DESCRIPTIVE MODEL OF PODIFORM CHROMITE

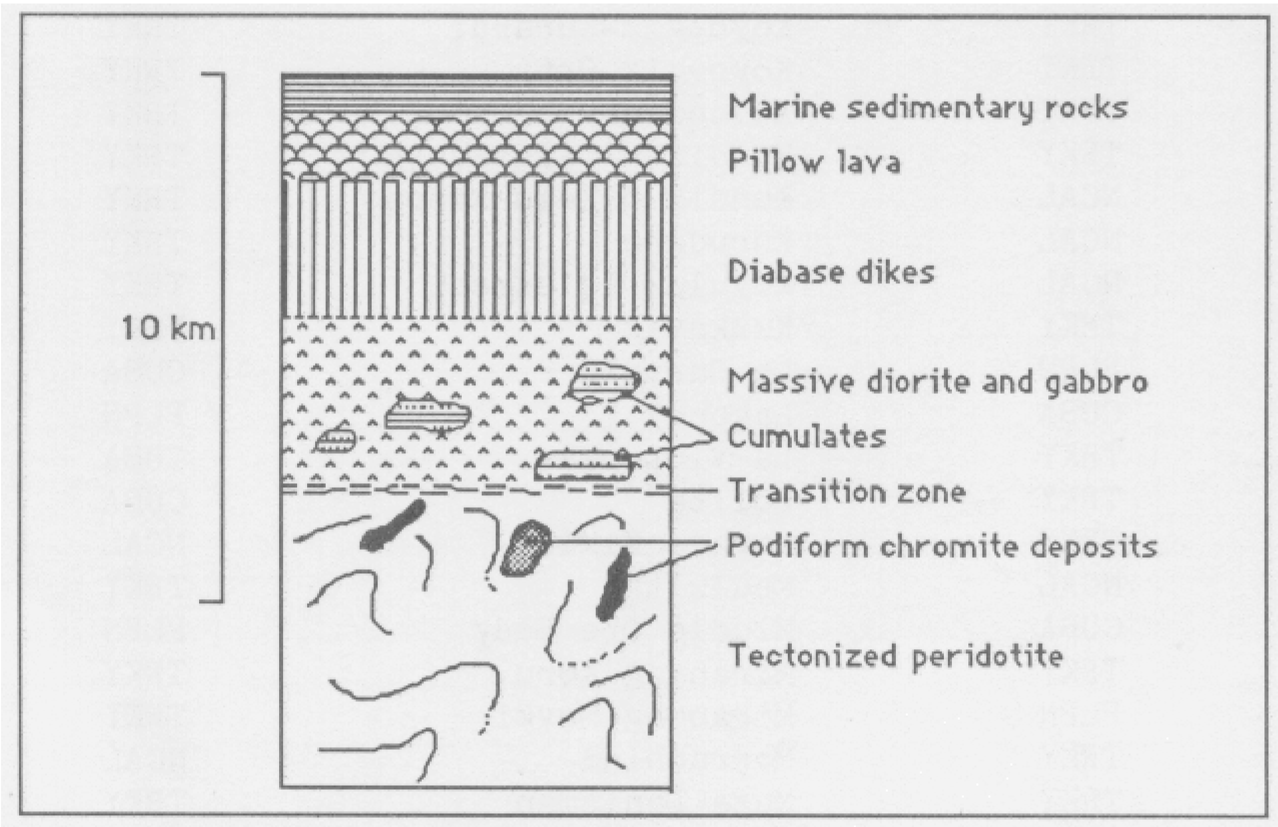
MODEL 8a and 8b

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)

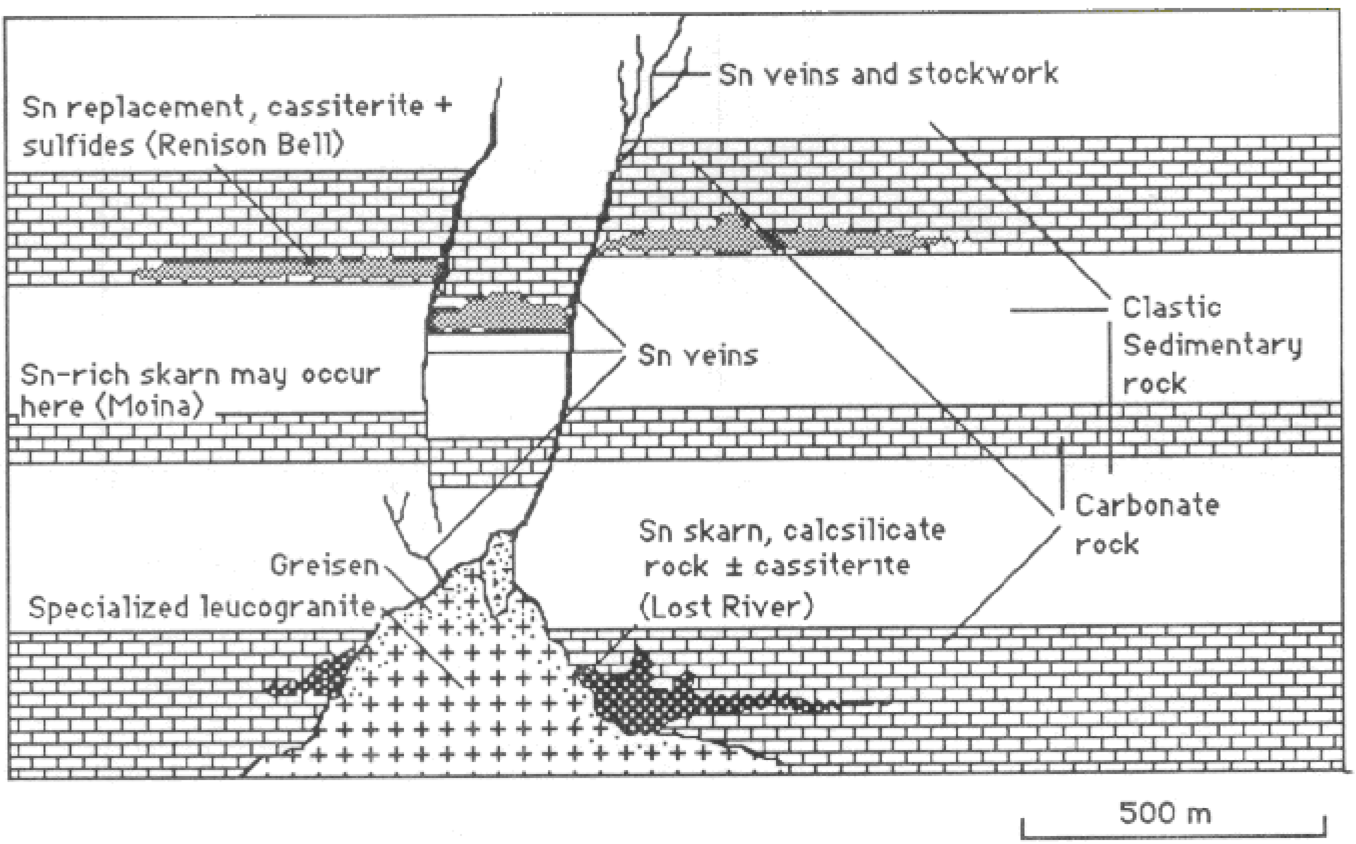
DESCRIPTIVE MODEL OF Sn SKARN DEPOSITS

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 SiO2 > 73 percent, K2O > 4 percent and are depleted in CaO, TiO2, 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 VEINS

MODEL 15b

By Bruce L. Reed

APPROXIMATE SYNONYM Cornish type lodes.

DESCRIPTION Simple to complex quartz-cassiterite ± wolframite and base-metal sulfide fissure fillings or replacement lodes in ore near felsic plutonic rocks (see fig. 34).

GENERAL REFERENCE Hosking (1974), Taylor (1979).

GEOLOGICAL ENVIRONMENT

Rock Types Close spatial relation to multiphase granitoids; specialized biotite and(or) muscovite leucogranite common; pelitic sediments generally present.

Textures Common plutonic textures.

Age Range Paleozoic and Mesozoic most common; may be any age.

Depositional Environment Mesozonal to hypabyssal plutons; extrusive rocks generally absent; dikes and dike swarms common.

Tectonic Setting(s) Foldbelts and accreted margins with late orogenic to postorogenic granitoids which may, in part, be anatectic; regional fractures common.

Associated Deposit Types Sn greisen, Sn skarn, and replacement Sn deposits.

DEPOSIT DESCRIPTION

Mineralogy Extremely varied; cassiterite ± wolframite, arsenopyrite, molybdenite, hematite, scheelite, beryl, galena, chalcopyrite, sphalerite, stannite, bismuthinite; although variations and overlaps are ubiquitous, many deposits show an inner zone of cassiterite ± wolframite fringed with Pb, Zn, Cu, and Ag sulfide minerals.

Texture/Structure Variable; brecciated bands, filled fissures, replacement, open cavities.

Alteration Sericitization (greisen development) ± tourmalization common adjacent to veins and granite contacts; silicification, chloritization, hematization. An idealized zonal relation might consist of quartz-tourmaline-topaz, quartz-tourmaline-sericite, quartz-sericite-chlorite, quartz-chlorite, chlorite.

Ore Controls Economic concentrations of tin tend to occur within or above the apices of granitic cusps and ridges; localized controls include variations in vein structure, lithologic and structural changes, vein intersections, dikes, and cross-faults.

Weathering Cassiterite in stream gravels, placer tin deposits.

Geochemical Signature Sn, As, W, B are good pathfinder elements; elements characteristic of specialized granites (F, Rb, Be, Nb, Cs, U, Mo, REE, see model 14b).

EXAMPLES

Cornwall, GRBR (Hosking, 1969)

Herberton, AUQL (Blake, 1972)

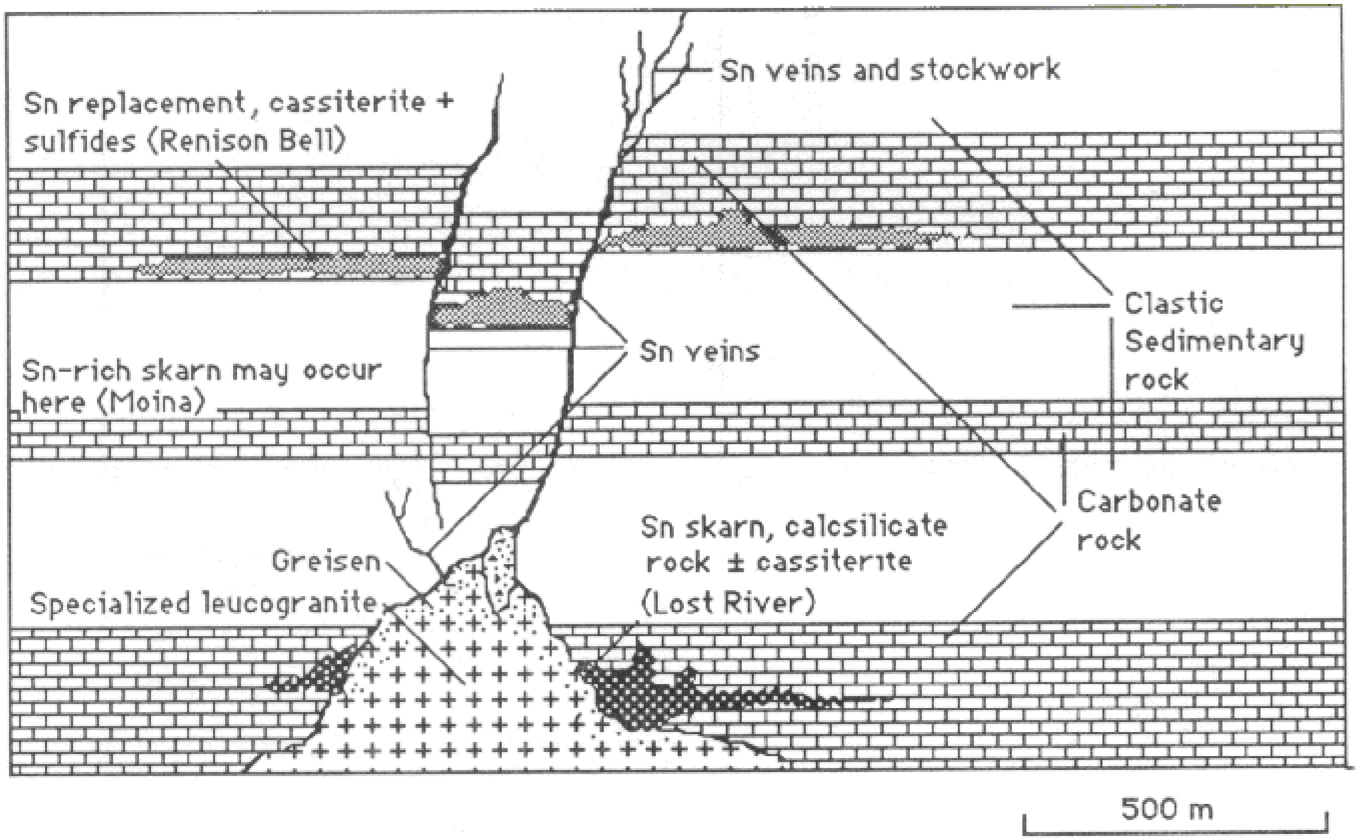
DESCRIPTIVE MODEL OF Sn GREISEN DEPOSITS

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

Rock Types 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

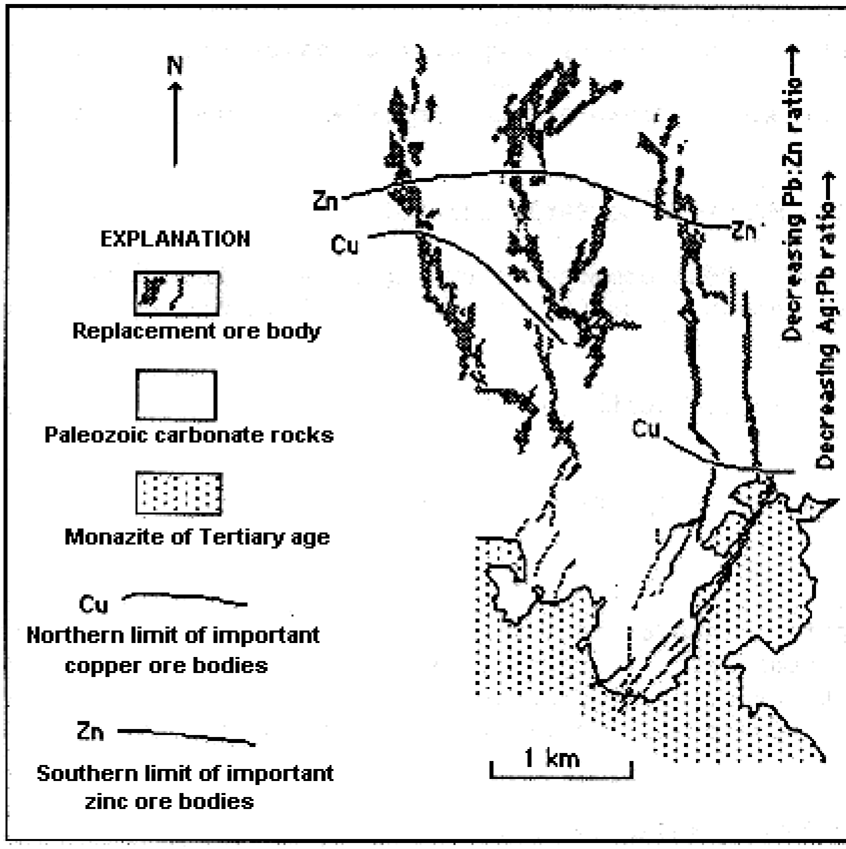
MODEL 19a

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)).



Metals	Dominant mineralogy Ore	Gangue
Zn-Mn	Sphalerite + rhodochrosite	Fine-grained pyritic jasperoid
Pb-Ag	Galena + sphalerite + argentite + Ag sulfosalts ± tetrahedrite	Fine-grained jasperoid with barite crystals and quartz-lined vugs
Cu-Au	Enargite-famatinite + tennantite-tetrahedrite + sphalerite + argentite + digenite	Medium-grained jasperoid and coarse crystals of quartz and barite

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 BASALTIC Cu

MODEL 23

By Dennis P. Cox

APPROXIMATE SYNONYM Volcanic redbed Cu (Kirkham, 1984).

DESCRIPTION A diverse group including disseminated native copper and copper sulfides in the upper parts of thick sequences of subaerial basalt, and copper sulfides in overlying sedimentary beds.

GENERAL REFERENCE Kirkham (1984).

GEOLOGICAL ENVIRONMENT

Rock Types Subaerial to shallow marine basalt flows, breccias and tuffs, red-bed sandstone, tuffaceous sandstone, conglomerate. Younger tidal facies limestone and black shale.

Textures Amygdules, flow-top breccias in lava. Laminated algal carbonate rocks. Sediments with high original porosity.

Age Range Proterozoic, Triassic and Jurassic, and Tertiary deposits known.

Depositional Environment Copper-rich (100-200 ppm) basalt interlayered with red clastic beds and overlain by mixed shallow marine and continental deposits formed near paleo-equator.

Tectonic Setting(s) Intracontinental rift, continental margin rift. Regional low-grade metamorphism may mobilize copper in some districts. Deposits are characteristic of the Triassic part of Wrangellia terrane in Alaska.

Associated Deposit Types Sediment-hosted copper. Volcanogenic Mn at Boleo, Mexico.

DEPOSIT DESCRIPTION

Mineralogy Native copper, native silver in flows and coarse clastic beds. Chalcocite and other Cu2S minerals and locally bornite and chalcopyrite are concentrated in overlying shale and carbonate rocks. Fine-grained pyrite is common but not abundant with copper sulfide minerals.

Texture/Structure Flow-top breccia and amygdule fillings in basalt. Fine grains in matrix and along shaley parting in clastics. Massive replacement of carbonates at Kennicott. Finely varved chalcopyrite sediment at Denali.

Alteration Calcite-zeolite + epidote + K-feldspar. Red coloration due to fine hematite.

Ore Controls Flow-top breccias, amygdules, fractures in basalt; organic shale, limestone in overlying sequence. Limestone is tidal, algal, with stromatolite fossils. Synsedimentary faulting may be important.

Weathering Widely dispersed copper nuggets in streams draining basalts.

Geochemical Signature Cu-Ag-Zn-Cd. Co at Boleo, Mexico. Cu:Zn ratio is very high. Au anomalously low.

EXAMPLES

Keweenaw, USMI (White, 1968)

Calumet, USMI (Ensign and others, 1968)

Kennicott, USAK (Bateman and McLaughlin, 1920)

Denali, USAK (Seraphim, 1975)

Boleo, MXCO (Wilson, 1955)

Buena Esperanza, CILE (Ruiz, 1965)

Redstone, CNNT (Ruelle, 1982)

Sustut, CNBC (Harper, 1977)

DESCRIPTIVE MODEL OF VOLCANOGENIC U

MODEL 25f

By William C. Bagby

DESCRIPTION Uranium mineralization in epithermal veins composed of quartz, fluorite, and iron, arsenic, and molybdenum sulfides.

GENERAL REFERENCE Nash (1981).

GEOLOGICAL ENVIRONMENT

Rock Types High-silica alkali rhyolite and potash trachytes. Peralkaline and peraluminous rhyolite host ore.

Textures Porphyritic to aphyric vesicular flows and shallow intrusive rocks.

Age Range Precambrian to Tertiary.

Depositional Environment Subaerial to subaqueous volcanic complexes. Near-surface environment, association with shallow intrusive rocks is important.

Tectonic Setting(s) Continental rifts and associated calderas.

Associated Deposit Types Roll-front uranium in volcaniclastic sediments. Fluorite deposits.

DEPOSIT DESCRIPTION

Mineralogy Coffinite, uraninite, brannerite are most common uranium minerals. Other minerals include pyrite, realgar/orpiment, leucoxene, molybdenite, fluorite, quartz, adularia, and barite. Gold is present in some deposits. Deposits associated with alkaline complexes may contain bastnaesite.

Texture/Structure Open-space filling in breccias. Uraninite commonly encapsulated in silica.

Alteration Kaolinite, montmorillonite, and alunite are common. Silicification, accompanied by adularia, affects wallrocks spatially most closely associated with ore.

Ore Controls Through-going fractures and breccias formed along the margins of shallow intrusives. Vugs in surface flows are of minor importance.

Weathering Near-surface oxidation produces jordisite and a variety of secondary uranium minerals. Supergene uranium enrichment is generally not important.

Geochemical Signature Li and Hg are zoned away from the ore. High anomalous As, Sb, F, Mo ± W occur near and with the ore. Mo is deep, Hg is shallow. REE may be highly anomalous. Anomalously radioactive.

EXAMPLES

Marysvale, USUT (Kerr and others, 1957)

Aurora prospect, USOR (Roper and Wallace, 1981)

Rexspar, CNBC (Joubin and James, 1956)

DESCRIPTIVE MODEL OF HOT-SPRING Hg

MODEL 27a

By James J. Rytuba

APPROXIMATE SYNONYM Sulphur Bank type of White (1981) or sulfurous type of Bailey and Phoenix (1944).

DESCRIPTION Cinnabar and pyrite disseminated in siliceous sinter superjacent to graywacke, shale, andesite, and basalt flows and diabase dikes.

GEOLOGICAL ENVIRONMENT

Rock Types Siliceous sinter, andesite-basalt flows, diabase dikes, andesitic tuffs, and tuff breccia.

Age Range Tertiary.

Depositional Environment Near paleo ground-water table in areas of fossil hot-spring system.

Tectonic Setting(s) Continental margin rifting associated with small volume mafic to intermediate volcanism.

Associated Deposit Types Hot-spring Au.

DEPOSIT DESCRIPTION

Mineralogy Cinnabar + native Hg + minor marcasite.

Texture/Structure Disseminated and coatings on fractures in hot-spring sinter.

Alteration Above paleo ground-water table, kaolinite-alunite-Fe oxides, native sulfur; below paleo ground-water table, pyrite, zeolites, potassium feldspar, chlorite, and quartz. Opal deposited at the paleo water table.

Ore Controls Paleo ground-water table within hot-spring systems developed along high-angle faults.

Geochemical Signature Hg + As + Sb + Au.

EXAMPLES

Sulfur bank, USCA (White and Roberson, 1962)

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

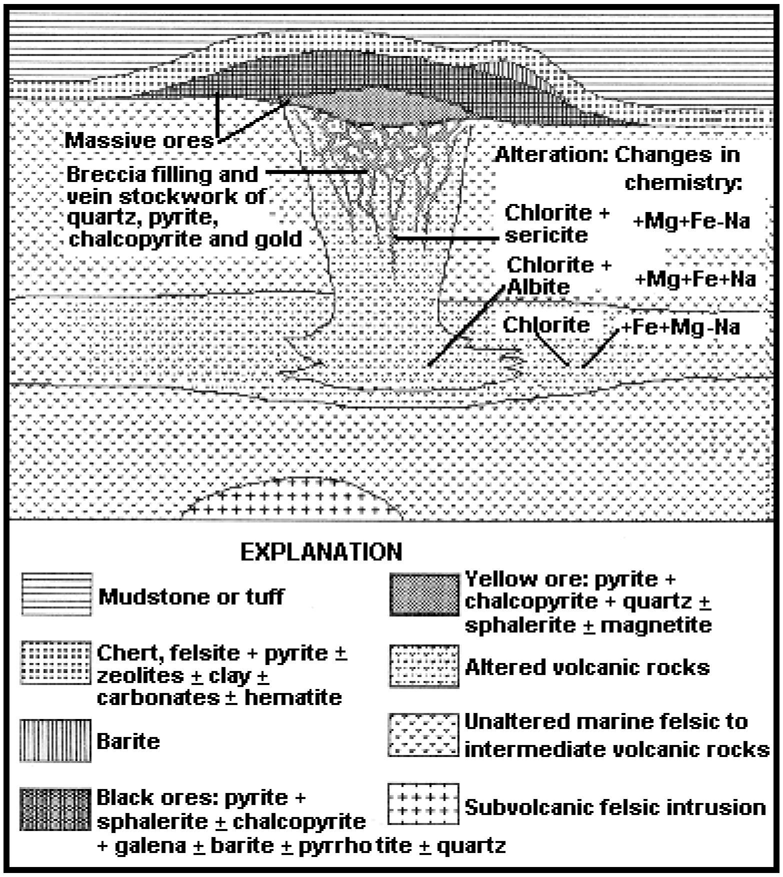
MODEL 28a

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).

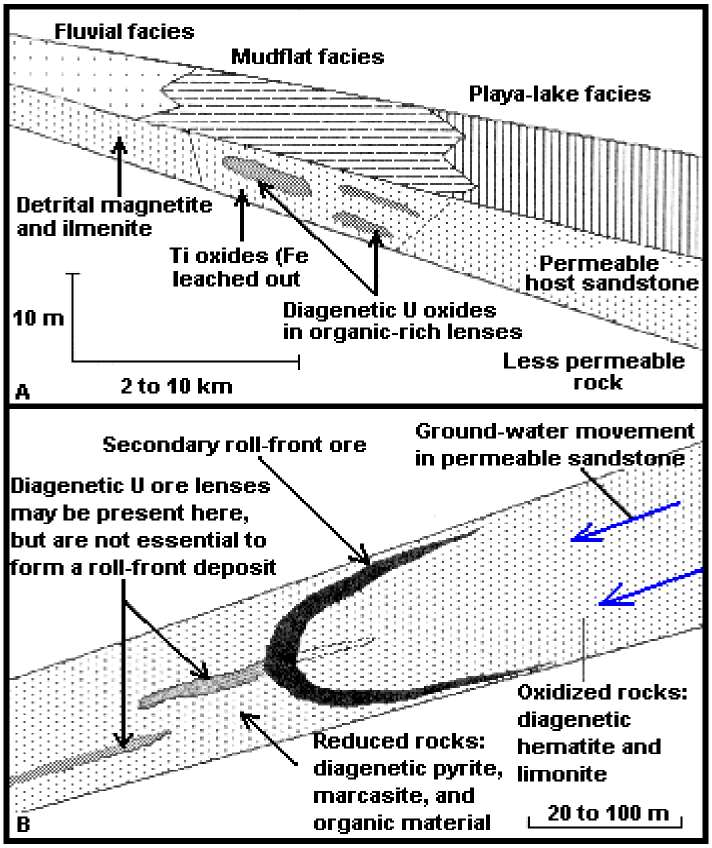
Textures Permeable--medium to coarse grained; highly permeable at time of mineralization, subsequently restricted by cementation and alteration.

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

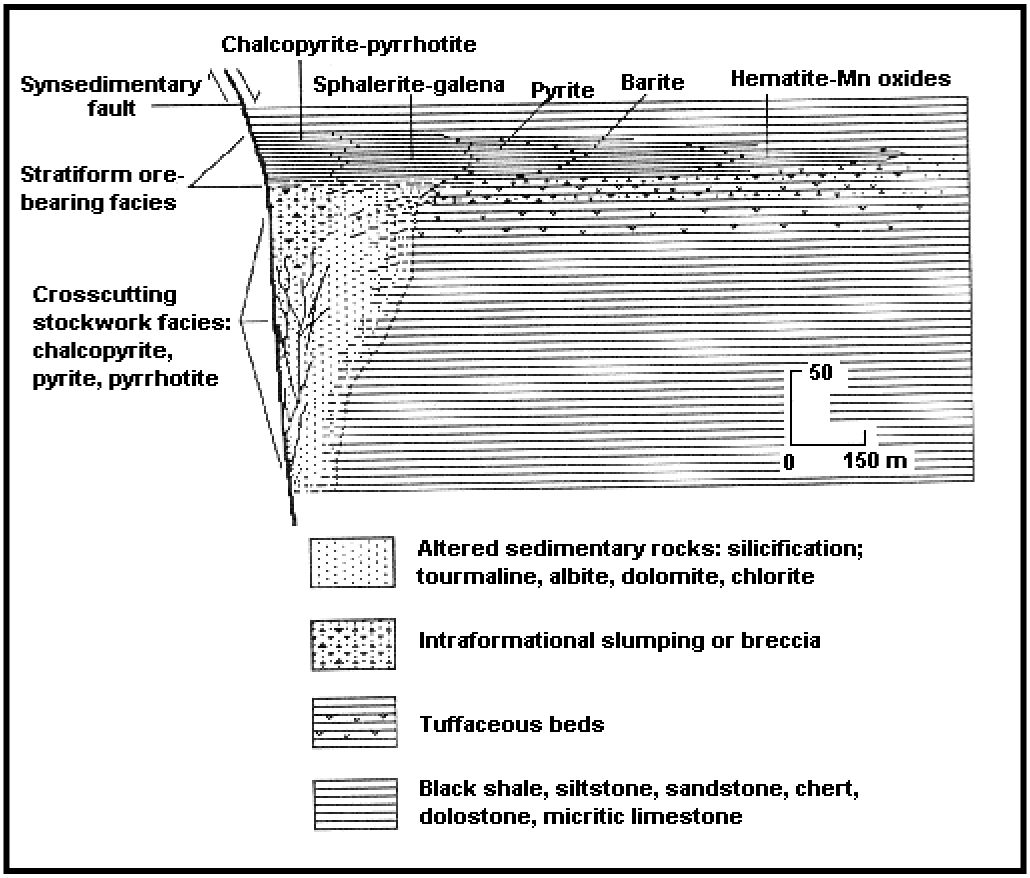
MODEL 31a

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 BEDDED BARITE

MODEL 31b

By Greta J. Orris

APPROXIMATE SYNONYM Stratiform barite.

DESCRIPTION Stratiform deposits of barite interbedded with dark-colored cherty and calcareous sedimentary rocks.

GEOLOGICAL ENVIRONMENT

Rock Types Generally dark-colored chert, shale, mudstone, limestone or dolostone. Also with quartzite, argillite, and greenstone.

Age Range Proterozoic and 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.

Associated Deposit Types Sedimentary exhalative Zn-Pb (see fig. 158).

DEPOSIT DESCRIPTION

Mineralogy Barite ± minor witherite ± minor pyrite, galena, or sphalerite. Barite typically contains several percent organic matter plus some H2S in fluid inclusions.

Texture/Structure Stratiform, commonly lensoid to poddy; ore laminated to massive with associated layers of barite nodules or rosettes; barite may exhibit primary sedimentary features. Small country rock inclusions may show partial replacement by barite.

Alteration Secondary barite veining; weak to moderate sericitization has been reported in or near some deposits in Nevada.

Ore Controls Deposits are localized in second- and third-order basins.

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 or regional manganese haloes. High organic C content.

EXAMPLES

Meggen, GRMY (Krebs, 1981)

Magnet Cove, USAR (Scull, 1958)

Northumberland, USNV (Shawe and others, 1969)

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.

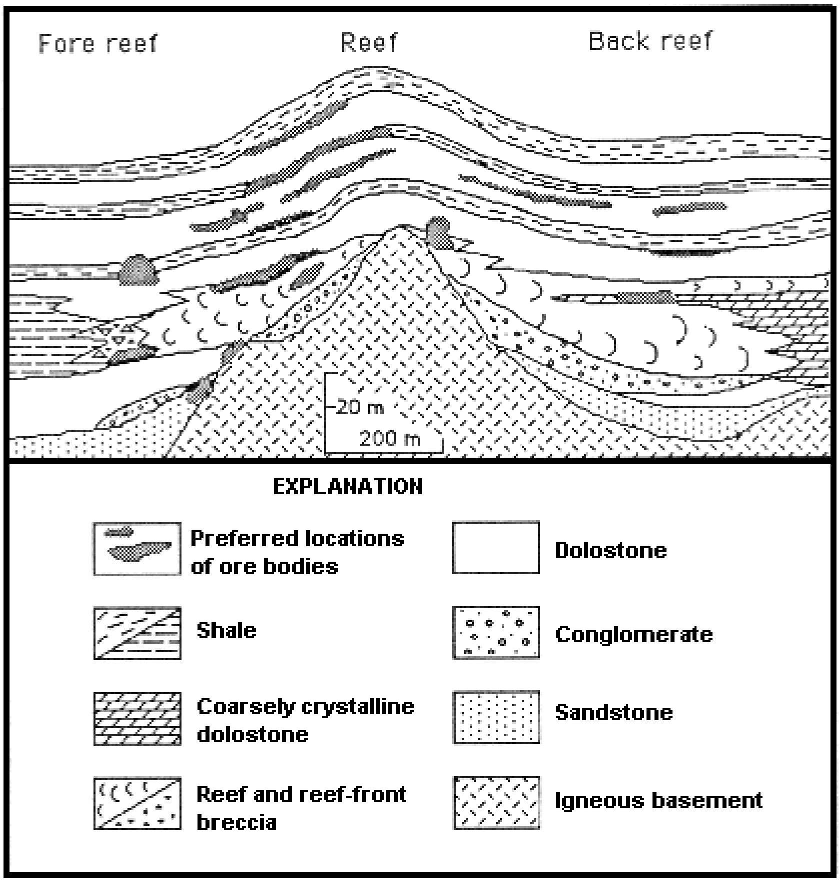
Textures Calcarenites are most common lithology. Tidalites, stromatolite finger reefs, reef breccias, slump breccias; oolites, crossbedding, micrites.

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.

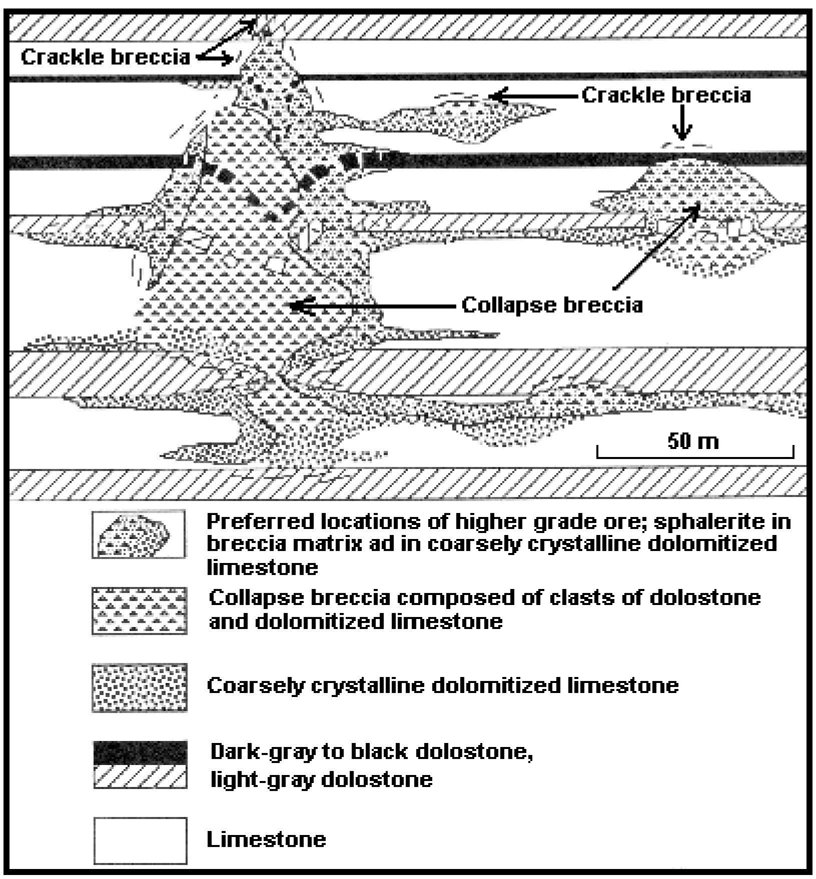
Textures Subtidal, intratidal, and supratidal textures with high porosity are common, especially in the dolostones; limestones are commonly micritic, some with birdseye textures.

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. Bituminuous 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.

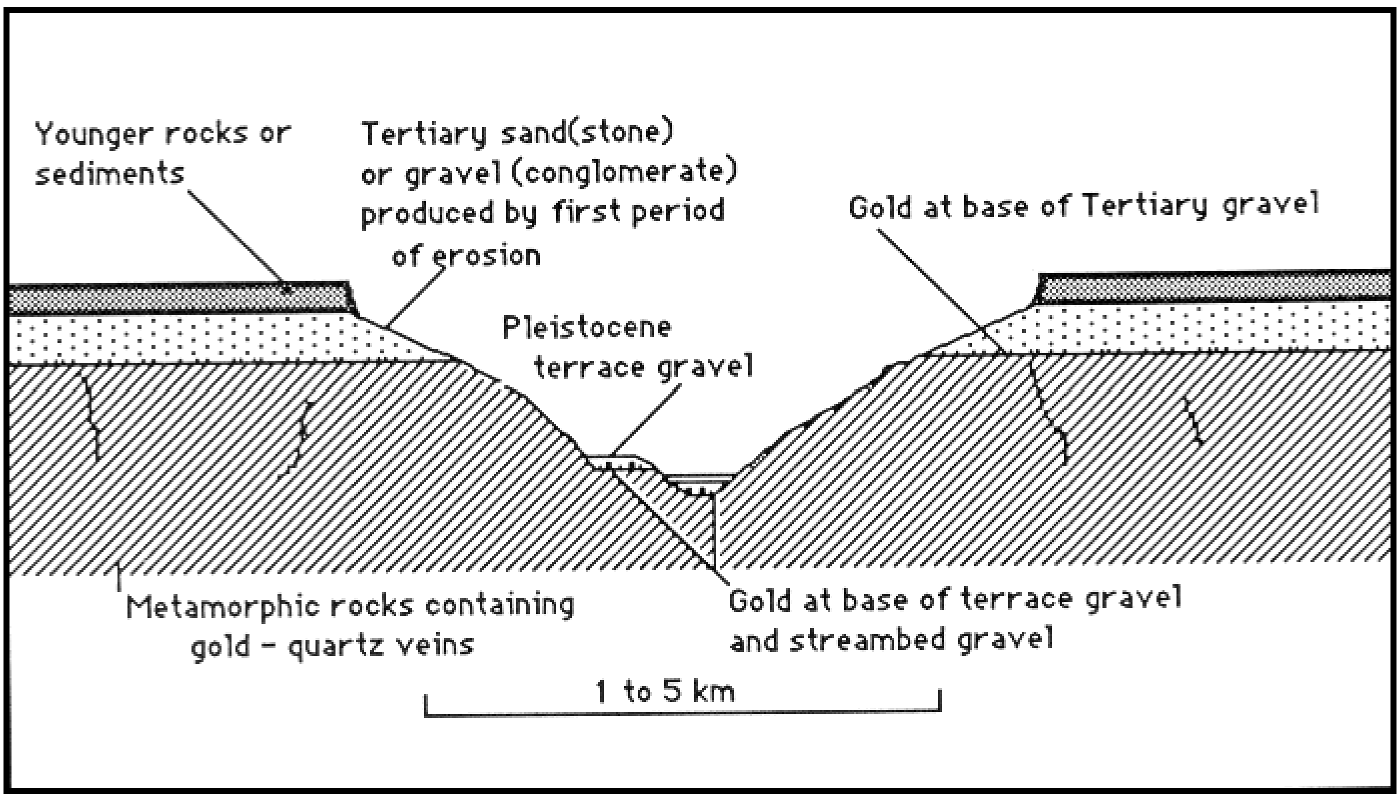
Textures Coarse clastic.

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 ALLUVIAL PLACER Sn

MODEL 39e

By Bruce L. Reed

DESCRIPTION Cassiterite and associated heavy minerals in silt- to cobble-size nuggets concentrated by the hydraulics of running water in modern and fossil streambeds.

GENERAL REFERENCES Hosking (1974), Taylor (1979), Sainsbury and Reed (1973).

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial sand, gravel, and conglomerate indicative of rock types that host lode tin deposits.

Textures Fine to very coarse clastic.

Age Range Commonly late Tertiary to Holocene, but may be any age.

Depositional Environment Generally moderate to high-level alluvial, where stream gradients lie within the critical range for deposition of cassiterite (for instance, where stream velocity is sufficient to result in good gravity separation but not enough so the channel is swept clean). Stream placers may occur as offshore placers where they occupy submerged valleys or strandlines.

Tectonic Setting(s) Alluvial deposits derived from Paleozoic to Cenozoic accreted terranes or stable cratonic foldbelts that contain highly evolved granitoid plutons or their extrusive equivalents (see Model 14b, geochemical signature). Tectonic stability during deposition and preservation of alluvial deposits.

Associated Deposit Types Alluvial gravels may contain by-product ilmenite, zircon, monazite, and, where derived from cassiterite-bearing pegmatites, columbite-tantalite. Economic placers are generally within a few (<8) kilometers of the primary sources. Any type of cassiterite-bearing tin deposit may be a source. The size and grade of the exposed source frequently has little relation to that of the adjacent alluvial deposit.

DEPOSIT DESCRIPTION

Mineralogy Cassiterite; varying amounts of magnetite, ilmenite, zircon, monazite, allanite, xenotime, tourmaline, columbite, garnet, rutile, and topaz may be common heavy resistates.

Texture/Structure Cassiterite becomes progressively coarser as the source is approached; euhedral crystals indicate close proximity to primary source. Where a marine shoreline intersects or transgresses a stream valley containing alluvial cassiterite the shoreline placers normally have a large length-to-width ratio.

Ore Controls Cassiterite tends to concentrate at the base of stream gravels and in traps such as natural riffles, potholes, and bedrock structures transverse to the direction of water flow. The richest placers lie virtually over the primary source. Streams that flow parallel to the margin of a tin-bearing granite are particularly favorable for placer tin accumulation.

Geochemical Signature Anomalously high amounts of Sn, As, B, F, W, Be, W, Cu, Pb, Zn. Panned concentrate samples are the most reliable method for detection of alluvial cassiterite.

EXAMPLES

Southeast Asian tin fields (Hosking, 1974)
(Newell, 1971)

(Simatupang and others, 1974)
(Westerveld, 1937)
