UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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MINERAL RESOURCE ASSESSMENT OF COLOMBIA: ADDITIONAL ORE DEPOSIT MODELS

By Dennis P. Cox, Editor

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INTRODUCTION

This compendium of descriptive deposit models is presented as a supplement to an earlier report (Cox, 1983) and is intended to be used in conjunction with tonnage-grade models presented by Singer and Mosier (1983a, 1983b) as an aid to mineral resource assessment. The models were developed for use in the mineral resource assessment of Colombia, however, because similar deposits occur in similar geologic environments world throughout the the models should be of general use.

The numbering system of the deposits described in this report is consecutive to the numeration of the 35 deposits types described by Cox (1983) such that each deposit type has a unique number.

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DEPOSIT TYPE Stratiform mafic-ultramafic SUBTYPE Ni-Cu

AUTHOR Norman J Page DATE 8/10/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Ni, Cu sulfides at base of large repetitively layered mafic-ultramafic intrusion

GENERAL REFERENCE Geol. Soc. South Africa, Special Publication #1 (1969), Economic Geology, v. 77, no. 6, (1982) and v. 71, no. 7 (1976)

GEOLOGICAL ENVIRONMENT

Rock Types Layered intrusive contains norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro.
Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix
Age Range Generally Precambrian, may be as young as Tertiary
Depositional Environment Intruded into granitic gneiss or volcanic-sedimentary terrane.
Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.

Associated Deposit Types Layered chromitite, PGE in anorthosite-gabbro and magnetite ilmenite in intrusive complex. PGE placers.
Metal Concentrations Ni, PGE, Cr, Ti, high Mg, low Na, K, and P.

DEPOSIT DESCRIPTION

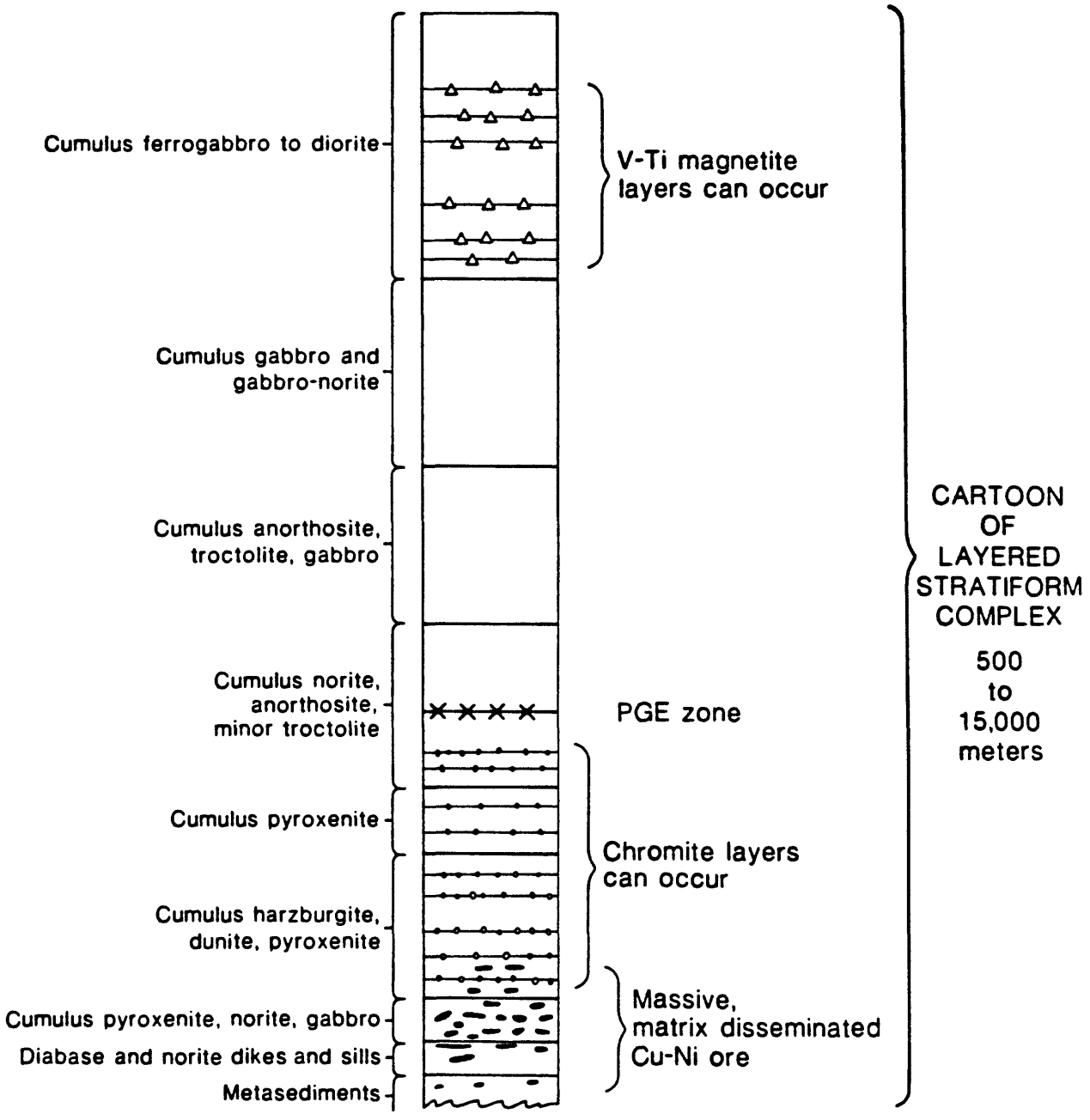
Ore Minerals: Pyrrhotite+chalcopyrite+pentlandite+cobalt+sulfides, by-product PGE.

Texture/Structure Locally massive; filling of silicate matrix; disseminated.

Alteration None related to ore
Ore Controls Basins in basal contact of intrusion with rapidly varying lithologies. Sulfides may intrude fractures in footwall country rock. Ingress of sulfur through fractures in footwall may be important ore control.
Weathering Gossan

Geochemical Signature: Cu, Ni, PGE, Co

Examples	References
Stillwater Complex	Page (1977)


Cumulus ferrogabbro to diorite
V-Ti magnetite layers can occur
Cumulus gabbro and gabbro-norite
Cumulus anorthosite, troctolite, gabbro
Cumulus norite, anorthosite, minor troctolite
PGE zone
Cumulus pyroxenite
Chromite layers can occur
Cumulus harzburgite, dunite, pyroxenite
Cumulus pyroxenite, norite, gabbro
Massive, matrix disseminated Cu-Ni ore
Diabase and norite dikes and sills
Metasediments
CARTOON OF LAYERED STRATIFORM COMPLEX
500 to 15,000 meters

DEPOSIT TYPE Stratiform mafic-ultramafic SUBTYPE Palladium-platinum

AUTHOR Norman J Page DATE 8/10/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Disseminated PGE-rich sulfides in olivine-rich rocks in anorthosite-gabbro zone of large layered intrusions.
GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro.
Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix.

Age Range Generally Precambrian, maybe as young as Tertiary.

Depositional Environment Intruded into granitic gneiss or into volcano-sedimentary terrane.

Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.

Associated Deposit Types

Metal Concentrations Ni, PGE, Cr, Ti, high Mg, low Na, K, P.

DEPOSIT DESCRIPTION

Ore Minerals: Pyrrhotite+chalcopyrite+pentlandite+chromite+sulfides, arsenides, tellurides, antimonides and alloys of platinum group metals. Maybe associated with pipes of Fe-rich olivine.
Texture/Structure Clots of massive sulfide and disseminated grains.
Alteration None related to ore

Ore Controls In layers near first reappearance of olivine as a cumulate phase after thick accumulation of plagioclase pyroxene rocks. May be related to introduction of new magma.
Weathering Difficult to see ore zone on weathered surface, exploration require extensive sampling and chemical analysis.

Geochemical Signature: PGE, Cu, Ni

Examples Bushveld
Stillwater Complex

References Vermaak & Hendriks (1976)
Todd and others (1982)

DEPOSIT TYPE Stratiform mafic-ultramafic SUBTYPE Fe, Ti, V

AUTHOR Norman J Page DATE 8/10/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Layers of Ti-V-rich magnetite in upper parts of large repetitively layered mafic-ultramafic intrusions

GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro
Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix.
Age Range Generally Precambrian, may be as young as Tertiary.
Depositional Environment Intruded into granitic gneiss or into volcanic-sedimentary terrane.
Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.

Associated Deposit Types

Metal Concentrations Ni, PGE, Cr, Ti, high Mg, low Na, K, P.

DEPOSIT DESCRIPTION

Ore Minerals: Vanadiun-bearing magnetite±ilmenite±traces of sulfides

Texture/Structure Massive magnetite-ilmenite, cumulus textures

Alteration None related to ore

Ore Controls Layers near top of intrusion. Layers may be cut by pipes and veins rich in ilmenite.

Weathering Blocks of magnetite in soil and alluvium.

Geochemical Signature: Fe, Ti, V

Examples Bushveld Complex

References Williams (1969) and Molyneux (1969)

DEPOSIT TYPE Synorogenic-Synvolcanic Ni SUBTYPE

AUTHOR Norman J Page DATE 10/11/83

APPROXIMATE SYNONYM Gabbroid class
Gabbroid associated of Marston, Groves, Hudson and Ross (1981)
OF (REFERENCE) Ross and Travis (1981)

DESCRIPTION Massive lenses, matrix and disseminated sulfide in small to medium sized gabbroic intrusions in greenstone belts.
GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Norite, gabbro-norite, pyroxenite, peridotite, troctolite, anorthosite forming layered or composite igneous complexes.

Textures Phase and cryptic layering sometimes present, rocks usually cumulates.

Age Range Archean to Tertiary, predominantly Archean and Proterozoic.
Depositional Environment Intruded synvolcanically or during orogenic development of the terrane into metamorphic rocks or volcanic piles.
Tectonic Setting(s) Unstable, metamorphic belts, greenstone belts, mobile belts.

Associated Deposit Types Komatiitic Ni, Dunitic-Ni, talc-carbonate Ni-Au.

Metal Concentrations

DEPOSIT DESCRIPTION

Ore Minerals: Pyrrhotite+pentlandite+chalcopyrite±pyrite±Ti-magnetite±Cr-magnetite±graphite--by-product Co and PGE.

Texture/Structure Predominantly disseminated sulfides; often highly deformed and metamorphosed so primary textures and mineralogy have been altered. Deformation about the same age as the deposit.

Alteration None associated with ore.

Ore Controls Linear folded and faulted belts; in basaltic parts of the intrusion, however, pipe-like discordant sulfides occur. Ores frequently in more ultramafic parts of the complex.
Weathering Lateritic
Geochemical Signature: Ni, Cu, Co, PGE

Examples
Sally Malay, Australia
Rana, Norway

References Thornett (1981)
Boyd and Mathiesen (1979)

DEPOSIT TYPE Dunitic-Ni SUBTYPE

AUTHOR Norman J Page DATE 8/10/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Low grade (0.4-1% Ni) and high grade (1-3% Ni) disseminated sulfide mineralization in intrusive dunites.

GENERAL REFERENCE Marston, Goves, Hudson, and Ross (1981); Ross and Travis (1981)

GEOLOGICAL ENVIRONMENT

Rock Types Olivinite, olivine peridotite in subconcordant lenses 500-1,000 m long, 50-1,100 m thick.
Textures Olivinite; coarse-grained (2-20 mm) subequant olivine (Fo_{87-95}) interlocked to give polygonal to mosaic texture; olivine peridotite; ovate olivine with intercumulus pyroxene, sulfide and oxide minerals.
Age Range Precambrian

Depositional Environment Intruded into contacts between clastic sedimentary and felsic volcanic rocks and mafic to ultramafic volcanic rocks.
Tectonic Setting(s) Greenstone belts.

Associated Deposit Types Komatiitic Ni, Synorogenic-Synvolcanic-Ni Talc-carbonate Ni-Au, layered sedimentary Ni
Metal Concentrations Ni, Cr, Mg, PGE

DEPOSIT DESCRIPTION

Ore Minerals: High Grade: pyrrhotite+pentlandite+magnetite+pyrite+chalcopyrite+chromite; Low Grade: the same minerals+millerite+heazlewoodite+godlevskite+polydymite+vaesite+awaruite+bravolite+cobaltite+nickeliferous linnaeite+cubanite+Fe-Ni arsenides.
Texture/Structure Lenticular shoots of massive, matrix, and breccia ores fine to medium grained, also occurs as interstitial films. Olivine is commonly rounded when sulfide present.
Alteration Prograde and retrograde serpentinization after deposition; usually metamorphosed.

Ore Controls Dunitic lenses close to major strike slip faults and at high stratigraphic position in volcanic pile; most Ni-rich ores concentrated at one margin- perhaps base of intrusion.
Weathering Lateritic zones may be enriched in PGE.

Geochemical Signature: Ni, Cu, PGE, Cr, Co. Ni/Cu = 19-70+, Ni/Co=30-70. Massive sulfide ores 6-9 percent Ni, disseminated ores up to 3 percent Ni.

Examples Agnew (Perseverance)
Mt. Keith

References Martin and Allchurch (1975)
Burt and Sheppy (1975)

DEPOSIT TYPE Chrysotile asbestos SUBTYPE

AUTHOR Norman J Page DATE 8/15/83

APPROXIMATE SYNONYM Quebec Type OF (REFERENCE) Shride (1973)

DESCRIPTION Chyrsotile asbestos developed in stockworks in serpentinized ultramafic rocks.

GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Serpentinites, dunite, harzburgite, pyroxenite

Textures Highly fractured and veined, serpentinized ultramafic rocks

Age Range Paleozoic-Mesozoic-Tertiary

Depositional Environment Usually part of an ophiolite sequence

Tectonic Setting(s) Unstable accreted oceanic terranes.

Associated Deposit Types Podiform chromite.

Metal Concentrations

DEPOSIT DESCRIPTION

Ore Minerals: Chrysotile asbestos±magnetite±brucite±talc±tremolite-actinolite

Texture/Structure Stockworks of veins in serpentinized ultramafic rocks.

Alteration None associated with ore, but silica-carbonate, talc may be developed.

Ore Controls Two periods of serpentinization, an earlier pervasive one and a later period near the end of intense deformation accompanied by hydrothermal activity perhaps as a function of intrusion of acidic, igneous rocks highly dependent upon major faulting, and fracture development.

Weathering

Geochemical Signature:

Examples Thetford-Black Lake deposit Asbestos

References Riordon (1957) Shride (1973)

DEPOSIT TYPE Komatiitic Ni SUBTYPE

AUTHOR Norman J Page DATE 8/10/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Lenticular, irregular elongate to tabular, pipelike Ni-Cu sulfides associated with komatiitic volcanic extrusive rocks.

GENERAL REFERENCE Arndt and Nisbet, (1982)

GEOLOGICAL ENVIRONMENT

Rock Types Dunite, pyroxenite, peridotite, basalt, komatiites, komatiitic basalts.
Textures Bladed olivine or pyroxene with skeletal appearance in random or parallel orientations; spinifex textures, fracture or joint patterns that resemble pillows
Age Range Archean-Proterozoic generally, some may be in Cretaceous-Tertiary.
Depositional Environment Greenstone belts with mafic to felsic rocks containing numerous volcanic events.
Tectonic Setting(s) Unstable areas.

Associated Deposit Types Dunitic Ni

Metal Concentrations Ni, Cu, Mg, PGE; Rocks contain more than 15% MgO and approach 40% MgO.

DEPOSIT DESCRIPTION

Ore Minerals: Pyrite±pyrrhotite+chalcopyrite-pentlandite, by-product PGE

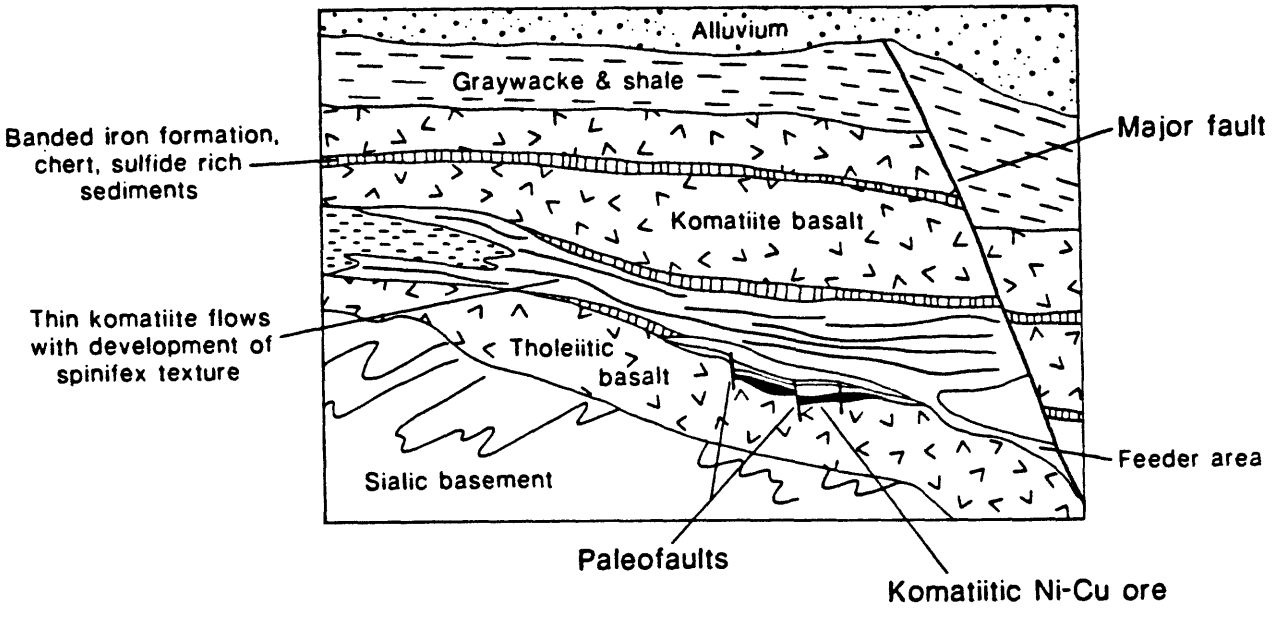
Texture/Structure Sulfide contents vary from base to top of deposit. Base contains massive sulfide grading into net-textured or matrix sulfide into disseminated sulfide.
Alteration None related to ore.
Ore Controls In lowermost flows more than 10 m thick; in zones of increased spinfex development; and near feeder areas for the flows. Show evidence of paleofaulting at the time the flows were deposited and have thickening and thinning of flows along strike. Ore occurs in irregularities at bottom of flows. Unit contains greater than 1,000 ppm or sulfide-bearing cherts, argillites; shales or iron carbonate sequences occur below flows.
Weathering Develop gossans, laterites.
Geochemical Signature: Gossan contain 15 to 30 ppb Pd and 5 to 10 ppb Ir over known Ni-Cu deposits where Cu and Ni are leached out of the gossan.

Examples Kambalda, Australia
Damba, Zimbabwe
Langmuir, Canada

References Gresham & Loftus-Hills (1981)
Williams (1979)
Green and Naldrett (1981)

CARTOON CROSS-SECTION

Modified from Marsten, et al. (1981)



DEPOSIT TYPE Volcanogenic manganese SUBTYPE

AUTHOR Randolph A. Koski DATE June 8, 1983

APPROXIMATE SYNONYM Volcanogenic-sedimentary OF (REFERENCE) Roy (1981)

DESCRIPTION Lenses and stratiform bodies of manganese oxide, carbonate, and silicate in volcanic-sedimentary sequences. Genesis related to volcanic (volcanogenic) processes.
GENERAL REFERENCE Roy, Supriya, 1981, Manganese deposits: New York, Academic Press, 458 p.

GEOLOGICAL ENVIRONMENT

Rock Types Chert-shale-graywacke-tuff-basalt; chert-jasper-basalt (ophiolite); basalt-andesite-rhyolite (island-arc); basalt-limestone; conglomerate-sandstone-tuff-gypsum.
Textures
Age Range Cambrian to Pliocene
Depositional Environment Seafloor hot springs, generally deep water; some shallow water marine; some may be enclosed basin
Tectonic Setting(s) Oceanic ridge, marginal basin, island arc, young rifted basin; all can be considered eugeosynclinal.
Associated Deposit Types Stratiform massive Fe-Cu-Zn sulfided deposits, stratiform barite, ferruginous chert and limestone; gypsum.
Metal Concentrations Mn, Fe, Ba, Zn, Pb, Cu

DEPOSIT DESCRIPTION

Ore Minerals: Rhodochrosite, Mn-calcite, braunite, hausmannite, bementite, neotocite, alleghenyite, spessartine, rhodonite, Mn-opal, manganite, pyrolusite, coronadite, cryptomelane, hollandite, todorokite, amorphous MnO_2.
Texture/Structure Fine-grained massive crystalline aggregates, botryoidal, colloform in bedded and lensoid masses.
Alteration Spilitic or greenschist facies alteration of associated mafic lavas, silicification, hematitization.
Ore Controls Sufficient structure and porosity to permit subseafloor hydrothermal circulation and seafloor venting; redox potential at seafloor/seawater interface around hot spring; supergene enrichment to upgrade Mn content.
Weathering Strong development of secondary Mn oxides (todorokite, birnessite, pyrolusite, amorphous MnO_2) at the surface and along fractures.
Geochemical Signature: Although Mn is only moderately mobile and relatively abundant in most rocks, Mn minerals may incorporate many other trace elements.

Examples Olympic Peninsula
Franciscan type

References Park (1942; 1946); Sorem & Gunn (1967); Taliaferro & Hudson, (1943); Cerar and others (1982); Snyder (1978); Kuypers & Denyer (1979)

DEPOSIT TYPE Bedded barite SUBTYPE

AUTHOR G. J. Orris DATE June 29, 1983

APPROXIMATE SYNONYM Stratiform barite OF (REFERENCE)

DESCRIPTION Stratiform basin deposits of barite interbedded with chert, shale, and limestone or dolostone.
GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Generally dark-colored chert, shale, limestone or dolostone.

Age Range Proterozoic-Paleozoic.

Depositional Environment Epicratonic marine basins or embayments (often with smaller local restricted basins).
Tectonic Setting(s) Some deposits associated with hinge zones controlled by synsedimentary faults (sediment-hosted, submarine exhalative model).

Associated Deposit Types Sediment-hosted, submarine exhalative Zn-Pb.

Metal Concentrations Ba (peripherally Pb, Zn, Mn)

DEPOSIT DESCRIPTION

Ore Minerals: Barite±minor witherite±minor pyrite, galena, or sphalerite.

Texture/Structure Stratiform - often lensoid to poddy; ore laminated to massive with associated layers of barite nodules or rosettes; barite may exhibit primary sedimentary features.

Alteration Secondary barite veining.

Ore Controls Basins form morphological traps

Weathering Indistinct - generally resembling limestone or dolostone; occasionally weathered-out rosettes or nodules
Geochemical Signature: Ba; where peripheral to sediment-hosted Zn-Pb, may have lateral (Cu)-Pb-Zn-Ba zoning and/or regional manganese halos

Examples Meggen, Germany
Magnet Cove, Arkansas
Northumberland, Nevada

References Krebs (1981)
Scull (1958)
Shawe and others (1969)

DEPOSIT TYPE Sedimentary exhalative Cu-Zn SUBTYPE

AUTHOR Dennis P. Cox DATE 10/1/83

APPROXIMATE SYNONYM Besshi Type, Kieslager OF (REFERENCE)

DESCRIPTION Thin, sheet-like bodies of massive to well-laminated pyrite and chalcopyrite within thinly laminated clastic sediments and mafic tuffs.
GENERAL REFERENCE Klau and Large (1980)

GEOLOGICAL ENVIRONMENT

Rock Types Clastic terrigenous sedimentary rocks and tholeiitic to andesitic tuffs and breccias. Locally, black shale, oxide facies iron formation, and red chert.
Textures Thinly laminated clastic rocks. All known examples are in strongly deformed metamorphic terrane. Rocks are quartzose and mafic schists.
Age Range Mainly Paleozoic and Mesozoic.

Depositional Environment Uncertain. Possibly deposition by submarine hot springs related to basaltic volcanism. Ores may be localized within permeable sediments and fractured volcanics in anoxic marine basins.
Tectonic Setting(s) Uncertain. Possibly rifted basin in island arc or back arc. Possibly spreading ridge underlying terrigenous sediment at continental slope.
Associated Deposit Types Volcanogenic chert-manganese

Metal Concentrations Cu, Ni, Co, Cr, Mn

DEPOSIT DESCRIPTION

Ore Minerals:
Pyrite+pyrrhotite+chalcopyrite+sphalerite±magnetite±valeriite±galena±bornite± tetrahedrite±cobaltite±cubanite. Quartz, carbonate, albite, white mica, chlorite, amphibole, and tourmaline.

Texture/Structure Fine-grained, massive to thinly laminated ore with colliform and framboidal pyrite. Breccia or stringer ore. Cross cutting veins contain chalcopyrite, pyrite, calcite or galena, sphalerite, calcite.
Alteration Difficult to recognize because of metamorphism.

Ore Controls Uncertain. Deposits tend to cluster in enechelon pattern.
Weathering Gossan.

Geochemical Signature: Cu, Zn, Co, Ni, Cr, Co/Ni 0.78, Au (up to 4 ppm) Ag 60 ppm.

Examples Besshi, Japan
Kieslager, Austria
Raul, Peru

References Kanehira and Tatsumi (1970)
Derkman and Klemm (1977)
Ripley and Ohmoto (1977)

DEPOSIT TYPE Subaerial volcanogenic manganese SUBTYPE

AUTHOR D. L. Mosier DATE July 1983

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Manganese mineralization in epithermal veins filling faults and fractures in subaerial volcanic rocks.
GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Flows, tuffs, breccias, and agglomerates of rhyolitic, dacitic, andesitic or basaltic composition.
Textures

Age Range Tertiary
Depositional Environment Volcanic centers

Tectonic Setting(s) Through-going fracture systems

Associated Deposit Types Epithermal gold-silver

Metal Concentrations Mn, Fe, P, (Pb, Ag, Au, Cu)

DEPOSIT DESCRIPTION

Ore Minerals: Psilomelane, pyrolusite, braunite, wad, manganite, rhodochrosite, cryptomelane, hollandite, coronadite, Fe oxides, manganocalcite, calcite, quartz chalcedony, barite, zeolites.
Texture/Structure Veins, bunches, stringers, nodular masses, disseminations.
Alteration Kaolinitization

Ore Controls Through-going faults and fractures; brecciated volcanic rocks.

Weathering Oxidized zone contains abundant manganese and iron oxides and kaolinite.
Geochemical Signature:

Examples Talamantes, Mexico
Gloryana, New Mexico
Sardegna, Italy

References Rocha and Wilson (1948)
Farnham (1961)
Burckhardt and Falini (1956)

DEPOSIT TYPE Carbonate-hosted manganese replacement SUBTYPE

AUTHOR D. L. Mosier DATE July 1983

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Manganese mineralization occurs as epigenetic veins or cavity-fillings in limestone, dolomite, or marble, which may be associated with intrusive complexes.
GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types Limestone, dolomite, marble, and associated sedimentary rocks; granite and granodiorite plutons.

Textures

Age Range Mainly Paleozoic and Mesozoic, but may be any age.

Depositional Environment Miogeosynclinal sequences intruded by small plutons.

Tectonic Setting(s) Continental margin, late orogenic magmatism.

Associated Deposit Types Silver-bearing replacement vein deposit; skarn deposits; replacement lead-zinc.

Metal Concentrations Mn, Fe, P, Cu, Ag, Au, Pb, Zn

DEPOSIT DESCRIPTION

Ore Minerals:
Psilomelane+pyrolusite+rhodochrosite+wad±manganite±rhodonite±braunite+calcite+quartz±barite±fluorite±jasper±manganocalcite±pyrite±chalcopyrite±galena±sphalerite.

Texture/Structure Tabular veins, irregular open space fillings, lenticular pods, pipes, chimneys.

Alteration

Ore Controls Open space filling in carbonate rocks. May be near intrusive contact.
Weathering Limonite and kalolinite.
Geochemical Signature:

Examples Lake Valley, New Mexico
Philipsburg, Montana
Lammereck, Austria

References Farnham (1961)
Prinz (1963)
Lechner and Plochinger (1956)

DEPOSIT TYPE Volcanic hosted massive SUBTYPE

AUTHOR Dennis Cox DATE 5/20/83

APPROXIMATE SYNONYM Enargite massive sulfide OF (REFERENCE) Sillitoe, 1983

DESCRIPTION Stratabound massive copper sulfosalt deposits in volcanic flows, breccias and tuffs near porphyry system.

GENERAL REFERENCE Sillitoe, 1983

GEOLOGICAL ENVIRONMENT

Rock Types Andesite, dacite, flows, breccias and tuffs

Textures Fine grained, porphyritic, brecciated

Age Range Mainly Tertiary

Depositional Environment Volcanic terrane, uppermost levels of intrusive systems

Tectonic Setting(s) Continental margins and island arcs

Associated Deposit Types Porphyry Cu-Mo

Metal Concentrations Cu, Ag, As, Sb, Zn, Mo

DEPOSIT DESCRIPTION

Ore Minerals: All contain pyrite. In addition, enargite+luzonite+tennantite (Lepanto), enargite+covellite+chalcocite+bornite+chalcopyrite (Bor), enargite+luzonite+tetrahedrite (Resck), tetrahedrite+sphalerite+chalcopyrite+arsenopyrite (Sam Goosly). Most contain a few ppm Au, Sam Goosly is Ag-rich.
Texture/Structure Breccia filling, replacement of clasts by sulfides

Alteration Chalcedony, alunite, pyrophyllite, diaspore, dickite andalusite dumortierite, tourmaline, barite, and scorzalite.
Ore Controls Tuff-breccias or breccia pipes are the channel ways for ore solutions originating from younger porphyry copper systems.
Weathering

Geochemical Signature: As, Sb, Cu, Zn, Ag, Au, Sn (Lepanto), W, (Sam Goosely).

Examples Lepanto, Philippines
Recsk, Hungary; Bor, Yugoslavia
Sam Goosly (Equity Silver),
B. C. Canada

References
Gonzales (1956)
Sillitoe (1983)
Schroeter (1980)

DEPOSIT TYPE Quartz pebble conglomerate Au-U-Os-Ir SUBTYPE

AUTHOR D. Cox DATE 8/9/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION

GENERAL REFERENCE Pretorius (1981)

GEOLOGICAL ENVIRONMENT

Rock Types Conglomerate and sandstone deposited on Archean granite-greenstone. Basal volcanic rocks. Sequence grades upward to fine then to coarse sediments.
Textures Clast supported conglomerate. Well rounded, well packed pebbles of vein quartz, chert and, locally, pyrite. Matrix is quartz, mica, chlorite, pyrite and fuchsite.
Age Range Major deposits are Archean to L. Proterozoic 3,100-2,200 m.y. Tarkwa is 1900 m.y.
Depositional Environment Elongate basins or half-graben. Middle and basal reaches of alluvial fans deposited on steeper side of basins.

Tectonic Setting(s) Moderate uplift and erosion of Archean granite-greenstone terrane and cover rocks so as to remove Phanerozoic strata and retain lower Proterozoic rocks.
Associated Deposit Types Recent gold placer deposits. Low-sulfide gold quartz veins and massive sulfide in underlying basement rocks.

Metal Concentrations

DEPOSIT DESCRIPTION

Ore Minerals: Gold, pyrite, uraninite, brannerite, osmium-iridium alloys, isoferro platinum and sperrylite. By-product Ag. Middle Proterozic and Phanerozoic occurrences have only traces of pyrite.

Texture/Structure Pyrite may occur as rounded grains and pebbles.

Alteration

Ore Controls Alluvial fans, trough-cross bedding, current- or wave winnowed bedding surfaces. Carbonaceous layers derived from algal mats deposited at low-energy base of fan contain U and fine Au.
Weathering
Geochemical Signature:

Examples Witwatersrand, S. Africa
Elliot Lake, Ontario
Jacobina, Brazil
Tarkawa, Ghana

References Pretorius (1981); Feather (1976); Roscoe (1969); Gross (1968); Cox (1967); Sestini (1973)

DEPOSIT TYPE Diamond placers (and pipes) SUBTYPE

AUTHOR Dennis Cox DATE 5/13/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Diamonds in kimberlite diatremes and in sedimentary rocks and alluvial- and beach-sediments derived from them.

GENERAL REFERENCE Orlov (1973), Lampietti and Sutherland (1978)

GEOLOGICAL ENVIRONMENT

Rock Types Kimberlite diatremes. Conglomerate beds may contain paleoplacers. Modern placers may be derived from kimberlites or conglomerate.
Textures Pipes: porphyritic igneous texture. Breccias with inclusions of many rocks from mantle, basement and overlying sequences.
Age Range Most productive pipes are 80-100, 250, and 1,000-1,100 m.y. in age
Depositional Environment Alluvial deposits may be 1,000 km from source in sandstone, conglomerate or modern river and beach sediment
Tectonic Setting(s) Some pipes occur at intersections of regional zones of weakness visible in LANDSAT or SLAR
Associated Deposit Types Placer Au, PGE

Metal Concentrations

DEPOSIT DESCRIPTION

Ore Minerals: Diamond, bort or carbonado (polycrystalline generally dark colored), ballas (spherulitic polycrystalline), and amorphous carbonado. Diamonds derived from sedimentary rocks may retain sand grains cemented to grooves or indentations in the crystal.
Texture/Structure

Alteration Diamonds may have patches of greenish coloration which, on heating above 400° turn brown. Therefore brown patches indicate derivation from metamorphosed sediment rather than kimberlite.
Ore Controls Both pipe and placer deposits are heterogeneous in their diamond distribution. Alluvial diamonds decrease in size but increase in quality with distance from source.
Weathering

Geochemical Signature: Anomalous Ni, Nb, and heavy minerals such as pyrope garnet, and Mg-ilmenite indicate nearby pipes.

Examples African Placer deposits
Venezuela placer deposits

References Sutherland (1982)
Fairbairn (1971) and Reid and Bisque (1975)

DEPOSIT TYPE Placer Au, PGE (high energy) SUBTYPE

AUTHOR Warren Yeend DATE 8/12/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Elemental gold and platinum-group alloys in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, aeolin, and (rarely) glacial deposits.
GENERAL REFERENCE Boyle (1979), Wells (1973), Lindgren (1910)

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial gravel and conglomerate with white quartz clasts, and heavy minerals indicative of low-grade metamorphic terrane. Sands and sandstones of secondary importance.
Textures Coarse clastic

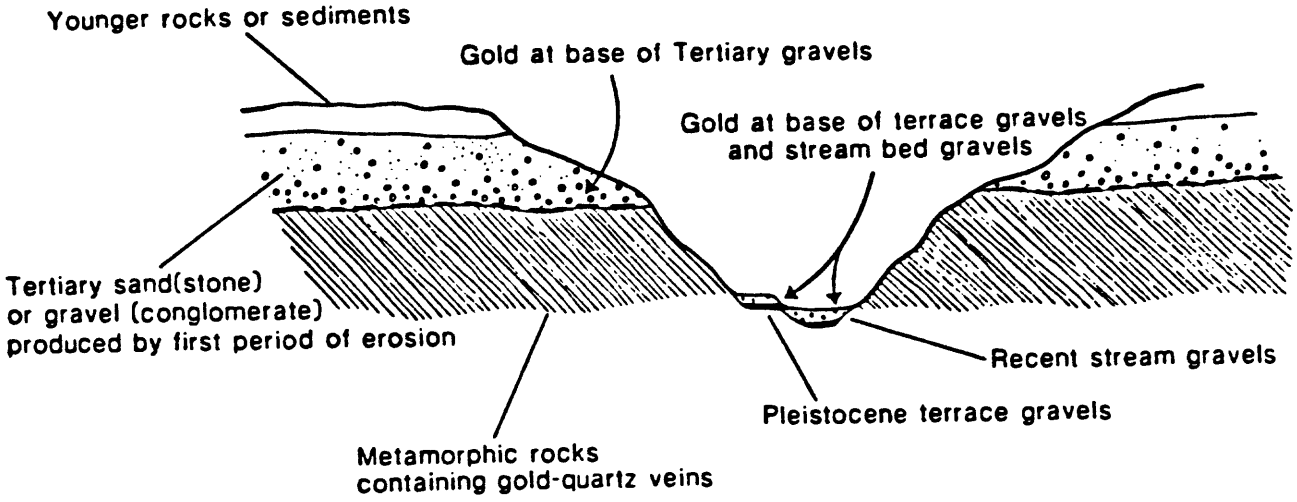
Age Range Cenozoic (see attached sketch showing multic-cycle placer gold)

Depositional Environment High energy alluvial where gradients flatten, and river velocities lessen as inside of meanders, below rapids and falls, beneath boulders, vegetation mats; raised, present, and submerged beaches.
Tectonic Setting(s) Tertiary conglomerates along major fault zones, shield areas where erosion has proceeded for a long time producing multicycle sediments; high-level terrace gravels.
Associated Deposit Types Black sands (magnetite, ilmenite, chromite), garnet, zircon, monazite (yellow) sands; low grade metamorphic rock terrains--slate, phyllite, schist with abundant quartz veins and pods; secondary pyrite; serpentine.
Metal Concentrations As, Ag, Sb, Cu, Hg, Cr, Ni

DEPOSIT DESCRIPTION

Ore Minerals: Au, platinum-iron alloys, osmium alloys; gold commonly with attached quartz, magnetite and/or ilmenite.
Texture/Structure Flattened, rounded edges, flaky, flour gold extremely fine grained flakes; very rarely equidimensional nuggets.
Alteration
Ore Controls See depositional environment above; gold "traps" as natural riffles in floor of river or stream as fractured bedrock, slates, schists, phyllites, dikes, bedding planes, all structures trending transverse to direction of water flow; for PGE, ophiolite or zoned "Alaskan type" ultramafic complexes as source rocks.
Weathering
Geochemical Signature: Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, and heavy minerals-magnetite, chromite, ilmenite, hematite, pyrite, zircon, garnet, rutile
Examples The Choco, Colombia
Nevada, California
Victoria, Australia

References Emmons (1937); Meyer Sierra (1941); Lindgren (1911); Yeend (1974); Knight (1975)


Younger rocks or sediments
Gold at base of Tertiary gravels
Gold at base of terrace gravels
and stream bed gravels
Tertiary sand(stone)
or gravel (conglomerate)
produced by first period of erosion
Recent stream gravels
Pleistocene terrace gravels
Metamorphic rocks
containing gold-quartz veins

DEPOSIT TYPE Placer (medium to low energy) SUBTYPE

AUTHOR Warren Yeend DATE 8/16/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Elemental gold and platinum-group alloys and certain heavy minerals in eluvium, alluvial, beach, and aeolin sands and silts.

GENERAL REFERENCE Wells (1973); Jenkins (1964)

GEOLOGICAL ENVIRONMENT

Rock Types Beach sands (raised, modern and submerged), eluvium, alluvial sands and fine-grained gravels, aeolin.

Textures Medium clastic

Age Range Recent, Quaternary, rarely Tertiary

Depositional Environment Marine (near shore), rivers and streams (medium to low gradient), desert (aeolin) sand dunes, in-situ weathering.

Tectonic Setting(s) Within and adjacent to modern and ancient plate margin mountain systems.
Associated Deposit Types Black sands, both high and low grade metamorphic terranes, both felsic and mafic plutonic igneous terranes; ophiolite and ultramafic terranes, tin granites.
Metal Concentrations As, Ag, Sb, Cu, Hg, Cr, Sn, Pb, Cr

DEPOSIT DESCRIPTION

Ore Minerals: Au, PGE, monazite, rutile, magnetite, ilmenite, cassiterite, garnet, zircon, chromite, spinel
Texture/Structure Stream tin (cassiterite) and spinel as rolled pebbles; zircon and garnet as rounded grains; magnetite, ilmenite, chromite as equidimensional grains, gold and platinum-iron alloys as flattened grains, osmium alloys as irregular sometimes hexagonal grains.
Alteration

Ore Controls See depositional environment above; gold "traps" in natural riffles in floor of river or stream, in fractured bedrock, slates, schists, phyllites, dikes, bedding planes, and in structures trending transverse to direction of water flow. For PGE, ophiolite or zoned "Alaskan" type complexes as source rocks.
Weathering
Geochemical Signature: Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, Cr
Examples Netherlands Indies References Westerveld (1937)

DEPOSIT TYPE Sedimentary manganese SUBTYPE

AUTHOR Cannon, W. F,. and Force, E. R. DATE 5/13/83

APPROXIMATE SYNONYM Bath tub-ring Mn OF (REFERENCE) Cannon & Force (1983)

DESCRIPTION Shallow marine (non-volcanogenic) sedimentary Mn deposits formed around rims of anoxic basins during transgression.

GENERAL REFERENCE Cannon and Force (1983)

GEOLOGICAL ENVIRONMENT

Rock Types Shallow marine sediments, most commonly carbonates, clays, and glauconitic sands, commonly with shellbeds, in transgressive sequences associated with anoxic basins.
Textures

Age Range Mostly in "Anoxic events," narrow time periods within the lower Paleozoic, Jurassic, and mid-Cretaceous, but may be in rocks of any age associated with anoxic basins.
Depositional Environment Shallow (50-300 m) marine, commonly in sheltered sites around paleo-islands.
Tectonic Setting(s) Cratonic or nearly so.

Associated Deposit Types Locally, sedimentary phosporites

Metal Concentrations Mn

DEPOSIT DESCRIPTION

Ore Minerals: Wide variety of Mn carbonates (mostly basinward) and oxides (mostly landward).

Texture/Structure Commonly as oolites, pisolites, laminae, and shell replacements.
Alteration Supergene alteration to high grade ore is common.
Ore Controls Oxidation-reduction interface (involves age, paleobasin reconstruction, paleodepth of site) and lack of clastic dilution.
Weathering Mn carbonates may weather to brown, nondescript rock. Black secondary oxides are common.
Geochemical Signature: none known.

Examples Molango, Mexico (Jurassic)
Nikopol, USSR (Oligocene)
Groote Eylanot, Australia (Cretaceous)

References

DEPOSIT TYPE Marine phosphate-upwelling type SUBTYPE

AUTHOR D. L. Mosier DATE 10/3/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Phosphorite sediments form a major stratigraphic unit within a sequence of marine sediments in basins with good connection to the open sea and upwelling areas.

GENERAL REFERENCE Slansky (1980); Sheldon (1964)

GEOLOGICAL ENVIRONMENT

Rock Types Phosphorites, marls, shales, cherts, limestones, dolomites, and volcanic materials.

Textures

Age Range Precambrian through Miocene.

Depositional Environment Marine sedimentary basins with good connection to the open sea and upwelling, areas highly productive of plankton. Deposition occurs mostly in warm latitudes, mostly between the 40th parallels.
Tectonic Setting(s) Intra-plate shelf, platform, miogeosynclines, and eugeosynclines.
Associated Deposit Types Sedimentary manganese.

Metal Concentrations

DEPOSIT DESCRIPTION

Ore Minerals: Apatite+fluorapatite+dolomite+calcite+quartz+clays (montmorillonite or illite)±halite±gypsum±iron oxides±siderite± pyrite±carnotite

Texture/Structure Pellets, nodules, phosphatized shell and bone material.

Alteration

Ore Controls Basins, or parts of basins, favorable for the accumulation of organic rich sediments and for their evolution into phosphorites. Individual beds may be several feet thick and may extend over hundreds of square miles.
Weathering Limonite and goethite.
Geochemical Signature: P, N, F, C, and U.

Examples Southeast Idaho, Idaho — References Gulbrandsen and Krier (1980)
Meskala, Morocco — British Sulphur Corp. Ltd. (1980)
Stra Quertane, Tunisia — British Sulphur Corp. Ltd. (1980)

DEPOSIT TYPE Marine phosphate-warm current type SUBTYPE

AUTHOR D. L. Mosier DATE 10/3/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Phosphorites formed in warm currents along the eastern coasts of continents -- consist of phosphatic limestones or sandstone.

GENERAL REFERENCE Cathcart and Gulbrandsen (1973); Sheldon (1964); Zellers-Williams, Inc. (1978)

GEOLOGICAL ENVIRONMENT

Rock Types Phosphatic limestone and sandstone; chert and diatomaceous material may be present.
Textures

Age Range Lower Cretaceous through Pliocene.
Depositional Environment Basins of structural lows on the flanks of rising domes, at the mouths of rivers and estuaries. Deposition occurs in warm latitudes, mostly between the 40th parallels. Deposits are formed by dynamic upwelling or by the cool counter current associated with warm density current.
Tectonic Setting(s) Continental shelf; may be associated with eugeosynclinal rocks.
Associated Deposit Types

Metal Concentrations

DEPOSIT DESCRIPTION

Ore Minerals:
Fluorapatite+quartz+dolomite+montmorillonite+kaolinite+calcite±wavellite± crandallite±illite±clinoptilolite±altapulgite±smectite±collophane
Texture/Structure Phosphatic pellets and fossils fragments with a carbonate matrix.
Alteration

Ore Controls Stratigraphic phosphatic horizons within embayments and estuarine environments in proximity to the open seas. Basins on flanks of structural highs (domes, arches, anticlines) are important controls for phosphate deposition.
Weathering Geothite
Geochemical Signature: P, C, U, N, F

Examples Paulista, Brazil
East North, and South Florida
Offshore Savannah, Georgia

References British Sulphur Corp. Ltd. (1980);
Zellers-Williams Inc. (1978)

DEPOSIT TYPE Nickel laterite SUBTYPE Oxide & Silicate type

AUTHOR Donald Singer and M. P. Foose DATE 6/83

APPROXIMATE SYNONYM OF (REFERENCE)

DESCRIPTION Nickel-rich in situ lateritic weathering products developed from peridotites. Ni silicates predominate in some deposits, Ni rich iron oxides in others.

GENERAL REFERENCE Evans and others (1979)

GEOLOGICAL ENVIRONMENT

Rock Types Ultramafic rocks-particularily peridotites, dunites, and serpentenized peridotites.
Textures Pisolitic soils
Age Range Precambrian to Tertiary source rocks, typically Cenozoic weathering.
Depositional Environment Relatively high rates of chemical weathering (warm-humid climates) and relatively low rates of physical erosion.
Tectonic Setting(s) Unstable tectonic areas.

Associated Deposit Types Podiform chromite, PGE placers

Metal Concentrations Co, Cr, Mn

DEPOSIT DESCRIPTION

Ore Minerals: Garnierite, hydrous silicates, nickeliferous quartz, and goethite. In oxide type, Ni goethite is abundant.

Texture/Structure Red-brown pisolitic soils.
Alteration Zoned-from top: (1) Red, yellow, and brown limonite soils; (2) saprolites--continuous transition from soft saprolite below soils through hard saprolite and saprolitized peridotite to fresh peridotite. Boxwork of chalcedony and garnierite.
Ore Controls Upper limonite zone containing 1-2 percent Ni in oxides is more common in the oxide type; lower saprolite and boxwork zone contain 2-3 percent Ni in hydrous silicates. The oxide and silicate types are end members with most deposits inbetween.
Weathering Red-brown pisolitic soils representing the products of leached ultramafics.
Geochemical Signature: Enriched in Ni, Co, Cr; depleted in MgO relative to fresh periodite (i.e. less than 40 percent MgO)

Examples Poro, Tiebaghi, New Caledonia
Cerro Matoso, Colombia
Nickel Mountain, Oregon USA
Greenvale, Queensland, Australia

References Troly and others (1979)
Gomez and others (1979)
Chace and others (1969)
Burger (1979)

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