MINISTÉRIO DE MINAS E ENERGIA - MME
COMPANHIA DE PESQUISA DE RECURSOS MINERAIS – CPRM

PLATINUM-GROUP METAL PROSPECTING NATIONAL PROGRAM
- A SUMMARY -

1996

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NATIONAL PROGRAM - A SUMMARY

1. PLATINUM-GROUP METALS (PGM)

1.1 - INTRODUCTION

The platinum-group metals consist of six chemical elements: platinum, palladium, rhodium, ruthenium, osmium and iridium. They have similar physical and chemical proprieties and they occur associated in Nature. Like gold and silver, they are known as precious or noble metals. They show extraordinary proprieties, such as refractory at high temperatures, chemically inert to a number of materials and excellent catalytic activities. They have very high densities (iridium being the densest chemical element in nature, with a density of 22.65). They also possess very high fusion points (osmium 3,045^{o}C, platinum 1,769^{o}C).They are to be found nearly always in mafic-ultramafic rocks as chemical compounds or natural alloys, in almost one hundred mineral species with a complex and variform mineralogy.

In chemical compounds, the platinum-group metals, acting as cathions, are combined with oxygen, sulphur, arsenic, antimony, bismuth, tellurium, tin and lead which represent the anions. In natural alloys, the platinum-group metals are combined into a high degree of proportions, sometimes associated with titanium, iron, gold, mercury, among others. The most common minerals are sperrylite ($PtAs_2$), braggite [(Pt, Ni)S], cooperete [(Pt, Pd)S], native platinum, native palladium and osmiridium.

1.2 - USES

Uses of platinum-group metals their remarkable physical and chemical proprieties. In addition to the use in jewellery and as an investment as a valuable reserve, they have important applications in various industrial fields, mainly electro-electronics and in devices for controlling the environmental pollution (e.g. as a catalyst for cars). Their use in advanced technology is growing up like in fuel cells, new electronic products and for medical purposes.

1.3 - INTERNATIONAL SCENARIO

World reserves are extremely concentrated in South Africa with a second position for Russia. These two countries are responsible for 98.5% of the world reserves. The same phenomena occur regarding production. The table below shows the numbers regarding this scenario:

PLATINUM-GROUP METALS		
COUNTRY	MINE PRODUCTION (kg) 1994	BASE RESERVES (kg) 1994
South Africa	150,000	59,000,000
Russia	74,000	6,000,000
United States	8,300	780,000
Canada	13,000	280,000
Other	5,000	31,000
Round Total	250,000	66,000,000

Source: Mineral Commodity Summaries / 1995

The following table shows the price of platinum-group metals and gold for comparison purposes.

PRICES (US$ / TROY OUNCE)			
METAL	1994 (AVERAGE)	1994 (HIGHEST)	1995 SEPTEMBER
Platinum	405	428	432
Palladium	143	161	147
Rhodium	803	980	350-390
Ruthenium	23	27	21-25
Iridium	70	70	50-65
Gold	384	396	383

1.4 - NATIONAL ENVIRONMENT

There are no data regarding platinum-group metals production or reserves in Brazil. According to the DNPM (National Department for Mineral Production), 1994, since 1993 consumption has been increasing related to the automobiles catalyst industries that used 77.8% of the total apparent consumption that was 2,994kg in that year.

Except the prospeting works carried out by CPRM, very little has been done so far. It is important to point out the UNAMGEN exploration work in Ceara State, apparently unsuccessful and, presently, in Goias State, mainly in the Niquelandia Complex.

1.5 - IMPORTANCE OF PGM

The great international importance of the platinum-group metals is due to a sum of factors that can be summarized as follows:

a) They are, in some cases, precious metals with a very high significance as an investment as a financial asset, regarding its capability to act as a valuable reserve with its prices at the same level but generically higher than those of gold (platinum an rhodium, respectively);

b) Use in environmental pollution control devices and in up-to-date technology, including foreseeig the third millenium environment;

c) Growing demand - in 1994 platinum demand climbed 11% in relation to 1993, achieving a record of 4.5 million troy ounces;

d) Car industries demand for platinum (catalytic devices uses) and jewellery industries demand grows up at the very high rates of 11% and 7% for 1994 and 1993, respectively;

e) Platinum average price in 1994 climbed 8% in relation to 1993, worthing of US$ 405 / troy ounce;

f) The strategic rank of metals the ore reserves and mine production of which are concentrated in two countries only (South Africa and Russia);

g) Regarding Brazil, one has to emphasize this importance, thanks to its geological potential and to the political and social unstability in South Africa and Russia that, eventually, may, in the future, have a negative influence on the level of their productions.

2. GEOLOGICAL SETTING
QUANTITATIVE GITOLOGY

Platinum-group metals mineralizations can occur in various geological environments, but almost exclusively in the mafic-ultramafic complexes domains. These various kinds of environments, that contain the economic and productive mineral deposits and the potential ones are classified through the Quantitative Gitology that deals with the evaluation of the geologic and economic aspects of such types, in regard to the total amount of the ore reserves and world production ascribed to them. In this sense, *FARINA* (1988) distinguishes 15 kinds of environments, formulating its concepts and showing the respective values given to their world productions and reserves. In the tables he presents, there are three most important types which are responsible for about 99% of the world reserves and 98% of the world production.

These three types arranged in rank of geologic-economic importance, are as follows:

⇒ Complex layered intrusions of mafic-ultramafic nature, in an intracontinental environment without relations with flood basalt, in intraplates or anorogenic zones. They are herein represented by the symbol LI (for layered intrusions);

⇒ Intrusions, principally sills-like, mainly composed of diabases and gabbros, generally layered, related to continental rifting and flood basalts lavas into intraplates or anorogenic zones. Herein, they are represented by the symbol FB (for flood basalts);

⇒ Mainly lavas and layered intrusions many times of komatiitic composition in greenstone belts. Herein, they are represented by the symbol GB (for greenstone belts).

The table that follows, shows examples of some of these types and their world reserves and production.

TYPE	EXAMPLES	WORLD RESERVE BASE (1988) %	WORLD PRODUCTION (1988) %
LI	• Bushveld (South Africa) • Sudbury (Ontario, Canada) • Stillwater (Montana, USA) • Great Dike (Rodesia)	90.2	50
FB	• Norilsk, Talmakh, Maiak e Taymir (Siberia, Russia)	8.0	37
GB	• Thompson, Manitoba (Canada) • Kambalda (West Australia) • Fortaleza de Minas (Minas Gerais, Brazil)	1.2	11
OTHERS		0.6	2
TOTAL		100	100

Our present knowledge is not sufficient to the characterization of certain areas or orebodies among the 15 types recognized. Because of that a provisional gitologic types has been established and, despite their importance, cannot be firmly applied. In this sense, two types were established, that are:

AL - Anorogenic Mafic-ultramafic intrusions. Complementary surveys and future studies shall lead to the characterization of this type as LI or other maficultramafic type future inexistent gitologic importance.

MU - Complexes or mafic and / or ultramafic unclassified bodies with some degree of interest and demanding a gitologic typology definition.

3. THE NATIONAL PROGRAM OF PLATINUM-GROUP METALS

GENERAL REMARKS

The program already started by CPRM, is based upon four main factors as follows:

(a) the very high economic and strategic importance of platinum-group metals;
(b) high potential of the Brazilian geological context, very rich regarding mafic-ultramafic complexes;
(c) a tremendous lack of prospection surveys and
(d) a national production of platinoids that is absent.

The program started in the middle of 1990 when the goals were determined and the scientific basements of its operational methods were found. The program has a permanent character (with one grand step that will end at 1995's final), it has a national framework, including all favourable geologic regions of the Brazilian territory. It encompasses 10 Projects with offices in the CPRM's regional units. It has 11 geologists working full time and a coordination and technical supervision core composed of three geologists that work on a part-time basis.

The program has the attributes of a government activity, intends to support and subsidize private companies, working in the activities of regional prospecting and of those of gitology, without the aim of carrying out mineral exploration in detailed scale such as ore bodies inventory and its economic feasibility. The program works in all potential areas for platinum, notwithstanding who is the owner of the mineral rights. That means that the project does not deal with claims and does not ask for mineral certificates on behalf of CPRM.

The main goals of the program are the following:

a) To open the screen regarding platinum-metals group potentiality, represented by favourable geological environments, occurrences and platinum, palladium, rhodium, ruthenium, osmium and iridium mineral deposits;

b) To stimulate the discovery of platinum ore bodies and to promote its economical recovering, as a supplement to the private enterprises activities;

c) To contribute to the production of raw materials in the country, which are essential to the environmental control, mainly platinum, palladium and rhodium.

4. PROSPECTING METHODOLOGY

Methodologies that govern the project are being improved at the same time as the works are being carried out and information is collected and interpretation is achieved.

4.1 - TRAINING

After the organization of the teams and the first grass roots works have been performed, there was a number of courses and trainings that became a priority among the activities during the year of 1991. All these events were supported by field works as practical as possible. Regarding the duration, the courses are short and vary from one to three weeks in each case.

They are summarized as follows:

TITLE	SITE	INSTRUCTOR
Geology and petrology of ultramafic and mafic complexes	Brasilia and Goias State interland	Ariplinio A. Nilson, of UNB
Mineralogy of the deposits of platinum-group metals and its associates	Fortaleza de Minas - Minas Gerais State	Celina M.L. Marchetto - Independent Consultant
Greenstone Belts ultramafic associations mineralizations	Fortaleza de Minas - Minas Gerais State	Noevaldo A. Teixeira, of RTZ
An introduction to the study of lateritic bodies and gossans	Belem and Para State interland	Marcondes L. da Costa, of UFPA
Geochemical prospection training	Goiania and Goias State interland	Carlos A.C. Lins, of CPRM/Recife
Platinum-group element deposits and their exploration methods	Rio de Janeiro and interland of Sergipe, São Paulo and Parana States	A.J. Naldrett, of the University of Toronto

These courses are complemented by periodical workshops that aim at presenting and discussing the various teams activities and their goal is to reach the best performance.

4.2 - TARGET SELECTION

Target selection was made taking into consideration information already available, duly interpreted, through the following principal elements:

a) A scanning in the basic geological mapping already done in search of mafic-ultramafic bodies, mainly the largest ones;

b) Information obtained from airborne geophysical surveys, with emphasis on magnetometry;

c) Anomalous geochemical environment in Ni, Cu and Co (Cr);

d) Sulfide mineralizations in Ni-Cu (and chromite);

e) Quantitative gitology criteria, as a function of the priority types as indicated in item 2.

4.3 - Selective Geological Mapping

This means a geological mapping “sensu strictu” or adaptations and improvements of geological mappings already done. They are made with a selective character, meaning that these mappings are focused on specifical conditioning which controls platinum elements mineralizations. Scales of these geological mappings vary, depending on each case but they are mainly between 1:50,000 and 1:10,000 scales.

4.4 - Mineralogical Pan-Concentrate Prospecting

Taking into account the very high density of platinum minerals (natural alloys with a density of almost 20, are very common), the alluvial prospecting by means of pan-concentrates plays a very important role. This method is used as a routine and a 15 to 20 litres original sample is very common. In some specific cases, prospecting is also done in residual soils.

4.5 - Geochemical Prospecting

As a routine, two ways of sampling are used: pan-concentrates and steam sediments both of them in the same sampling place. In some cases, there is a complement with residual soils sampling.

4.6 - Ground Geophysical Prospecting

It is used in specific cases, only. Magnetometry and induced polarization are the methods commonly used in this project.

4.7 - Exploraton Drillings Services

They are rare, until the present date only 04 (four) holes were bored with a average depth of 136m. These wells were drilled at the locality of Nova Brasilandia, Rondonia State.

4.8 - Lab Analysis

As a routine, the following analyses are effected:

a) Rocks: petrography.
b) Sulfide-Bearing Rocks: petrography, chalcography, determination of Pt, Pd, Au, Cu, Co, Ni and Mg.
c) Gossans: determination of Cu, Co, Zn, Ni and, eventually, Pt, Pd and Au.

d) Pan-concentrates: mineralogy with a stereoscopic microscope plus scanning electron microscopy using grains carefully selected. Determination of Pt, Pd, Au, Cr and, eventually, Ir.

e) Thin stream sediments and soils: determination of Cu, Ni, Co, Zn, Au and Cr.

Occasionally, the following analyses are made in rocks: 13 oxides, REE, S, Ba, Sr, Rb, H_2O^+ and H_2O^-

4.9 - DATA PROCESSING

There are a field files for all samples submitted to geochemical analysis and they show all basic information regarding each individual sample such as: location, geology, etc.

Said data, in association with analytical results are digitalized and incorporated to the Geochemical Sampling Statistical System. Various listing and geochemical interpretations can be generated, after these procedures.

4.10 - MAPS AND REPORTS DEVELOPPING

All information obtained in the field or in the labs is duly discussed and interpreted for the elaboration of progress and annual technical reports and maps.

4.11 - RESULTS RELEASE

Program's technical reports, their special maps and computer listings are available for consulting or acquisiton purposes for people dealing with this matter.

CPRM makes the distribution of the works already done, their evolution and data acquired through events like congresses, symposia, technical articles and through the press in a general way. CPRM, acting as the Geological Survey of Brazil, aims at informing the mining industries, companies, government agencies, universities, etc. All concerned persons should contact CPRM's DEPARTAMENTO E PROJETOS ESPECIAIS (SPECIAL PROJECTS DEPARTMENT) at Av. Pasteur, 404 in the city of Rio de Janeiro, phone # (0215460321 or Fax # (021)542.3647., e-mail derem@cprm.gov.br

5. WORKS ALREADY DONE

5.1 - FIELD WORKS PERIODS

The following table shows the effective field periods regarding each of the projects covered by the program. It is understood that effective periods are the number of days already worked in prospection activities, not including moving to the field, rest and other impediments

EFFECTIVE PERIODS ALREADY WORKED IN THE FIELD (GEOLOGISTS / DAY)					
PROJECT	1992	1993	1994	UNTILL JUNE, 1995	TOTAL
Platinum RS / SC	20	9	0	-	29
Platinum SP / PR	37	116	7	0	160
Platinum MG	55	27	62	0	144
Platinum BA / SE	19	95	79	11	204
Platinum PA / AP	48	97	57	0	202
Platinum AM / RR	-	20	14	20	54
Platinum GO / TO	30	60	100	65	255
Platinum RO	70	55	129	40	294
Platinum MT	-	-	16	36	52
Platinum PI / MA	23	333	33	-	89
TOTAL	302	512	497	172	1.483
Average / On-Going Projects	38	57	50	19	148
Number of On-Going Projects	8	9	10	9	10

5.2 - SAMPLES ALREADY COLLECTED AND ANALYSED

The following table shows the amount of samples collected and analysed in the period from 1992 to june, 1995. The difference between the amount of these samples and the totals means the quantities of samples to be analysed after june, 1995, except for rocks that are sent to the laboratory with only their macroscopic description.

PROJECT	PAN CONCENTRATE		STEAM SEDIMENTS		SOILS		ROCKS		TOTALS	
	C	A	C	A	C	A	C	A	C	A
Platinum RS/SC	41	41	0	0	0	0	359	162	400	203
Platinum PI / MA	419	210	440	440	48	48	278	207	1.185	905
Platinum RO	4,572	1.633	3.030	1.352	3.372	3.124	954	590	11.928	6.699
Platinum MG	342	163	315	315	8	8	234	112	899	598
Platinum GO/TO	3.160	62	2.101	2.063	0	0	165	97	5.426	2.222
Platinum SP/PR	258	247	133	123	27	27	382	162	800	559
Platinum BA/SE	895	167	621	454	433	375	599	497	2.548	1.493
Platinum PA/AP	1.469	1.029	408	388	1.128	826	710	710	3.805	2.953
Platinum MT	129	0	4	0	0	0	34	0	167	0
Platinum AM/RR	152	37	12	0	33	19	72	38	269	94
TOTAL	11.437	3.589	7.064	5.135	5.139	4.427	3.787	2.575	27.427	15.726

C = Sampled A = Analysed

5.3 - WORK AREAS CHARACTERIZATION

Regarding all Brazil's States, the following table shows the work areas concerning the geological types and accordingly to the stage that prospective surveys achieved.

WORK AREAS CHARACTERIZATION
(UNTILL JUNE, 1995)

TYPES / STATE	LI	FB	GB	AI	MU	TOTAL	A	B	C
RS	0	4	0	0	0	4	0	0	4
SC	0	3	0	0	0	3	0	0	3
PR	1	4	0	0	0	5	0	0	5
SP	1	11	0	0	1	13	0	0	13
MG	0	0	14	0	0	14	0	14	0
GO	11	0	3	0	6	20	18	2	0
TO	2	0	1	0	6	9	9	0	0
BA	7	0	2	1	3	13	8	5	0
SE	0	0	0	1	0	1	1	0	0
PI	0	17	0	0	0	17	0	0	17
MA	0	4	0	0	0	4	0	0	4
PA	3	5	17	11	8	44	40	4	0
AP	0	0	5	0	0	5	5	0	0
AM	0	0	0	1	0	1	0	1	0
RR	0	0	0	5	2	7	1	6	0
RO	1	2	0	6	15	24	15	9	0
MT	0	7	6	1	3	17	15	2	0
MS	0	0	0	0	1	1	1	0	0
TOTAL	26	57	48	26	45	202	115	40	47

LI = Layered Intrusions
FB = Flood Basalts
GB = Greenstone Belts
AI = Anorogenic Intrusions
MU = Unclassified Mafic - Ultramafic Complexes

A = Selected Areas for Prospecting Surveys Purposes
B = On-Going Prospecting Areas
C = Concluded Prospecting Surveys Areas

5.4 - MAPS AND REPORTS ALREADY DONE

The following chart shows the number of the various reports and thematic maps already undertaken from the period of 1992 until june 1995. The most important thematic maps are the geological, geochemistry and sampling ones.

PROJECT	1992, UNTILL JUNE, 1995		THEMATIC MAPS				
	ANNUAL REPORTS	PROGRESS AND FINAL REPORTS	1992	1993	1994	UNTILL JUNE, 1995	TOTAL
Platinum RS/SC	3	1	0	5	0	-	5
Platinum SP/PR	3		1	14	1	-	16
Platinum MG	3		3	3	6	-	12
Platinum BA/SE	3		9	14	17	-	40
Platinum PA/AP	3		1	9	4	-	14
Platinum AM/RR	2		-	5	4	-	9
Platinum GO/TO	3	2	3	6	4	-	13
Platinum RO	3		7	12	4	13	36
Platinum MT	1		-	-	1	-	1
Platinum PI / MA	3	1	5	5	2	2	14
GENERAL	-	-	1	1	-	1	3
TOTAL	27	4	30	74	43	16	163

6. RESULTS

Results are presented for the various gitologic types as previously described in item 2 of this paper, namely LI, FB, GB, AI and MU. For each State, emphasis is given to the best working areas.

6.1 - LAYERED INTRUSIOS - LI TYPE

a) Serra da Onça - Located in the counties of São Felix do Xingu and Parauapebas, Para State, it corresponds to a mafic-ultramafic complex, nonorogenic, stratified, intrusive of Lower Proterozoic Age and has a 75 km^2 area of outcropping. Lithologies are: serpentinite dunites, pyroxenites, gabbros and norites. In pan concentrates samples some platiniferous minerals grains were detected and confirmed by means of scanning electron microscopy in five sampling points. Platinoid grades in weight percent are the following:

SAMPLE	Pt	Pd	Ir	Os
01	62,1	7,6	-	-
02	42,1	24,2	-	-
03	-	-	1,6	2,3
04	80,9	11,5	-	-
05	87,8	-	-	-

Chemical analysis of the same kind of samples disclosed the presence of Pt in 36 samples (40 to 800 ppb) and Pd in 42 samples (10 to 400 ppb).

b) Serra da Puma and Igarape Carapanã in the county of São Felix do Xingu, Para State, are areas very similar to those of Serra do Onça. Nevertheless, prospecting works are in at initial phase and analytical results are not available yet.

c) Cacoal, in Rondonia State, is a layered mafic-ultramafic complex with predominance of troctolites and gabbros and also with peridotites and hazburgites and a outcropping area of 30 km^2. Mineralographic studies have detected pentlandite, chalcopyrite, bornite, pyrrhotite, chromite and, probably, an unidentified platinum-group mineral. Pan concentrates showed a grade of 10-20 ppb of Pt and 30 pph of Pd, both associated to gold (10 up to 1,450 ppb). In soil samples copper was detected with grades between 450 to 900 ppm and Ni between 1,600 and 3,000 ppm.

d) Serra do Colorado, in Alta Floresta D'Oeste county, Rondonia State, seems to be an important area with LI type, but its prospection is at a very initial phase.

e) Barro Alto, in the county of the same name, Goias State is a layered mafic-ultramafic complex with an outcropping area of 2,860 km^2. In 47 samples of pan concentrates into the ultramafic zone, Pt was detected in 17 of them with a maximum grade of 440 ppb. It is important to say that most of the samples of this particular complex have not been analysed yet.

f) Tapuruquara, in Santa Isabel do Rio Negro county, Amazon State is a mafic-ultramafic complex with gabbros, norites, pyroxenites and anorthosites with a probably layered structure. Here, also the works are at an initial phase.

6.2 FB TYPE - FLOOD BASALTS

Studied areas are mainly those that have Mesosoic diabase sills and some few intrusions of a not very well defined shape, in Parana Basin (Rio Grande do Sul, Santa Catarina, Parana and São Paulo States) and Parnaiba Basin (Piaui and Maranhão States). In comparison to Norilsk model, general conditionings are present such as geotectonic environment, general toleiitic magmatic nature and the magmatism age. Sedimentogenic environment sulfur fountains in the Parnaiba Basin are represented by gypsite layers of Pedra do Fogo and Motuca formations and by piryte in the Devonian shales and Carboniferous coal. In the case of Parana Basin, gypsite is very rare and is only known in Irati Formation of Permian Age. Nevertheless, coal with pyrite is quite frequent. Both Brazilian sedimentary basins and that of Siberia Region that includes Norilsk are very similar. Its magmatogenesis, always associated with continental rifting, including diabases, gabbros, alkaline rocks and, sometimes, carbonatites, are also similar.

Notwithstanding, some specific conditioning factors were not found and the most important are the following:

a) Basic rocks massive sulfides - Commonly there are pyrite disseminations only, with rare chalcopyrite with a total of sulfides hardly higher than 1 or 2%.

b) Nickel and copper huge concentrations - Only some chalcopyrite and malachite punctuations are found and they have not a quantitative meaning.

c) Magmatogenic layering.

d) Presence of olivine, giving place to picritic rocks. Olivine is absent in most sills. Exceptions are the metropolitan region of Porto Alegre and in Jose Fernandes, Parana State, the aspects of which are focused further on.

e) Assimilation and recrystallization of country rocks - one can observe only a low thermal effect with some baking.

f) Pan concentrates with the presence of platinum minerals.

Among type FB studied intrusions, there are additional comments to be made in respect to two areas that show picritic rock:

⇒ Porto Alegre metropolitan region - picritic rocks are present as an irregular intrusion with almost 6 km^2 of outocropping area in the Santa Tecla locality also named Lomba Grande, in the Gravatai county and in sills that lay deeply whose samples were studied in core samples of coal exploration project. Olivine grades into diabases and gabbros reach 17 to 36% and they rarely reach 50%. Regarding items "a", "b", "c", "e" and "f" such conditioning has not been found. Only as a curiosity one can mention that, in Santa Tecla, by means of metallographic studies, very little and very rare chalcopyrite punctuations were identified, native copper and maucherite (a nickel arseniate) without quantitative significance.

⇒ Jose Fernandes Gabbro - It lies in Adrianopolis county, Parana State, with a 5 km^2 of outcropping area and a indefinite shape. Olivine is a 15 to 20% component of the rock. Country rocks are Precambrian various sequences. It becomes the single Mesozoic occurence already studied outside the Parana Basin. Presence of some sulfides was determined in polished sections but they were of little proportions: pyrrotite, chalcopyrite, pentlandite, cubanite, sphalerite and macknawire - Some gold spots were detected in pan concentrates. Conditionings of items "a", "b", "e" and "f" have not been found.

6.3 - GB TYPE - GREENSTONE BELTS
ULTRAMAFIC FACIES

Studied areas are located in the states of Minas Gerais and Bahia. There are important areas in the states of Para, Amapa, Goias, and Mato Grosso but they were not studied yet. Mineralizations already studied are of a limited significance, and we will make a concise reference to the most important of them, as follows:

a) Fortaleza de Minas, in the State of Minas Gerais - This is a Ni/Cu ore deposit, mainly.

Owner's information is that grades, in the sulfur ore are as follows: Ni = 2.6%, Cu = 0.4%, CO = 0.06%, Pt = 0.32 ppm, Pd = 0.47 ppm, Rh = 0.06 ppm, Ir = 0.1 ppm, Os = 0.09 ppm, Ru = 0.2 ppm, Au = 0.09 ppm and PGE + Au = 1.33 ppm.

In the oxidation zone of the ore body, grades are the following: Ni = 0.74%, Cu = 0.48%, Co = 0.03% and PGE + Au = 1.76ppm. Reserves are almost 5.3×10^6 ton for sulfur ore body and 445×10^3 ton for the oxidized one.

It is very interesting to emphasize that the widespread presence of gossans are very important formations regarding prospection works.

Another relevant factor is that the medium thickness of the mineralized level is 3 meters, only.

According to *MARCHETTO* (1990), main lithologies associated to sulfur ore body are serpentinites, pyroxenites and actinolite-schists of a komatiitic sequence. Platinum-group minerals most common are kotulskite-melonite (that is a Ni, Bi and Pd telurete), sperrylite ($PtAs_2$) and irarsite (IrAsS).

b) Serro and Morro do Pilar, State of Minas Gerais - Since ancient times some occurrences of platinum minerals in alluvial deposits were known. The sites are Ribeirão Limeira in the county of Pilar and Corrego Bom Sucesso in Serro county.

CPRM works have confirmed these occurrences. From 89 samples of pan concentrates analysed, 13 showed the presence of platinum with a grade varying from 60 to 3,550 ppb and 24 samples had palladium with a grade between 10 to 10,000 ppb, always in association with gold. Scanning electron microscopy analyses in pan conentrate grains from Corrego Bom Sucesso revealed grades of 92.2% of Pt, 5.9% of Pd and 2% of Ti (CENPES / PETROBRAS Lab). Other grains of the same locality, analysed by COPPETEC (Federal University of Rio de Janeiro) showed Pt variing between 40 and 83% and Pd from 13 and 56%. In the primary environment PGE has not been found yet.

Precambrian Espinhaço Super Group rocks, outcrops in the area of hydrographyc basins where platinum minerals were found, include fine-grained quartzites to conglomerates and hematite phyllites. Platinum origin is not known yet. It is suggested that it can come from altered greenstone belts remains or quartz veins, after having migrated to quartzite-conglomerates and, at the end, into present alluvial placers.

c) Guajeru, State of Bahia - This area is situated in the Guajeru, Malhada das Pedras and Janio Quadros countries. A few pan concentrates showed Pt + Pd grades between 40 and 720 ppb with a very frequent association with gold (10 to 1,380 ppb).

6.4 - AI Type - Anorogenic Intrusions

In the great majority of areas of anorogenic intrusions, works have not started yet or are in an initial phase. There are interesting areas mainly in Rondonia, Para and Roraima States.

Pedra Preta and Cotingo in the State of Roraima, including various counties, mainly Boa Vista and Normandia Counties - They are not well known extensive sills that, to a certain degree can be dykes. They are Proterozoic anorogenic intrusions mainly consisting of diabases. They have a length over 100 km only in the Brazilian territory but show an important extension within in Venezuela and Guyana territories. These bodies in the terrain can reach up to 2 km width.

6.5 - MU Type - Unclassified Mafic-Ultramafic Complexes

a) Rio Branco / Alta Floresta - This area is located in the counties of Alta Floresta D'Oeste and Sao Miguel do Guapore, in the State of Rondonia. Main lithologies of the complex are gabbros, troctolites, metagabbros and amphibolites. One can see metamorphic effects and very clear shear zones, in these areas. Metagabbros show the following paragenesys: pentlandite, chalcopyrite, pyrite, pyrrhotite, arsenopyrite, bravoite, violarite, sphaleryte and, probably, platinum-group minerals. In pan concentrates, some grains of platinum minerals were identified by means of a scanning electron microscopy analysis. Pt varying from 64 up to 95%, Pd with 1.8% and Rh with 4.7% were found. Within this same assembly, 8 samples of pan concentrates showed grades of 30-660 ppb of Pt and 10 to 220 ppb of Pd. In fine-grained stream sediments there are obvious Cu and Ni anomalies.

b) São Felipe / Santa Luzia, in Santa Luzia D'Oeste and Pimenta Bueno counties, State of Rondonia is an area with a complex of gabbros, norites, olivine-gabbros, hornblendites and frequent metagabbros such as chalcopyrite, pentlandite, violarite, bravoite, pyrite, pyrrotite and, probably, platinum-group minerals. Notwithstanding the fact that fine-grained stream sediments have Cu and Ni geochemical anomalies, platinum minerals have not been found in pan concentrates, until now.

c) Nova Brasilandia is situated in Nova Brasilandia D'Oeste county and represents a complex with various fine-grained to coarse grained metabasic rocks, metagabbros and hornblendites. They are rocks partially metamorphic, shear zones are evident and there are zones with a hydrothermal metamorfism, as well. Identified metallic minerals in metagabbros are: pyrite, pyrrotite, chalcopyrite, pentlandite, bravoite, violarite and arsenopyrite. 44 of pan concentrates samples had Pt with grades between 60 and 21,890 ppb and Pd varying between 10 and 7,890 ppb. A very little number of grains of the pan concentrates were confirmed using scanning electron microscopy and showing 59.7% of Pt, 1% of Rh and only one of them with Ir, qualitatively detected. Fine-grained stream sediments have, as a maximum content of Ni, Cu and Co, respectively 270, 120 and 175

ppm. Among four exploratory drillings, with depths varying from 94 up to 181m, and located accordingly to IP and geochemical anomalies a very strong sulfur mineralization was found (until 25% of sulfhide ore) with a basic composition of pyrite and pyrrotite and an epigenetic hydrotermal origin. That results in little or no interest regarding platinum-group minerals. There are other orthomagmatic sulphur zones with a potential for platinum minerals.

7. FINAL REMARKS

Prospection of platinum-group metals and, as a consequence, the discovery of deposits of economic significance is a very difficult and complex work. This is very clear when one studies the world production, very concentrated in a quite few number of productive mines the U.S. example is a very good picture, because it has a single large mine, Stillwater, notwithstanding the low productions, as a by-product, from cooper mines. In spite of the very good geological knowledge and the sophisticated exploration methodologies already used in that country, this still happens. Stillwater discovery and start-up is almost recent but there was a lot of time spent in doing so. According to *CONN* (1979), bibliographic studies and target selection through Bushveld analogies started in 1962, and they developed after intense prospection activities and research. Exploitation works only started in 1987. It took, therefore, 25 years to reach success. In Stillwater, as in similar geological cases, one has very large layers total thicknesses and very thin mineralizations thicknesses. In this particular case, the total thickness is 7,400 m and the mineralized zone is only 1 to 3 m of thick (*BUCHANAN*, 1988).

Beyond the scarcity of ore deposits in the world, another fact that makes prospection difficult is the lower background grades that platinum metals occur in nature at ppb ranges. Such low ranges lead to lab methodologies that are very sensitive and with a detection limit also compatible with background grades. Regarding Pt and Pd the lowest recommended detection limits are 0.1 and 0.4 ppb, respectivelly. *BUCHANAN* (op.cit.) says that the worst problem one can face in PGE exploration is the analytical detection of these elements, found in a concentration that is very close to the limit of detection of usual instruments. *MORRISSEY* (1988) insists that analytical procedures are absolutelly crucial for the sucess of a given exploration project.

Analyses of Pt and Pd of this program are made in CPRM's central lab and some of them are made in other Brazilian private labs. CPRM's central lab methodology consists of fusion assay with a PbO collector followed by flame atomic absortion spectrometry. Sample weight is 50 g and detection limits are 40 ppb for Pt and 10 ppb for Pd. External labs use the same methodology but Pt detection limits are lower: 20 to 30 ppb. In the near future CPRM's lab will operate a new equipment, with an argon inductively coupled plasma emission spectrometric device (ICAP) that will allow it to reach units of ppb level of detection.

Investments in the program for the 1991-95 period are linked to a budget of US$12,064,000.00 that is modest if compared with its goals. Nevertheless, until June, 1995, only US$5,236,000.00 were effectively alloted to the program, due to budgetary difficulties.

Field systematic works have started in 1992, and carried out until june, 1995 almost 1.483 geologist / day with an annual average/project of 46 geologist/day that means 1.5 months/year that is of course, a very low number. This is due to various operational factors, but budgetary difficulties and financial resources scarcity are the main reason.

Notwithstanding those difficulties, the PLATINUM-GROUP METAL PROSPECTING NATIONAL PROGRAM is doing a very good work and achieving good results. 202 targets were selected. From this total, 47 had their prospective surveys already done and there are 40 areas with on-going works with very good chances. For the other 115 remaining areas, the works have not started yet.

These remaining areas have a total extent of almost 93,000 km^2, 5,000 km^2 of which linked to the LI type, 7,500 km^2 to the AI type and 17,000 km^2 to the MU type. These three types, considered the most important ones, reach a total of 29,500 km^2. The remmant 63,500 km^2 belong to the FB and GB types.

Up to June, 1995, 27,427 samples were collected and 15,720 analysed in the lab. The great majority of them were analysed by means of chemical analyses and their analytical results together with the field data were processed by the computer system allowing various geochemical interpretations.

At the same time, 31 technical reports were prepared, supplying descriptions of the works and their respective results, including 163 thematic maps (geological, samplings, geochemical, and so on).

The program is allowing to the characterization of some dozen areas, putting into evidence very important environments to shelter mineralizations. In addition to this various Pt and Pd geochemical anomalies constellations in pan concentrates were detected, many times related to stream and soil sediments anomalies. This is remarkable in the case of Cu, Ni and Co because of their association with platinum-group metals. In several areas in the State of Rondonia a mineral association was identified including chalcopyrite, pentlandite, and, more rarely, violarite, covelite, cobaltite and macknawite. Within this association, are to be found some "white" minerals with a very high reflectivity which can be platinum-group minerals.

Identification of platinum minerals, confirmed through scanning electron mycroscopy in Rondonia and Para states are absolutely unknown findings in the past.

At the same time as there is a growing geologic-prospecting experience in Brazil together with a specific methodology improvement, it also becomes evident that a continuous program supported by addquate and uninterrupted investments has become a necessity.

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All documents of the Program are
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