing environments for conventional and unconventional PGE deposits, (5) compile a computer database of important characteristics of these environments, and (6) analyze numerous samples from the areas thus defined.

Within the conterminous United States, Alaska and Puerto Rico, there are many areas with unexamined environments that by analogy, projection, or association are similar to areas that host platinum-group metals either as the major or by-product metals (Figure 1, 2). Maps identifying these areas or tracts were prepared using available geologic maps and reports, geochemical associations, and geophysical properties of rocks.

This report briefly summarizes our ideas on conventional and unconventional deposit types and presents a preliminary compilation of environments that could host PGE's in the United States. We began by assembling a list of geologic environments and ore deposit types in which platinum is known or suspected to occur (Table 1). The list is quite extensive and goes well beyond the mafic-ultramafic rock related environments that are traditionally thought to host PGE deposits. While only deposits of a few types are mined primarily for their PGE content, many deposit types could have significant by-product or even co-product production; however, most types of deposits would have by-product production (Table 2). Using this list as a guide, maps were prepared at a scale of 1:5M for conterminous U.S. and 1:2.5M for Alaska that show the areas or tracts for geologic environments that may host deposits of PGE's (Figures 1 and 2). The maps were prepared utilizing existing geologic maps and reports and previously compiled occurrence maps. Geophysical targets were outlined utilizing the digital aeromagnetic and gravity data for the conterminous United States. The assessment was done between May 15 and July 24, 1987. Because of the limited time available and knowledge base for the development of the maps, they are not all inclusive of the possible permissive environments.

After the inital compilation, it was decided to simplify the map to show 4 units: (1) yellow colored areas that are past or present producers, (2) red-colored areas that contain conventional environments, (3) blue colored areas that contain unconventional environments, and (4) brown colored areas that correspond to geophysical anomalies or known subsurface occurrences that are suggestive of buried mafic and ultramafic rocks that are less than 1000m deep (Table 3).

Yellow colored areas enclose tracts containing present or past producers of platinum-group elements. Some areas produced these metals as by-products of mining other metals (Bingham, Utah); other areas contain producers that were most active from 1850 to 1900 (California-Oregon placers) and 1930 to 1950 (Goodnews Bay, Alaska). One area is currently producing platinum-group elements as the major product (Stillwater Complex, Montana). In addition, the yellow colored areas are permissive for the occurrence of undiscovered deposits and some contain identified reserves that are not being mined presently. While we have a moderate level of understanding of these areas, modern examination of these areas would increase the knowledge necessary to lead to the discovery of new deposits.

Orange and blue areas illustrate conventional and unconventional environments, respectively. Conventional environments are largely those associated with mafic and ultramafic rocks but also include a few distinct, readily defined environments where PGE are known to occur in the U.S. or elsewhere in the world Unconventional environments include rocks that may contain PGE deposits or deposits with by-product PGE. Several reasons may result in classification of an area as unconventional. First, the understanding of the environment that contains some PGE deposits is inadequate to unambiguously identify similar environments elsewhere (e.g., Sierra Pelada), (2) descriptive or deposit models of unique PGE occurrence may not exist, (3) geologic mapping suggests some potential for PGE-bearing deposits, but is not sufficiently detailed to identify targets, (4) geochemical characteristics of some deposit types suggest they would contain PGE, but analyses have not been done. By their very nature, the identification of these areas is speculative and little or no evaluation has been done in most areas. Table 3 shows how the deposit types and geologic environments were classified for the purpose of the preliminary assessment.

Brown colored areas also merit further explanation. Most of these areas were identified from manipulation of digital geophysical data for the conterminous United States. First, a digital depth to bedrock map was generated using the basement rock map of the United States (Bayley and Muehlberger, 1968). All areas over 1000m deep was excluded. Second, correlation coefficients for gravity and pseudogravity data were calculated. The coefficients are calculated on 49 grid points within a 28 km^2 blocks. A correlation coefficient of 0.7 or higher was used to identify those blocks where the gravity and pseudogravity were correlated. Third, specific areas of interest within these broad areas where gravity and pseudogravity correlate and depth was less than 1000m were made by superimposing the high frequency magnetic and 1st derivative gravity maps.

There are several reasons for compiling a PGE assessment map, as simple and nonspecific as it is. First, it highlights those geographic areas where basic geologic work might be concentrated, such as northwestern Arizona where Ni-sulfide occurrences, mafic gneisses with ultramafic composition, and unstudied gabbroic bodies suggest this area could benefit from basic geologic studies. Second, it identifies areas that could contain types of PGE occurrences that are generally not known to exist in the U.S. and are not fully documented. An example of this would be the La Plata mining district in southwestern Colorado. Disseminated deposits of chalcopyrite are associated with syenite stocks in the central part of this district. Samples of rocks from one of these deposits have PGE contents that range from .16 g/t to 18 g/t. This occurrence may be similar to several PGE occurrences associated with alkalic rocks in Canada (i.e., the Coldwell Complex in Ontario). The geologic environment associated with alkalic magmatic rocks is one upon which work could be focussed. Third, it identifies PGE occurrences that have inadequate descriptive and grade-tonnage models. Such an example may be the Kupferschiefer in Poland. Are there similarities between the Kupferschiefer and the sediment-hosted Cu deposits in the Creta Formation and Flowerpot shale in Oklahoma, Texas, and Kansas, the Nonesuch shale in Minnesota, the Abo and Santa Rosa Formations in New Mexico, and the Belt Supergroup in Montana? Finally, it highlights those environments which may contain PGE's but for which analytical data are absent. Organic-rich shales, southwest Missouri Pb-Zn deposits, and Colorado Plateau breccia pipe U-Cu-Ag deposits have anomolous concentrations of Co, Ni, Ag, and/or Cr but have never had their PGE contents studied.

What Needs To Be Done:

First, identify and describe known PGE localities in order to develop deposit models. PGE in ophiolites associated with podiform chromitities represents a well described deposit type. By combining descriptive and grade-tonnage models, it is possible to design optimal exploration strategies for these deposits if the economics warrant it. Second, produce an up-to-date PGE-occurrence map. Third, produce a digital map of geologic environments permissive for PGE-bearing deposits. On this map different geologic environments could be keyed out separately as opposed to the preliminary map where they are combined. It may be published at a scale of 1:2.5M. Fourth, produce a database describing the characteristics of these environments. Fifth, analyze numerous samples (10 to 20 thousand) from the identified areas to assess their PGE potential and build a geochemical database for the PGE in a wide variety of geologic environments.

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List of Figures (slides)

Table 1: Genetic classification of deposit types that could contain PGE. Model numbers refer to descriptive models in Cox and Singer (1986)

Deposit Types	Deposit model number or reference
I. Deposits formed by surface P-T processes.	
• Placer Au-PGE	39a,b
• Quartz-pebble conglomerate Au-U	29a
• Homestake Au	36b
• Mn crusts	Halbach and others, 1984
• Lateritic Ni	38a
• Organic-rich shale Zn-V-Cr-Mo-Ni-Ag-Se	Vine and Tourtelot (1970)
• Coal	Chyi (1982)
II. Deposits formed at or near surface by low to moderate T hydrothermal fluids.	
• Sediment-hosted Cu	30b
• Southeast Missouri Pb-Zn	32a
• Unconformity U-Au	37a
• Hot-spring Hg	27a
• Hot-spring Au-Ag	25a
• Carbonate-hosted Au-Ag	26a
• Epithermal quartz-alunite Au	25e
• Blackbird Co-Cu	24d
• Limassol Forest Co-Ni	8c
• Colorado Plateau breccia pipe U-Cu-Ag	Weinrich (1985)
III. Deposits formed at shallow levels in the crust by moderate to high T hydrothermal processes in or near intermediate to felsic igneous intrusions.	
• Volcanic-hosted Cu-As-Sb	22a
• Cordilleran lode and vein Cu-Zn-Mn-Pb-Ag	Meyers and others (1968)
• Porphyry Cu	18a
• Au-skarns	Orris and others (1987)
IV. Deposits formed at shallow levels in the crust by moderate to high T hydrothermal processes.	
• Low sulfide Au-quartz veins	36a
• Basaltic Cu	23
• Sierra Pelada Au	
• Revais Creek Cu-Ag-Au-PGE	Crowley (1963)
• New Rambler Cu-Ag-PGE	McCallum and others (1976)
• Cobalt Co-Ag-Ni-As	No. 22 in Eckstrand (1984)

V. Deposits formed at shallow levels in the crust by moderate to high T hydrothermal to magmatic processes in or near alkaline igneous intrusions.

o Carbonatite	10
o Au-Ag-Te veins	22b
o Syenite/gabbro-hosted Cu-Ag-PGE	Mutschler and others (1985)

VI. Deposits formed by magmatic processes.

o Bushveld chromite	2a
o Podiform chromite	8a
o Anorthosite Ti	7b
o Sudbury Ni-Cu	Pye and others (1984)
o Duluth Cu-Ni-PGE	5a
o Stillwater Ni-Cu	1
o Komatiitic Ni-Cu	6a
o Noril'sk Cu-Ni-PGE	5b
o Acoje ophiolitic Ni-Cu	Abrajano and Bauita (1982)
o Synorogenic-synvolcanic Ni-Cu	7a
o Merensky Reef PGE	2b
o Alaska PGE	9

Table 2. Deposit types grouped according to their known or suspected PGE contents. Locality abbreviations are explained in Appendix A of Cox and Singer (1986).

	Deposit types	Examples	References for grade information
I.	**Deposits that have primary PGE production or potential.**		
	• Merensky Reef PGE	Merensky Reef, SAFR; Plat Reef, SAFR; J-M Reef, USMT; Great Dyke, ZIMB	Sutphin and Page (1986); Buchanan (1987)
	• Bushveld chromitite	UG2, SAFR	" " " " " "
	• Zoned Alaska-type PGE	Nizhnii Tail, USSR	Razin (1976)
	• Placer PGE-Au	Goodnews Bay, USAK	Yeend (1986); Yeend and Page (1986); Singer and Page (1986), Orris and Bliss (1986)
II.	**Deposits that have significant by-product or possible primary PGE production or potential.**		
	• Noril'sk Cu-Ni-PGE	Noril'sk Talnakh, URKZ	Sutphin and Page (1986); Buchanan (1987)
	• Sudbury Ni-Cu		Sutphin and Page (1986)
	• Komatiitic Ni-Cu	Kambalda, AUWA	Singer and others (1986b); Hudson (1986)
	• Duluth Cu-Ni-PGE		Sabelin and others (1986)
	• Sierra Pelada Au		
	• Sediment-hosted Cu	Zechstein copper deposits, PLND	Kucha (1982, 1983)
	• Synorogenic-synvolcanic Ni-Cu	Rana, NRWY; Moxie pluton, USMA	Page (1986); Singer and others (1986c)
	• Syenite/gabbro-hosted Cu-Ag PGE	Coldwell Complex, CNON; La Plata district, USCO; Goose Lake area, USMT	Dahl and others (1986); Eckel (1949); Simons and others (1979)
	• Unconformity U-Au	Uranium City area, CNSK; Shinkolobwe, ZIRE	Anonymous (1987); Bowles and others (1985)
	• Au-skarns	Carr Fork mine, USUT; Muara Sipongi area, INDS	Cameron and Garmoe (1987); Bowles and others (1985)
	• Revais Creek Cu-Ag-Au-PGE	Drake mine, USMT	Crowley (1963)
	• New Rambler Cu-Au-PGE	New Rambler mine, USWY	McCallum and others (1976)
	• Mn crusts	Ratak Chain, Marshall Islands	Halbach and others (1984); Hodge and others (1985); Schwab and others (1986)
	• Acoje ophiolitic Ni-Cu		Abrajano and Bauita (1982)
III.	**Deposits that have by-production PGE production or potential.**		
	• Stillwater Ni-Cu		Zientek and others (1986)
	• Homestake Au	Dome Mine, CNON	Fryer and others (1979)
	• Cordilleran lode and vein Cu-Zn-Mn-Pb-Ag	Butte, USMT	Sillitoe (1983)
	• Porphyry Cu	Ely, USNV	Page and Briskey (unpublished data)
	• Volcanic-hosted Cu-As-Sb	Bor, YUGO	Lewis (1983)
	• Podiform chromitite		Albers (1986); Singer and others (1986a)
	• Quartz-pebble conglomerate Au-U	Witwatersrand Au deposits, SAFR	Cousins (1973)
	• Hot-spring Hg	McDermitt, USNV	Page (unpublished data)
	• Hot-spring disseminated Au-Ag	Delamar, USID	"
	• Carbonate-hosted Au-AG	Preble, USNV	"
	• Epithermal quartz-alunite Au	Adelaide, USNV	"
	• Carbonatite	Palabora, SAFR	Palabora Mining Company Ltd. Mine and Geological Staff (1976)
IV.	**Deposits in which PGE are known to occur but abundance level uncertain.**		
	• Low sulfide Au-quartz veins		
	• Lateritic Ni		
	• Limassol Forest Co-Ni		
	• Coal		
	• Blackbird Co-Cu		
V.	**Deposits that are suspected to contain PGE but for which no information is available.**		
	• Basaltic Cu		
	• Au-Ag-Te veins		
	• Southeast Missouri Pb-Zn		
	• Colorado Plateau breccia pipe U-Cu-Ag		
	• Organic-rich shale Zn-V-Cr-Mo-Ni-Ag-Se		
	• Anorthosite Ti		
	• Cobalt Co-Ag-Ni-As		

Table 3: Classification of deposit types as shown on Figures 1 and 2.

I. Producers-yellow

- Placer AU-PGE
- J-M Reef, Stillwater Complex, Montana
- Alaska PGE
- Porphyry Cu
- Syenite/gabbro-hosted Cu-Ag-PGE
- New Rambler Cu-Au-PGE
- Revais Creek Cu-Ag-Au-PGE

II. Conventional-red

- Podiform chromitite
- Acoje ophiolitic Ni-Cu
- Quartz-pebble conglomerate U-Au
- Carbonatite
- Syenite/gabbro-hosted Cu-Ag-PGE
- New Rambler Cu-Au-PGE
- Revais Creek Cu-Ag-Au-PGE
- Komatiitic Ni-Cu
- Stillwater Ni-Cu
- Synorogenic-synvolcanic Ni-Cu
- Duluth Cu-Ni-PGE
- Blackbird Co-Cu

III. Unconventional-blue

- Noril'sk Cu-Ni-PGE
- Sediment-hosted Cu
- Mn crusts
- Hot-spring Hg
- Hot-spring Au-Ag
- Carbonate-hosted Au-Ag
- Low sulfide Au-quartz veins
- Lateritic Ni
- Limassol Forest Co-Ni
- Coal
- Basaltic Cu
- Au-Ag-Te veins
- Southeast Missouri Pb-Zn
- Colorado Plateau breccia pipe U-Cu-Ag
- Organic-rich shale Zn-V-Cr-Mo-Ni-Ag-Se
- Anorthosite Ti

IV. Brown areas

- Geophysical anomalies at less than 1000m interpreted to be mafic/ultramafic rocks.