Au SKARNS

K04

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IDENTIFICATION

SYNONYMS: Pyrometasomatic, tactite, or contact metasomatic Au deposits.

COMMODITIES (*BYPRODUCTS*): Au (*Cu, Ag*).

EXAMPLES (British Columbia - *Canada/International*): Nickel Plate (092HSE038), French (092HSE059), Canty (092HSE 064), Good Hope (092HSE060), QR - Quesnel River (093A121); *Fortitude, McCoy and Tomboy-Minnie (Nevada, USA), Buckhorn Mountain (Washington, USA), Diamond Hill, New World district and Butte Highlands (Montana, USA), Nixon Fork (Alaska, USA), Thanksgiving (Philippines), Browns Creek and Junction Reefs-Sheahan-Grants (New South Wales, Australia), Mount Biggenden (Queensland, Australia), Savage Lode, Coogee (Western Australia, Australia), Nambija (Ecuador), Wabu (Irian Jaya, Indonesia).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Gold-dominant mineralization genetically associated with a skarn gangue consisting of Ca - Fe - Mg silicates, such as clinopyroxene, garnet and epidote. Gold is often intimately associated with Bi or Au-tellurides, and commonly occurs as minute blebs (<40 microns) that lie within or on sulphide grains. The vast majority of Au skarns are hosted by calcareous rocks (calcic subtype). The much rarer magnesian subtype is hosted by dolomites or Mg-rich volcanics. On the basis of gangue mineralogy, the calcic Au skarns can be separated into either pyroxene-rich, garnet-rich or epidote-rich types; these contrasting mineral assemblages reflect differences in the hostrock lithologies as well as the oxidation and sulphidation conditions in which the skarns developed.

TECTONIC SETTINGS: Most Au skarns form in orogenic belts at convergent plate margins. They tend to be associated with syn to late island arc intrusions emplaced into calcareous sequences in arc or back-arc environments.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Most deposits are related to plutonism associated with the development of oceanic island arcs or back arcs, such as the Late Triassic to Early Jurassic Nicola Group in British Columbia.

AGE OF MINERALIZATION: Phanerozoic (mostly Cenozoic and Mesozoic); in British Columbia Au skarns are mainly of Early to Middle-Jurassic age. The unusual magnesian Au skarns of Western Australia are Archean.

HOST/ASSOCIATED ROCK TYPES: Gold skarns are hosted by sedimentary carbonates, calcareous clastics, volcaniclastics or (rarely) volcanic flows. They are commonly related to high to intermediate level stocks, sills and dikes of gabbro, diorite, quartz diorite or granodiorite composition. Economic mineralization is rarely developed in the endoskarn. The I-type intrusions are commonly porphyritic, undifferentiated, Fe-rich and calc-alkaline. However, the *Nambija, Wabu* and *QR* Au skarns are associated with alkalic intrusions.

DEPOSIT FORM: Variable from irregular lenses and veins to tabular or stratiform orebodies with lengths ranging up to many hundreds of metres. Rarely, can occur as vertical pipe-like bodies along permeable structures.

TEXTURE/STRUCTURE: Igneous textures in endoskarn. Coarse to fine-grained, massive granoblastic to layered textures in exoskarn. Some hornfelsic textures. Fractures, sill-dike margins and fold hinges can be an important loci for mineralization.

ORE MINERALOGY (Principal and *subordinate*): The gold is commonly present as micron-sized inclusions in sulphides, or at sulphide grain boundaries. To the naked eye, ore is generally indistinguishable from waste rock. Due to the poor correlation between Au and Cu in some Au skarns, the economic potential of a prospect can be overlooked if Cu-sulphide-rich outcrops are preferentially sampled and other sulphide-bearing or sulphide-lean assemblages are ignored. The ore in pyroxene-rich and garnet-rich skarns tends to have low Cu:Au (<2000:1), Zn:Au (<100:1) and Ag/Au (<1:1) ratios, and the gold is commonly associated with Bi minerals (particularly Bi tellurides).

Magnesian subtype: Native gold ± pyrrhotite ± chalcopyrite ± pyrite ± *magnetite* ± *galena* ± *tetrahedrite*.

Calcic subtype:

Pyroxene-rich Au skarns: Native gold ± pyrrhotite ± arsenopyrite ± *chalcopyrite* ± *tellurides* (e.g. *hedleyite, tetradymite, altaite* and *hessite*) ± *bismuthinite* ± *cobaltite* ± *native bismuth* ± *pyrite* ± *sphalerite* ± *maldonite*. They generally have a high sulphide content and high pyrrhotite:pyrite ratios. Mineral and metal zoning is common in the skarn envelope. At Nickel Plate for example, this comprises a narrow proximal zone of coarse-grained, garnet skarn containing high Cu:Au ratios, and a wider, distal zone of finer grained pyroxene skarn containing low Cu:Au ratios and the Au-sulphide orebodies.

Garnet-rich Au skarns: Native gold ± chalcopyrite ± pyrite ± arsenopyrite ± sphalerite ± magnetite ± hematite ± *pyrrhotite* ± *galena* ± *tellurides* ± *bismuthinite*. They generally have a low to moderate sulphide content and low pyrrhotite:pyrite ratios.

Epidote-rich Au skarn: Native gold ± chalcopyrite ± pyrite ± arsenopyrite ± hematite ± magnetite ± *pyrrhotite* ± *galena* ± *sphalerite* ± *tellurides*. They generally have a moderate to high sulphide content with low pyrrhotite:pyrite ratios.

EXOSKARN MINERALOGY (GANGUE):

Magnesian subtype: Olivine, clinopyroxene (Hd2-50), garnet (Ad7-30), chondrodite and monticellite. Retrograde minerals include serpentine, epidote, vesuvianite, tremolite-actinolite, phlogopite, talc, K-feldspar and chlorite.

Calcic subtype:

Pyroxene-rich Au skarns: Extensive exoskarn, generally with high pyroxene:garnet ratios. Prograde minerals include diopsidic to hedenbergitic clinopyroxene (Hd 20-100), K-feldspar, Fe-rich biotite, low Mn grandite garnet (Ad 10-100), wollastonite and vesuvianite. Other less common minerals include rutile, axinite and sphene. Late or retrograde minerals include epidote, chlorite, clinozoisite, vesuvianite, scapolite, tremolite-actinolite, sericite and prehnite.

Garnet-rich Au skarns: Extensive exoskarn, generally with low pyroxene:garnet ratios. Prograde minerals include low Mn grandite garnet (Ad 10-100), K-feldspar, wollastonite, diopsidic clinopyroxene (Hd 0-60), epidote, vesuvianite, sphene and apatite. Late or retrograde minerals include epidote, chlorite, clinozoisite, vesuvianite, tremolite-actinolite, sericite, dolomite, siderite and prehnite.

Epidote-rich Au skarns: Abundant epidote and lesser chlorite, tremolite-actinolite, quartz, K-feldspar, garnet, vesuvianite, biotite, clinopyroxene and late carbonate. At the *QR* deposit, epidote-pyrite and carbonate-pyrite veinlets and coarse aggregates are common, and the best ore occurs in the outer part of the alteration envelope, within 50 m of the epidote skarn front.

ENDOSKARN MINERALOGY (GANGUE): Moderate endoskarn development with K-feldspar, biotite, Mg-pyroxene (Hd 5-30) and garnet. Endoskarn at the epidote-rich *QR* deposit is characterized by calcite, epidote, clinozoisite and tremolite whereas at the *Butte Highlands* Mg skarn it contains argillic and propyllitic alteration with garnet, clinopyroxene and epidote.

WEATHERING: In temperate and wet tropical climates, skarns often form topographic features with positive relief.

ORE CONTROLS: The ore exhibits strong stratigraphic and structural controls. Orebodies form along sill-dike intersections, sill-fault contacts, bedding-fault intersections, fold axes and permeable faults or tension zones. In the pyroxene-rich and epidote-rich types, ore commonly develops in the more distal portions of the alteration envelopes. In some districts, specific suites of reduced, Fe-rich intrusions are spatially related to Au skarn mineralization. Ore bodies in the garnet-rich Au skarns tend to lie more proximal to the intrusions.

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GENETIC MODEL: Many Au skarns are related to plutons formed during oceanic plate subduction. There is a worldwide spatial, temporal and genetic association between porphyry Cu provinces and calcic Au skarns. Pyroxene-rich Au skarns tend to be hosted by siltstone-dominant packages and form in hydrothermal systems that are sulphur-rich and relatively reduced. Garnet-rich Au skarns tend to be hosted by carbonate-dominant packages and develop in more oxidising and/or more sulphur-poor hydrothermal systems.

ASSOCIATED DEPOSIT TYPES: Au placers (C01,C02), calcic Cu skarns (K01), porphyry Cu deposits (L04) and Au-bearing quartz and/or sulphide veins (I01, I02). Magnesian subtype can be associated with porphyry Mo deposits (L05) and possibly W skarns (K05). In British Columbia there is a negative spatial association between Au and Fe skarns at regional scales, even though both classes are related to arc plutonism. Fe skarns are concentrated in the Wrangellia Terrane whereas most Au skarn occurrences and all the economic deposits lie in Quesnellia.

COMMENTS: Most Au skarns throughout the world are calcic and are associated with island arc plutonism. However, the *Savage Lode* magnesian Au skarn occurs in the Archean greenstones of Western Australia and the *Butte Highlands* magnesian Au skarn in Montana is hosted by Cambrian platformal dolomites. Note: although the Nickel Plate deposit lies distal to the Toronto stock in the pyroxene-dominant part of the skarn envelope, the higher grade ore zones commonly lie adjacent to sills and dikes where the exoskarn contains appreciable amounts of garnet with the clinopyroxene.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Au, As, Bi, Te, Co, Cu, Zn or Ni soil, stream sediment and rock anomalies, as well as some geochemical zoning patterns throughout the skarn envelope (notably in Cu/Au, Ag/Au and Zn/Au ratios). Calcic Au skarns (whether garnet-rich or pyroxene-rich) tend to have lower Zn/Au, Cu/Au and Ag/Au ratios than any other skarn class. The intrusions related to Au skarns may be relatively enriched in the compatible elements Cr, Sc and V, and depleted in lithophile incompatible elements (Rb, Zr, Ce, Nb and La), compared to intrusions associated with most other skarn types.

GEOPHYSICAL SIGNATURE: Airborne magnetic or gravity surveys to locate plutons. Induced polarization and ground magnetic follow-up surveys can outline some deposits.

OTHER EXPLORATION GUIDES: Placer Au. Any carbonates, calcareous tuffs or calcareous volcanic flows intruded by arc-related plutons have a potential for hosting Au skarns. Favorable features in a skarn envelope include the presence of: (a) proximal Cu-bearing garnet skarn and extensive zones of distal pyroxene skarn which may carry micron Au, (b) hedenbergitic pyroxene (although diopsidic pyroxene may predominate overall), (c) sporadic As-Bi-Te geochemical anomalies, and, (d) undifferentiated, Fe-rich intrusions with low Fe_2O_3/FeO ratios. Any permeable calcareous volcanics intruded by high-level porphyry systems (particularly alkalic plutons) have a potential for hosting epidote-rich skarns with micron Au. During exploration, skarns of all types should be routinely sampled and assayed for Au, even if they are lean in sulphides.

ECONOMIC IMPORTANCE

TYPICAL GRADE AND TONNAGE: These deposits range from 0.4 to 13 Mt and from 2 to 15 g/t Au. Theodore *et al.* (1991) report median grades and tonnage of 8.6 g/t Au, 5.0 g/t Ag and 213 000 t. *Nickel Plate* produced over 71 tonnes of Au from 13.4 Mt of ore (grading 5.3 g/t Au). The 10.3 Mt *Fortitude* (Nevada) deposit graded 6.9 g/t Au whereas the 13.2 Mt *McCoy* skarn (Nevada) graded 1.5 g/t Au. The *QR* epidote-rich Au skarn has reserves exceeding 1.3 Mt grading 4.7 g/t Au.

IMPORTANCE: Recently, there have been some significant Au skarn deposits discovered around the world (e.g. *Buckhorn Mountain, Wabu, Fortitude*). Nevertheless, total historic production of Au from skarn (more than 1 000 t of metal) is minute compared to production from other deposit types. The *Nickel Plate* deposit (Hedley, British Columbia) was probably one of the earliest major Au skarns in the world to be mined. Skarns have accounted for about 16 % of British Columbia's Au production, although nearly half of this was derived as a byproduct from Cu and Fe skarns

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