UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

U.S. GEOLOGICAL SURVEY-INGEOMINAS

MINERAL RESOURCE ASSESSMENT OF COLOMBIA: ADDITIONAL ORE DEPOSIT MODELS

By Dennis P. Cox, Editor

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

Menlo Park, California
1983
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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References
**DEPOSIT TYPE**  Stratiform mafic-ultramafic  
**SUBTYPE**  Ni-Cu  

**AUTHOR**  Norman J Page  
**DATE**  8/10/83  

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


**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.  
**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**  Stillwater Complex  
**References**  Page (1977)
Cumulus ferro-gabbro to diorite

Cumulus gabbro and gabbro-norite

Cumulus anorthosite, troctolite, gabbro

Cumulus norite, anorthosite, minor troctolite

Cumulus pyroxenite

Cumulus harzburgite, dunite, pyroxenite

Cumulus pyroxenite, norite, gabbro

Diabase and norite dikes and sills

Metasediments

V-Ti magnetite layers can occur

CARTOON OF LAYERED STRATIFORM COMPLEX

500 to 15,000 meters

PGE zone

Chromite layers can occur

Massive, matrix disseminated Cu-Ni ore
DEPOSIT TYPE  Stratiform mafic-ultramafic  SUBTYPE  Palladium-platinum

AUTHOR  Norman J Page  DATE  8/10/83

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

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)  Cratonic, 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

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

AUTHOR  Norman J Page  DATE  8/10/83

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:  Vanadium-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  
**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 (Fo87-95) 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)
Reference  Martin and Allchurch (1975)
Mt. Keith
Burt and Sheppy (1975)
DEPOSIT TYPE  Chrysotile asbestos  

AUTHOR  Norman J Page  

DATE  8/15/83  

APPROXIMATE SYNONYM  Quebec Type  

OF (REFERENCE)  Shride (1973)  

DESCRIPTION  Chrysotile 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

AUTHOR  Norman J Page

DATE  8/10/83

APPLICATION SYNONYM

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 spinifex 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

Banded iron formation, chert, sulfide rich sediments

Thin komatiite flows with development of spinifex texture

Major fault

Feeder area

Komatiitic Ni-Cu ore

Paleofaults

Sialic basement

Tholeiitic basalt

Komatiite basalt

Graywacke & shale

Alluvium
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.


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, todogokite, amorphous MnO₂.

Texture/Structure Fine-grained massive crystalline aggregates, botryoidal, colloform in bedded and lensoid masses.

Alteration Spilitic or greenschist facies alteration of associated mafic lavas, silification, 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 MnO₄) 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

AUTHOR  G. J. Orris

DATE  June 29, 1983

APPROXIMATE SYNONYM  Stratiform barite

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

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

References  Krebs (1981)

Magnet Cove, Arkansas

Scull (1958)

Northumberland, Nevada

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
cchalcopyrite within thinly laminated clastic sediments and mafic tuffs.
GENERAL REFERENCE Klau and Large (1980)

GEOLGICAL ENVIRONMENT

Rock Types Clastic terrigenous sedimentary rocks and tholeitic 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+galena+bromite+
tetrahedrite+cobaltite+cubanite. Quartz, carbonate, albite, white mica,
chlorite, amphibole, and tourmaline.

Texture/Structure Fine-grained, massive to thinly laminated ore with
colliform and frambooidal 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. Hosier  
DATE July 1983

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

### 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

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+chalcolite+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 Goosly).

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

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

Elliot Lake, Ontario

Jacobina, Brazil

Tarkawa, Ghana
DEPOSIT TYPE  Diamond placers (and pipes)  SUBTYPE

AUTHOR  Dennis Cox  DATE  5/13/83

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°C 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, aeolian, 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 multicyle 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  References  Emmons (1937); Meyer Sierra Nevada, California (1941); Lindgren (1911); Yeend (1974); Victoria, Australia

Knight (1975)
Younger rocks or sediments

Tertiary sandstone or gravel (conglomerate) produced by first period of erosion

Metamorphic rocks containing gold-quartz veins

Gold at base of Tertiary gravels

Gold at base of terrace gravels and stream bed gravels

Recent stream gravels

Pleistocene terrace gravels
DEPOSIT TYPE  Placer (medium to low energy)  SUBTYPE
AUTHOR  Warren Yeend  DATE  8/16/83

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)
<table>
<thead>
<tr>
<th>DEPOSIT TYPE</th>
<th>Sedimentary manganese</th>
<th>SUBTYPE</th>
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**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 phosphorites

**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) References Nikopol, USSR (Oligocene) Groote Eylanot, Australia (Cretaceous)
DEPOSIT TYPE Marine phosphate-upwelling type

AUTHOR D. L. Mosier

DATE 10/3/83

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
Meskala, Morocco
Stra Quertane, Tunisia

References Gulbrandsen and Krier (1980)
British Sulphur Corp. Ltd. (1980)
British Sulphur Corp. Ltd. (1980)
DEPOSIT TYPE  Marine phosphate-warm current type  SUBTYPE

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

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

GENERAL REFERENCE  Cathcart and Gulbransen (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+altapugite+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  References  British Sulphur Corp. Ltd. (1980);
East North, and South Florida
Offshore Savannah, Georgia  Zellers-Williams Inc. (1978)
DEPOSIT TYPE | Nickel laterite
---|---
SUBTYPE | Oxide & Silicate type

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

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—particularly 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 peridotite (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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