Contents

DESCRIPTIVE MODEL OF PODIFORM CHROMITE

MODEL 8a and 8b

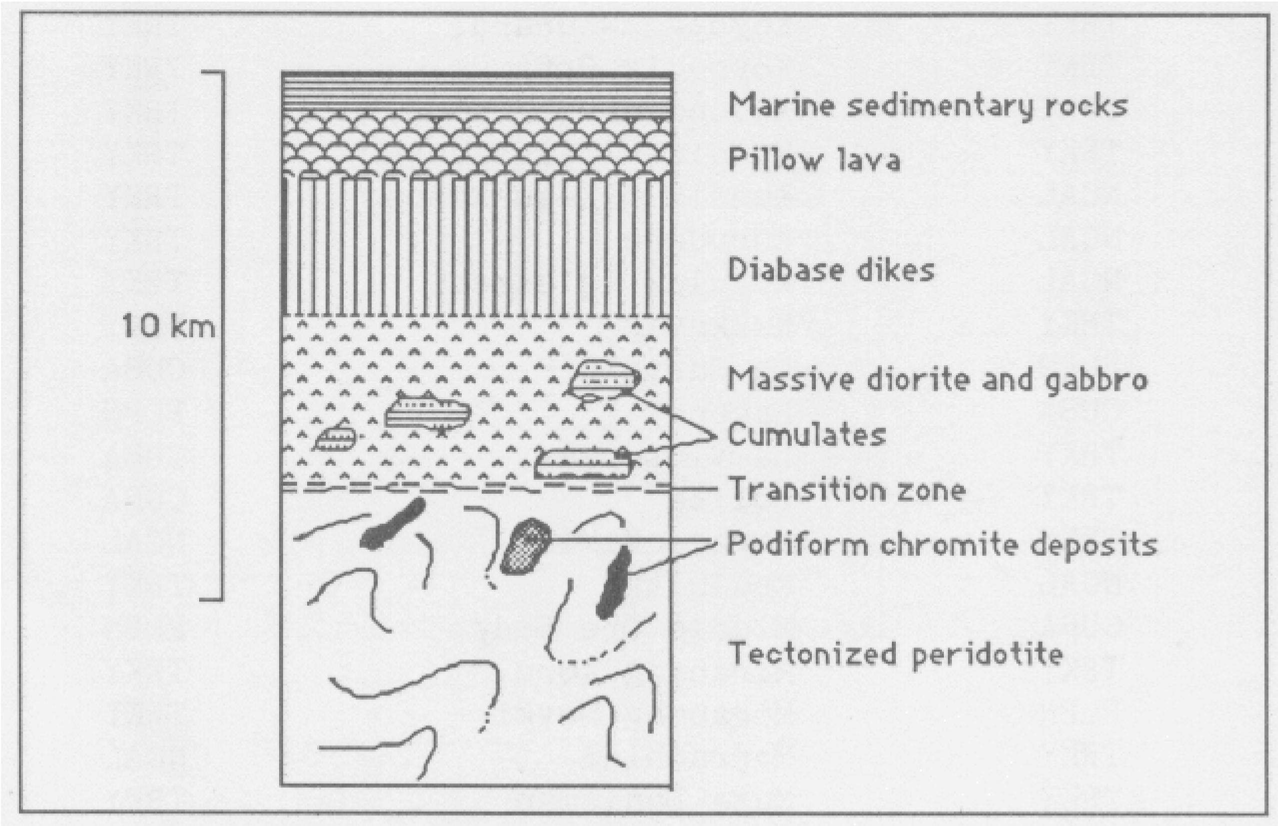
By John P. Albers

APPROXIMATE SYNONYM Alpine type chromite (Thayer, 1964).

DESCRIPTION Podlike masses of chromitite in ultramafic parts of ophiolite

complexes (see fig. 20).

Figure 20. Cartoon cross section of a typical ophiolite sequence showing locations of podiform chromite deposits from Dickey (1975).



GENERAL REFERENCE Dickey (1975).

GEOLOGICAL ENVIRONMENT

Rock Types Highly deformed dunite and harzburgite of ophiolite complexes; commonly serpentinized.

Textures Nodular, orbicular, gneissic, cumulate, pull-apart; most relict textures are modified or destroyed by flowage at magmatic temperatures.

Age Range Phanerozoic.

Depositional Environment Lower part of oceanic lithosphere.

Tectonic Setting(s) Magmatic cumulates in elongate magma pockets along spreading plate boundaries. Subsequently exposed in accreted terranes as part of ophiolite assemblage.

Associated Deposit Types Limassol Forest Co-Ni-S-As.

DEPOSIT DESCRIPTION

Mineralogy Chromite ± ferrichromite ± magnetite ± Ru-Os-Ir alloys ± laurite.

Texture/Structure Massive coarse-grained to finely disseminated.

Alteration None related to ore.

Ore Controls Restricted to dunite bodies in tectonized harzburgite or lower portions of ultramafic cumulate (see fig. 99).

Weathering Highly resistant to weathering and oxidation.

Geochemical Signature None recognized.

EXAMPLES

High Plateau, Del Norte Cty, USCA (Wells and others, 1946)

Coto Mine, Luzon, PLPN (LeBlanc and Violette, 1983)

DESCRIPTIVE MODEL OF SERPENTINE-HOSTED ASBESTOS

MODEL 8d

By Norman J Page

APPROXIMATE SYNONYM Quebec Type (Shride, 1973).

DESCRIPTION Chrysotile asbestos developed in stockworks in serpentinized ultramafic rocks.

GEOLOGICAL ENVIRONMENT

Rock Types Serpentinites, dunite, harzburgite, pyroxenite.

Textures Highly fractured and veined, serpentinized ultramafic rocks.

Age Range Paleozoic to Tertiary.

Depositional Environment Usually part of an ophiolite sequence. Later deformation and igneous intrusion may be important.

Tectonic Setting(s) Unstable accreted oceanic terranes.

Associated Deposit Types Podiform chromite.

DEPOSIT DESCRIPTION

Mineralogy 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.

Geochemical signature None.

EXAMPLES

Thetford-Black Lake, CNQU (Riordon, 1957)

DESCRIPTIVE MODEL OF W SKARN DEPOSITS

By Dennis P. Cox

MODEL 14a

DESCRIPTION Scheelite in calc-silicate contact metasomatic rocks.

GENERAL REFERENCE Einaudi and Burt (1982), Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite, granodiorite, quartz monzonite; limestone.

Textures Granitic, granoblastic.

Age Range Mainly Mesozoic, but may be any age

Depositional Environment Contacts and roof pendants of batholith and thermal aureoles of apical zones of stocks that intrude carbonate rocks.

Tectonic Setting(s) Orogenic belts. Syn-late orogenic.

Associated Deposit Types Sn-W skarns, Zn skarns.

DEPOSIT DESCRIPTION

Mineralogy Scheelite ± molybdenite ± pyrrhotite ± sphalerite ± chalcopyrite ± bornite ± arsenopyrite ± pyrite ± magnetite ± traces of wolframite, fluorite, cassiterite, and native bismuth.

Alteration Diopside-hedenbergite + grossular-andradite. Late stage spessartine + almandine. Outer barren wollastonite zone. Inner zone of massive quartz may be present.

Ore Controls Carbonate rocks in thermal aureoles of intrusions.

Geochemical Signature W, Mo, Zn, Cu, Sn, Bi, Be, As.

EXAMPLES

Pine Creek, USCA (Newberry, 1982)

MacTung, CNBC (Dick and Hodgson, 1982)

Strawberry, USCA (Nokleberg, 1981)

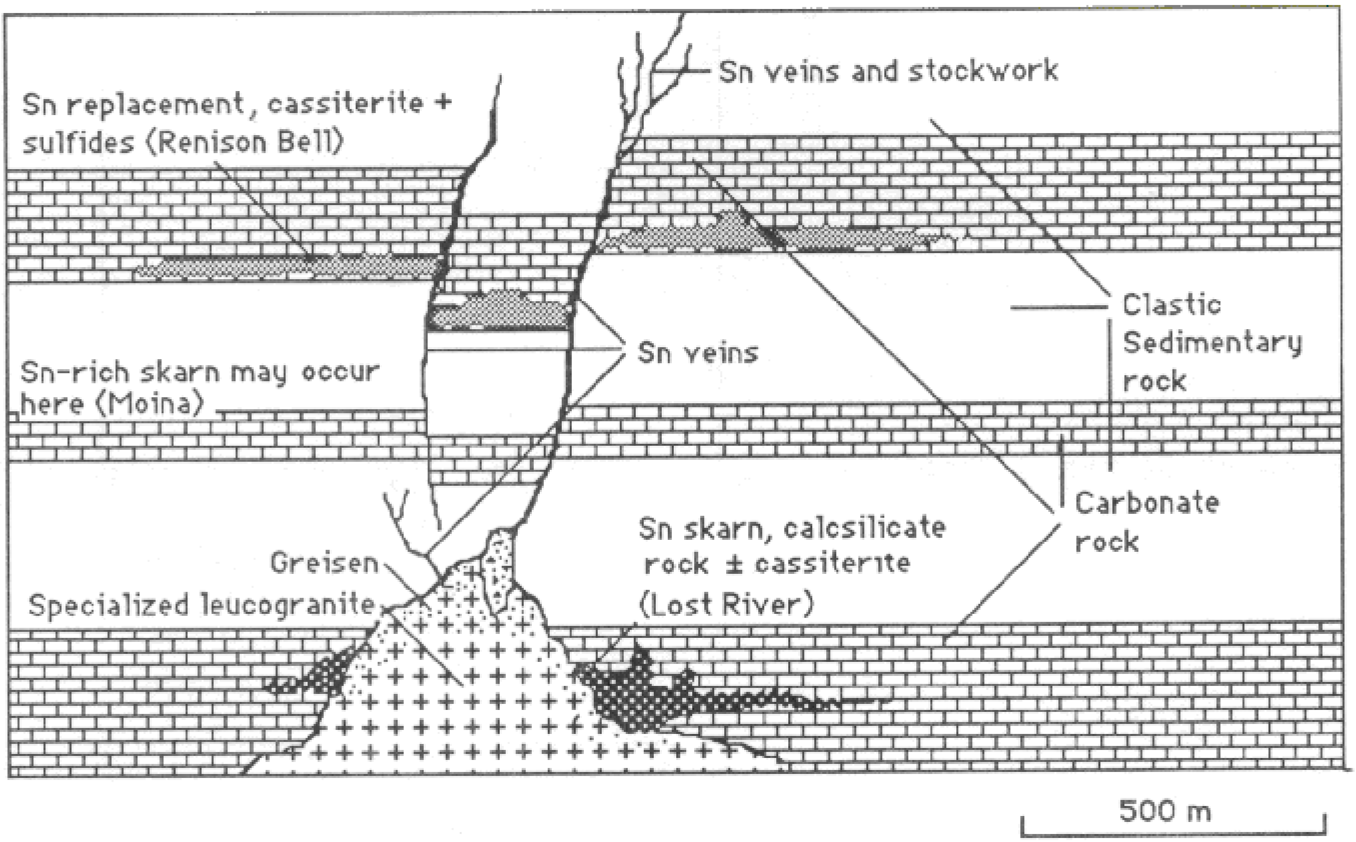
DESCRIPTIVE MODEL OF Sn SKARN DEPOSITS

MODEL 14b

By Bruce L. Reed and Dennis P. Cox

DESCRIPTION Tin, tungsten, beryllium minerals in skarns, veins, stockworks and greisens near granite-limestone contacts (see fig. 34).

Figure 34. Cartoon cross section showing between Sn skarn, replacement Sn and Sn vein deposits, and granite intrusions.



GENERAL REFERENCE Einaudi and Burt (1982), Einaudi and others (1981), Scherba (1970).

GEOLOGICAL ENVIRONMENT

Rock Types Leucocratic biotite and(or) muscovite granite, specialized phase or end members common, felsic dikes, carbonate rocks.

Textures Plutonic textures most common (granitic, seriate, fine-grained granitic). Also porphyritic-aphanitic; skarn is granoblastic to hornfelsic, banded skarn common.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Epizonal(?) intrusive complexes in carbonate terrane.

Tectonic Setting(s) Granite emplacement generally late (post orogenic).

Associated Deposit Types W skarn, Sn greisen, and quartz-cassiterite-sulfide veins; at increasing distances from intrusive-carbonate contact Sn replacement and fissure lodes may develop (as at Renison Bell).

DEPOSIT DESCRIPTION

Mineralogy Cassiterite ± minor scheelite ± sphalerite + chalcopyrite ± pyrrhotite ± magnetite ± pyrite ± arsenopyrite ± fluorite in skarn. Much Sn may be in silicate minerals and be metallurgically unavailable.

Texture/Structure Granoblastic skarn, wrigglite [chaotic laminar pattern of alternating light (fluorite) and dark (magnetite) lamellae], stockworks, breccia.

Alteration Greisenization (quartz-muscovite-topaz ± tourmaline, fluorite, cassiterite, sulfides) near granite margins and in cusps. Topaz tourmaline greisens. Idocrase + Mn-grossular-andradite ± Sn-andradite ± malayaite in skarn. Late-stage amphibole + mica + chlorite and mica + tourmaline + fluorite.

Ore Controls Mineralized skarns may or may not develop at intrusive contact with carbonate rocks; major skarn development up to 300 m from intrusion controlled by intrusion-related fractures; cross-cutting veins and felsic dikes.

Weathering Erosion of lodes may lead to deposition of tin placer deposits.

Geochemical Signature Sn, W, F, Be, Zn, Pb, Cu, Ag, Li, Rb, Cs, Re, B. Specialized granites characteristically have SiO_2 > 73 percent, K_2O > 4 percent and are depleted in CaO, TiO_2, MgO, and total Fe. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta, and most REE. They are depleted in Ni, Cu, Cr, Co, V, Sc, Sr, La, and Ba.

EXAMPLES

Lost River, USAK (Dobson, 1982)

Moina, AUTS (Kwak and Askin, 1981)

(Scherba, 1970

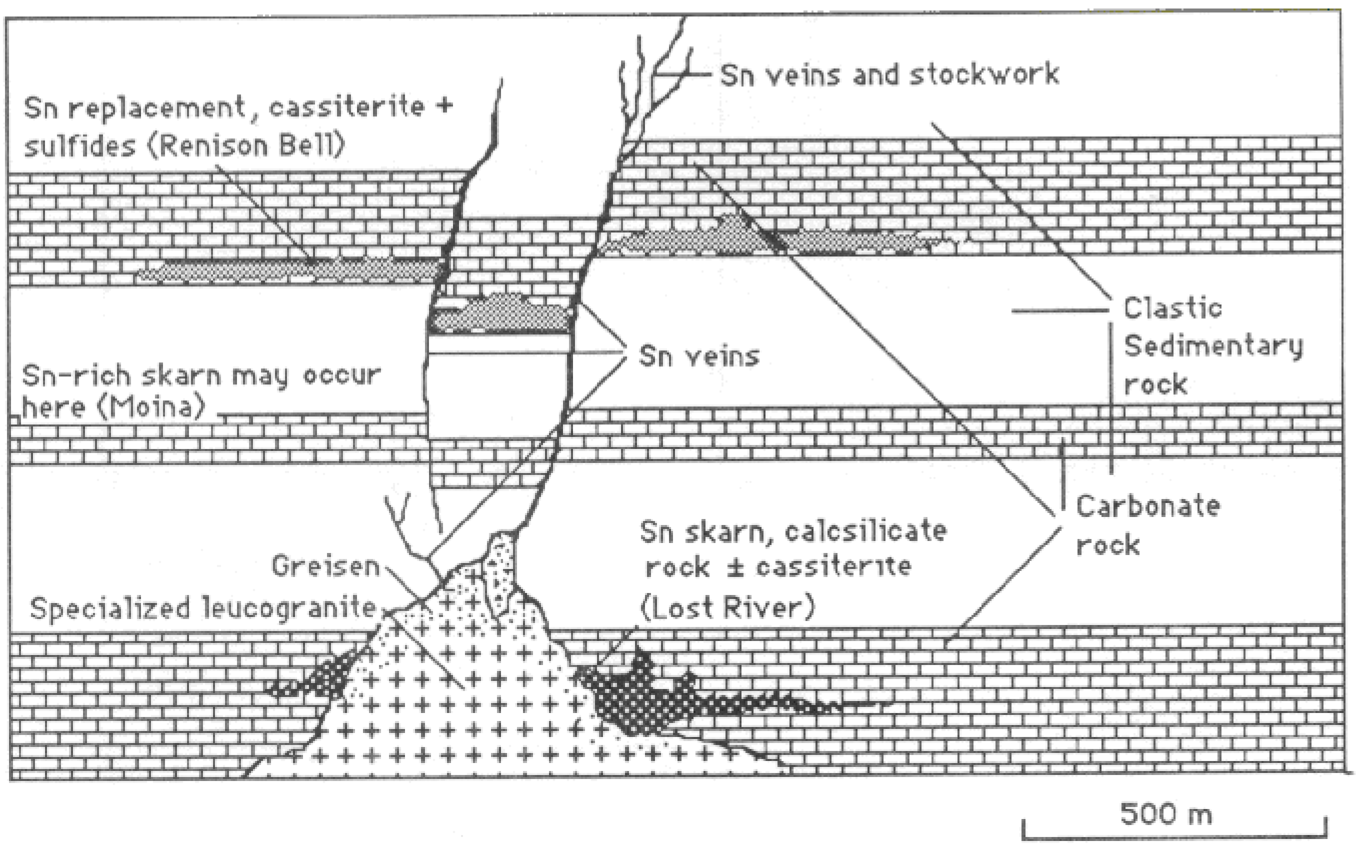
DESCRIPTIVE MODEL OF Sn GREISEN DEPOSITS

MODEL 15c

By Bruce L. Reed

DESCRIPTION Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenized granite (see fig. 44).

Figure 44. Cartoon cross section of a Sn greisen.



GENERAL REFERENCE Scherba (1970), Taylor (1979), Reed (1982), Tischendorf (1977).

GEOLOGICAL ENVIRONMENT

<u>Rock Types</u> Specialized biotite and(or) muscovite leucogranite (S-type); distinctive accessory minerals include topaz, fluorite, tourmaline, and beryl. Tin greisens are generally post-magmatic and associated with late fractionated melt.

Textures Common plutonic rock textures, miarolitic cavities may be common; generally nonfoliated; equigranular textures may be more evolved (Hudson and Arth, 1983); aplitic and porphyritic textures common.

Age Range May be any age; tin mineralization temporally related to later stages of granitoid emplacement.

Depositional Environment Mesozonal plutonic to deep volcanic environment.

Tectonic Setting(s) Foldbelts of thick sediments ± volcanic rocks deposited on stable cratonic shield; accreted margins; granitoids generally postdate major folding.

Associated Deposit Types Quartz-cassiterite sulfide lodes, quartz-cassiterite ± molybdenite stockworks, late complex tin-silver-sulfide veins.

DEPOSIT DESCRIPTION

Mineralogy General zonal development of cassiterite + molybdenite, cassiterite + molybdenite + arsenopyrite + beryl, wolframite + beryl + arsenopyrite + bismuthinite, Cu-Pb-Zn sulfide minerals + sulphostannates, quartz veins ± fluorite, calcite, pyrite.

Texture/Structure Exceedingly varied, the most common being disseminated cassiterite in massive greisen, and quartz veinlets and stockworks (in cupolas or in overlying wallrocks); less common are pipes, lenses, and tectonic breccia.

Alteration Incipient greisen (granite): muscovite ± chlorite, tourmaline, and fluorite. Greisenized granite: quartz-muscovite-topaz-fluorite, ± tourmaline (original texture of granites retained). Massive greisen: quartz-muscovite-topaz ± fluorite ± tourmaline (typically no original texture preserved). Tourmaline can be ubiquitous as disseminations, concentrated or diffuse clots, or late fracture fillings. Greisen may form in any wallrock environment, typical assemblages developed in aluminosilicates.

Ore Controls Greisen lodes located in or near cupolas and ridges developed on the roof or along margins of granitoids; faults and fractures may be important ore controls.

Weathering Granite may be "reddened" close to greisen veins. Although massive greisen may not be economic as lodes, rich placer deposits form by weathering and erosion.

Geochemical Signature Cassiterite, topaz, and tourmaline in streams that drain exposed tin-rich greisens. Specialized granites may have high contents of SiO (>73 percent) and K2O (>4 percent), and are depleted in CaO, TiO2, MgO, and total FeO. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta, and most REE, and impoverished in Ni, Cu, Cr, Co, V, Sc, Sr, La, and Ba.

EXAMPLES

Lost River, USAK (Dobson, 1982; Sainsbury, 1964)

Anchor Mine, AUTS (Groves and Taylor, 1973)

Erzgebirge, CZCL (Janecka and Stemprok, 1967)

DESCRIPTIVE MODEL OF Fe SKARN DEPOSITS

MODEL 18d

By Dennis P. Cox

DESCRIPTION Magnetite in calc-silicate contact metasomatic rocks_

GENERAL REFERENCES Einaudi and Burt (1982), Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Gabbro, diorite, diabase, syenite, tonalite, granodiorite, granite, and coeval volcanic rocks. Limestone and calcareous sedimentary rocks.

Textures Granitic texture in intrusive rocks; granoblastic to hornfelsic textures in sedimentary rocks.

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

Depositional Environment Contacts of intrusion and carbonate rocks or calcareous clastic rocks.

Tectonic Setting(s) Miogeosynclinal sequences intruded by felsic to mafic plutons. Oceanic island arc, Andean volcanic arc, and rifted continental margin.

DEPOSIT DESCRIPTION

Mineralogy Magnetite ± chalcopyrite ± Co-pyrite ± pyrite ± pyrrhotite. Rarely cassiterite in Fe skarns in Sn-granite terranes.

Texture/Structure Granoblastic with interstitial ore minerals.

Alteration Diopside-hedenbergite + grossular-andradite + epidote. Late stage amphibole ± chlorite ± ilvaite.

Ore Controls Carbonate rocks, calcareous rocks, igneous contacts and fracture zones near contacts. Fe skarn ores can also form in gabbroic host rocks near felsic plutons.

Weathering Magnetite generally crops out or forms abundant float.

Geochemical and Geophysical Signature Fe, Cu, Co, Au, possibly Sn. Strong magnetic anomaly.

EXAMPLES

Shinyama, JAPN (Uchida and Iiyana, 1982)

Cornwall, USPA (Lapham, 1968)

Iron Springs, USUT (Mackin, 1968)

DESCRIPTIVE MODEL OF Zn-Pb SKARN DEPOSITS

MODEL 18c

By Dennis P. Cox

DESCRIPTION Sphalerite and galena in calc-silicate rocks.

GENERAL REFERENCES Einaudi and Burt (1982); Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Granodiorite to granite, diorite to syenite. Carbonate rocks, calcareous clastic rocks.

Textures Granitic to porphyritic; granoblastic to hornfelsic.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Miogeoclinal sequences intruded by generally small bodies of igneous rock.

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

Associated Deposit Types Copper skarn.

DEPOSIT DESCRIPTION

Mineralogy Sphalerite + galena ± pyrrhotite ± pyrite ± magnetite ± chalcopyrite ± bornite ± arsenopyrite ± scheelite ± bismuthinite ± stannite ± fluorite. Gold and silver do not form minerals.

Texture/Structure Granoblastic, sulfides massive to interstitial.

Alteration Mn-hedenbergite ± andradite ± grossular ± spessartine ± bustamite ± rhodonite. Late stage Mn-actinolite ± ilvaite ± chlorite ± dannemorite ± rhodochrosite.

Ore Controls Carbonate rocks especially at shale-limestone contacts. Deposit may be hundreds of meters from intrusive.

Weathering Gossan with strong Mn oxide stains.

Geochemical Signature Zn, Pb, Mn, Cu, Co, Au, Ag, As, W, Sn, F, possibly Be.

Magnetic anomalies.

EXAMPLES

Ban Ban, AUQU (Ashley, 1980)

Hanover-Fierro district, USNM (Hernon and Jones, 1968)

DESCRIPTIVE MODEL OF POLYMETALLIC REPLACEMENT DEPOSITS

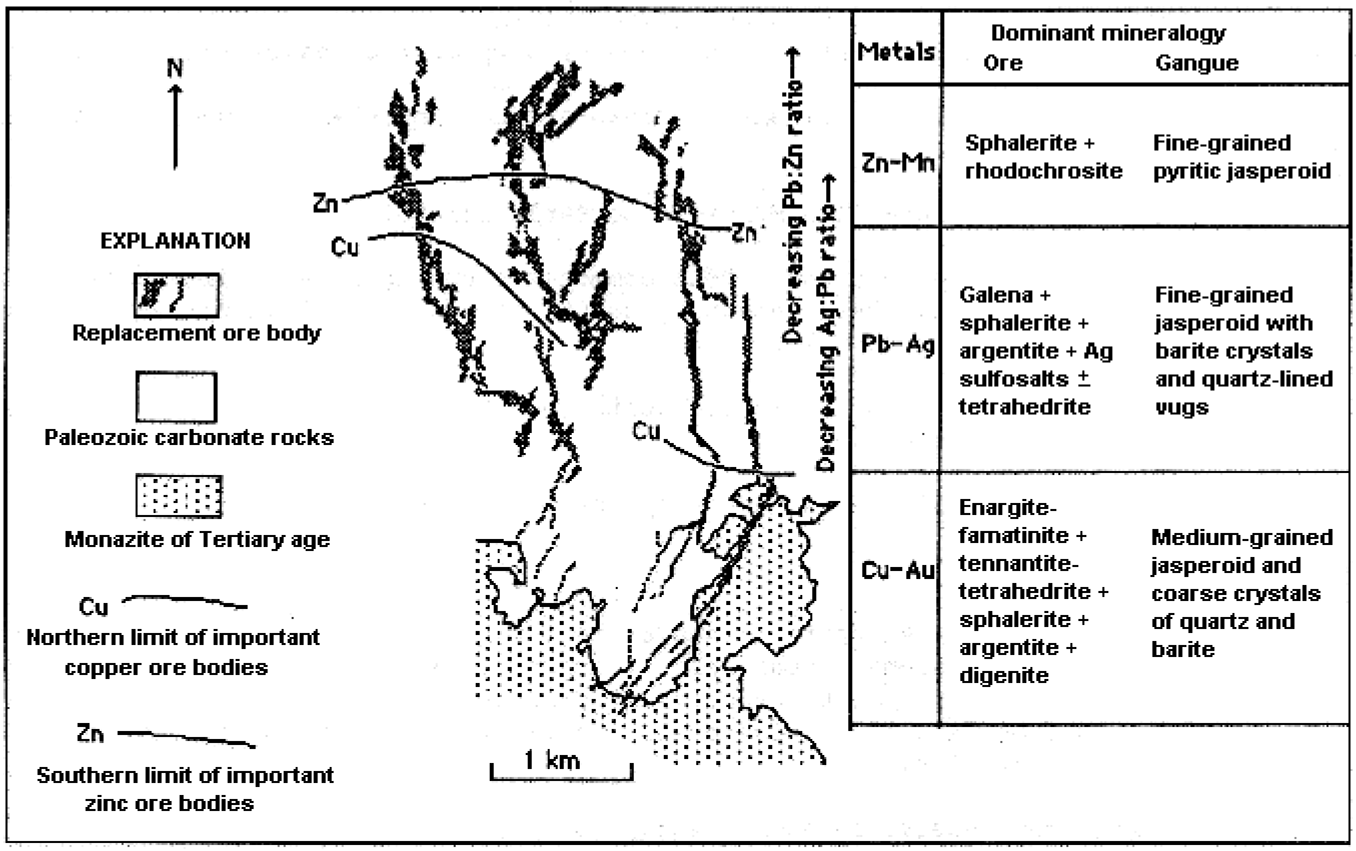
MODEL 19a

By Hal T. Morris

APPROXIMATE SYNONYM Manto deposits, many authors.

DESCRIPTION Hydrothermal, epigenetic, Ag, Pb, Zn, Cu minerals in massive lenses, pipes and veins in limestone, dolomite, or other soluble rock near igneous intrusions (see fig. 68).

Figure 68. Generalized map showing metal and mineral zoning in polymetallic replacement deposits in the Main Tintic district, Utah. Modified from Morris (1968)).



GENERAL REFERENCE Jensen and Bateman (1981), p. 134-146.

GEOLOGICAL ENVIRONMENT

Rock Types Sedimentary rocks, chiefly limestone, dolomite, and

shale, commonly overlain by volcanic rocks and intruded by porphyritic, calc-alkaline plutons.

Textures The textures of the replaced sedimentary rocks are not important; associated plutons typically are porphyritic.

Age Range Not important, but many are late Mesozoic to early Cenozoic.

Depositional Environment Carbonate host rocks that commonly occur in broad sedimentary basins, such as epicratonic miogeosynclines. Replacement by solutions emanating from volcanic centers and epizonal plutons. Calderas may be favorable.

Tectonic Setting(s) Most deposits occur in mobile belts that have undergone moderate deformation and have been intruded by small plutons.

Associated Deposit Types Base metal skarns, and porphyry copper deposits.

DEPOSIT DESCRIPTION

Mineralogy Zonal sequence outward: enargite + sphalerite + argentite + tetrahedrite + digenite ± chalcopyrite, rare bismuthinite; galena + sphalerite + argentite ± tetrahedrite ± proustite ± pyrargyrite, rare jamesonite, jordanite, bournonite, stephanite, and polybasite; outermost sphalerite + rhodochrosite (see fig. 68). Widespread quartz, pyrite, marcasite, barite. Locally, rare gold, sylvanite, and calaverite.

Texture/Structure Ranges from massive to highly vuggy and porous.

Alteration Limestone wallrocks are dolomitized and silicified (to form jasperoid); shale and igneous rocks are chloritized and commonly are argillized; where syngenetic iron oxide minerals are present, rocks are pyritized. Jasperoid near ore is coarser grained and contains traces of barite and pyrite.

Ore Controls Tabular, podlike and pipelike ore bodies are localized by faults or vertical beds; ribbonlike or blanketlike ore bodies are localized by bedding-plane faults, by susceptible beds, or by preexisting solution channels, caverns, or cave rubble.

Weathering Commonly oxidized to ochreous masses containing cerrusite, anglesite, hemimorphite, and cerargyrite.

Geochemical Signature On a district-wide basis ore deposits commonly are zoned outward from a copper-rich central area through a wide lead-silver zone, to a zinc- and manganese-rich fringe. Locally Au, As, Sb, and Bi. Jasperoid related to ore can often be recognized by high Ba and trace Ag content.

EXAMPLES

East Tintic district, USUT (Morris and Lovering, 1979)

Eureka district, USNV (Nolan, 1962)

Manto deposit, MXCO (Prescott, 1926)

DESCRIPTIVE MODEL OF PORPHYRY Mo, LOW-F

MODEL 21b

By Ted G. Theodore

APPROXIMATE SYNONYM Calc-alkaline Mo stockwork (Westra and Keith, 1981).

DESCRIPTION Stockwork of quartz-molybdenite veinlets in felsic porphyry and in its nearby country rock.

GENERAL REFERENCE Westra and Keith (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite, granodiorite, and monzogranite.

Textures Porphyry, fine aplitic groundmass.

Age Range Mesozoic and Tertiary.

Depositional Environment Orogenic belt with calcalkaline intrusive rocks.

Tectonic Setting(s) Numerous faults.

Associated Deposit Types Porphyry Cu-Mo, Cu skarn, volcanic hosted Cu-As-Sb.

DEPOSIT DESCRIPTION

Mineralogy Molybdenite + pyrite + scheelite + chalcopyrite + argentian tetrahedrite. Quartz + K-feldspar + biotite + calcite + white mica and clays.

Texture/Structure Disseminated and in veinlets and fractures.

Alteration Potassic outward to propylitic. Phyllic and argillic overprint (see table 3).

Ore Controls Stockwork in felsic porphyry and in surrounding country rock.

Weathering Yellow ferrimolybdite after molybdenite. Secondary copper enrichment may form copper ores in some deposits.

Geochemical Signature Zoning outward and upward from Mo + Cu ± W to Cu + Au to Zn + Pb, + Au, + Ag. F may be present but in amounts less than 1,000 ppm.

EXAMPLES

Buckingham, USNV (Blake and others, 1979)

USSR deposits (Pavlova and Rundquist, 1980)

DESCRIPTIVE MODEL OF POLYMETALLIC VEINS

MODEL 22c

By Dennis P. Cox

APPROXIMATE SYNONYM Felsic intrusion-associated Ag-Pb-Zn veins (Sangster, 1984).

DESCRIPTION Quartz-carbonate veins with Au and Ag associated with base metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes.

GEOLOGICAL ENVIRONMENT

Rock Types Calcalkaline to alkaline, diorite to granodiorite, monzonite to monzogranite in small intrusions and dike swarms in sedimentary and metamorphic rocks. Subvolcanic intrusions, necks, dikes, plugs of andesite to rhyolite composition.

Textures Fine- to medium-grained equigranular, and porphyroaphanitic.

Age Range Most are Mesozoic and Cenozoic, but may be any age.

Depositional Environment Near-surface fractures and breccias within thermal aureol of clusters of small intrusions. In some cases peripheral to porphyry systems.

Tectonic Setting(s) Continental margin and island arc volcanic-plutonic belts. Especially zones of local domal uplift.

Associated Deposit Types Porphyry Cu-Mo, porphyry Mo low-F, polymetallic replacement. Placer Au.

DEPOSIT DESCRIPTION

Mineralogy Native Au and electrum with pyrite + sphalerite ± chalcopyrite ± galena ± arsenopyrite ± tetrahedrite-tennantite ± Ag sulfosalts ± argentite ± hematite in veins of quartz + chlorite + calcite ± dolomite ± ankerite ± siderite ± rhodochrosite ± barite ± fluorite ± chalcedony ± adularia.

Texture/Structure Complex, multiphase veins with comb structure, crustification, and colloform textures. Textures may vary from vuggy to compact within mineralized system.

Alteration Generally wide propylitic zones and narrow sericitic and argillic zones. Silicification of carbonate rocks to form jasperoid.

Ore Controls Areas of high permeability: intrusive contacts, fault intersections, and breccia veins and pipes. Replacement ore bodies may form where structures intersect carbonate rocks.

Weathering Minor gossans and Mn-oxide stains. Zn and Pb carbonates and Pb sulfate. Abundant quartz chips in soil. Placer gold concentrations in soils and stream sediments. Supergene enrichment produces high-grade native and horn silver ores in veins where calcite is not abundant.

Geochemical Signature Zn, Cu, Pb, As, Au, Ag, Mn, Ba. Anomalies zoned from Cu-Au outward to Zn-Pb-Ag to Mn at periphery.

EXAMPLES

St. Anthony (Mammoth), USAZ (Creasey, 1950)

Wallapai District, USAZ (Thomas, 1949)

Marysville District, USMT (Knopf, 1913)

Misima I., PPNG (Williamson and Rogerson, 1983)

Slocan District, CNBC (Cairnes, 1934)

DESCRIPTIVE MODEL OF SIMPLE Sb DEPOSITS

MODEL 27d

By James D. Bliss and Greta J. Orris

APPROXIMATE SYNONYM Deposits of quartz-stibnite ore (Smirnov and others, 1983).

DESCRIPTION Stibnite veins, pods, and disseminations in or adjacent to brecciated or sheared fault zones.

GENERAL REFERENCES White (1962), Miller (1973).

GEOLOGICAL ENVIRONMENT

Rock Types One or more of the following lithologies is found associated with over half of the deposits: limestone, shale (commonly calcareous), sandstone, and quartzite. Deposits are also found with a wide variety of other lithologies including slate, rhyolitic flows and tuffs, argillite, granodiorite, granite, phyllite, siltstone, quartz mica and chloritic schists, gneiss, quartz porphyry, chert, diabase, conglomerate, andesite, gabbro, diorite, and basalt.

Textures Not diagnostic.

Age Range Known deposits are Paleozoic to Tertiary.

Depositional Environment Faults and shear zones.

Tectonic Setting(s) Any orogenic area.

Associated Deposit Types Stibnite-bearing veins, pods, and disseminations containing base metal sulfides + cinnabar + silver + gold + scheelite that are mined primarily for lead, gold, silver, zinc, or tungsten; low-sulfide Au-quartz veins; epithermal gold and gold-silver deposits; hot-springs gold; carbonate-hosted gold; tin-tungsten veins; hot-springs and disseminated mercury, gold-silver placers; infrequently with polymetallic veins and tungsten skarns.

DEPOSIT DESCRIPTION

Mineralogy Stibnite + quartz ± pyrite ± calcite; minor other sulfides frequently less than 1 percent of deposit and included ± arsenopyrite ± sphalerite ± tetrahedrite ± chalcopyrite ± scheelite ± free gold; minor minerals only occasionally found include native antimony, marcasite, calaverite, berthierite, argentite, pyrargyrite, chalcocite, wolframite, richardite, galena, jamesonite; at least a third (and possibly more) of the deposits contain gold or silver. Uncommon gangue minerals include chalcedony, opal (usually identified to be -cristobalite by X-ray), siderite, fluorite, barite, and graphite.

Texture/Structure Vein deposits contain stibnite in pods, lenses, kidney forms, pockets (locally); may be massive or occur as streaks, grains, and bladed aggregates in sheared or brecciated zones with quartz and calcite. Disseminated deposits contain streaks or grains of stibnite in host rock with or without stibnite vein deposits.

Alteration Silicification, sericitization, and argillization; minor chloritization; serpentinization when deposit in mafic, ultramafic rocks.

Ore Controls Fissures and shear zones with breccia usually associated with faults; some replacement in surrounding lithologies; infrequent open-space filling in porous sediments and replacement in limestone. Deposition occurs at shallow to intermediate depth.

Weathering Yellow to reddish kermesite and white cerrantite or stibiconite (Sb oxides) may be useful in exploration; residual soils directly above deposits are enriched in antimony.

Geochemical Signature Sb ± Fe ± As ± Au ± Hg; Hg ± W ± Pb ± Zn may be useful in specific cases.

EXAMPLES

Amphoe Phra Saeng, THLD (Gardner, 1967)

Caracota, BLVA (U.S. Geological Survey Mineral Resources Data System)

Coimadai Antimony Mine, AUVT (Fisher, 1952)

Last Chance, USNV (Lawrence, 1963), Lake George, CNNB (Scratch and others, 1984)

DESCRIPTIVE MODEL OF KUROKO MASSIVE SULFIDE

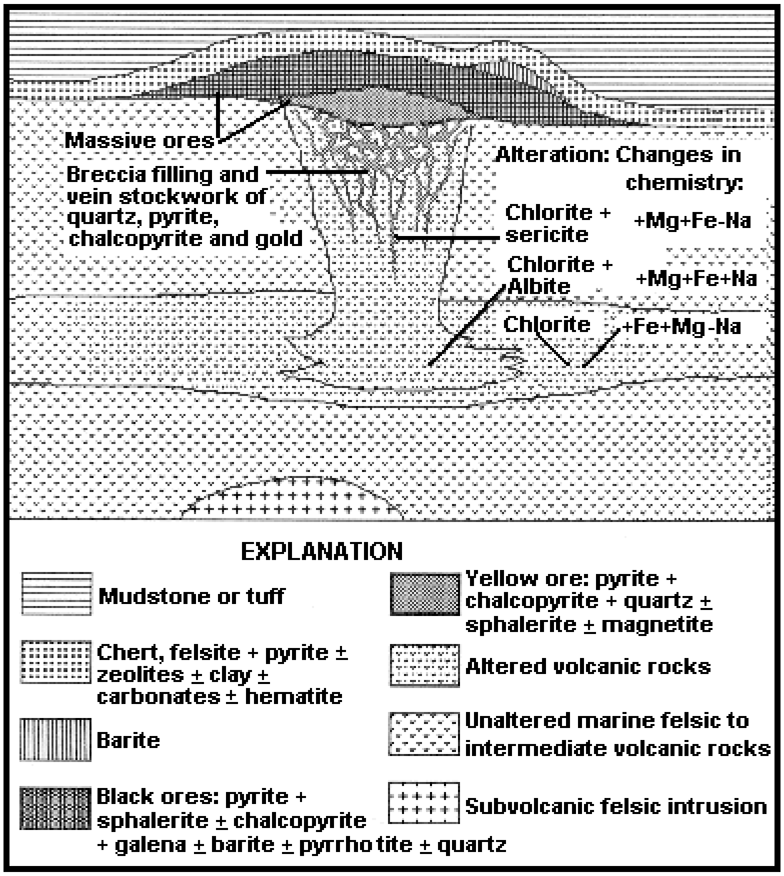
MODEL 28a

By Donald A. Singer

APPROXIMATE SYNONYM Noranda type, volcanogenic massive sulfide, felsic to intermediate volcanic type.

DESCRIPTION Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition (see fig. 145).

Figure 145. Cartoon cross section of kuroko massive sulfide deposit. Modified from Franklin and others (1981).



GENERAL REFERENCES Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983).

GEOLOGICAL ENVIRONMENT

Rock Types Marine rhyolite, dacite, and subordinate basalt and associated sediments, principally organic-rich mudstone or shale. Pyritic, siliceous shale. Some basalt.

Textures Flows, tuffs, pyroclastics, breccias, bedded sediment, and in some cases felsic domes.

Age Range Archean through Cenozoic.

Depositional Environment Hot springs related to marine volcanism, probably with anoxic marine conditions. Lead-rich deposits associated with abundant fine-grained volcanogenic sediments.

Tectonic Setting(s) Island arc. Local extensional tectonic activity, faults, or fractures. Archean greenstone belt.

Associated Deposit Types Epithermal quartz-adularia veins in Japan are regionally associated but younger than kuroko deposits. Volcanogenic Mn, Algoma Fe.

DEPOSIT DESCRIPTION

Mineralogy Upper stratiform massive zone (black ore)--pyrite + sphalerite + chalcopyrite ± pyrrhotite ± galena ± barite ± tetrahedrite - tennantite ± bornite; lower stratiform massive zone (yellow ore)--pyrite + chalcopyrite ± sphalerite ± pyrrhotite ± magnetite; stringer (stockwork) zone--pyrite + chalcopyrite (gold and silver). Gahnite in metamorphosed deposits. Gypsum/anhydrite present in some deposits.

Texture/Structure Massive (>60 percent sulfides); in some cases, an underlying zone of ore stockwork, stringers or disseminated sulfides or sulfide-matrix breccia. Also slumped and redeposited ore with graded bedding.

Alteration Adjacent to and blanketing massive sulfide in some deposits--zeolites, montmorillonite (and chlorite?); stringer (stockwork) zone--silica, chlorite, and sericite; below stringer--chlorite and albite. Cordierite and anthophyllite in footwall of metamorphosed deposits, graphitic schist in hanging wall.

Ore Controls Toward the more felsic top of volcanic or volcanic-sedimentary sequence. Near center of felsic volcanism. May be locally brecciated or have felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by sulfide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo depressions in the seafloor. In Japan, best deposits have mudstone in hanging wall.

Weathering Yellow, red, and brown gossans. Gahnite in stream sediments near some deposits.

Geochemical Signature Gossan may be high in Pb and typically Au is present. Adjacent to deposit-enriched in Mg and Zn, depleted in Na. Within deposits--Cu, Zn, Pb, Ba, As, Ag, Au, Se, Sn, Bi, Fe.

EXAMPLES

Kidd Creek, CNON (Walker and others, 1975)

Mt. Lyell, AUTS (Corbett, 1981)

Brittania, CNBC (Payne and others, 1980)

Buchans, CNNF (Swanson and others, 1981)

DESCRIPTIVE MODEL OF SANDSTONE U

MODEL 30c

By Christine E. Turner Peterson and Carroll A. Hodges

APPROXIMATE SYNONYMS Tabular U ore, roll front U.

DESCRIPTION Microcrystalline uranium oxides and silicates deposited during diagenesis in localized reduced environments within fine- to medium-grained sandstone beds; some uranium oxides also deposited during redistribution by ground water at interface between oxidized and reduced ground (see fig. 157).

Figure 157. Cartoon cross section showing: A. Diagenetic mineralization (from Turner-Peterson and Fishman, 1986); B. roll-front mineralization in U deposits (from Nash and others, 1981).

GENERAL REFERENCE Turner-Peterson and Fishman (1986), Granger and Warren (1969).

GEOLOGICAL ENVIRONMENT

Rock Types Host rocks are feldspathic or tuffaceous sandstone. Pyroclastic material is felsic in composition. Mudstone or shale commonly above and/or below sandstones hosting diagenetic ores (see fig. 157A).

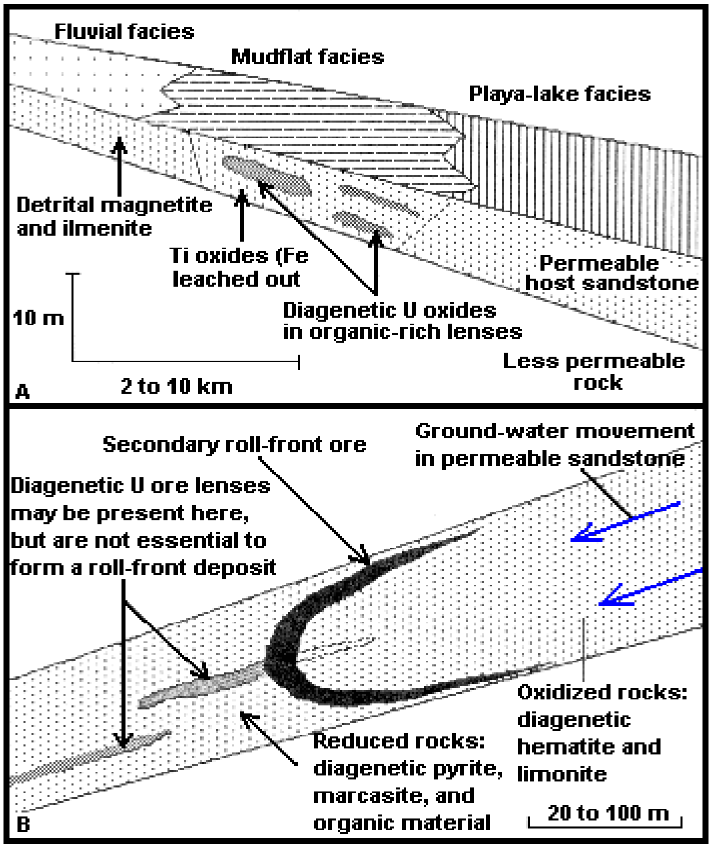
Textures Permeable--medium to coarse grained; highly permeable at time of mineralization, subsequently restricted by cementation and alteration.

Age Range Most deposits are Devonian and younger. Secondary roll-front deposits mainly Tertiary.

Depositional Environment Continental-basin margins, fluvial channels, braided stream deposits, stable coastal plain. Contemporaneous felsic volcanism or eroding felsic plutons are sources of U. In tabular ore, source rocks for ore-related fluids are commonly in overlying or underlying mud-flat facies sediments.

Tectonic Setting(s) Stable platform or foreland-interior basin, shelf margin; adjacent major uplifts provide favorable topographic conditions.

Associated Deposit Types Sediment-hosted V may be intimately associated with U. Sediment-hosted Cu may be in similar host rocks and may contain U.



DEPOSIT DESCRIPTION

Mineralogy Uraninite, coffinite, pyrite in organic-rich horizons. Chlorite common.

Texture/Structure Stratabound deposits. Tabular U--intimately admixed with pore-filling humin in tabular lenses suspended within reduced sandstone (fig. 157A). Replacement of wood and other carbonaceous material. Roll front U--in crescentic lens that cuts across bedding, at interface between oxidized and reduced ground (fig. 157B).

Alteration Tabular--Humic acid mineralizing fluids leach iron from detrital magnetite-ilmenite leaving relict TiO2 minerals in diagenetic ores. Roll front--Oxidized iron minerals in rock updip, reduced iron minerals in rock downdip from redox interface.

Ore Controls Permeability. Tabular--Humin or carbonaceous material the main concentrator of U. Roll front--S species, "sour" gas, FeS2. Bedding sequences with low dips; felsic plutons or felsic tuffaceous sediments adjacent to or above host rock are favorable source for U. Regional redox interface marks locus of ore deposition.

Weathering Oxidation of primary uraninite or coffinite to a variety of minerals, notably yellow carnotite as bloom in V-rich ores.

Geochemical and Geophysical Signature U, V, Mo, Se, locally Cu, Ag. Anomalous radioactivity from daughter products of U. Low magnetic susceptibility in and near tabular ores.

EXAMPLES

Colorado Plateau (Fischer, 1974)

Grants, USNM (Turner-Peterson and Fishman, 1986)

Texas Gulf Coast (Reynolds and Goldhaber, 1983)

USWY (Granger and Warren, 1969)

DESCRIPTIVE MODEL OF SEDIMENTARY EXHALATIVE Zn-Pb

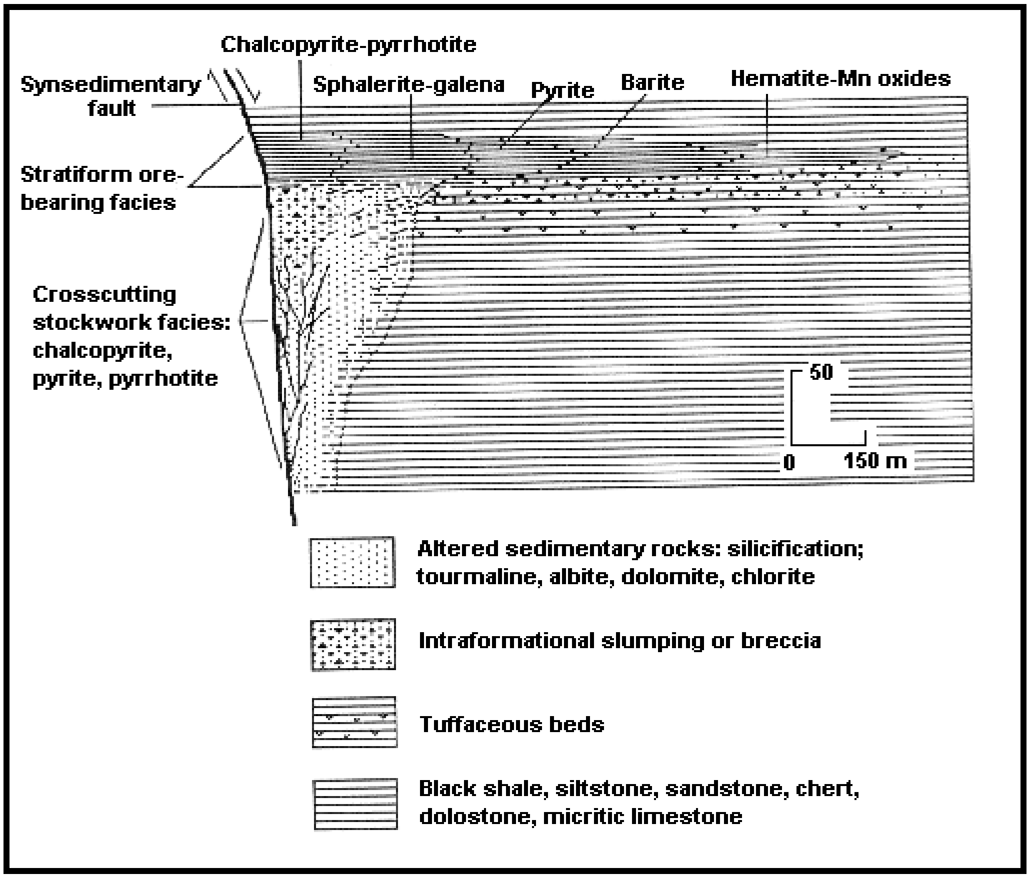
MODEL 31a

By Joseph A. Briskey

APPROXIMATE SYNONYMS Shale-hosted Zn-Pb; sediment-hosted massive sulfide Zn-Pb.

DESCRIPTION Stratiform basinal accumulations of sulfide and sulfate minerals interbedded with euxinic marine sediments form sheet- or lens-like tabular ore bodies up to a few tens of meters thick, and may be distributed through a stratigraphic interval over 1,000 m (see fig. 158).

Figure 158. Cartoon cross section showing mineral zoning in sedimentary exhalative Zn-Pb deposits (modified from Large, 1980)



GENERAL REFERENCES Large (1980, 1981, 1983).

GEOLOGICAL ENVIRONMENT

Rock Types Euxinic marine sedimentary rocks including: black (dark) shale, siltstone, sandstone, chert, dolostone, micritic limestone, and turbidites. Local evaporitic sections in contemporaneous shelf facies. Volcanic rocks, commonly of bimodal composition, are present locally in the sedimentary basin. Tuffites are the most common. Slump breccias, fan conglomerates, and similar deposits, as well as facies and thickness changes, are commonly associated with synsedimentary faults.

Textures Contrasting sedimentary thicknesses and facies changes across hinge zones. Slump breccias and conglomerates near synsedimentary faults.

Age Range Known deposits are Middle Proterozoic (1,700-1,400 m.y.); Cambrian to Carboniferous (530-300 m.y.).

Depositional Environment Marine epicratonic embayments and intracratonic basins, with smaller local restricted basins (second- and third-order basins).

Tectonic Setting(s) Epicratonic embayments and intracratonic basins are associated with hinge zones controlled by synsedimentary faults, typically forming half-grabens. Within these grabens (first-order basins), penecontemporaneous vertical tectonism forms smaller basins (second-order basins) and associated rises. Smaller third-order basins (tens of kilometers) within the second-order basins (102-105 km) are the morphological traps from the stratiform sulfides.

Associated Deposit Types Bedded barite deposits.

DEPOSIT DESCRIPTION

Mineralogy Pyrite, pyrrhotite, sphalerite, galena, sporadic barite and chalcopyrite, and minor to trace amounts of marcasite, arsenopyrite, bismuthinite, molybdenite, enargite, millerite, freibergite, cobaltite, cassiterite, valleriite, and melnikovite.

Texture/Structure Finely crystalline and disseminated, monomineralic sulfide laminae are typical. Metamorphosed examples are coarsely crystalline and massive.

Alteration Stockwork and disseminated sulfide and alteration (silicification, tourmalization, carbonate depletion, albitization, chloritization, dolomitization) minerals possibly representing the feeder zone of these deposits commonly present beneath or adjacent to the stratiform deposits. Some deposits have no reported alteration. Celsian, Ba-muscovite, and ammonium clay minerals may be present.

Ore Controls Within larger fault-controlled basins, small local basins form the morphological traps that contain the stratiform sulfide and sulfate minerals. The faults are synsedimentary and serve as feeders for the stratiform deposits. Euxinic facies.

Weathering Surface oxidation may form large gossans containing abundant carbonates, sulfates, and silicates of lead, zinc, and copper.

Geochemical Signature Metal zoning includes lateral Cu-Pb-Zn-Ba sequence extending outward from feeder zone; or a vertical Cu-Zn-Pb-Ba sequence extending upward. NH3 anomalies may be present. Exhalative chert interbedded with stratiform sulfide and sulfate minerals; peripheral hematite-chert formations. Local (within 2 km) Zn, Pb, and Mn haloes. Highest expected background in black shales: Pb = 500 ppm; Zn = 1,300 ppm; Cu = 750 ppm; Ba = 1,300 ppm; in carbonates: Pb = 9 ppm; Zn = 20; Cu = 4 pmm; Ba = 10.

EXAMPLES

Sullivan mine, CNBC (Hamilton and others, 1982)

Meggen mine, GRMY (Krebs, 1981)

Navan, Silvermines, Tynagh, IRLD (Boyce and others, 1983; Taylor, 1984)

DESCRIPTIVE MODEL OF SOUTHEAST MISSOURI Pb-Zn

MODEL 32a

By Joseph A. Briskey

SYNONYMS Carbonate-hosted Pb-Zn; Mississippi Valley type.

DESCRIPTION Stratabound, carbonate-hosted deposits of galena, sphalerite, and chalcopyrite in rocks having primary and secondary porosity, commonly related to reefs on paleotopographic highs (see fig. 166). (For grade-tonnage model see Appalachian Zn deposit model.)

Figure 166. Cartoon cross section of a southeast Missouri Pb-Zn deposit (modified from Evans, 1977).

GENERAL REFERENCES Snyder and Gerdemann (1968), Thacker and Anderson (1977).

GEOLOGICAL ENVIRONMENT

Rock Types Dolomite; locally ore bodies also occur in sandstone, conglomerate, and calcareous shales.

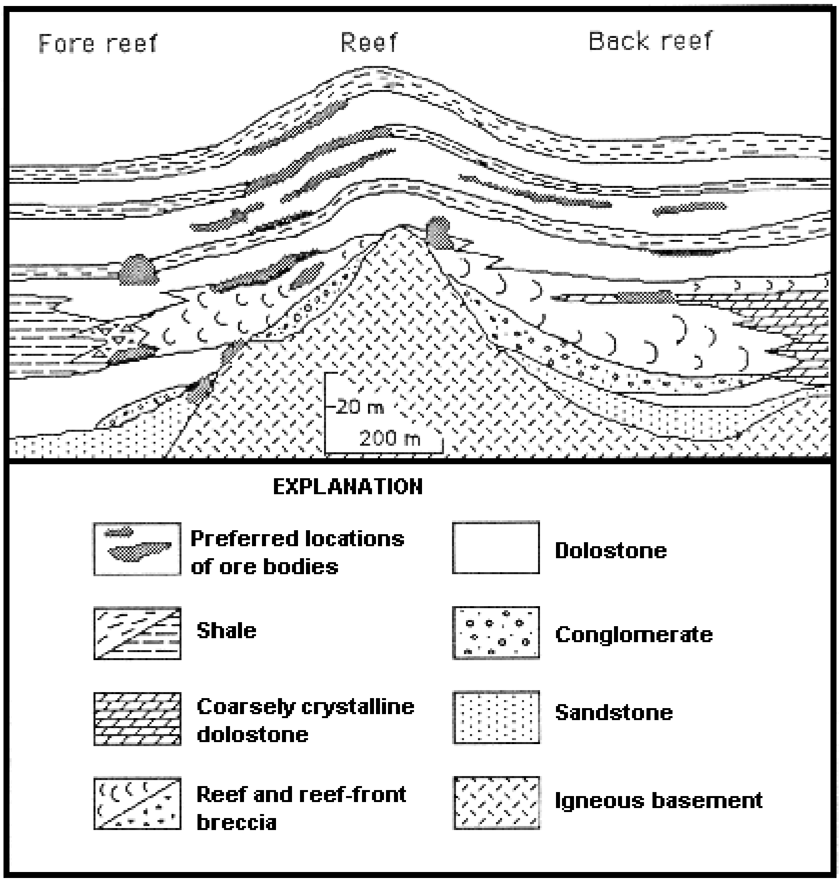
Textures Calcarenites are most common lithology. Tidalites, stromatolite finger reefs, reef breccias, slump breccias; oolites, crossbedding, micrites.

Age Range Known deposits are in Cambrian to Lower Ordovician strata.

Depositional Environment Host rocks are shallow-water marine carbonates, with prominent facies control by reefs growing on flanks of paleotopographic basement highs. Deposits commonly occur at margins of clastic basins.

Tectonic Setting(s) Stable cratonic platform.

Associated Deposit Types Precambrian volcanic-hosted magnetite; Ba-Pb deposits occur higher in the Cambrian section.



DEPOSIT DESCRIPTION

Mineralogy Galena, sphalerite, chalcopyrite, pyrite, marcasite. Minor siegenite, bornite, tennantite, barite, bravoite, digenite, covellite, arsenopyrite, fletcherite, adularia, pyrrhotite, magnetite, millerite, polydymite, vaesite, djurleite, chalcocite, anilite, and enargite in order of abundance. Dolomite and minor quartz.

Texture/Structure Early fine-grained replacement; main stage coarse-grained replacement and vuggy or colloform open space filling. Hypogene leaching of galena is common.

Alteration Regional dolomitization; latter brown, ferroan, and bitumen-rich dolomite; extensive carbonate dissolution and development of residual shale; mixed-layer illite-chlorite altered to 2M muscovite; dickite and kaolinite in vugs; very minor adularia.

Ore Controls Open-space filling and replacement, most commonly at the interface between gray and tan dolomite, but also in traps at any interface between permeable and impermeable units. Any porous units may host ore: sandstone pinchouts; dissolution collapse breccias; faults; permeable

reefs; slump, reef, and fault breccias; coarsely crystalline dolostone.

Geochemical Signature Regional anomalous amounts of Pb, Zn, Cu, Mo, Ag, Co, and Ni in insoluble residues. Zoning is roughly Cu (± Ni ± Co)-Pb-Zn-iron sulfide going up section; ores contain about 30 ppm Ag; inconsistent lateral separation of metal zones. Background for carbonates: Pb = 9 ppm; Zn = 20; Cu = 4.

EXAMPLES

Viburnum subdistrict, USMO (Economic Geology 1977; Heyl, 1982)

DESCRIPTIVE MODEL OF APPALACHIAN Zn

MODEL 32b

By Joseph A. Briskey

SYNONYMS Carbonate-hosted Zn; Mississippi Valley type.

DESCRIPTION Stratabound deposits of sphalerite and minor galena in primary and secondary voids in favorable beds or horizons in thick platform dolostone and limestone (see fig. 167).

Figure 167. Cartoon cross section showing relationship of zinc ore to collapse breccia and dolomitized limestone in the Mascott-Jefferson City district, Tennessee. Modified from Armstrong and Lawrence (1983).

GENERAL REFERENCE Hoagland (1976).

GEOLOGICAL ENVIRONMENT

Rock Types Dolostone and limestone.

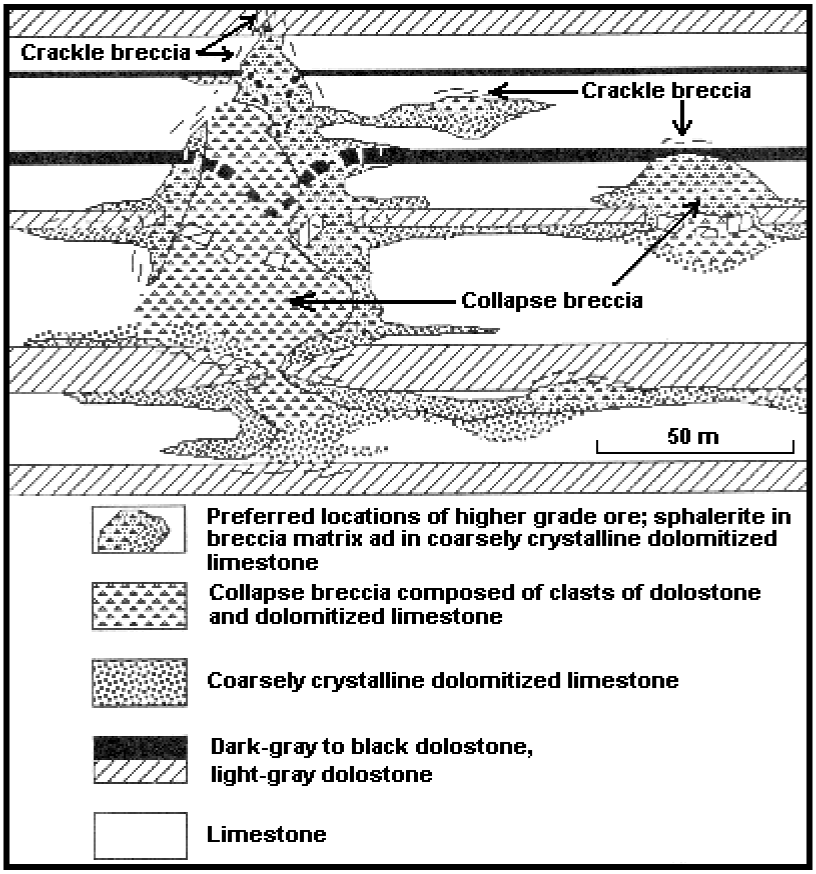
Textures Subtidal, intratidal, and supratidal textures with high porosity are common, especially in the dolostones; limestones are commonly micritic, some with birdseye textures.

Age Range Appalachian deposits occur in rocks of Cambrian to Middle Ordovician age. Other deposits are in rocks as old as Proterozoic and as young as Triassic.

Depositional Environment Shallow-water, tidal and subtidal marine environments.

Tectonic Setting(s) Stable continental shelf.

Associated Deposit Types Stratabound carbonate-hosted deposits of barite-fluorite-sphalerite.



DEPOSIT DESCRIPTION

Mineralogy Sphalerite, with variable but subordinate pyrite and minor marcasite, and with minor barite, fluorite, gypsum, and anhydrite. Galena is usually absent or rare, but may be abundant locally.

Texture/Structure Mainly open space filling of coarse to medium crystalline sphalerite and pinkish dolomite. Sphalerite commonly displays banding. Locally, fine sphalerite in finely varved dolomite composes the breccia matrix.

Alteration Extensive finely crystalline dolostone occurs regionally and coarse crystalline dolomite is more common nearer to ore bodies. Silicification is typically closely associated with ore bodies. Extensive limestone dissolution and development of residual shale.

Ore Controls Ore occurs within dissolution collapse breccias that occur (1) throughout readily soluble limestone beds, or (2) in paleo-aquifer solution channels controlled by fractures or folds in limestone. Breccias commonly have domal cross sections above limestone aquifers that have been thinned by solution.

Weathering Zinc silicate and carbonate ores form in the zone of weathering and oxidation.

Geochemical Signature Readily detectable zinc anomalies in residual soils and in stream sediments. Primary zinc haloes in carbonate rocks near ore are not large enough to assist in exploration. Background in carbonate rocks: Zn = 20 ppm; Pb = 9 ppm.

EXAMPLES

Mascot-Jefferson City district, USTN

(Crawford and Hoagland, 1968; McCormick and others, 1971; Fulweiler and McDougal, 1971)

Copper Ridge district, USTN (Hill and others, 1971)

DESCRIPTIVE MODEL OF KIPUSHI Cu-Pb-Zn

MODEL 32c

By Dennis P. Cox and Lawrence R. Bernstein

DESCRIPTION Massive base-metal sulfides and As-sulfosalts in dolomite breccias characterized by minor Co, Ge, Ga, U, and V.

GEOLOGICAL ENVIRONMENT

Rock Types Dolomite, shale. No rocks of unequivocal igneous origin are related to ore formation. [The pseudoaplite at Tsumeb is herein assumed to be a metasedimentary rock following H. D. LeRoex (1955, unpublished report).]

Textures Fine-grained massive and carbonaceous, laminated, stromatolitic dolomites.

Age Range Unknown; host rocks are Proterozoic in Africa, Devonian in Alaska, Pennsylvanian in Utah.

Depositional Environment High fluid flow along tabular or pipe-like fault- or karst (?)-breccia zones.

Tectonic Setting(s) Continental platform or shelf terrane with continental or passive margin rifting. Ore formation at Tsumeb and Ruby Creek predates folding.

Associated Deposit Types Sedimentary copper, U-veins, barite veins. Sedimentary exhalative Pb-Zn may be a lateral facies.

DEPOSIT DESCRIPTION

Mineralogy Ruby Creek: pyrite, bornite, chalcocite, chalcopyrite, carrollite, sphalerite, tennantite. Tsumeb: galena, sphalerite, bornite, tennantite, enargite. Kipushi: sphalerite, bornite, chalcopyrite, carrollite, chalcocite, tennantite, pyrite. Less abundant minerals in these deposits are linnaeite, Co-pyrite, germanite, renierite, gallite, tungstenite, molybdenite, and native Bi. Bituminous matter in vugs. At Apex mine, marcasite.

Texture/Structure Massive replacement, breccia filling, or stockwork. Replacement textures of pyrite after marcasite at Ruby Creek and Apex.

Alteration Dolomitization, sideritization, and silicification may be related to mineralization. Early pyrite or arsenopyrite as breccia filling or dissemination.

Ore Controls Abundant diagenetic pyrite or other source of S acts as precipitant of base metals in zones of high porosity and fluid flow. Bitumens indicate reducing environment at site of ore deposition.

Weathering Malachite-azurite, black Co-oxide, or pink Co-arsenate. Oxidation at Tsumeb has produced large crystals of many rare minerals. Oxidized Ge-Ga ore at Apex consists of iron oxides and jarosite; Ge and Ga minerals are not observed.

Geochemical and Geophysical Signature Cu, Zn, Pb, As, Co, Ag, Ge, Ga, Mo, W, Sn, Bi, U and V. Metal ratios: high Cu/Fe and locally high Cu/S in interior zones; high Co/Ni, As/Sb and Ag/Au. May be weakly radioactive.

EXAMPLES

Ruby Creek, ASAK (Runnels, 1969)

Tsumeb, NAMB (Sohnge, 1964); Wilson, 1977)

Kipushi, ZIRE (Intiomale and Oosterbosch, 1974)

Apex Mine, USUT (Bernstein, 1986)

DESCRIPTIVE MODEL OF LOW-SULFIDE Au-QUARTZ VEINS

By Byron R. Berger

Model 36a

APPROXIMATE SYNONYMS Mesothermal quartz veins, Mother Lode veins.

DESCRIPTION Gold in massive persistent quartz veins mainly in regionally metamorphosed volcanic rocks and volcanic sediments.

GEOLOGICAL ENVIRONMENT

Rock Types Greenstone belts; oceanic metasediments: regionally metamorphosed volcanic rocks, graywacke, chert, shale, and quartzite. Alpine gabbro and serpentine. Late granitic batholiths.

Age Range Precambrian to Tertiary.

Depositional Environment Continental margin mobile belts, accreted margins. Veins age generally post-metamorphic and locally cut granitic rocks.

Tectonic Setting(s) Fault and joint systems produced by regional compression.

Associated Deposit Types Placer Au-PGE, kuroko massive sulfide, Homestake gold.

DEPOSIT DESCRIPTION

Mineralogy Quartz + native gold + pyrite + galena + sphalerite + chalcopyrite + arsenopyrite ± pyrrhotite. Locally tellurides ± scheelite ± bismuth ± tetrahedrite ± stibnite ± molybdenite ± fluorite. Productive quartz is grayish or bluish in many instances because of fine-grained sulfides. Carbonates of Ca, Mg, and Fe abundant.

Texture/Structure Saddle reefs, ribbon quartz, open-space filling textures commonly destroyed by vein deformation.

Alteration Quartz + siderite and (or) ankerite + albite in veins with halo of carbonate alteration. Chromian mica + dolomite and talc + siderite in areas of ultramafic rocks. Sericite and disseminated arsenopyrite + rutile in granitic rocks.

Ore Controls Veins are persistent along regional high-angle faults, joint sets. Best deposits overall in areas with greenstone. High-grade ore shoots locally at metasediment-serpentine contacts. Disseminated ore bodies where veins cut granitic rocks.

Weathering Abundant quartz chips in soil. Gold may be recovered from soil by panning.

Geochemical Signature Arsenic best pathfinder in general; Ag, Pb, Zn, Cu.

EXAMPLES

Grass Valley, USCA (Lindgren, 1896)

Mother Lode, USCA (Knopf, 1929)

Ballarat Goldfield,
Victoria, AUVT (Baragwanath, 1953)

Goldfields of Nova Scotia, CNNS (Malcolm, 1929)

DESCRIPTIVE MODEL OF PLACER Au-PGE

MODEL 39a

By Warren E. Yeend

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, eolian, and (rarely) glacial deposits (see fig. 195).

Figure 195. Cartoon cross section showing three stages of heavy mineral concentration typical of placer Au-PGE deposits.

GENERAL REFERENCES Boyle (1979), Wells (1973), Lindgren (1911).

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial gravel and conglomerate with white quartz clasts. Sand and sandstone of secondary importance.

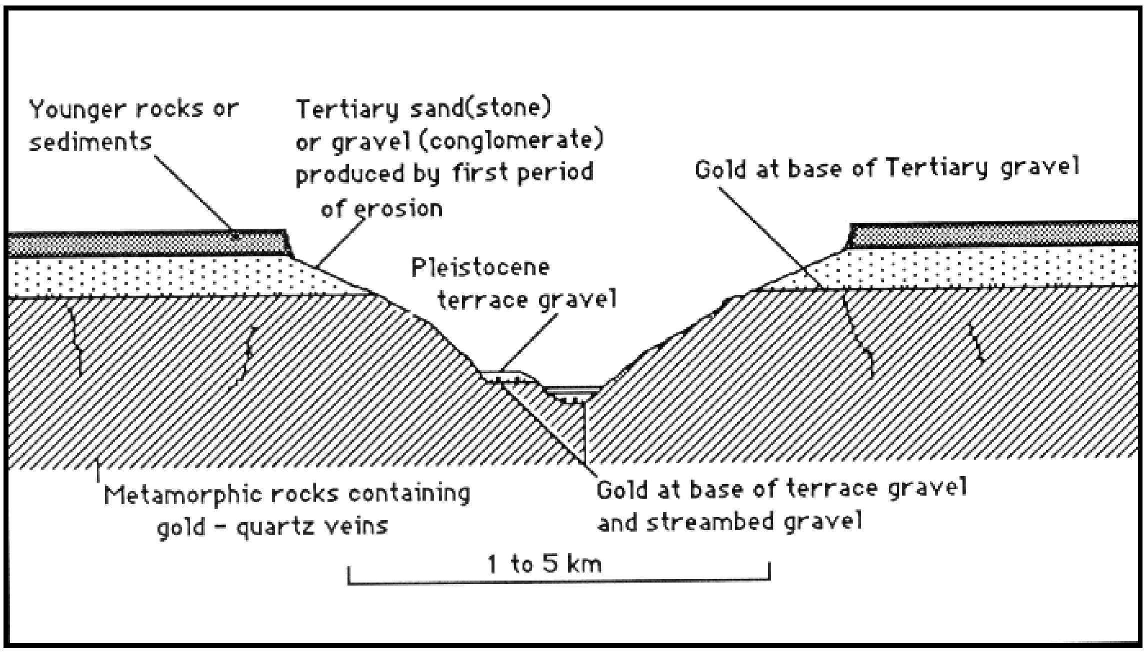
Textures Coarse clastic.

Age Range Cenozoic. Older deposits may have been formed but their preservation is unlikely.

Depositional Environment High-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, beneath boulders, and in vegetation mats. Winnowing action of surf caused Au concentrations in 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); yellow sands (zircon, monazite). Au placers commonly derive from various Au vein-type deposits as well as porphyry copper, Cu skarn, and polymetallic replacement deposits.



DEPOSIT DESCRIPTION

Mineralogy Au, platinum-iron alloys, osmium-iridium alloys; gold commonly with attached quartz, magnetite, or ilmenite.

Texture/Structure Flattened, rounded edges, flaky, flour gold extremely fine grained flakes; very rarely equidimensional nuggets.

Ore Controls Highest Au values at base of gravel deposits in various gold "traps" such as natural riffles in floor of river or stream, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, all structures trending transverse to direction of water flow. Au concentrations also occur within gravel deposits above clay layers that constrain the downward migration of Au particles.

Geochemical Signature Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, and heavy minerals magnetite, chromite, ilmenite, hematite, pyrite, zircon, garnet, rutile. Au nuggets have decreasing Ag content with distance from source.

EXAMPLES

Sierra Nevada, USCA (Lindgren, 1911; Yeend, 1974)

Victoria, AUVT (Knight, 1975)

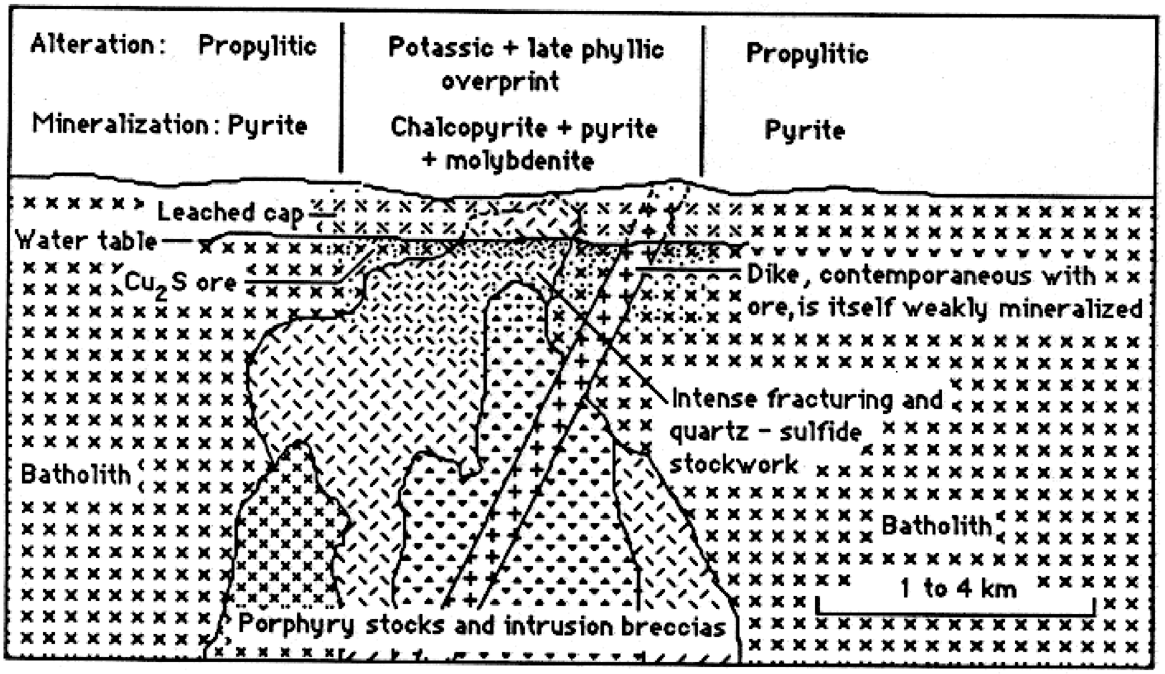
DESCRIPTIVE MODEL OF PORPHYRY Cu-Mo

MODEL 21a

By Dennis P. Cox

DESCRIPTION Stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion. Ratio of Au (in ppm) to Mo (in percent) less than 3 (See fig. 82).

Figure 82. Cartoon cross section of porphyry Cu-Mo deposit showing relationship between mineral- and alteration-zoning and igneous intrusion.



GENERAL REFERENCE Titley (1982).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite stocks and breccia pipes intrusive into batholithic, volcanic, or sedimentary rocks.

Textures Intrusions contemporaneous with ore commonly are porphyries with fine- to medium-grained aplitic groundmass. Porphyry texture may be restricted to small dikes in some deposits (Brenda).

Age Range Mainly Mesozoic to Tertiary, but can be any age.

Depositional Environment High-level intrusive porphyry contemporaneous with abundant dikes, faults, and breccia pipes. Cupolas of batholiths.

Tectonic Setting(s) Numerous faults in subduction-related volcanic plutonic arcs. Mainly along continental margins but also in oceanic convergent plate boundaries.

Associated Deposit Types Cu, Zn, or Fe skarns may be rich in gold, gold + base-metal sulfosalts in veins, gold placers. Volcanic-hosted massive replacement and polymetallic replacement.

DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite + pyrite + molybdenite. Peripheral vein or replacement deposits with chalcopyrite + sphalerite + galena ± gold. Outermost zone may have veins of Cu-Ag-Sb-sulfides, barite, and gold.

Texture/Structure Veinlets and disseminations or massive replacement of favorable country rocks.

Alteration Quartz + K-feldspar + biotite (chlorite) ± anhydrite (potassic alteration) grading outward to propylitic. Late white mica + clay (phyllic) alteration may form capping or outer zone or may affect the entire deposit. High-alumina alteration assemblages may be present in upper levels of the system (see table 3).

Ore Controls Ore grade is, in general, positively correlated with spacing of veinlets and mineralized fractures. Country rocks favorable for mineralization are calcareous sediments; diabase, tonalite, or diorite.

Weathering Intense leaching of surface; wide areas of iron oxide stain. Fractures coated with hematitic limonite. Supergene copper as chalcocite may form blanket below leached zone. Residual soils may contain anomalous amounts of rutile.

Geochemical Signature Cu + Mo + Ag ± W + B + Sr center; Pb, Zn, Au, As, Sb, Se, Te, Mn, Co, Ba, and Rb in outer zone. Locally Bi and Sn form distal anomalies. High S in all zones. Ratio of Au (ppm): Mo (percent)<3. Magnetic low.

EXAMPLES

Brenda, CNBC (Soregaroli and Whitford, 1976)

Sierrita Esperanza, USAZ (West and Aiken, 1982)

DESCRIPTIVE MODEL OF APPALACHIAN Zn

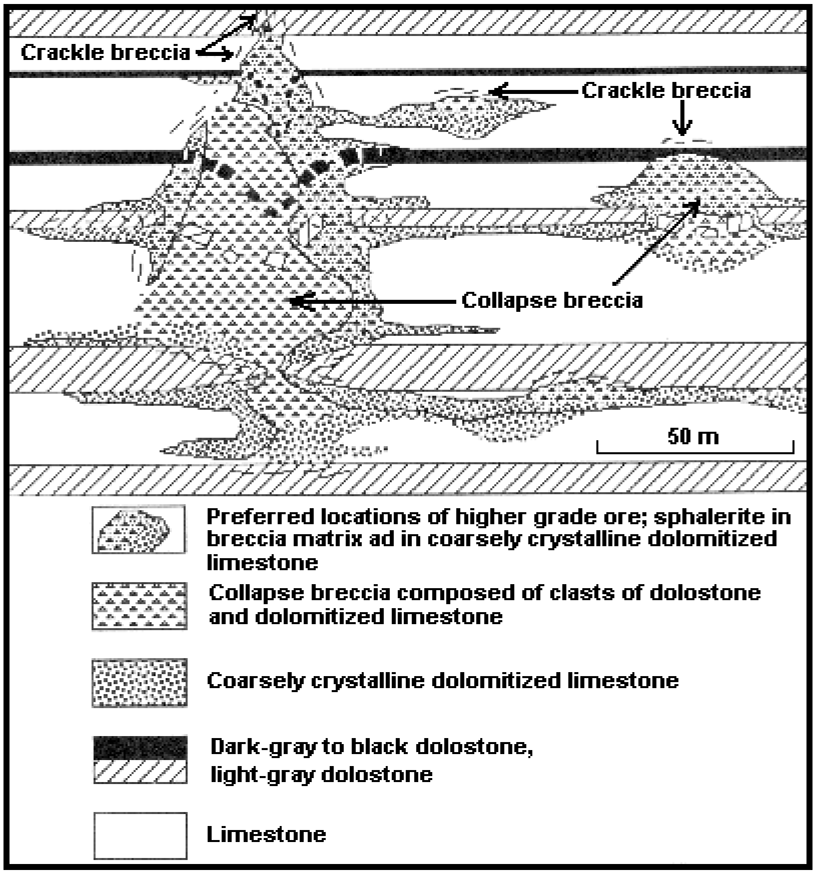
MODEL 32b

By Joseph A. Briskey

SYNONYMS Carbonate-hosted Zn; Mississippi Valley type.

DESCRIPTION Stratabound deposits of sphalerite and minor galena in primary and secondary voids in favorable beds or horizons in thick platform dolostone and limestone (see fig. 167).

Figure 167. Cartoon cross section showing relationship of zinc ore to collapse breccia and dolomitized limestone in the Mascott-Jefferson City district, Tennessee. Modified from Armstrong and Lawrence (1983).



GENERAL REFERENCE Hoagland (1976).

GEOLOGICAL ENVIRONMENT

Rock Types Dolostone and limestone.

Textures Subtidal, intratidal, and supratidal textures with high porosity are common, especially in the dolostones; limestones are commonly micritic, some with birdseye textures.

Age Range Appalachian deposits occur in rocks of Cambrian to Middle Ordovician age. Other deposits are in rocks as old as Proterozoic and as young as Triassic.

Depositional Environment Shallow-water, tidal and subtidal marine environments.

Tectonic Setting(s) Stable continental shelf.

Associated Deposit Types Stratabound carbonate-hosted deposits of barite-fluorite-sphalerite.

DEPOSIT DESCRIPTION

Mineralogy Sphalerite, with variable but subordinate pyrite and minor marcasite, and with minor barite, fluorite, gypsum, and anhydrite. Galena is usually absent or rare, but may be abundant locally.

Texture/Structure Mainly open space filling of coarse to medium crystalline sphalerite and pinkish dolomite. Sphalerite commonly displays banding. Locally, fine sphalerite in finely varved dolomite composes the breccia matrix.

Alteration Extensive finely crystalline dolostone occurs regionally and coarse crystalline dolomite is more common nearer to ore bodies. Silicification is typically closely associated with ore bodies. Extensive limestone dissolution and development of residual shale.

Ore Controls Ore occurs within dissolution collapse breccias that occur (1) throughout readily soluble limestone beds, or (2) in paleo-aquifer solution channels controlled by fractures or folds in limestone. Breccias commonly have domal cross sections above limestone aquifers that have been thinned by solution.

Weathering Zinc silicate and carbonate ores form in the zone of weathering and oxidation.

Geochemical Signature Readily detectable zinc anomalies in residual soils and in stream sediments. Primary zinc haloes in carbonate rocks near ore are not large enough to assist in exploration. Background in carbonate rocks: Zn = 20 ppm; Pb = 9 ppm.

EXAMPLES

Mascot-Jefferson City district, USTN

(Crawford and Hoagland, 1968; McCormick and others, 1971; Fulweiler and McDougal, 1971)

Copper Ridge district, USTN (Hill and others, 1971)

DESCRIPTIVE MODEL OF COMSTOCK EPITHERMAL VEINS

MODEL 25c

By Dan L. Mosier, and Donald A. Singer, and Byron R. Berger

APPROXIMATE SYNONYM Epithermal gold (quartz-adularia) alkali-chloride type.

DESCRIPTION Gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic to intermediate volcanic rocks that overlie predominantly clastic sedimentary rocks, and their metamorphic equivalents (see fig. 106).

GENERAL REFERENCES Buchanan (1980), Boyle (1979).

GEOLOGICAL ENVIRONMENT

Rock Types Host rocks are andesite, dacite, quartz latite, rhyodacite, rhyolite; and associated sedimentary rocks. Mineralization related to calc-alkaline or bimodal volcanism.

Textures Porphyritic.

Age Range Mainly Tertiary (most are 40-3.7 m.y.).

Depositional Environment Calc-alkaline and bimodal volcanism and associated intrusive activity over basement rocks composed of clastic sedimentary rocks and their metamorphic equivalents. Volcanic-related geothermal systems lack access to saline fluids from basement sources.

Tectonic Setting(s) Through-going fracture systems, major normal faults, fractures related to doming, ring fracture zones, joints.

Associated Deposit Types Placer gold and epithermal quartz-alunite Au.

DEPOSIT DESCRIPTION

Mineralogy Argentite + gold or electrum ± silver sulfosalts ± laumannite. Galena, sphalerite, chalcopyrite, tellurides, hematite, and arsenopyrite are moderate to sparse. Gangue minerals are quartz + pyrite ± adularia ± calcite ± sericite ± chlorite. Barite, fluorite, rhodochrosite, kaolinite, and montmorillonite are moderate to sparse. Ore minerals constitute only a few percent of vein.

Texture/Structure Banded veins, open space filling, lamellar quartz, stockwork.

Alteration From top to bottom of system: quartz + kaolinite + montmorillonite ± zeolite ± barite ± calcite; quartz + illite; quartz + adularia ± illite; quartz + chlorite; presence of adularia is variable.

Ore Controls Through-going anastomosing fracture systems, centers of intrusive activity. Hanging wall more favorable.

Weathering Bleached country rock, limonite, jarosite, goethite, alunite, hematite, argillization with kaolinite.

Geochemical Signature Higher in system Au + As + Sb + Hg or Au + As + Cu; Au + Ag + Pb + Cu; also Te and W.

EXAMPLES

Comstock, USNV (Becker, 1882)

Guanajuato, MXCO (Buchanan, 1980; Wandke and Martinez, 1928)

DESCRIPTIVE MODEL OF CYPRUS MASSIVE SULFIDE

MODEL 24a

By Donald A. Singer

APPROXIMATE SYNONYM Cupreous pyrite.

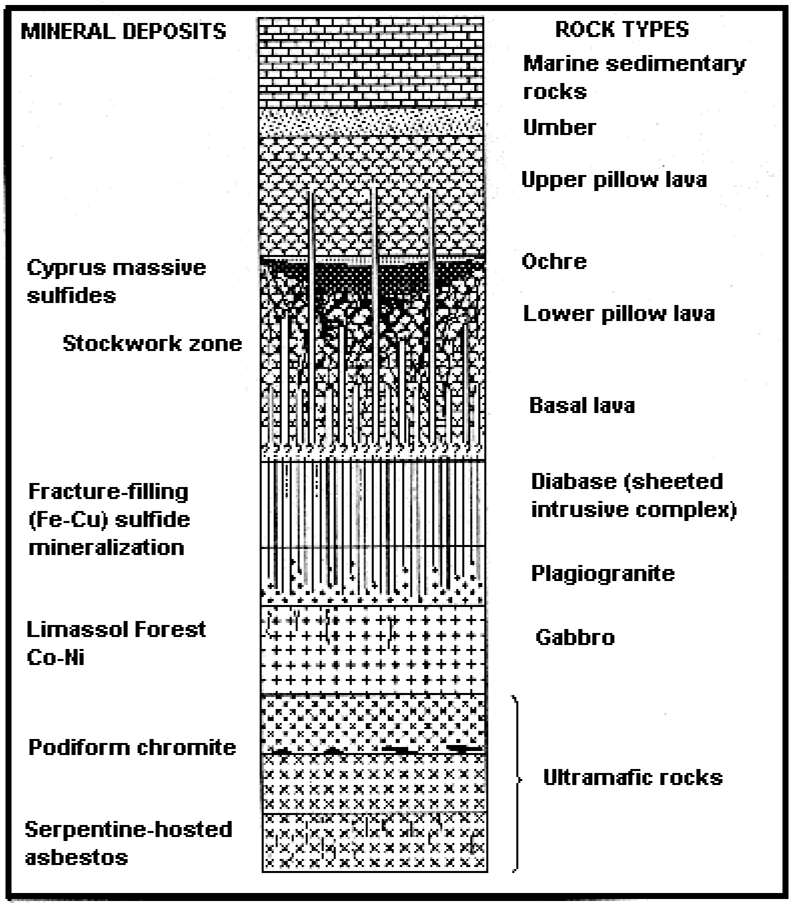
DESCRIPTION Massive pyrite, chalcopyrite, and sphalerite in pillow basalts (see figs. 95, 96).

GENERAL REFERENCE Franklin, and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Ophiolite assemblage: tectonized dunite and harzburgite, gabbro, sheeted diabase dikes, pillow basalts, and fine-grained metasedimentary rocks such as chert and phyllite (fig. 95).

Figure 95. Generalized stratigraphic column through the Troodos ophiolite showing Cyprus massive sulfides and other deposit types and their associated rock types. Modified from Constantinou (1980).

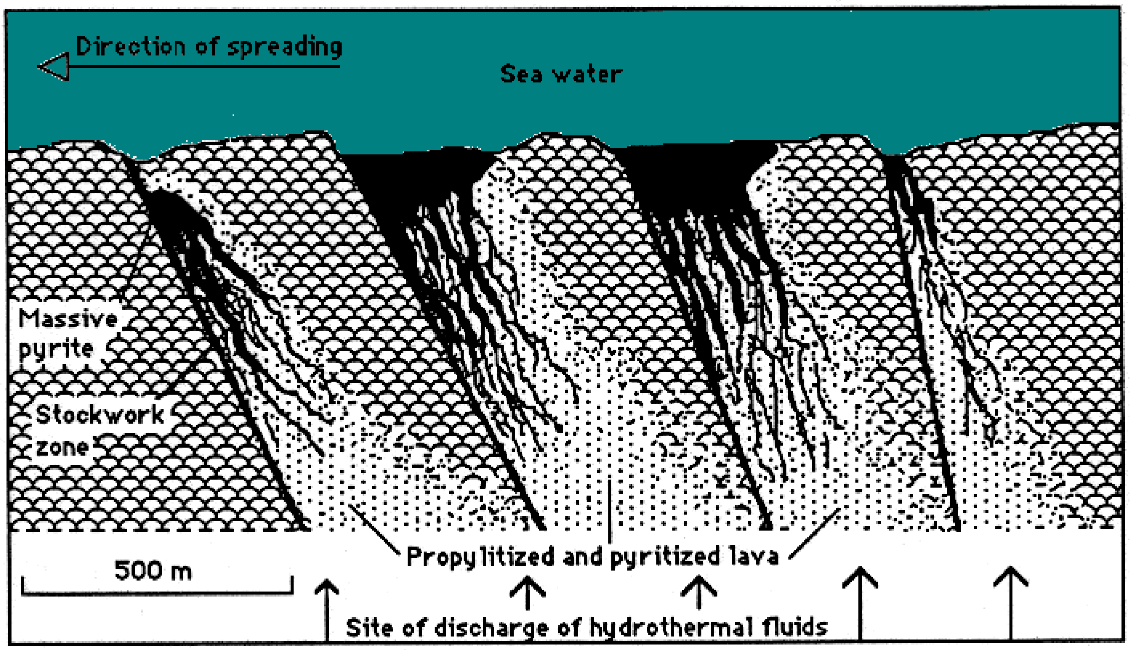


Textures Diabase dikes, pillow basalts, and in some cases brecciated basalt.

Age Range Archean(?) to Tertiary--majority are Ordovician or Cretaceous.

Depositional Environment Submarine hot spring along axial grabens in oceanic or back-arc spreading ridges. Hot springs related to submarine volcanoes producing seamounts (fig. 96).

Figure 96. Cross section through the Kalavos district, Cyprus, showing relationship of massive sulfide deposits to faults and alteration zones. Section is drawn normal to the spreading axis and represents a time period prior to deposition of a thick sequence of pillow lavas and sedimentary rocks. Modified from Adamides (1980).



Tectonic Setting(s) Ophiolites. May be adjacent to steep normal faults.

Associated Deposit Types Mn and Fe-rich cherts regionally.

DEPOSIT DESCRIPTION

Mineralogy Massive: pyrite + chalcopyrite + sphalerite + marcasite + pyrrhotite. Stringer (stockwork): pyrite + pyrrhotite, minor chalcopyrite and sphalerite (cobalt, gold, and silver present in minor amounts).

Texture/Structure Massive sulfides (>60 percent sulfides) with underlying sulfide stockwork or stringer zone. Sulfides brecciated and recemented. Rarely preserved fossil worm tubes.

Alteration Stringer zone--feldspar destruction, abundant quartz and chalcedony, abundant chlorite, some illite and calcite. Some deposits overlain by ochre (Mn-poor, Fe-rich bedded sediment containing goethite, maghemite, and quartz).

Ore Controls Pillow basalt or mafic volcanic breccia, diabase dikes below; ores rarely localized in sediments above pillows. May be local faulting.

Weathering Massive limonite gossans. Gold in stream sediments.

Geochemical Signature General loss of Ca and Na and introduction and redistribution of Mn and Fe in the stringer zone.

EXAMPLES

Cyprus deposits, CYPS (Constantinou and Govett, 1973)

Oxec, GUAT (Peterson and Zantop, 1980)

York Harbour, CNNF (Duke and Hutchinson, 1974)

Turner-Albright, USOR (Koski and Derkey, 1981)

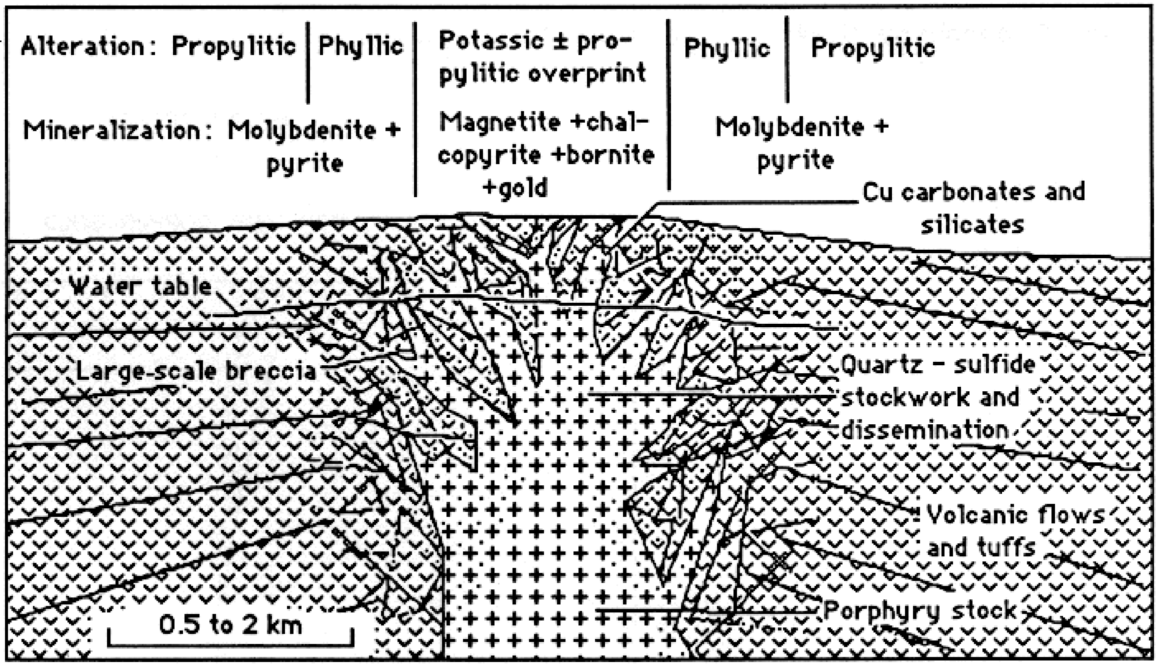
DESCRIPTIVE MODEL OF PORPHYRY Cu-Au

MODEL 20c

By Dennis P. Cox

DESCRIPTION Stockwork veinlets of chalcopyrite, bornite, and magnetite in porphyritic intrusions and coeval volcanic rocks. Ratio of Au (ppm) to Mo (percent) is greater than 30 (see fig. 77).

Figure 77. Cartoon cross section of porphyry Cu-Au deposit. Modified from Langton and Williams (1982).



GENERAL REFERENCES Sillitoe (1979), Cox and Singer (in press).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite; dacite, andesite flows and tuffs coeval with intrusive rocks. Also syenite, monzonite, and coeval high-K, low-Ti volcanic rocks (shoshonites).

Textures Intrusive rocks are porphyritic with fine- to medium-grained aplitic

groundmass.

Age Range Cretaceous to Quaternary.

Depositional Environment In porphyry intruding coeval volcanic rocks. Both involved and in large-scale breccia. Porphyry bodies may be dikes. Evidence for volcanic center; 1-2 km depth of emplacement.

Tectonic Setting(s) Island-arc volcanic setting, especially waning stage of volcanic cycle. Also continental margin rift-related volcanism.

Associated Deposit Types Porphyry Cu-Mo; gold placers.

DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite ± bornite; traces of native gold, electrum, sylvanite, and hessite. Quartz + K-feldspar + biotite + magnetite + chlorite + actinolite + anhydrite. Pyrite + sericite + clay minerals + calcite may occur in late-stage veinlets.

Texture/Structure Veinlets and disseminations.

Alteration Quartz ± magnetite ± biotite (chlorite) ± K-feldspar ± actinolite, ± anhydrite in interior of system. Outer propylitic zone. Late quartz + pyrite + white mica ± clay may overprint early feldspar-stable alteration.

Ore Controls Veinlets and fractures of quartz, sulfides, K-feldspar magnetite, biotite, or chlorite are closely spaced. Ore zone has a bell shape centered on the volcanic-intrusive center. Highest grade ore is commonly at the level at which the stock divides into branches.

Weathering Surface iron staining may be weak or absent if pyrite content is

low in protore. Copper silicates and carbonates. Residual soils contain anomalous amounts of rutile.

Geochemical Signature Central Cu, Au, Ag; peripheral Mo. Peripheral Pb, Zn, Mn anomalies may be present if late sericite pyrite alteration is strong. Au (ppm):Mo (percent) >30 in ore zone. Au enriched in residual soil over ore body. System may have magnetic high over intrusion surrounded by magnetic low over pyrite halo.

EXAMPLES

Dos Pobres, USAZ (Langton and Williams, 1982)

Copper Mountain, CNBC (Fahrni and others, 1976)

Tanama, PTRC (Cox, 1985)

DESCRIPTIVE MODEL OF ALASKAN PGE

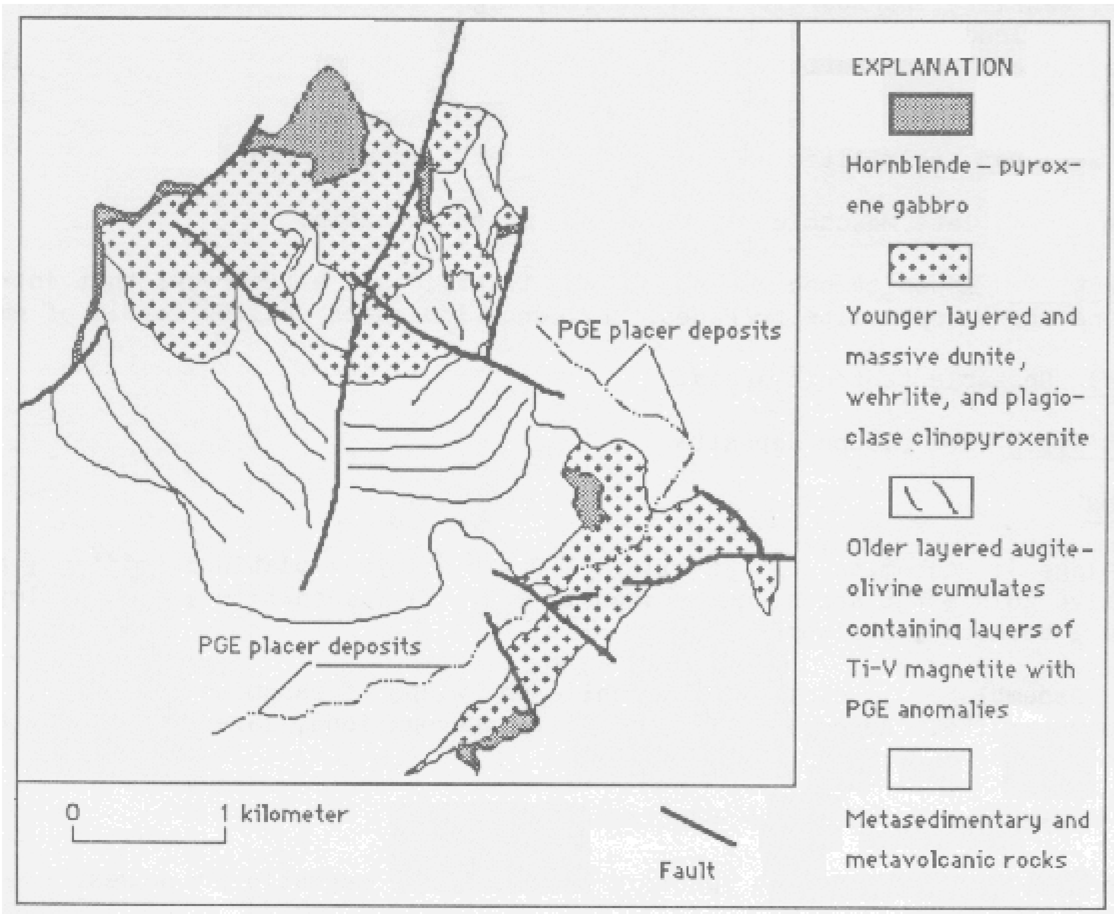
MODEL 9

By Norman J Page and Floyd Gray

APPROXIMATE SYNONYMS Zoned ultramafic Cr-Pt; Kachkanar-type (Cabri and Naldrett, 1984).

DESCRIPTION Crosscutting ultramafic to felsic intrusive rocks with approximately concentric zoning of rock types containing chromite, platinum, and Ti-V-magnetite (see fig. 29).

Figure 29. Generalized geologic map of zoned ultramafic complex at Lower Coon Mountain, Calif. (from Gray and Page, 1985). V-rich magnetite layers and anomalous PGE concentrations typical of Alaskan Cr-Pt deposits are associated with plutos of this type.



GEOLOGICAL ENVIRONMENT

Rock Types Dunite, wehrlite, harzburgite, pyroxenite, magnetite-hornblende pyroxenite, two-pyroxene gabbros, hornblende gabbro, hornblende clinopyroxenite, hornblende-magnetite clinopyroxenite, olivine gabbro, norite. Post-orogenic tonalite and diorite are commonly spatially related. Orthopyroxene-bearing rocks absent in Klamath Mountains.

Textures Cumulus textures, poikilitic, mush flow textures, lineated fabrics, layered.

Age Range Precambrian to late Mesozoic, most Paleozoic and Mesozoic.

Depositional Environment Deposits occur in layered ultramafic and mafic rocks that intrude into granodiorite, island arc or ophiolite terranes. Evidence indicates shallow levels of emplacement.

Tectonic Setting(s) Unstable tectonic areas.

Associated Deposit Types PGE placer deposits.

DEPOSIT DESCRIPTION

Mineralogy Assemblage 1: chromite + Pt-Fe alloys + Os-Ir alloys + platinum-iridium ± pentlandite ± pyrrhotite ± native gold ± PGE arsenides. Assemblage 2: Ti-V magnetite ± Tt-Fe alloys ± Os-Ir alloys ± cooperite ± bornite ± chalcopyrite.

Texture/Structure Assemblage 1: clots, pods, schlieren, wisps of chromite in dunite, clinopyroxenite, harzburgite. Assemblage 2: magnetite segregations, layers in wehrlite, pyroxenite, gabbro (see fig. 29).

Alteration None: post-mineralization serpentinization.

Ore Controls Appear to be restricted to specific rock types by magmatic processes.

Weathering Mechanical weathering produces placers; chemical weathering could produce laterites.

Geochemical Signature Cr, PGE, Ti, V, Cu, Ni, S, As. Assemblage 2 ores in Klamath Mountains are low in Cr and Ni.

EXAMPLES

Urals, USSR (Duparc and Tikonovitch, 1920)

Duke Island, USAK (Irvine, 1974)

Guseva-Gora, USSR (Razin, 1976)

Tin Cup Peak, USOR (Page and others, 1982a)

DESCRIPTIVE MODEL OF SUPERIOR Fe

MODEL 34a

By William F. Cannon

DESCRIPTION Banded iron-rich sedimentary rock, generally of great lateral extent, typically layered on centimeter scale with siliceous (chert) beds interlayered with iron-rich beds.

GENERAL REFERENCE James (1954).

GEOLOGICAL ENVIRONMENT

Rock Types Commonly interlayered with quartzite, shale, dolomite.

Textures Iron-formations and host rocks commonly contain sedimentary textures typical of shallow-water deposition in tectonically stable regions.

Age Range Mostly Early Proterozoic (2.0± 0.2 b.y.). Less commonly Middle and Late Proterozoic.

Depositional Environment Stable, shallow-water marine environment, commonly on stable continental shelf or intracratonic basin.

Tectonic Setting(s) Now commonly preserved in forelands of Proterozoic orogenic belts.

Associated Deposit Types Sedimentary manganese deposits may occur stratigraphically near or be interbedded with iron-formations.

DEPOSIT DESCRIPTION

Mineralogy Hematite, magnetite, siderite, fine-grained quartz.

Texture/Structure Nearly always banded at centimeter scale; very fine grained where not metamorphosed.

Alteration None related to ore deposition. Commonly metamorphosed to varying degrees or weathered and enriched by supergene processes.

Ore Controls No primary controls of local importance. Supergene ores may be localized by irregularities in present or paleo erosion surface.

Weathering Alteration of original iron mineral to Fe-hydroxides and hematite. Silica partly to totally leached. End product of weathering is high-grade supergene ore.

Geophysical Signature Magnetic anomalies.

EXAMPLES

Mesabi Range, USMN (James, 1983)

DESCRIPTIVE MODEL OF UPWELLING TYPE PHOSPHATE DEPOSITS

MODEL 34c

By Dan L. Mosier

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

GENERAL REFERENCES Slansky (1980), Sheldon (1964).

GEOLOGICAL ENVIRONMENT

Rock Types Phosphorite, marl, shale, chert, limestone, dolomite, and volcanic materials.

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.

DEPOSIT DESCRIPTION

Mineralogy 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 None related to ore.

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 a meter thick or more and may extend over hundreds of square kilometers.

Weathering Limonite and goethite.

Geochemical Signature P, N, F, C, and U. Anomalously radioactive.

EXAMPLES

Southeast, USID (Gulbrandsen and Krier, 1980)

Meskala, MRCO (British Sulphur Corp. Ltd., 1980)

Stra Quertane, TUNS (British Sulphur Corp. Ltd., 1980)
