Part III

CONCLUSION AND PROPOSAL

Part III Conclusion and Proposal

Chapter 1: Conclusion

Analysis of existing data, analysis of satellite images, and a geological survey were conducted in this fiscal year for regional survey of Ni-Cu-PGE ore deposit accompanied with the Paraná flood basalt. The analysis of existing data covered flood basalt volcanism in the world, the Noril'sk ore deposit and geology of the Paraná basin, while the analysis of satellite images focused on JERS-1/SAR images. The geological survey included mainly whole rock analysis, geochemical analysis of trace elements and isotope analysis of the Paraná flood basalt.

1-1 Analysis of Existing Data

Flood Basalt : The well differentiated continental crust contains little platinum group elements (PGE) because the PGE was enriched in the core in the genesis of the Earth, and they are enriched basically in solid phase. Consequently, it is appropriate to trace the origin of the PGE in flood basalt to the mantle. Since a magma of flood basalt generates in a larger quantity than magmas of normal igneous rocks, a large-scale melting occurred. As the result, a comparatively large quantity of PGE what is enriched generally in solid phase may probably be contained in the melt produced. On these premises, it can be said that it is desirable that the origin of flood basalt magma, which causes PGE mineralization, was derived from the mantle plume, and was generated by large-scale partial melting of the plume and mantle materials surrounding the plume. These premises concern large igneous province (LIP) in general. Such factors that affect the enrichment of PGE such as supply of sulfur and silicate components due to crust contamination and also local tectonic setting would be more important for formation of PGE ore deposit,

Noril'sk ore deposit : The magma which genarated the deposit is considered to have been picritic to basaltic, PGE-enriched and sulfur-undersaturated. The magma was contaminated by crustal material, which caused the separation of the immiscible sulfide melt from the silicate magma. The immiscible sulfide melt dissolved much PGE reacting with a large amount of silicate magmas in the center of magmatic activity. These events are considered to be the origin of the Noril'sk ore deposit. From the above, three points can be listed as the requirements of the Noril'sk type ore deposit generation: (1) generation of sulfur-undersaturated magma and the ascending to a shallow crustal level, (2) generation of immiscible sulfide melt due to crustal contamination, and (3) reaction of the immiscible sulfide melt with a large quantity of silicate magma.

Furthermore, As the key factors of the exploration that satisfy the above requirements, the

followings can be listed: (1) existence of "Low-Ti" type and PGE-rich magma as lavas or intrusions, (2) existence of magmas depleted in PGE and contaminated by crustal matrials as lavas or intrusions, (3) being center of volcanic activity where crustal suture has developed and large quantity of silicate magmas ascended from the mantle, and (4) existence of high temperature picrite magma which apt to cause contamination of crustal materials as lavas or intrusions.

Paraná basin : it is one of the continental inland basins formed in the western part of the Gondwana paleo-continent. The lithosphere of the basin is thinner inferred by analysis of tidal gravity anomaly and the mantle plume is located more shallowly than those of cratons and orogenic belts. Paraná basin deposited from the late Ordovician to the late Cretaceous. The sequences are divided into the Rio Ivai, Paraná, Gondwana I, Gondwana II, Gondwana III, and Bauru Supersequences. The Gondwana I supersequence was formed immediately after the Hercynian orogeny while the Gondwana III supersequence is a thick flood basalt lava pile. The sedimentary sequences deposited more thickly along Paraná River from the western part of Paraná province to the southwestern part of São Paulo province.

It is considered that, when a mantle plume enters into the lithosphere of the intracratonic basin, the lithosphere shrinks instantly, subsides by the weight of the plume, and the sedimentation of the basin starts. The attenuation factor (e) of lithosphere has been calculated from the analysis of drilling data etc. High e zones are observed along the Paraná River in the NE-SW direction, extending from the western part to the northwestern part of the Paraná province, then to the southwestern part of San Paulo province. In these areas, intrusions of numerous dolerite sills and dikes, thick basalt lava pile, and normal sediment deposits are observed. Gravity anomaly becomes high due to the thinner lithosphere of intracratonic basin such as in the Midcontinet rift in the United States. In Paraná basin, high residual gravity anomaly is often observed in high e zones such as that along the Paraná River.

Tectonics of the Paraná basin: Relationships between regional stress fields and ore deposits were examined about the Noril'skore deposit, Duluth ore deposit and the Paraná basin. Conjugate shear fractures form diagonal secondary shear fractures like echelon inside them as a lateral movement progresses (Cymoid Loop) and a shear fracture of conjugate shear fractures is developed to a rift while the other is developed to a transformed fault. In the Duluth ore deposit, it is considered that the Duluth complex intruded into the tensional fracture formed by the lateral movement of two parallel transform faults, and the Ni- Cu- PGE ore deposit was formed there based on the anomalies of gravity and airborne magnetic anomalies. From the above, The principal maximum compressive stress axis (σ_1) is the NE-SW direction and the principal minimum compressive stress axis (σ_3) the NW-SE direction in the regional stress field.

The Noril'sk ore deposit is controlled by the Noril'sk-Kharayelakh dextral strike- slip shear

fault in the NNE-SSW direction and the Kayerkansky-Pyasinsky anticline in the NNW-SSE direction. Since the NNW-SSE direction coincides with that of Gydansk-Omsk rift, it is presumed to be the direction of σ_1. From the direction of σ_1, the σ_3 is presumed to show the ENE-WSW direction perpendicular to the Kayerkansky-Pyasinsky anticline. The Talnakh ore deposit of the west of the fault in the shape of a triangle stretching to the northwest is considered to have been formed in the tensional fissure zone. The Noril'sk ore deposit are located at the crossing of both NNE-SSW direction and NNW-SSE direction and, at the same time, they are located at the thickest part of the Nadezhinsky basalt lava unit, i.e. at the volcano-center.

A series of faults and fractures in the Paraná basin can be interpreted as a regional stress field in the rift zone. The high ε zone, the high gravity anomaly zone, and the thick doleritic sills and dikes are found in the NE-SW direction along the Paraná River from the western part of the Paraná province to the southwestern part of the San Paulo province. These events suggest that the zone was a rift. Assuming that the rift has the NE-SW direction, the stress axis in the NE-SW direction will be the σ_1 and the NW-SE direction perpendicular to the rift will be the σ_3 and a dextral transform fault. The zone where many fractures such as Ponta Grossa arch, Abreu- Mourao fault, and Rio Piquiri fault concentrate, is the most noteworthy among the NW-SE direction shear fractures. The zone is a tensional fracture zone formed by the lateral movement and it is estimated that a large quantity of sills and dikes intruded in the zone. The tensional fracture zone in the western part of Paraná province is formed at the intersection between the NE-SW rift and the NW-SE transform fault and the tensional fracture zone in Ponta Grossa arch at the intersection between the ENE-WSW shear fracture and the NW-SE transform fault. It is proposed that they are the first priority exploration targets of Ni-Cu-PGE ore deposit. Then, The ENE-WSW trending fractures also predominate in the Paraná basin. The fractures divide the cratons of the basement and the Brasilian- Pan African orogenic belts. The fracture directions intersect with the σ_1 axis (NE-SW) at an angle of about 30 degrees and be sinistral strike- slip shear fractures. They are not accompanied with doleritic sills and dikes.

1-2 Analysis of Satellite Images

Digital mosaic images of JERS-1 Synthetic Aperture Radar (SAR) data were read and analyzed for area where crosses the central part of Paraná basin from east to west from the viewpoint of geological structures. The survey area covers about 500,000 km^2 where corresponds to JERS-1/SAR data in 131 scenes. Most of the survey area crossing Paraná basin from east to west is extensively covered by flood basalt that erupted from the Jurassic to the Cretaceous. In the northeast part of the area, sedimentary rocks of the Palaeozoic and granitic rocks of the basement are distributed. To read and analyze the geological structure, lineaments

(including faults) and circular structures were extracted.

In Ponta Grossa Arch where is situated at the northeast part of the survey area, sedimentary rocks of the Palaeozoic and granitic rocks of the basement are distributed, and also exist a lot of dolerite dikes, which are considered to be the feeder of the flood basalt. The dikes extend as long as maximum 80 kilometers in NW-SE direction. They are identified clearly as lineaments on the interpretation images. It is considered to be the reason why dikes in sedimentary rocks which are relatively weak in resistance to erosion form a continuously ridging topographical feature. However, no dike has been identified in the basement. It is considered to be the reason why dikes do not form a ridge as the dikes and granite are not much different in erosion resistance. In regard to flood basalt distribution, large lineament groups were identified in the NE-SW direction in the central part of the area. It should be noted that these lineament groups are not indicated in existing geologic maps. The lineament density in the flood basalt distribution area is extremely low compared with the sedimentary rock area. In particular, in the low land around Paraná River in the survey area, a horst and graben structure in NE-SW in the basement was estimated through airborne magnetic survey and gravity prospecting. However, no lineament corresponding to this has been identified on SAR images. This may show that the basement structure has not given significant structural influence on the distribution of flood basalt, and no large structural movement has taken place in this area since the eruption of flood basalt.

As to circular structure, alkaline composite rock bodies existing in Lages area are clearly extracted as corresponding to circular structure on geologic map definitely.

1-3 Geological Survey

The current survey revealed that the Paraná basin flood basalt was classified into three types: a "Low-Ti" type (Gramado and Esmeralda), a transitional type (Paranapaneme-Ribeira), and a "High-Ti" type (Pitanga and Urubicí). The three types of lavas have the following geochemical features.

(1) Judging from the Th, Ta, Y, and Zr content and the Nd isotopic ratio, the Esmeralda of "Low-Ti" type is the least undifferentiated. (2) The Gramado and Esmeralda of "Low-Ti" type contain a relatively large quantity of crustal enriched elements such as Th, U, and Rb. This tendency is particularly conspicuous in Gramado. This was also confirmed from the isotopes of strontium and neodymium. (3) The magmas of "High-Ti" type and "Intermediate-Ti" type may have been little affected by the upper continental crustal material, originated from the mantle, and probably erupted directly to the surface of the earth. (4) Each type of magma was probably generated by a difference in degree of partial melting. Among these, the magma of "Low-Ti" type has the largest degree of partial melting and may have assimilated the upper

continental crustal material in varying degree. (5) The average content of Pt of the Paranapanema-Ribeira flood baslt of "Intermediate-Ti" type is 9.7 ppb and that of Pd is 15.5 ppb. The "Intermediate-Ti" type shows the highest Pt and Pd contents of all the types. These content values are higher than those of the lava richest in PGE of the Noril'sk ore deposit. The magma of "Low-Ti" type (Gramado and Esmeralda) is the second highest in content of Pt and Pd. For the Gramado magma, which was greatly affected by the crustal contamination, some samples are depleted of PGE and others are not depleted of them. On the other hand, the Pitanga magma of "High-Ti" type is very low in content of Pt and Pd. The study of the chemical composition of lava revealed that magma having a high content of PGE which may generate an orthomagmatic sulfide ore deposit of Noril'sk type would exist in the Paraná basin area.

The analysis of major components and trace elements of the intrusive rock showed the wide variety of sill composition (picritic～dacitic sill) in the Lomba Grande area. On the other hand, it was clarified that the variety of composition of the Ponta Grossa Arch sills and dikes is limited and all of them are basaltic. Like the lava, the former is richer in Th, U, and Rb than the latter. This agrees with the features of the magma of "Low-Ti" type shown by the lava. The 130m thick large-scale sill (basaltic～andesitic) that exists in the northeastern part and eastern part of the Lomba Grande area shows a relatively high content of Pt and Pd. In particular, some samples that contain more than 20 ppb of Pt were found in the sill of the northeastern part. In contrast to this, the picritic～basaltic and andesitic～dacitic sills that exist in the central part of the Lomba Grande area are depleted of Pt and Pd. In particular, the andesitic - dacitic sill contains little Pt and Pd. The content of Pt and Pd of the sills and dikes in Ponta Grossa Arch varies. Some of them contain more than 20 ppb of Pd, but others are depleted of Pd.

As described above, the geochemical study of the lava and intrusive rock conducted in fiscal 2001 clarified that magma (Paranapanema-Ribeira etc.) with a high content of PGE that may generate an orthomagmatic sulfide ore deposit of Noril'sk type exists in the Paraná basin area. The crustal contamination and the depletion of PGE were found in some samples of the Gramado of "Low-Ti" type. Also, although the crustal contamination is not clear, the depletion of PGE was recognized in some dikes and sills of Ponta Grossa Arch.

The EPMA revealed that sills and dikes of the Ponta Grossa Arch and the northeastern part of the Lomba Grande area contain a trace of chalcopyrite. In particular, we detected a trace of sphalerite and a cobalt arsenic mineral containing nickel from sills and dikes of Ponta Grossa Arch, which are interesting.

Chapter 2: Suggestion for Phase II Survey

In Phase I survey, we carried out a survey mainly in the central part of the flood baslt distribution area. Analyses of lava and intrusive rocks of flood basalt based on Phase I survey clarified geochemical features of the magmas. We also examined what kind of magma and geological conditions would cause the occurrence of a Ni-Cu-PGE ore deposit, taking the Noril'sk ore deposit and Duluth ore deposit as an example.

We are planning to conduct Phase II survey of the entire survey area, following Phase I survey. We will carry out a geological survey and collect analysis samples, particularly in the northern and southern parts of the survey area where enough analysis samples have not been obtained yet. The samples of lava and intrusive rock will be obtained from the ground surface and coal exploration drilling. The contents of analysis items and elements will be almost the same in order to maintain consistency with Phase I survey.

MINEROPAR in the Paraná province and CPRM in Rio Grande do Sul have conducted geochemical prospecting of stream sediment. The analyzed values of both prospectings reflect the own chemical composition of flood basalt relatively well. A geochemical prospection of stream sediment may be effective for an area where there is little outcrop of flood basalt sequences and will be conducted as a supplementary means to an outcrop survey as appropriate.

The survey of the geology and geological structure of the Paraná basin and basement rock revealed that the activity of flood basalt is controlled by a regional stress field. We will continue the survey of the geological structure of basin sediment and basement rock to determine the eruption sites of flood basalt where the occurrence of the ore deposit is expected.

We will also continue to analyze the SAR and TM images obtained through JERS-1 in order to clarify the geology and geological structure of the Paraná basin.

We will keep appealing to organizations concerned to obtain the data on drilling cores and a geophysical prospecting possessed by PETROBRAS.

We will bring together the Phase I and II survey results to make an analysis in a comprehensive manner, and eventually examine the potential for the occurrence of the Ni-Cu-PGE ore deposit in the Paraná basin, present the guidelines for the exploration, and extract promising areas for the exploration.

REFERENCES

References

Ahern, J.L. and Mrkvicka, S.R. (1984) A mechanical and thermal model for the evolution of the Williston Basin. Tectonics, vol.3, no.1, pp.79-102.

Anderson, D.L. (1982) Hotspots, poler wander, Mesozoic convection and geoid. Nature, vol. 297, no.3, pp.391-393.

Anderson, D.L. (1994) Superplumes or supercontinents? Geology, vol.22, pp.39-42.

Anderson, D.L. (1994) The sublithospheric mantle as the source of continental flood basalts; the case against the continental lithosphere and plume head reservoirs. Earth and Planetary Science Letters, vol.123, pp.269-280.

Arioli, E.E. (2000) The Mesozoic Igneous rocks of the Parana basin. Curitiba, MINEROPAR.

Arnason, J.G. and Bird, D.K. (2000) A gold- and platinum-mineralized layer in gabbros of the Kap Edvard Horm Complex: field, petrologic, and geochemical relations. Economic Geology, vol.95, no.5, pp.945-970.

Bailes, A.H., Christiansen, E.H., Galley, A.G., Jenner, G.A., Keith, J.D., Kerrich, R., Lentz, D.R., Lesher, C.M., Lucas, S.B., Ludden, J.N., Pearce, J.A., Peloquin, S.A., Stern, R.A., Stone, W.E., Syme, E.C., Swinden, H.S., Wyman, D.A. (1996) Trace element geochemistry of volcanic rocks: Application for massive sulphude exploration. edt: Wyman, D.A., Geological Association of Canada, WINNPEG'96 Short course note 12.

Barner, S.J. and Maier, W.D. (1999): The Fractionation of Ni, Cu and the Noble Metals in Silicate and Sulphide Liquids, in Keays, R.R., Lesher, C.M., Lightfoot, P.C. and Farrow, C.E.G. (editors), Dynamic Processes in Magmatic Ore Deposits and their Application in Mineral Exploration; Geological Association of Canada, Short Course Notes, no.13, pp.69-106.

Barnes, S.-J., Makovicky, E., Makovicky, M., Rose-Hansen, J. and Karup-Moller, S. (1997) Partition coefficients for Ni, Cu, Pd, Pt, Rh, and Ir between monosulfide solid solution and sulfide liquid and the formation of compositionally zoned Ni-Cu sulfide bodies by fractional crystallization of sulfide liquid. Canadian Journal of Earth Sciences, vol.34, pp.366-374.

Belliene, G. Comin-Chiaramonti, P., Marques, L.S., Martinez, L.A., Melfi. A.J., Nardy, A.J.R., Piccirillo, E.M. And Stolfa, D. (1986a) Petrogenetic aspects of acid and basic lavas from the Parana plateau (Brazil): geological, mineralogical and petrochemical relationship. Journal of Petrology, vol.27, pp.915-944.

Belliene, G., Brotzu, P., Comin-Chiaramonti, P., Ernesto, M., Melfi, A.J., Pacca, I.G. and Piccirillo, E.M. (1984a) Flood basalt to rhyolite suites in the southern Paraná plateau (Brazil): paleomagnetism, petrogenesis and geodynamic implications. Journal of Petrology, vol.25, pp.579-618.

Bennett, V.C., Norman, M.D. and Garcia, M.O. (2000) Rhenium and platinum group element abundances correlated with mantle source components in Hawaiian picrites: sulphides in the plume. Earth and Planetary Science Letters, vol.183, no.3-4, pp.513-526.

Bonatti, E. (1996) Anomalous opening of the Equatorial Atlantic due to an equatorial mantle thermal minimum. Earth and Planetary Science Letters, vol.143, no.1-4 pp.147-160.

Bond, G.C., Kominz, M.A. (1984) Construction of tectonic subsidence curves for the early Paleozoic miogeocline, southern Canadian Rocky Mountains: Implications for subsidence mechanisms, age of breakup, and crustal thinning. Geological Society of America Bulletin, vol.95, pp.155-173.

Bott, M.H.P. (1976) Mechanisms of basin subsudence - an introductory review. Tectono Physics, vol.36, pp.1-4.

Brooks, C.K. (1973) Rifting and doming in Southern East Greenland. Nature Physical Science, vol.244, pp.23-25

Brooks, C.K., Keays, R.R., Lambert, D.D., Frick, L.R., Nielsen, T.F.D. (1999) Re-Os isotope geochemistry of Tertiary picritic and basaltic magmatism of East Greenland: constrains on plume-lithosphere interactions and the genesis of the Platinova reef, Skaergaard intrusion. Lithos, vol.47, pp.107-126.

Brügmann, G.E., Naldrett, A.J., Asif, M., Lightfoot, P.C., Gorbachev, N.S. and Fedorenko, V.A. (1993) Siderophile and chalcophile metals as tracers of the evolution of the Siberian Trap in the Noril'sk region, Russia. Geochimica et Cosmochimica Acta, vol.57, pp.2001-2018.

Brügmann, G.E., Naldrett, A.J., Asif, M., Lightfoot, P.C., Gorbachev, N.S. and Fedorenko, V.A. (1993) Siderophile and chalcophile metals as tracers of the evolution of the Siberian Trap in the Noril'sk region,

Russia. Geochimica et Cosmochimica Acta, vol.57, pp.2001-2018.

Buchanan, D.L. (1998) Platinum-Group Element Exploration, Chapter 7 Exploration Guidelines, Chapter 8 Evaluation Guidelines, Chapter 9 Summary and Conclusions. DEVELOPMENT IN ECONOMIC GELOGY, 26, ELSEVIER 1988.

Castillo, P.R., Natland, J.H., Niu, Y. and Lonsdale, P.F. (1998) Sr, Nd and Pb isotopic variation along the Pacific-Antarctic risecrest, 53-57°S: Implications for the composition and dynamics of the South Pacific upper mantle. Earth and Planetary Science Letters, vol.154no.1-4, pp.109-125.

CBC (1986) Mapa Geologico Resional. 1/50,000, Projet Lavras do Sul. Companhia Brasileira do Cobre.

Celso Pinto Ferraz (2000) Brazil. Mining Annual Review 2000.

Chai, G. and Naldrett, A.J. (1992) Characteristics of Ni-Cu-PGE Mineralization and Genesis of the Jinchuan Deposit, Northwest China. Economic Geology, vol.87, pp.1475-1495.

Chai, G. and Naldrett, A.J. (1992) The Jinchuan ultramafic intrusion: cumulate of a high-Mg basaltic magma. Journal of Petrology, vol.33, part 2, pp.277-303.

Chase, C.G. and Gilmer, T.H. (1973) Precambrian plate tectonics: the midcontinent gravity high. Earth and Planetary Science Letters, vol.21, pp.70-78.

Chen, J.Y., Mingliang, J. (1987) Jin Chuan Nickel: difficult mining problems confront expansion at China's Jin Chuan mines. Engineering and Mining Journal, September, pp.44-57.

CIA. Nacional de Mineraçao (1995) Palnta de Detalhe (Index maps of mining licence).

Cloos, E. (1955) Experimental analysis of fracture patterns. Bulletin of the Geological Society of America, vol.66, pp.241-256.

Coffin, M.F., Eldholm, O. (1994) Large igneous provinces: crustal structure, dimensions, and external consequences. Reviews of Geophysics, vol.32, no.1, pp.1-36.

Courtillot, V., Jaupart, C., Manighetti, I., Tapponnier, P. and Besse, J. (1999) On causal links between flood basalts and continental breakup. Earth and Planetary Science Letters, vol.166, no.3-4, pp.177-195.

Cox, K.G. (1980) A model for flood basalt vulcanism. Journal of Petrology, vol.21, part 4, pp.629-650.

CPRM (1994) Carta de Previsao pare Planejamento de Acoes Governamentais.

CPRM (1995) Mapa de Indice de Prospectividade Demandata Area RS-01, Lavras do Sul/Casapava do Sul-RS. Programa Nacional de Prospecsao de Ouro-PNPO.

CPRM (1995b) Mapa de Jazimentos Auriferos, Area RS-01, Lavras do Sul/Cas[ava dp Sul-RS.

CPRM (1998) Mapeamento Geologica Integrado da Bacia Hidrografica do Guaiba (1/500,000).

CPRM (2000) Mapa Gemologico do Estado do Rio Grande do Sul/Percio de Moraes Blanco; Claudio Antonio Gil.-Porto Alegre.

CPRM (2000a) Cobre de Bom Jardim, Estado de Goias. Goiania 2000, Serie Oportunidades Minerais-Exame atualizado de Projeto, 03, Informe de Recursos Minerais.

CPRM (2000b) Ouro de Natividade, Estado de Tocantins. Goiania 2000, Serie Oportunidades Minerais-Exame atualizado de Projeto, 08, Informe de Recursos Minerais.

CPRM GOIANIA (2000) Field Excursion Guide for MMAJ Mission.

CRM (1977) Volta Grande, Condicionamento Estrutural. 1/8,000. and others., Companhia Riograndense de Minerasao, Estado do Rio Grande do Sul.

Crocket J.E. (1981) Geochemistry of the platinum-group elements. In Platinum-Group Elements: Mineralogy, Geology, Recovery, Chapter 4 (ed: Cabri, L.J.), Canadian Institute of Mining and Metallurgy Spec., vol.23, pp.49-64.

Czamanske, G.K., Zen'ko, T.E., Fedorenko, V.A., Calk, L.C., Budahn, J.R., Bullock Jr., J.H., Fries, T.L., King, B.W. and Seims, D.F. (1995) Petrographic and Geochemical Characterization of Ore-bearing Intrusions of the Noril'sk Type, Siberia; With Dissccussion of Their Origin. Resource Geology Special Issue, no.18, pp.1-48.

Czamanske, G.K., Zen'ko, T.E., Fedorenko, V.A., Calk, L.C., Budahn, J.R., Bullock Jr., J.H., Fries, T.L., King, B.W. and Siems, D.F. (1995) Petrographic and geochemical characterization of ore-bearing intrusion of the Noril'sk type, Siberia; with discussion of their origin. Resource Geology Special Issue, no.18.

Deckart, K, Féraud, G, Marques, L.S. and Bertrand, H. (1998) New time constraints on dyke swarms related to the Paraná-Etendeka magmatic province, and subsequent South Atlantic opening, southeastern

Brazil. Journal of Volcanology and Geothermal Research, vol.80, no.1-2, pp.67-83.

DNPM (1975) Availiação regional do setor Mineral- Rio Grande do Sul. Brasilia.

DNPM (1983) Carta Metalogenetica, Sao Gabriel Folha SH.21-S-B. Projeto Mapas Metalogenieticos e de Previsao de Recursos Minerais.

DNPM (1984) Carta Metalogenetica, Cachoeira do Sul, Folho SH22-Y-A. Projet Mapas Metalogeneticos e de Previsao de Recusos Minerais.

DNPM (1986) Mapa Geológico do Estado de Santa Catarina (1:500,000). República federativa do Brazil, Ministerio das Minas e Energia, Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia-DGM, Distrito Regional do DNPM; Governo do Estado de Santa Catarina, Secretaria da Indústrial e Comércio, CODISC, Superintendéncia de Tecnologia Minas e Energia, Coordenação dos Recursos Minerais.

DNPM (1987) Cachoeira do Sul Folha SH.22-Y-A, Carta Metalogenetica, Carta de Previsao de Recursos Minerais, Carta de Previsao de Asoes Governamentais, Escala 1/250,000., Texto e Mapas.

DNPM (1989) Mapa Geológico do Estado de Paraná (1:650,000). República federativa do Brazil, Ministerio das Minas e Energia, Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia-DGM, Distrito Regional do DNPM; Governo do Estado de Paraná, Secretário Especial da Ciência, Tecnologai e Desenvolvimento Econômico, Minerais do Paraná S.A.-MINEROPAR.

DNPM (1989) Mapa Geológico do Estado de Rio Grande do Sul (1:600,000). República federativa do Brazil, Ministerio das Minas e Energia, Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia-DGM, Distrito Regional do DNPM.

DNPM (1989) Mapa Geologico do Estado do Rio Grande do Sul, escala 1/1,000,000 e Parte do Escudo Sul-Rio-Grandense, escala 1/600,000.

DNPM (1995) 2nd Edition, Geologic Map of Brazil and Adjoining Ocean Floor including Mineral Deposits (1981), 1/2,500,000. DNPM, MME. (4 Sheets).

DNPM (1995) Economia mineral do Brasil, mapas, DNPM, Estudis de Oikutuca e Economia Mineral, 8, 280p.

DNPM (2000) Mineral Summary 2000. DNPM, Brasilia.

DNPM (2000) Mining in Brazil - Basic Information for the Investor. Brasilia. p.88.

DNPM-CGMW-UNESCO (1978) Tectonic Map of Souith America 1:5,000,000; Explanatory Note. Brasilia.

DNPM-CPRM (1973) Projeto Hidrogeologia da Fronteira Sudoeste do Rio Grande do Sul. Mapa Geológico (1:250,000) : Alegrete, SH.21-X-C, Anexo 18.

DNPM-CPRM (1973) Projeto Hidrogeologia da Fronteira Sudoeste do Rio Grande do Sul. Mapa Geológico (1:250,000) : Cacequi, SH.21-X-D, Anexo 19.

DNPM-CPRM (1973) Projeto Hidrogeologia da Fronteira Sudoeste do Rio Grande do Sul. Mapa Geológico (1:250,000) : Livramento, SH.21-Z-A, Anexo 21.

DNPM-CPRM (1973) Projeto Hidrogeologia da Fronteira Sudoeste do Rio Grande do Sul. Mapa Geológico (1:250,000) : São Gabriel, SH.21-Z-B, Anexo 22.

DNPM-CPRM (1984) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Castro, SF.22-X-A-V, MI-2824, Anexo 36. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1984) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Irati, SG.22-X-C-I, MI-2839, Anexo 38. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1984) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Jaguariaíva, SG.22-X-A-III, MI-2808, Anexo 31. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1984) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Ponta Grossa, SG.22-X-C-II, MI-2840, Anexo 39. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1984) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Reserva, SG.22-X-A-IV, MI-2823, Anexo 35. Companhia de Pesquisa de Recursos Minerais Superintendência

Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1984) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Venceslau Brás, SF.22-Z-C-VI, MI-2787, Anexo 23. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a borda leste da bacia do Paraná: integração geológia e avaliação econômica. Figura 9c (Geological section). Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Alegrete, SH.21-X-C-VI, Anexo 65. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Arroio Piraju, SH.21-X-C-III, Anexo 62. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : S. Francisco de Assis, SH.21-X-D-IV, Anexo 66. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Mapa Geológico (1:100,000) : Vila Kramer, SH.21-X-D-I, Anexo 63. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Relatório Final Volume I - Texto. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre, 210p.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Relatório Final Volume I - Texto. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

DNPM-CPRM (1986) Projeto a Borda Leste Da Bacia Do Paraná: Integração Geológica e Avaliação Econômica. Relatório Final Volume XIV - Anexos. Companhia de Pesquisa de Recursos Minerais Superintendência Regional de São Paulo Superintendência Regional de Porto Alegre.

Doan, D.B. and Bond, A.R. (1994) Russia's Platinum-Group Metals: A Current Survey, International Geology Review. vol.36, pp. 92-100.

Dunbar, J.A. and Sawyer, D.S. (1988) Continental rifting at pre-existing lithospheric weaknesses. Nature, vol.333, no.2, pp.450-452.

Duncan, R.A. and Richards, M.A. (1991) Hotspots, mantle plumes, flood basalts, and true polar wander. Reviews of Geophysics, vol.29, no.1, pp.31-50.

E.I.U. (2000) Country Profile Brazil 1999-2000. The Economic Intelligence Unit. 15 Regent St., London SW1Y 4LR, United Kingdom.

Ebel, D.S. and Naldrett, A.J. (1996) Fractional Crystallization of Sulfide Ore Liquids at High Temperature. Economic Geology, vol.91, pp.607-621.

Eckstrand, O.R. (1996) Magmatic nickel-copper-platinum group elements; in Geology of Canadian Mineral Deposit Types. Eckstrand, O.R., Sinclair, W.D. and Thorpe, R.I. (Eds), Geological Survey of Canada, Geology of Canada, no.8, pp.583-614.

"Eckstrand, O.R., Good, D.J. (2000) World distribution of nickel deposits. Geological Survey of Canada Open File 3791a, 19p.

"

Erlank, A.J., Marh, J.S., Duncan, A.R., Miller, R.McG, Hawkesworth, C.J., Betton, P.J. and Rex, D.C. (1984) Geochemistry and petrogenesis of the Etendeka volcanic rocks from SWA/Namibia. Geological Society of Africa, Special Publication vol.13, pp.195-245.

Farina, M. (1996) Platinum-Group Metal Prospecting National Program -A Summary-. CPRM.

Farina, M. (1996) Programma Nacional de Prospecson de

Metais do Grupo da Platina-Uma Sintese (parte 1). A Terra em Revista, no.1, pp.50-56.

Farina, M., Matos, G.M.M. and Gallart, R. (1998) Programa Nacional de Porspecção de Oouro Natureza e Metodos. Serie Ouro- Informe Gerais, no.02, Informe de Recusos Minerais. CPRM, Txt and two maps (Lavras do Sul/Casapava do Sul).

Farrow, C.E.G. and Watkinson, D.H. (1999) An Evaluation of the Role of Fluids in Ni-Cu-PGE-Bearing, Mafic-Ultramafic Systems. in Keays, R.R., Lesher, C.M., Lightfoot, P.C. and Farrow, C.E.G. (eds), Dynamic Processes in Magmatic Ore Deposits and their Application in Mineral Exploration; Geological Association of Canada, Short Course Notes, vol.13, pp.31-67.

Fedorenko, V.A., Lightfoot, P.C., Naldrett, A.J., Czamanske, G.K., Hawkesworth, C.J., Wooden, J.L. and Ebel, D.S. (1996) Petrogenesis of the Flood-Basalt Sequence at Noril'sk, North Central Siberia. International Geology Review, vol.38, pp.99-135.

Fodor, R.V. (1987) Low and high TiO2 flood basalts of Southern Brazil: origin from picritic parentage and a commom mantle source. Earth and Planetary Science Letters, vol.84, pp.423-430.

Fodor, R.V., Corwin, C. and Roisenberg, A. (1985) Petrology of Serra Geral (Paraná) continental flood basalts, southern Brazil: crustal contamination, source material, and South Atlantic magmatism. Contributions of Mineralogy and Petrology, vol.91, pp.54-65.

Fontignie, D. and Schilling, J-G. (1996) Mantle heterogeneities beneath the South Atlantic: a Nd-Sr-Pb isotope study along the Mid-Atlantic Ridge (3°S-46°S). Earth and Planetary Science Letters, vol.142, no.1-2, pp.209-221.

Friedinger, P.J.J. (1988) Basta - Subsidence and paleotemperature modeling of rift basins. Computers & Geosciences, vol.14, no.4, pp.505-526.

Fujii, T. (1998) Eruption of flood basaltic magma. Magma and Earth, The 12th "The university and science" disclosure symposium. (in Japanease)

Gallagher, K & Hawkesworth, C.J. (1992) Dehydration melting and the generation of continental flood basalts. Nature, vol.358, pp.57-59.

Garfunkel, Z. (1986) Review of oceanic transform activity and development. Journal of the Geological Society, London, vol.143, pp.775-784.

Garland, F., Turner, S. and Hawkesworth, C. (1996) Shifts in the source of the Paraná basalts through time. Lithos, vol.37, no.2-3, pp. 223-243.

Garland, F.E., Hawkesworth, C.J., Mantovani, M.S.M. (1995) Description and Petrogenesis of the Paraná Rzhyolites, Southern Brazil. Journal of Petrology, vol.36, no.5, pp.1193-1227.

Geul, J.J.C. (1970) Geology of Devon and Pardee Townships and the Stuart Location; district of Thunder Bay. Ontario department of mines (pbs), Geological Report 87, pp.31-36.

Governo do Estado do Rio Grande do Sul Secretaria da Coordenação e Planejamento Pró-Guaiba (1998) Cntrole e Administração Ambiental da Bacia Hidrográfica do Guaíba Módulo I - Subprojeto Monitoramento do Uso e Ocupação Territorial; Mapeamento Geológico Integrado da Bacia Hidrográfica do Guaíba, Escala 1:250,000.

Green, J.C. (1983) Geologic and geochemical evidence for the nature and development of the Middle Proterozoic (Keweenawan) midcontinent rift of North America. Tectonophysics, vol.94, pp.413-437.

Griffiths, R.W. and Campbell, I.H. (1990) Stirring and structure in mantle starting plumes. Earth and Planetary Science Letters, vol.99, pp.66-78.

Griselin, M., Arndt, N.T. and Baragar, W.R.A. (1997) Plume-lithosphere interaction and crustal contamination during formation of Coppermine River basalts, Northwest Territories, Canada. Canadian Journal of Earth Science s , vol.34, pp.958-975.

Hamlyn, P.R., Keays, R.R., Cameron, W.E., Crawford, A.J. and Waldron, H.M. (1985) Precious metals in magnesian low-Ti lavas: implications for metallogenesis and sulfur saturation in primary magmas. Geochimica et Cosmochimica Acta, vol.49, pp.1797-1811.

Handbook of exploration geochemystry, volume 6 Drainage geochemystry

Hauri, E.H. (1996) Major-element variability in the Hawaiian mantle plume. Nature, vol.382, pp.415-419.

Hawkesworth, C.J., Gallagher, K., Kelley, S., Mantovani, M.S.M., Peate, D.W., Regelous, M., Rogers, N.W. (1992) Paraná magmatism and the opening of South Atlantic. in: "Magmatism and the causes of continental break-up". eds.: Storey, B.C. , Alabaster, T. and Pankhurst, R.J., Geological Society, Special

Publication, no.68, pp.221-240.

Hawkesworth, C.J., Gallagher, K., Kirstein, L., Mantovani, M.S.M., Peate, D.W., Turner, S.P. (2000) Tectonic controls on magmatism associated with continental break-up: an example from the Paraná-Etendeka Province. Earth and Planetary Science Letters, vol.179, no.2, pp.335-349.

Hawkesworth, C.J., Mantovani, M.S., Peate, D.W. (1988) Lithosphere remobilization during Paraná CFB magmatism. In Menzies & Coxx (eds.) Oceanic and continental lithosphere: similaritie and differences. Journal of Petrology, Special Volume, pp. 205-223.

Hawkesworth, C.J., Mantovani, M.S.M., Taylor, P.N. and Palacz, Z. (1986) Evidence from the Parana of South Brazil for a Continental Contribution to Dupal Basalts. Nature, vol.322, no.24, pp.356-359.

Hirose, K. and Kushiro, I. (1993) Partial melting of dry peridotites at high pressures: determination of compositions of melts segregated from peridotite using aggregates of diamond. Earth and Planetary Science Letters, vol.114, pp.477-489.

Hulbert, l., Grégoire, D.C., Wildner, W., Albuquerque, L.F.F. and Chieregati, L.A. (1999) Geochemical examination of Paraná magmatism in Southern and South-central Brazil with respect to potential for Noril'sk-type Ni-Cu-PGE deposits. Canada-Brazil Cooperation Project for suitainable development in the mineral sector. CPRM special paper, 74p.

Humphris, S.E., Thompson, G., Schilling, J.G., Kingsley, R.H. (1985) Petrological and geochemical variations along the mid-Atlantic ridge between S and S: Influence of the Tristan da Cunha mantle plume. Geochimica et Cosmochimica Acta. Vol.49, pp.1445-1464.

Iwamori, H., McKenzie, D., Takahashi, E. (1995) Melt generation by isentropic mantle upwelling. Earth and Planetary Science Letters, vol.134, pp.253-266.

Iwata, N. (1997) Geochronological study of the Deccan volcanism by the 40Ar-39Ar method. docter's thesis, University of Tokyo.

Jackson, S.E., Fryer, B.J., Gosse, W., Healey, D.C., Longerich, H.P. and Strong, D.F. (1990) Determination of the precious metals in geological materials by inductively coupled plasma-mass spectrometry (ICP-MS) with nickel sulphide fire-assay collection and tellurium coprecipitation. Chemical Geology, vol.83, pp.119-132.

Jefferson, C.W., Hulbert, L.J., Rainbird, R.H., Hall, G.E.M., Gregorie, L.I. and Grinenko, L.I. (1994) Mineral Resource Assessment of the Neoproterozoic Franklin Igneous Events of Arctic Canada: Comparison with the Permo-Triassic Noril'sk-Talnakh Ni-Cu-PGE Deposits of Russia. Geological Survey of Canada, open file 2789.

Keays, R.R. (1995) The role of komatiitic and picritic magmatism and S-saturation in the formation of ore deposits. Lithos, vol.34, pp.1-18.

Keays, R.R. (1997) Requirements for the formation of giant Ni-Cu-PGE sulfide deposits: the role of magma generation. Transactions of the American Geophysical Union, 1997 Fall Meeting, V32F MC:304 Web 1330h, Geodynamics of giant magmatic ore systems II, p.F799.

Kurita, K. and Kobayashi, Y. (1991) Activity of the continental flood basalt as global event. Monthly The Earth.

Kushiro, I. (1996) Partial melting of a fertile mantle peridotite at high pressures: an experimental study using aggregates of diamond. American Geophysical Union, Earth Processes: Reading the Isotopic Code, Geophysical Monograph 95, pp.109-122.

Lambert, D.D., Foster, J.G., Frick, L.R., Ripley, E.M. and Zientek, M.L. (1998) Geodynamics of Magmatic Cu-Ni-PGE Sulfide Deposits: New Insights from the Re-Os Isotope System. Economic Geology, vol.93, no.2, pp.121-136.

Lesher, C.M., Burnham, O.M., Keays, R.R., Barnes, S.J. and Hulbert, L. (1999) Geochemical Discrimination of Barren and Mineralized Komatiites in Dynamic Ore-forming Magmatic Systems, in Keays, R.R., Lesher, C.M., Lightfoot, P.C. and Farrow, C.E.G. (eds), Dynamic Processes in Magmatic Ore Deposits and their Application in Mineral Exploration; Geological Association of Canada, Short Course Notes, vol.13, pp.451-477.

Licht, O.A.B. (2000, unpublished-3) Mineral prospection in the State of Parana Third Plateau. For MMAJ Mission Guidance. Secretaria de Estado da Industria, Comercia e Desenvolviento Economico Minerais do Parana S.A.

Licht, O.A.B. (2000-2) Conceptual model for Cu-Ni-sulfides and PGM mineralizations in the Parana Basin igneous rocks. Otavio Augusto Boni Licht. Mineropar, Curitiba, October 2000. Unbublished

Licht, O.A.B. (2001) A geoquímica multielementar na gestão

ambiental - identificação e caracterização de províncias geoquímicas naturais, alterações antrópicas da paisagem, áreas favoráveis à prospecção mineral e regiões de risco para a saúde no estado do Paraná , Brasil. Universidade Federal do Paraná; Tese.

Lightfoot, P.C., Hawkesworth, C.J., Devey, C.W., Rogers, N.W. and Van Calsteren, P.W.C. (1990) Source and differentiation of Deccan Trap lavas: implications of geochemical and mineral chemical variations. Journal of Petrology, vol.31, part 5, pp.1165-1200.

Lightfoot, P.C., Hawkesworth, C.J., Hergt, J., Naldrett, A.J., Gorbachev, N.S., Fedorenko, V.A. and Doherty, W. (1993) Remobilisation of the continental lithosphere by a mantle plume: major-, trace-element, and Sr-, Nd-, and Pb-isotope evidence from picritic and tholeiitic lavas of the Noril'sk District, Siberian Trap, Russia. Contribution of Mineralogy and Petrology, vol.114, pp.171-188.

Lightfoot, P.C., Naldrett, A.J., Gorbachev, N.S., Doherty, W. and Fedorenko, V.A. (1990) Geochemistry of the Siberian Trap of the Noril'sk area, USSR, with implications for the relative contributions of crust and mantle to flood basalt magmatism. Contributions to Mineralogy and Petrology, vol.104, pp.631-644.

Lorand, J.-P., Pattou, L. and Gros, M. (1999) Fractionation of Platinum-group elements and gold in the upper mantle: a detailed study in Pyrenean orogenic lherzolites. Journal of Petrology, vol.40, issue6.

Maksimov, Y.M. and Rudkevich, M.Y. (1971) Quantitative evaluation of the dynamics of Mesozoic and Cenozoic vertical movements over the West-Siberian plate. Geotectonics, no.1-6, pp.245-248.

Mantovani, M.S.M. & Hawkesworth, C.J. (1990) An inversion approach to assimilation and fractional crystallisation processes. Contribution of Mineralogy and Petrology, vol.105, pp.289-302.

Mantovani, M.S.M., Freitas, S.R.C., Shukowsky, W. (2001) Tidal gravity anomalies as a tool to measure rheological properties of the continental lithosphere: application to the South American Plate. Journal of South American Earth Sciences, vol.14, pp.1-14.

Mantovani, M.S.M., Marques, L.S., Sousa, M.A., Civetta, L., Atalla, L.T. and Innocenti, F. (1985) Trace element and strontium isotope constraints on the origin and evolution of Paraná continental flood basalts of Santa Catarina State (Southern Brazil). Journal of Petrology, vol.26, part 1, pp.187-209.

Mantovani, M.S.M., Wildner, W., Juchem, P.L. (2000) Paraná basin magmatism, stratigraphy and mineralization (southern Brazil). 31st International Geological Congress, Pre-congress Field Trip-Bft01.

Mapa das Trencheitras-DNPM-No.810526/93, Terra Santa.

"Maruyama, S., Isozaki, Y., Kimura, G. and Terabayashi, M. (1997) Paleogeographic maps of the Japanese Islands: plate tectonic synthesis from 750Ma to the Present. The Island Arc, vol.6, pp.121-142.

"

Matthey, J. (2000) Platinum 2000. Johnson Matthey Public Limited Company, 40-42 Hatton Garden, London EC1N 8EE, England. (Japanease version: Tanaka noble metal Co., Ltd.)

McDonough, W.F., Sun, S.-s. (1995) The composition of the Earth. Chemical Geology, vol.120, pp.223-253.

McDougall, J.D. (edt.) (1988) Continental flood basalts. Kluwer Academic Publishers, 341p.

McKenzie, D. (1978) Some remarks on the development of sedimentary basin. Earth and Planetary Science Letters, vol.40, pp.25-32.

Mckenzie, D. and Bickle, M.J. (1988) The volume and composition of melt generated by extention of the lithosphere. Journal of Petrology, vol.29, part3, pp.625-679.

Metal Mining Agency of Japan (1977) Magmatic Segregation copper-nickel deposits of the Soviet Union, Data of Survey Analysis Committee, Mineral Resources Information Center, no.26.

Metal Mining Agency of Japan (2000) Rare Metals Data book (Revised Edition), Platinum Group Metals. (in Japanese)

Metal Mining Agency of Japan (2001) Rare Metals Stockpiling Data (31 rare metals). (in Japanese)

Milani E.J. (1997) Evoluçãao tectono-estratigráfica da bacia do Paraná e seu relacionamento com a geodinâmica fanerozóica do Gondwana sul-ocidental. volume I -Texto, Porto Alegre. UFRGS. CPGG. Tese de Doutorado. 2v.

Milani, E.J., Faccini, U.F., Scherer, C.M., Araújo, L.M. and Cupertino, J.A. (1998) Sequences and Stratigraphic Hierarchy of the Paraná Basin (Ordovician to Cretaceous), Southern Brazil. Bol. IG. USP, série científica, no.29.

MINERAR (1997) Mina Volta Grande. Minerar, Consultoria e Projetos.

Minerar-CRM (1997) Mapa Geologico da Retiao de Lavras do Sul. Diagnostico do Potencial Mineral do Municipio de Lavras do Sul.

MINEROPAR (1986) Geologia do Estado do Paraná (1:1,400,000).

MINEROPAR (1986) Geologia do Estado do Paraná. 1/500,000 Mapa geologico(1984) da Mineropar. Secretaria de Estado da Industria e do Comercio, Governo do Estado do Paraná, 1998.

MINEROPAR (1994) Parana, Avaliasao Regional do Sector Mineral, Boletim no. 60, Governo do Estado do Parana.

MINEROPAR (2000) Field Trip Guidance for MMAJ Mission.

Mining Journal Ltd.(Publisher) (2000) Greenland. Mining Journal and Mining Magazine country and area review, pp.1-16.

MSS (2000) Programa Levantamentos Geológicos Básicos do Brasil-PLGB; Subprograma de Integração geológica-Metalogenética Projeto Folhas Porto Alegre Sh.22E Lagoa Mirim SI.22,A0 Milionésimo, Carta Geológica Escala 1:250,000.

Nakagawa, M. and Ohta, E. (1995) Preponderance of Ir-Os-Ru Alloys in Depleted Ophiolite, Hokkaido, Japan: A Window to the Mantle. Resource Geology Special Issue, no.18, pp.49-56.

"Naldrett, A.J. (1989) Magmatic Sulfide Deposits. Oxford University Press, Oxford Monographs on Geology and Geophysics No.14, 181p.

"

Naldrett, A.J. (1989) Selected Nickel-Sulfide Deposits, 4 Genetic Impications, Magmatic Sulfide Deposits. Clarendon Press, Oxford University Press 1989.

Naldrett, A.J. (1992) A model for the Ni-Cu-PGE Ores of the Noril'sk Region and Its Application to other Areas of Flood Basalt. Economic Geology, vol.87, no.8, pp.1945-1962.

Naldrett, A.J. (1992) A model for the Ni-Cu-PGE ores of the Noril'sk Region and its application to other areas of flood basalt. Economic Geology, vol.87, no.8, pp.1945-1962.

Naldrett, A.J. (1999) World-class Ni-Cu-PGE deposits: key factors in their genesis. Mineralium Deposita.

Naldrett, A.J., Fedorenko, V., Shushen, L., Asif, M., Kunilov, V.E., Stekhin, A.I., Lightfoot, P.C. and Gorbachev, N.S. (1996) Controls on the Composition of Ni-Cu Sulfide Deposits as Illustrated by Those at Noril'sk, Siberia. Economic Geology, vol.91, pp.751-773.

Naldrett, A.J., Llightfoot, P.C., Fedorenko, V., Doherty, W. and Gorbachev, N.S. (1992) Geology and Geochemistry of Intrusions and Flood Basalts of the Noril'sk Region, USSR, with Implications for the Origin of the NI-Cu Ores. Economic Geology, vol.87, no.4, pp.975-1004.

Naldrett, A.K. and Macdonald, A.J. (1980) Tectonic settings of Ni-Cu sulphide ores: their importance in genesis and exploration. The Continental Crust and Its Mineral Deposits(edt: Strangway, D.W.), Geological Association of Canada Special Paper 20, pp.633-657.

New Metals Association (2000) Nickel. New Metals Data Book 2000. (in Japanease)

Olson, P. and Singer, H. (1985) Creeping plumes. Journal of Fluid Mechanisums, vol.158, pp.511-531.

Oman, C.L., Finkelman, R.B. and Tewalt, S.J. (2001) Concentrations of platinum group elements in 122 U.S. coal samples. U,S, Geological Survey Open-File Report 97-53.

Onuma, N. and Montoya, M. (1984) Sr/Ca-Ba/Ca systematics of volcanic rocks from the central Andes, southern Peru, and its implication for Andean magmatism. Geochemical Journal, vol.18, pp.251-262.

Pearce, J.A. (1996): A use's guide to basalt discrimination diagrams. in Wyman, D.A. (editor), Geological Association of Canada, WINNPEG'96 Short Course Note, vol.12, pp.79-113.

Peate, D.W. and Hawkesworth, C.J. (1995) Lithospheric to asthenospheric transition in Low-Ti flood basalts from southern Paraná, Brazil. Chemical Geology, vol.127, no.1-3, pp.1-24.

Peate, D.W., Hawkesworth, C.J., Mantovani, M.S.M. (1992) Chemical stratigraphy of Paraná lavas (South America): classification of magma types and their spatial distribution. Bulletin of Volcanology, vol.55, pp.119-139.

Peate, D.W., Hawkesworth, C.J., Mantovani, M.S.M., Rogers, N.W., Turner, S.P. (1999) Petrogenesis and Stratigraphy of the High-Ti/Y Urubici Magma Type in the Paraná Flood Basalt Province and Implications for the Nature of "Dupal"-Type Mantle in the South Atlantic Region. Journal of Petrology, vol.40, no.3, pp.451-473.

Peate, D.W., Hawkesworth, C.J., Mantovani, M.S.M., Shukowsky, W. (1990) Mantle plumes and flood basalt stratigraphy in the Paraná, South America. Geology, vol.18, pp.1223-1226.

Petrini, R., Civetta, L., Piccirillo, E.M., Bellieni, G., Comin-Chiaramonti, P., Marques, L.S. and Melfi, A.J. (1987) Mantle heterogeneity and crustal contamination in the genesis of low-Ti continental flood basalts from the Paranà Plateau (Brazil): Sr-Nd isotope and geochemical evidence. Journal of Petrology, vol.28, part 4, pp.701-726.

Piccirillo, E. M. and Melfi, A. J. (eds.) (1988): The Mesozoic flood volcanism of the Paraná basin: petrogenetic and geophysical aspects. Sao Paulo, IAG-USP (Univ. Sao Paulo, Instituto Astronomico e Geofisico), 600p.

Piccirillo, E.M.; Melfi, A.J.; Comin-Chiaramonti, P.; Bellieni, G; Ernesto, M.; Pacca, I.G. (1988a) Continental flood vulcanism from the Parana Basin (Brazil). In: McDougall, J.D. ed. Continental Flood Basalts. Kluwer Academic Publishers, pp.195-238.

Quintas, M.C.L. (1995) O embasamento da bacia Paraná: reconstrução geofísica de seu arcabouço. Universidade de São Paulo (Dr. thesis), 213p.

Quintas, M.C.P., Mantovani, M.S.M. and Zalan, P.V. (1999) Contribuisao ao Estudo da Evolusao Mecanica da Bacia do Parana. Revista Brasileira de Geociencias, vol. 29, no. 2, pp.217-226.

R. Grant Cawthorn (1999) Seventy-fifth Anniversary of the Discovery of the Platiniferous Merensky Reef. Platinum-Metals Review, vol.43, no.4, pp.146-148.

Renne, P.R., Deckart, K., Ernesto, M., Féraud, G. and Piccirillo, E.M. (1996) Age of the Ponta Grossa dike swarm (Brazil), and implications to Paraná flood volcanism. Earth and Planetary Science Letters, vol.144, no.1-2, pp. 199-211.

Renne, P.R., Ernesto, M., Pacca, I.G., Coe, R.S., Glen, J.M., Prévot, M., Perrin, M. (1992) The age of Paraná Flood Volcanism, rifting of Gondwanaland, and the Jurassic-Cretaceous Boundary. Science, vol.25, pp.975-978.

Renne, P.R., Glen, J.M., Milner, S.C., Duncan A.R. (1996) Age of Etendeka flood volcanism and associated intrusions in southwestern Africa. Geology, v.24, no.7, p.659-662.

Ribeiro, M.J. (1978) Mapa Previsional do Cobre no Escudo Sul-Rio-Grandense, Brasilia. DNPM, Map and Explanation.

Richards, M.A., Duncan, R.A., Courtillot, V.E. (1989) Flood basalts and hot-spot tracks: plume heads abd tails. Science, vol.246, no.6, pp.103-107.

Ringwood, A.E. (1994) Role of the transition zone and 660 km discontinuity in mantle dynamics. Physics of the Earth and Planetary Interiors, vol.86, pp.5-24.

Ringwood, A.E. and Irifune, T. (1988) Nature of the 650-km seismic discontinuity: implications for mantle dynamics and differentiation. Nature, vol.331, no.14, pp.131-136.

Ripley, E.M. (1999): Systematics of Sulphur and Oxygen Isotopes in Mafic Igneous Rocks and Related Cu-Ni-PGE Mineralization, in Keays, R.R., Lesher, C.M., Lightfoot, P.C. and Farrow, C.E.G. (editors), Dynamic Processes in Magmatic Ore Deposits and their Application in Mineral Exploration; Geological Association of Canada, Short Course Notes, no.13, pp.133-158.

Roach, T.A. and Roeder, P.L. (1998) Composition of chromite in the upper chromitite, Muskox Layered Intrusion, Northwest Territories. The Canadian Mineralogist, vol.36, pp.117-135.

Romanini S.J., Albuwuerque L.F.F. (1996) Geological aspects of the basic intrusions characterized by CPRM's national program for prospection of the PGE in the Parana Basin. Port Alegre: CPRM. Internal Report.

Sano, T. (1996) Magma genesis of continental flood basalts: a case study of Deccan Trap basalts, India. docter's thesis, University of Tokyo.

Sano, T., Fujii, T., Deshmukh, S.S., Fukuoka, T. and Aramaki, S. (2001) Differentiation processes of Deccan Trap Basalts: contribution from geochemistry and experimental petrology. Juranal of Petrology.

Santos, E.L.D. (1999a) Geologia e Potencialidade das Mineralizasoes de Cobre (Au) e Ouro na Regiao de Lavras do Sul- RS. Porto Alegre.

Santos, E.L.D. (1999b) Potencialidade das Mineralizasoes de Cobre (Au e Ag), Chunbo e Zinco (Ag, Au e Cu) da Janela Bom Jardim-RS. Porto Alegre.

Santos, E.L.D., Azevedo, G.C., Maciel, L.A.C., Mossmann, R. (1994) Mapa Geiologico da Regiao Leste-Sudeste de São Gabriel-RS. Escala 1/50,000. Porto Alegre, DNPM, 1998.

Santos, E.L.D., Maciel, L.A.C., Filho, J.A.Z. (1998) Distritos Mineriros do Estado do Rio Grande do Sul. Porto Alegre, DNPM.

Scheibe, L.F. (1986) Geologia e petrologia do distrito alcalino

de Lages, SC. Universidade de São Paulo instituto de geociências; Tese de doutoramento, 224p.

Schouwstra, R.P., Kinloch, E.D. and Lee, C.A. (2000) Ashort Geological Review of the Bushveld Complex. Platinum-Metals Review, vol.44, no.1, pp.33-39.

Silver, P.G., Carlson, R.W. (1988) Deep slabs, geochemical heterogeneity, and the large-scale structure of mantle convection: investigation of an enduring paradox. Annual Revews of Earth Planetaly Science, vol.16, pp.477-541.

SMM (2001) Mineral exploration program in the Paraná basin, Brazil. Tecnical cooperation project between Brazil and Japan. in Oguino, K., Tadokoro, K. (Eds).

Stewart, K., Turner, S., Kelley, S., Hawkesworth, C.J., Kirstein, L., Mantovani, M.S.M. (1996) 3-D, 40Ar-39Ar geochronology in the Paraná continental flood basalt province, Earth and Planetary Science Letters, vol.143, no.1-4, pp. 95-109.

Sumiko Consultants CO., LTD. (2001a) Nickel of the world -Actual condition and the problem of the Ni resources-. (in Japanease)

Sumiko Consultants CO., LTD. (2001b) Nickel of the world II -Main articles on the nickel resources-. (in Japanease)

Sun, S.-s. and McDonough, W.F. (1989) Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. in Saunders, A.D. and Norry, M.J. (eds), Magmatism in the Ocean Basins, Geological Society Special Publication, no.42, pp.313-345.

Tadokoro, K. (2000) Report of Paraná area. (in Japanese)

Tadokoro, K. (2000) RGS Report. (in Japanease)

Takahahshi, E. (1996) Global mantle circulations and mantle plume. Earth Planetary Science Letters 1996 Fall Meeting, V72C-7 1525h, F769.

Takahashi, E, Nakajima, K. and Wright, T.L. (1998) Origin of the Columbia River basalts: melting model of a heterogeneous plume head. Earth and Planetary Science Letters, vol.162, no.1-4, pp.63-80.

Takahashi, E. (1986) Origin of basaltic magmas: implication from peridotite melting experiments and an olivine fractionation model. Volcanological Society of Japan, Volcano Spetial publication, vol.2, no.30, p.S17-S40.

Tamrazyan, G.P. (1971) Siberian continental drift. Tectonophysics, vol.11, pp.433-460.

The Geological Society of America Inc. (1989) Volcanism and tectonism in the Columbia River Flood Basalt Province. In Reidel, S.P., Hooper, P.R. (Eds.), Geological Society of America, spetial paper, 386p.

The World Economic Information Service (WEIS) (1999) ARC Report 1999, The Activity and Expectation of Brazil.

Theriault, R.D., Barnes, S.J. and Severson, M.J. (2000) Origin of Cu-Ni-PGE sulfide mineralization in the Partridge River Intrusion, Duluth Complex, Minnesota. Economic Geology, vol.95, no.5, pp.929-943.

Tommasi, A., Vauchez, A. (2001) Continental rifting parallel to ancient collisional belts: an effect of the mechanical anisotropy of the lithospheric mantle. Earth and Planetary Science Letters, vol.185, no.1-2, pp.199-210.

Turner, S., Hawkesworth, C. (1995) The nature of the sub-continental mantle: constraints from the major-element composition of continental flood basalts. Chemical Geology, vol.120, no.3-4, pp.295-314.

Turner, S., Hawkesworth, C.J., Gallagher, K., Stewart, K., Peate, D.W. and Mantovani, M.S.M. (1996) Mantle Plumes, flood basalts, and thermal models for melt generation beneath continents: Assessment of a conductive heating model and application to the Paraná. Journal of Geophysics Research, 101(B5): 11.503-11.518.

Turner, S., Regelous, M., Kelley, S., Hawkesworth, C.J., Mantovani, M.S.M., (1994) Magmatism and continental break-up in the South Atlantic: high precision 40Ar-39Ar geochronology. Earth Planetary Science Letters, vol.1221, pp.333-348.

Turner, S.P., Kirstein, L. A, Hawkesworth, C.J., Peate, D.W., Hallinan, S., Mantovani, M.S.M. (1999) Petrogenesis of an 800 metre lava sequence in eastern Uruguay: insights into magma chamber processes beneath the Paraná flood basalt province. Journal of Geodynamics, vol.28, no.4-5, pp.471-487.

Turner, S.P., Peate, D.W., Hawkesworth, C.J., Mantovani, M.S.M. (1999) Chemical stratigraphy of the Paraná basalt succession in western Uruguay: further evidene for the diachronous nature of the Paraná magma types. Journal of Geodynamics, vol.28, no.4-5, pp.459-469.

UFRGS (1996) Mecanismos de resfriamento, estruturação e processos pós-magmáticos em basaltos da bacia do Paraná - Região de Frederico Westphalen (RS) -

Brasil/Márcia Elisa Boscato Gomes - Porto Alegre.

Vidotti, R.M., Ebinger, C.J. and Fairhead, J.D. (1998) Gravity signature of the western Paraná basin, Brazil. Earth and Planetary Science Letters, vol.159, no.3-4, pp. 117-132.

Vogel, D.C. (1997) The petrogenesis and platinum-group element geochemistry of the Newer Volcanic Province, Victoria, Australia. Chemical Geology, vol.136, pp.181-204.

Weiblen, P.W. (1982) Keweenawan intrusive igneous rocks. Geological Society of America Memoir 156, pp.57-82.

Weiblen, P.W. and Morey, G.B. (1980) A summary of the stratigraphy, petrology, and structure of the Duluth Complex. American Journal of Science, vol.280-A, pp.88-133.

White, R. and McKenzie, D. (1989) Magmatism at rift zones: the generation of volcanic continental margins and flood basalts. Journal of Geophysical Research, vol.94, no.B6, pp.7685-7729.

White, R.S. and McKenzie, D. (1995) Mantle plumes and flood basalts. Journal of Geophysical Research, vol.100, no.B9, pp.17543-17585.

Wildner, W. (1998) Mapeamento Integrado da Bacia Hidrográfica do Guaíba, 1:250.000 (faciologia do vulcanismo Serra Geral). CPRM – Serviço Geológico do Brasil, documento interno, 10 folhas 1:250.000. Convênio CPRM, FEPAM.

Wildner, W., Silva, L.A.C. (1999) Minerais de Os-Ir-Pd em concentrados de Batéia folhas jacupiranga e Rio Guaraú - São Paulo. Report of CPRM.

Wooden, J.L., Czamanske, G.K., Bouse, R.M., Likhachev, A.P., Kunilov, V.E. and Lyul'ko, V. (1992) Pb Isotope data Indicate a Complex, Mantle Oigin for the Noril'sk-Talnakh Ores, Siberia. Economic Geology, vol.87, pp.1153-1165.

Wooden, J.L., Czamanske, G.K., Fedorenko, V.A., Arndt, N.T., Chauvel, C., Bouse, R.M., King, B-S.W., Knight, R.J. and Siems, D.F. (1993) Isotopic and trace-element constraints on mantle and crustal contributions to Siberian continental flood basalts, Noril'sk area, Siberia. Geochimica et Cosmochimica Acta, vol.57, pp.3677-3704.

Yasuda, A and Fujii, T. (1994) Melting phase relations of an anhydrous mid-ocean ridge basalt from 3 to 20 Gpa: implocations for the behavior of subducted oceanic crust in the mantle. Journal of Geophysical Research, vol.99, no.B5, pp.9401-9414.

Yasuda, A. and Fujita, T. (1994) The flood basalt and plateau. Monthly The Earth Special Issue. (in Japanese)

Zalán, P.V., Wolff, S., Conceição, J.C.J., Astolfi, M.A.M., Vieira, I.S., Appi, V.T. and Zanotto, O.A. (1987) Tectônia e Sedimentação da Bacia do Paraná. ATAS do III Simposio Sul-Brasileiro de Geologia, Curitiva. 1987, vol.1, pp.441-447. (in Portuguese)

Zalán, P.V., Wolff, S., Conceição, J.C.J., Astolfi, M.A.M., Vieira, I.S., Appi, V.T. and Zanotto, O.A. (1987) Tectonica e sedddimentacao da bacia do Parana. III Simposio Sul Burasileiro de Geologia. Curitiba. Proc. Soc. Brail. Geologia.

Zolotukhin, V.V. and Al'Mukhamedov, A.I. (1988) Trap of the Siberian Platform. Continental Flood Basalts (Kluwer Academic Publishers), pp.273-310.