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GOLD MINERALIZATION AND IGNEOUS ACTIVITY IN RELATION TO SYNMETAMORPHIC FOLDING, THRUSTING AND WRENCHING: A GENERAL MODEL FOR THE SOUTHEASTERN MARGIN OF THE CANADIAN APPALACHIANS

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Introduction

An important class of Atlantic Canadian gold deposits, including BP-Selco's Hope Brook Mine in Newfoundland, Western Mining's Forest Hill and Beaver Dam mines in Nova Scotia and the Gordex Mine at Cape Spencer, New Brunswick, occur near regional lineaments in Paleozoic rocks of the Appalachian Orogen. Most of these lineaments reflect ductile fault systems or tightly braided mylonite zones, the most significant of which record a protracted history of displacement and yield evidence of persistently high-heat flow. Economically significant lineaments are characterized by (1) their common location above Precambrian or Cambro–Ordovician ancestral structures, (2) repeated volcanism and plutonism along the fault lineament, (3) polymetamorphism of some or all of the gold-bearing rocks near the fault lineament, and (4) post-Devonian fault reactivation and lineament enhancement.

Regional Setting of Lineaments

Within the accreted, southeastern margin of the Appalachian Orogen, tectonostratigraphic terranes are commonly bound by large-scale transcurrent faults or dextral megashears that delimit wrench-fault systems varying between 10^3 to 10^5 km^2 in area. The principal shear planes or east-trending master faults initially formed at a relatively late stage in Acadian (Siluro–Devonian) regional deformation; however, many developed near older faults or were ductilely reactivated by Hercynian (Carboniferous) movements. Orogenic flexures or megakinks were produced where wrench-generated, northeast-trending, Acadian-aged folds, foliations and thrust faults were rotated, along with pre-existing structures, toward the ductile master faults. In Appalachian terranes, governed by either Acadian or Hercynian wrench-faulting, the regionally predominant periclinal folds, and slaty to spaced foliations are upright. However, narrow transitions to recumbent structures occur where the regional strain increases as the suprastructure of the orogen passes gradationally into its infrastructure or abruptly into its basement. Inhomogeneous shortening of the Acadian suprastructure was accommodated by fold-related thrusts, which formed during the development of low-grade regional foliation. Although platy-foliated, syntectonically-veined or mylonitic rocks are locally gold-bearing, the amount of stratigraphical separation across ductile faults of Acadian or Hercynian age is commonly inconsequential. Therefore, despite the fact that these faults affect suprastructure, infrastructure and basement, they are probably not deep structures, although they may be sited along ancestral fault zones that root in the lower crust or mantle.

Types of Gold Mineralization

Gold deposits in the Appalachian Meguma, Avalon, and Gander terranes occur preferentially in the suprastructure of the fold belt and are tectonically localized in slate belts composed of variable amounts of sedimentary and volcanic rocks. Less commonly, gneiss and schist belts near the infrastructure–suprastructure transition, or near basement-cover contacts, contain gold mineralization. The slate belts host two end-member types of mineralization: (1) nugget gold in Bendigo-type, saddle-reef, quartz–carbonate lodes (e.g., those in sandy and shaly flysch of the exotic Meguma Terrane of mainland Nova Scotia), and (2) disseminated gold in Carolina-type, high-alumina, high-silica, sericitic schist zones (e.g., those in pyroclastic and epiclastic deposits of the Gander (?) Terrane of southwest Newfoundland). The stratigraphy, terrane-type, age and composition of the mineralized country rocks are largely incidental.

Origin and Nature of Fluids

In many, although not in all gold districts, mineralization and alteration occur in association with igneous activity. Mineralizing fluids presumably originated from, or were heated by, granodiorite–tonalite plutons and satellite porphyries. In places, these granitoids are spatially associated with H_2O-, CO_2- and P-rich gabbro–diorite complexes and mafic dyke swarms, the loci of which are regularly spaced along some fault lineaments. All of these intrusive rocks probably formed in, or passed through, the deep basement and/or infrastructure of the orogen and ascended in sequence at various stages of regional deformation. Those of Acadian age were emplaced into the slate belts during high-T, low-P, dynamothermal metamorphism. Pseudoporphyroblasts of sulphides, carbonates, aluminosilicates and phosphates (some containing rotated inclusion trails), record the unique physicochemical conditions locally prevalent during periods of fluid-controlled, synmetamorphic, synplutonic alteration. Regional metamorphism at the time of emplacement of the gold-generating, felsic–mafic, composite intrusions and gold-

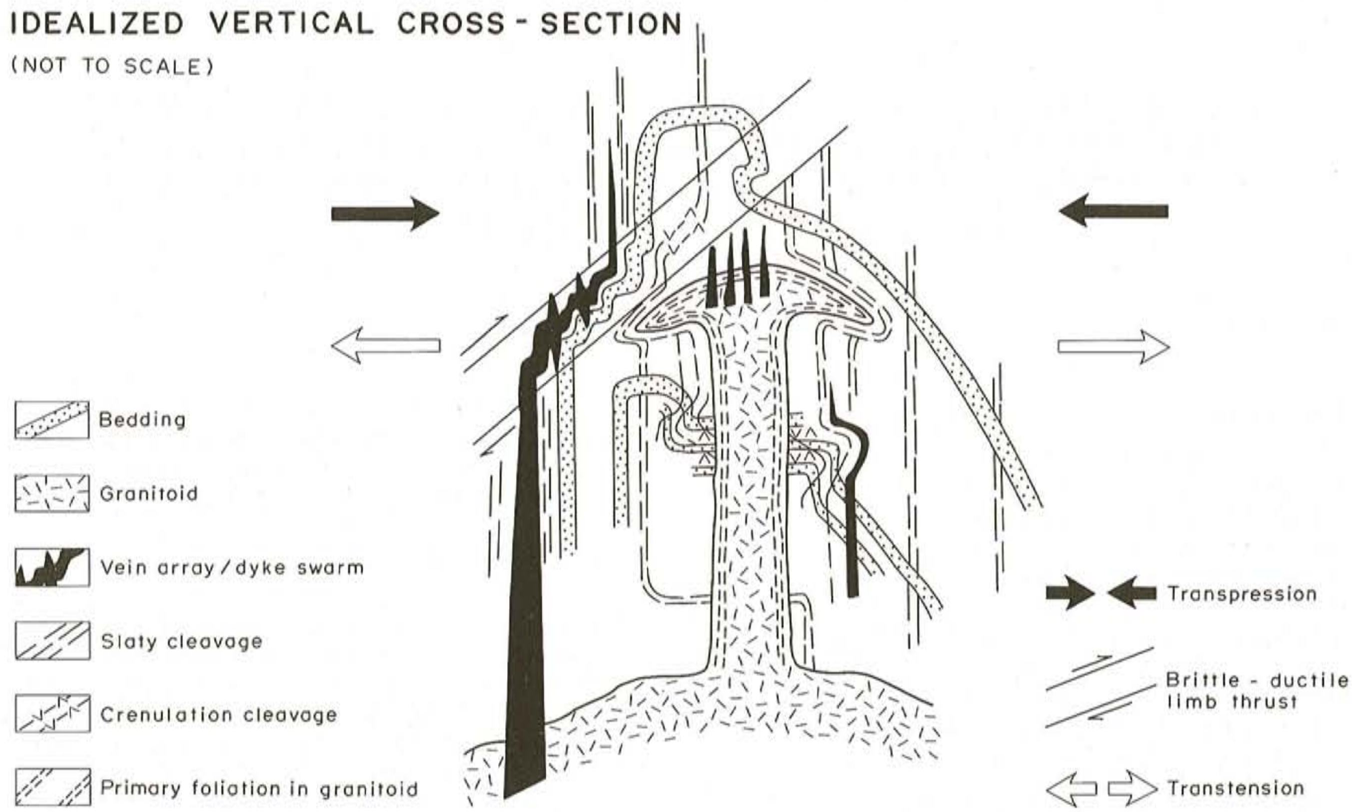

Figure 1. *Illustration of some geometric relationships between fold and thrust related foliations, and auriferous veins and intrusions. Note the direction of transpressional and transtensional forces.*

bearing, quartz–carbonate, crack-seal, vein arrays was generally in the greenschist facies, although some host rocks were metamorphosed in the amphibolite facies before or after the introduction of magma and fluids.

Deformation Kinematics and Dynamics near Gold Deposits

Viscoelastic deformation near gold deposits was accomplished by two complementary processes: (1) dilation and synchronous shortening of intrusive bodies and veins in localized parts of fault zones or fold-hinge zones, and (2) a more widespread extension and flattening of the country rocks through the progressive development of coaxial folds and fabrics.

Zones of large total strain are host to a greater variety and a larger number of syndynamic, synkinematic intrusions than zones that were never appreciably strained. Regardless of whether these zones are vertical or horizontal, quartz–carbonate veins and mafic -felsic sills and dykes are emplaced along and, to a lesser extent, across the foliation displaying the maximum anisotropy. Variably altered, mineralized, aged and foliated sheet-like plutons and sills occupy foliation-parallel shear fractures in the ductile fault zones at the expense of their conjugate, cross-strike pair. Whereas these rocks invariably suffer some of the strong regional deformation affecting the slate belts, gold veins and hypabyssal intrusions in the negligibly strained, simply folded areas between faults, illustrate two distinct deformation styles. An autokinematic style of deformation affects dykes displaying syn-intrusion offset of host-rock markers. Deformation of crystallizing magma between the walls of conjugate pairs of dilating dykes produced sigmoidal internal foliations that, in the case of one set, are perpendicular to the regional cleavage. In contrast, gold veins containing cleavage inclusions and laminated, fibrous or vuggy crystals are deformed by several orders and orientations of folds, and occupy systematic fractures parallel to the AB-, AC- and BC-kinematic planes of regional periclines.

Roles of Transtension and Transpression in Localizing Gold Deposits

Regional systems of interrelated folds, transcurrent faults and thrust faults (reactivated by normal fault movements) occur along the southeastern margin of the Canadian Appalachians. Within most of the known goldfields on this margin of the orogen, particular structures are identifiable that act as conduits and provide traps for gold-bearing fluids, in much the same way that similar tectonic features localize oilfields in southern California. Contemporaneous and cyclic, brittle–ductile episodes of horizontal extension (transtension) and horizontal shortening (transpression) were operative throughout these systems, but their effect on intrusions of all scales has special ramifications for the localization of gold deposits. Orthogonal and oblique extensions across developing foliations controlled the geometrical shapes, the growth textures and some of the deformation features of the gold quartz veins and variably altered hypabyssal intrusions. For example, in upright folds or faults invaded by vertical syntectonic intrusions, country-rock layering as well as foliation-parallel veins and dykes were bent into flat orientations by extension and then rebuckled into steep attitudes by compression as progressive regional deformation focused on particular structures (see Figure 1). Since these processes were continuous, some individuals in the vein arrays and dyke swarms were generated while others were being folded or boudinaged. In places, granitoid plutons rose along steeply dipping faults or upright fold axial surfaces and spread laterally where these structures became flat-lying or recumbent, or where the roofs of plutons behaved diapirically. Here, ductile horizontal stretching locally produced flat fabrics in the granitoids and distorted the once upright cleavage fans. It also caused the roofs of the granitoids and the adjacent parts of the fold-hinge zones or thrust sheets to fail in extension, as space was created for vertical satellite intrusions emanating from the plutons. Pulses of mineralization, alteration and igneous activity occurred during periods of extension intimately associated with fold and foliation development and fault movement.

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